Politecnico di Torino

THE METABOLISM OF TABRIZ

A Sustainable Scenario Interconnecting Urban Flows

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Finally, I dedicate this thesis to everyone who believed in me, even when I doubted myself. Your belief carried me through.

ABSTRACT

In response to the urgent global need for sustainable urban development, this thesis explores the application of urban metabolism as a framework to transform Tabriz, a major Iranian city, into a more resource-efficient and ecologically balanced urban system. Urban metabolism interprets the city as a living organism that consumes, transforms, and expels resources. By analyzing the city through this lens, the research identifies key material and energy flows - water, energy, waste, and food - that can be optimized to reduce environmental impact and enhance urban resilience.

After a review of existing literature on urban metabolism and international case studies, the thesis focuses on the case of Tabriz. Firstly, the city is studied at the territorial scale by adopting a methodology used in other international cases. Secondly and coherently with the literature, the thesis explores possible strategies.

To contextualize and test these strategies, three distinct areas in Tabriz were selected for detailed design application: Tarbiat Street (a dense commercial pedestrian corridor), Shahgoli Park (a historic and ecological green space), and various vacant urban lots. Each site was assessed based on its spatial potential and strategic relevance to urban flows, and custom interventions were proposed accordingly. The result is a vision for Tabriz as a metabolic city — where design enables the circulation, reuse, and minimization of resources in harmony with ecological and social systems.
This thesis contributes to the broader discourse on sustainable urbanism in the Middle East by offering locally grounded, future-oriented strategies that demonstrate how Iranian cities can transition toward greater environmental and metabolic efficiency.

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THE URBAN METABOLISM

1.1. Urban Metabolism

Background and Importance of Urban Metabolism
What is Urban Metabolism?

Urban metabolism is a way of understanding how cities use and move materials and energy. It looks at things like how energy flows through a city and how different systems—such as water, food, and waste—interact with one another. Researchers use this idea to study how cities grow, produce energy, and manage waste. The concept was defined more clearly in a 2007 article by C. Kennedy and his team, who described it as "the total of all the technical and social processes that happen in cities and lead to growth, energy production, and waste disposal." As concerns about climate change and environmental harm have grown, urbanmetabolism has become a useful tool for making cities more sustainable and healthier. It provides a way to look at a city as a whole, taking into account all the activities that happen in it. This approach treats cities as complex systems with interconnected parts, such as energy, water, food, and waste. These systems work together in what's called a "metabolic network," where how materials and energy move around impacts both daily life and the environment. Urban metabolism is valuable for planning and policymaking, helping city leaders spot areas of waste and find solutions to improve city life while also protecting the future.
With the rapid growth of cities, urban metabolism is becoming even more important in building cities that use resources efficiently and reduce waste. For cities facing challenges with limited resources, understanding how materials and energy flow can help use what's available wisely and protect the environment. (Newman & Kenworthy, 1999).

The Emergence of Urban Metabolism

Urban metabolism as a concept emerged from interdisciplinary research that combined ecological theories of metabolism with industrial processes. In the 1960s, scholars like Boulding (1966) and Odum (1969) introduced the concept of ecological metabolism, which viewed ecosystems as entities that exchanged materials and energy with their surroundings in order to maintain life. Inspired by these concepts, urban planners and scholars began to apply the metabolic framework to cities, viewing them as systems of material and energy flows that could be studied and optimized in much the same way as natural systems (Kennedy et al., 2007).

A major step in understanding how cities use resources came in 2007 when Kennedy and his team applied ideas from ecology to urban areas. They described urban metabolism as the way cities "consume" resources and "release" waste, focusing on the movement of water, energy, materials, and waste within a city. Their work highlighted the importance of building more sustainable cities and gave urban planners a useful way to study and improve these resource flows.

In recent years, urban metabolism has grown beyond just managing resources. It now includes ideas like sustainability and circular economies, which focus on reducing waste and reusing materials. Researchers like Fischer-Kowalski & Haberl (2007) and Girardet (1999) have expanded this concept to address bigger challenges in urban sustainability, considering social, environmental, and economic factors. Today, urban metabolism is more than just a way to measure resource use—it's a key framework for creating greener, more resilient cities.

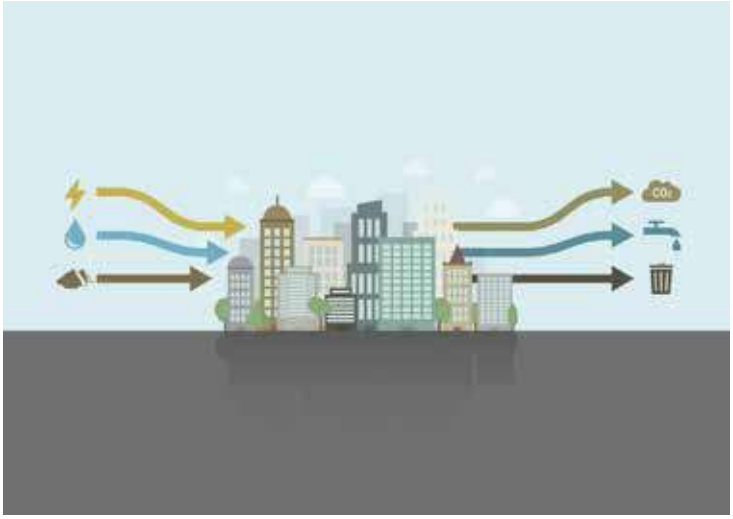


Figure1: Schematic diagram of urban metabolism

The Growing Importance of Urban Metabolism

The idea of urban metabolism is becoming more important because cities face big challenges on a global scale. Today, more than half of the world's population lives in cities, and these urban areas use the most resources and contribute heavily to environmental problems. Here are some key reasons why urban metabolism is now seen as essential for building more sustainable cities:

- Resource Shortages and Overuse

As cities grow, they need more energy, water, and raw materials. Right now, cities use over 75% of the world's natural resources (United Nations, 2018). In places where resources are already scarce, like water-stressed cities such as Tabriz, managing these resources wisely is crucial. Urban areas also account for 80% of global energy use (International Resource Panel, 2011), and many still rely on non-renewable energy sources. Moving toward renewable energy and more efficient resource use is key. Urban metabolism helps cities find ways to use resources more efficiently. For example, strategies like energy-saving technology, water recycling, and better material management can make a big difference. Rainwater harvesting and sustainable drainage systems, as suggested by Gibbs & Manning (2017), can help cities reduce water shortages.

- Pollution and Environmental Damage

Cities produce large amounts of pollution, from carbon emissions to waste and habitat destruction. The World Bank (2012) reports that urban areas generate about 70% of global carbon emissions, making them major contributors to climate change. By analyzing resource and energy flows, urban metabolism helps cities develop strategies to cut down waste, manage pollution, and shrink their carbon footprints. For instance, Cohen (2006) suggests that cities can lower emissions by improving public transportation, reducing energy use, and increasing recycling. A circular economy—where materials are reused instead of thrown away—is a key part of urban metabolism. Instead of the traditional "take, make, dispose" model, cities should adopt a "reduce, reuse, recycle" approach (Ellen MacArthur Foundation, 2012). This can help reduce pollution and make cities less dependent on external resources (Korhonen et al., 2018).

- Climate Change and Urban Resilience

Cities are especially vulnerable to climate change, facing rising temperatures, more flooding, and extreme weather. According to the IPCC (2014), urban areas are already experiencing heat islands, heavy rainfall, and flooding, which often hit poor communities the hardest. Urban metabolism can help cities become more resilient by identifying ways to reduce these risks.

For example, green infrastructure—such as permeable pavements, urban wetlands, and green roofs—can help manage stormwater, prevent flooding, and lower urban temperatures.

Sustainable water management also plays a crucial role in helping cities adapt to climate change while improving overall environmental health (Callegari et al., 2012).

- Rapid Urban Growth and Overpopulation

By 2050, the global urban population is expected to reach 6.7 billion (United Nations, 2018). This rapid growth puts pressure on resources, waste systems, and city infrastructure. Fast-growing cities like Tabriz struggle with high population density, ensuring access to essential services, and maintaining a balance between development and sustainability. Urban metabolism provides a way to study how cities use and distribute resources, helping governments create better policies. By improving the efficiency of water, energy, food, and waste management, cities can become more sustainable and fair for all residents. Haas et al. (2015) argue that shifting toward a circular economy—where resources are continuously reused—can ease the pressure of urbanization on the environment.

Urban Metabolism as a Pathway to Sustainability

Urban metabolism offers a powerful way to build more sustainable cities. It follows the key ideas of sustainable development and the circular economy, focusing on reducing waste, recycling materials, and using resources wisely. By applying urban metabolism, cities can become more efficient, lower their environmental impact, and better adapt to climate change. Here are some key principles of urban metabolism in sustainability:

- Resource Efficiency

Urban metabolism helps cities use resources like water, energy, and materials more efficiently while reducing waste. This can be achieved by adopting energy-saving technologies, improving infrastructure, and cutting down on unnecessary resource consumption (Barton, 2000).

- Environmental Sustainability

Urban metabolism helps cities shrink their environmental footprint by reducing carbon emissions, using energy more efficiently, and managing waste better. By adopting greener technologies and sustainable practices, cities can contribute to the global fight against climate change (Cohen, 2006).

1.2. Models and case studies

Urban Metabolism: Concepts and Models

Urban metabolism, as a conceptual framework, examines cities as living entities that consume resources, generate waste, and undergo transformation processes, much like biological organisms. This analogy enables researchers to analyze urban systems holistically, focusing on the flows of materials and energy that sustain urban life. The framework views cities as complex networks where inputs (such as water, food, and energy) are processed, leading to various outputs (waste, emissions, etc.) that impact both the city and its surroundings. This approach not only aids in understanding resource consumption and waste generation but also informs strategies to improve urban sustainability by identifying inefficiencies and proposing ways to optimize metabolic flows (Wolman, 1965; Kennedy et al., 2011).

Urban metabolism is a framework that allows us to think of cities as living systems, where resources are constantly consumed, processed, and transformed into waste. This perspective helps us understand how cities function and interact with their environment, showing us where improvements can be made for a more sustainable future. By studying the flow of resources—water, energy, food, materials—through cities, we can find ways to reduce waste and increase efficiency, which is crucial as urban areas continue to grow. The basic structure of urban metabolism is built around three key components: inputs, processes, and outputs. Inputs are the essential resources that a city needs to function—things like water, energy, raw materials, and consumer goods, but also intangible resources such as labor and financial capital. These come from both local and global sources, shaped by geography, trade, and policy. For example, a city might source its water from nearby rivers or import it when local supplies are low. Similarly, energy might come from a combination of fossil fuels and renewable sources. Once these resources are in the system, they go through various processes that turn them into usable goods and services. Water is purified and distributed to households, industries, and green spaces; food is stored, transported, and prepared; and energy is transformed to power homes and businesses. These processes are central to urban metabolism because they determine how well resources are used and how much waste is created. New technologies, like smart grids and closed-loop water systems, help cities use fewer resources and reduce environmental impacts.

However, no resource system is without waste. Outputs are the byproducts that cities produce after consuming resources. These can include things like municipal waste, wastewater, air pollutants, and industrial byproducts. If not properly managed, these outputs can lead to environmental degradation, including pollution and climate change. Urban metabolism models aim to reduce these negative impacts by finding ways to recycle or repurpose waste. Cities adopting waste-to-energy technologies or recycling programs are examples of efforts to close the loop and minimize the environmental footprint of urban activities.

In terms of material flows, cities are constantly moving physical goods through their systems—water, food, building materials, and consumer products. Material Flow Analysis (MFA) is a method used to track these movements and understand the efficiency of resource use. For example, a city might track the flow of water from rivers or reservoirs, through treatment plants, and into households, and then monitor wastewater treatment. Similarly, food is tracked from production to consumption to disposal. By understanding these flows, we can identify areas where improvements can be made, like reducing food waste or improving water efficiency. Water is one of the most critical materials in urban metabolism. Managing water sustainably is vital, especially in regions facing scarcity. This involves strategies like reducing consumption, fixing leaks, recycling wastewater, and capturing rainwater. Some cities have adopted closed-loop systems where wastewater is treated and reused, reducing demand for freshwater sources. Building materials also have a significant impact on urban metabolism. Concrete, steel, and timber are essential for infrastructure, but they also contribute to waste and resource depletion. By using recycled materials, optimizing building designs, and reducing construction waste, cities can minimize their material footprint and support a more sustainable built environment. Energy flows are another key part of urban metabolism. Cities rely on various sources of energy, from fossil fuels to renewable sources, to power homes, businesses, and transportation. Understanding how energy moves through a city and how efficiently it is consumed can help identify ways to reduce reliance on non-renewable energy and improve energy efficiency. Sustainable urban metabolism promotes cleaner energy sources, such as electric vehicles for transportation and energy-efficient heating systems like district heating.

The way cities interact with the environment also plays a crucial role in urban metabolism. Urban ecology looks at how human systems and natural ecosystems interact. This is essential for understanding how cities impact their surrounding environments and vice versa. For example, green spaces and urban agriculture contribute positively to metabolism by regulating temperature, filtering pollutants, and enhancing residents' quality of life. Ecosystem services, like clean air and water, are vital to city functions, and integrating these services into urban planning can reduce the need for artificial systems and reduce the metabolic load.

Finally, urban metabolism can be divided into two models: linear and circular. A linear metabolism follows a "take-make-dispose" approach, where resources are consumed and then discarded as waste. This model has led to significant environmental challenges, like resource depletion and pollution. In contrast, a circular metabolism aims to reduce waste and reuse resources in a closed-loop system. Organic waste can be composted for urban agriculture, and wastewater can be treated and used for non-potable applications. Adopting circular metabolism helps cities conserve resources, lower emissions, and support sustainable growth, which is essential as cities like Tabriz continue to expand.

Case Studies on Urban Metabolism

Barcelona, Spain:
Barcelona has integrated sustainability into its urban planning by focusing on water conservation, renewable energy, and waste management. The city has implemented strategies such as rainwater harvesting, wastewater recycling, and the use of smart water management systems. For waste, Barcelona promotes a circular economy with composting, recycling, and waste-to-energy plants to reduce landfill waste. The city has also invested in renewable energy sources like solar and wind to reduce carbon emissions and move towards energy independence.

London, UK:
London uses resource accounting to track materials, energy, and waste flows, improving resource efficiency across the city. To promote sustainability, London encourages local food production through urban farming and community gardens, which helps reduce the environmental impact of food transport. The city has also embraced green infrastructure, such as parks and green roofs, which absorb rainwater, reduce flooding, and improve air quality. Furthermore, London focuses on energy-saving measures in buildings and encourages public transport to reduce traffic and emissions.

New York City, USA:
New York has adopted various sustainability measures, including waste-to-energy plants that turn waste into usable energy, reducing the amount of waste sent to landfills. The city also promotes recycling through its curbside collection program, one of the largest in the world. New York focuses on energy efficiency by retrofitting old buildings and using renewable energy sources like solar and wind. The city's public transportation system helps reduce traffic congestion, and policies like congestion charging encourage less reliance on private cars.

Curitiba, Brazil:
Curitiba is famous for its efficient Bus Rapid Transit (BRT) system, which offers affordable, fast, and eco-friendly public transportation. The city also has an innovative recycling program that incentivizes residents to recycle by exchanging waste for food or transport vouchers. Additionally, Curitiba is committed to preserving green spaces and parks, which help with stormwater management, reduce heat, and improve the quality of life for residents.

Tokyo, Japan:
Tokyo uses smart technologies to manage its resources effectively. The city has a network of sensors to monitor energy, water, and waste use in real time, optimizing resource flow. Tokyo promotes energy efficiency in buildings with green design standards, such as natural lighting and renewable energy use. It also has an extensive waste sorting and recycling system, along with waste-to-energy plants that convert waste into electricity. The city’s public transportation system, which includes trains, buses, and subways, reduces reliance on cars and lowers pollution.

These case studies like Barcelona, London, New York, Curitiba, and Tokyo, and use their successful strategies can be used to address Tabriz's specific challenges. For example, Barcelona’s methods for saving water, such as recycling wastewater and using smart water management, can help Tabriz tackle its water scarcity issues. London’s resource tracking system can help Tabriz manage its energy, water, and waste more efficiently. New York’s waste-to-energy and recycling programs could help Tabriz manage its waste more effectively, while Curitiba’s bus system can offer ideas to improve public transport in Tabriz. Tokyo’s smart technology for resource management and energy-saving strategies can guide Tabriz in using modern tools to use resources more sustainably. By learning from these cities, this research will propose solutions to improve Tabriz's resource management and sustainability.

— THE CASE OF **TABRIZ**

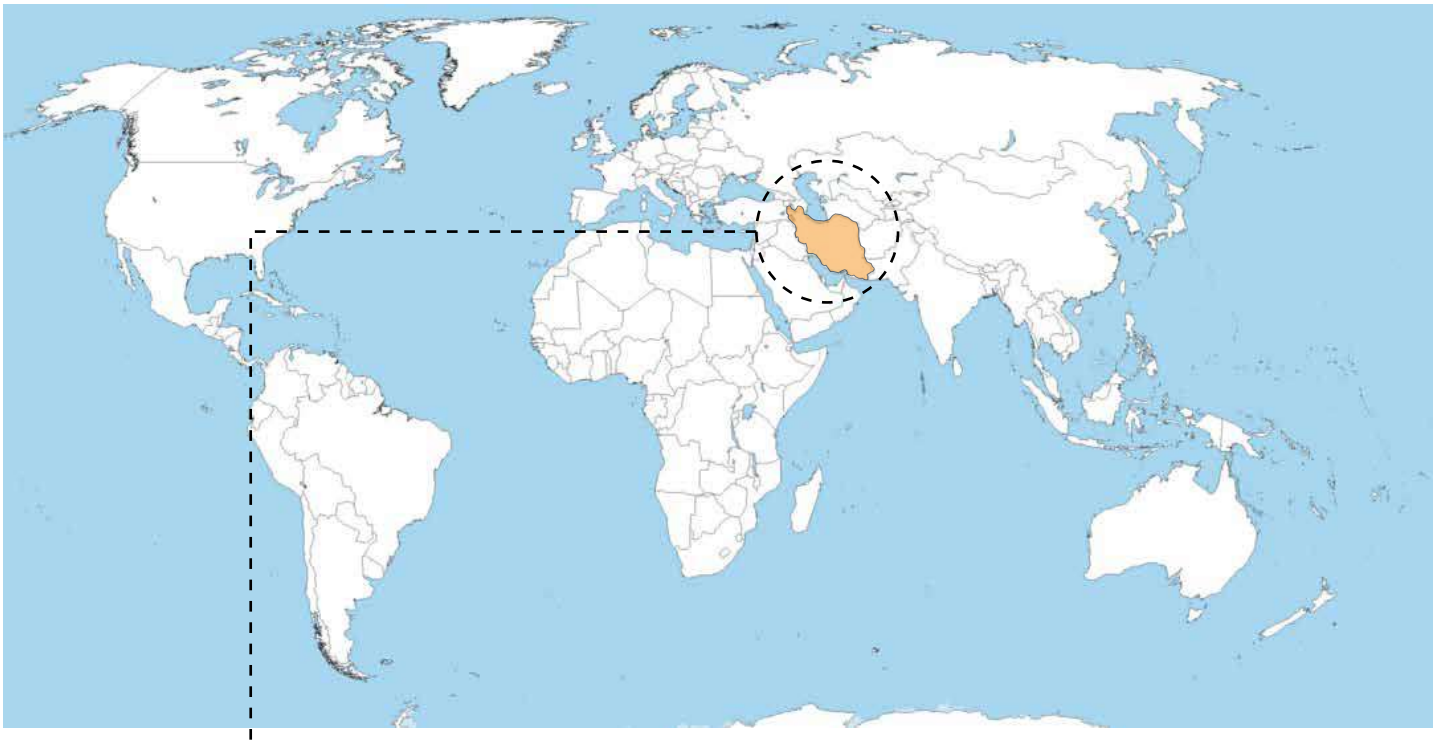
THE CITY AND TERRITORY —— WHY METABOLISM OF TABRIZ? —— METHODOLGY: WORKING ON METHABOLISM —— THINKING IN FLOWS —— FLOWS —— CHALLENGES AND OPPORTUNITIES

Tabriz - view from valiasr town - 11/04/2024

Tabriz - view from valiasr town - 02/08/2025

THE CASE OF TABRIZ

2.1. Tabriz



Iran

East Azaribaijan Province

Tabriz is a major city in northwest Iran and the capital of East Azerbaijan Province, located in a valley surrounded by the Sahand Mountains near the borders of Turkey, Azerbaijan, and Armenia. With a population of approximately 1.6 million, it is a cultural and economic hub, predominantly inhabited by Azeri (Azerbaijani) people.
Tabriz's urban planning combines historical preservation with modern expansion. The old city core, centered around the Tabriz Grand Bazaar, features traditional narrow streets and historic architecture, while newer districts in the northwest and southwest have seen rapid urbanization with high-rise buildings and commercial centers. The city has developed BRT (Bus Rapid Transit) and metro lines to improve public transportation and ease traffic congestion. Green spaces like El-Goli Park are being expanded to enhance air quality and recreational opportunities. Due to its seismic activity, earthquake-resistant construction is a priority, along with addressing water supply challenges and promoting pedestrian-friendly zones to create a more sustainable urban environment.

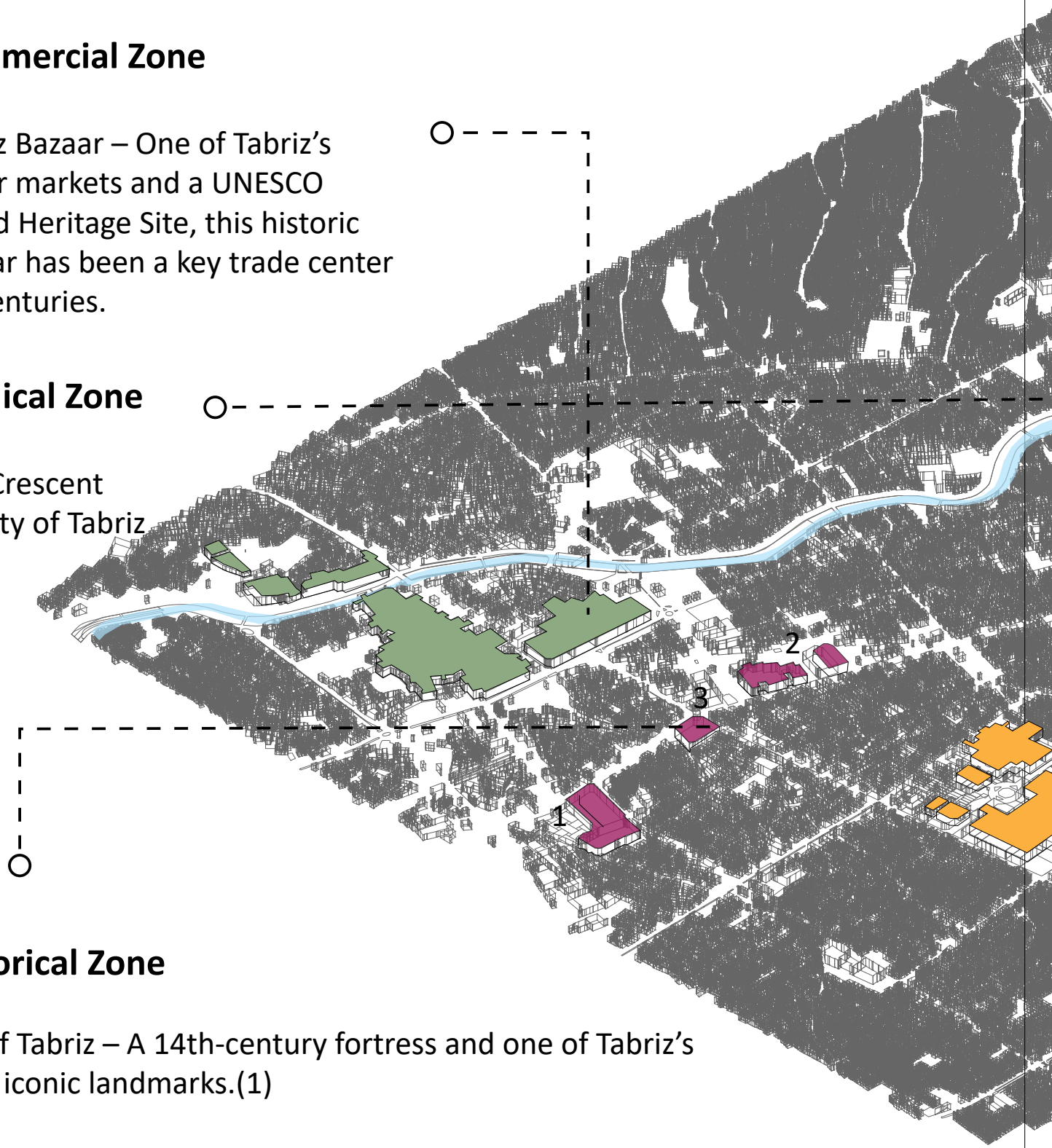
Urban Landmarks of Tabriz

Commercial Zone

Tabriz Bazaar – One of Tabriz's major markets and a UNESCO World Heritage Site, this historic bazaar has been a key trade center for centuries.

Medical Zone

Red Crescent Society of Tabriz



Historical Zone

Arg of Tabriz – A 14th-century fortress and one of Tabriz's most iconic landmarks.(1)

Blue Mosque – A 15th-century Timurid-era mosque known for its intricate blue tilework and fine calligraphy.(2)

Saat Square – The central square of Tabriz, featuring the historic municipality building with its clock tower. A key urban landmark, it serves as a cultural hub.(3)

Educational Zone

Tabriz University – One of Iran’s oldest and most prestigious universities, serving as a major academic and research center.

Sport Zone

Takhti Stadium and Sport Complex – One of Tabriz’s main sports venues, primarily used for football. It plays a key role in the city’s athletic activities.
Indoor facilities spread across the city, supporting various sports like basketball, volleyball, and wrestling.

Tabriz is a great example of how cities use and manage resources, especially since it's located in a region of Iran where water and other resources are limited. At the same time, the city is growing quickly, which puts even more pressure on these resources. Like many cities, Tabriz is struggling with several challenges that affect both its environment and its people.

2.2. Why study the metabolism of Tabriz?

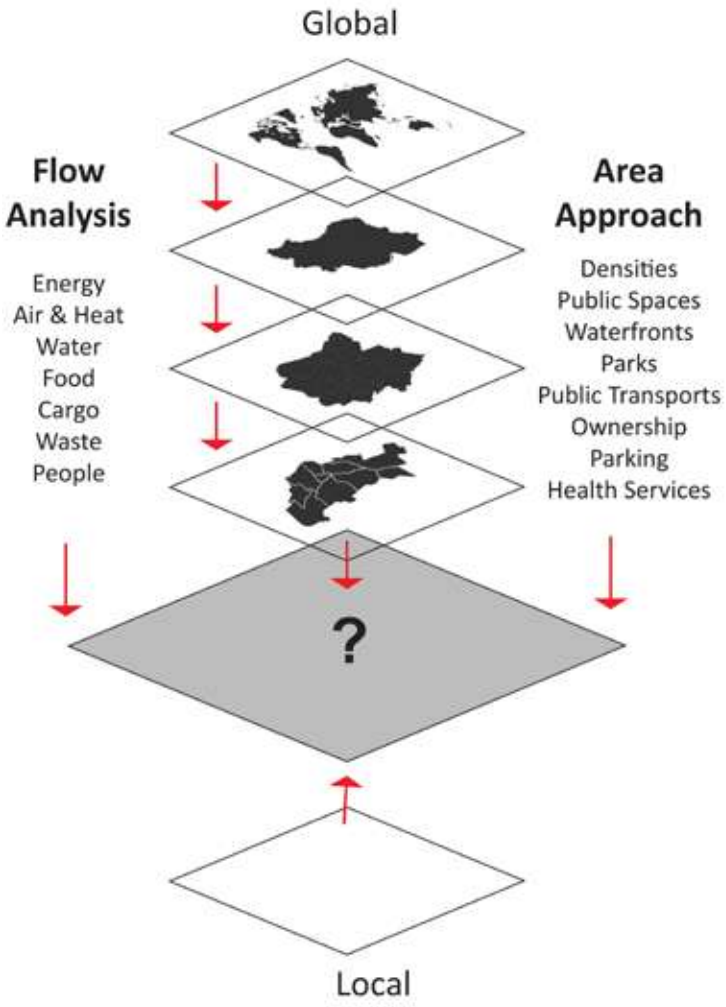
Tabriz has been growing fast over the past few years. More people are moving in, and the number of buildings and industries is increasing. With this growth, the city needs more resources like water, energy, and raw materials. At the same time, more waste and pollution are being produced. Understanding the city's metabolism—how it uses resources and handles waste—can help find ways to use resources more wisely, reduce waste, and create a more sustainable city.

Tabriz faces several environmental challenges. Air pollution is one of the biggest problems. The high number of cars on the roads, along with industrial activity, contributes to poor air quality. This leads to health issues like respiratory problems, especially during the colder months when pollution levels rise. In addition to air pollution, water shortages are a growing concern. Tabriz relies on nearby rivers and groundwater, but as the population and demand for water increase, these resources are being stretched thin. Poor waste management also adds to the city's environmental problems, with much of the waste being improperly disposed of, leading to pollution in streets and waterways. Studying how the city consumes resources and produces waste can help us come up with ways to reduce pollution and conserve water. Tabriz is an important economic hub in Iran, especially for industries like manufacturing, textiles, and food production. These industries bring in money and create jobs, but they also consume a lot of energy and raw materials. This puts pressure on the environment as factories use large amounts of resources and produce waste. For example, the textile industry requires a lot of water and chemicals, which can end up polluting rivers. By studying how resources flow through these industries, we can figure out how to make them more efficient, reduce waste, and lower their environmental impact. To build a more sustainable city, Tabriz needs careful urban planning. The city is expanding, and with this growth comes the need for better infrastructure, and waste management systems.

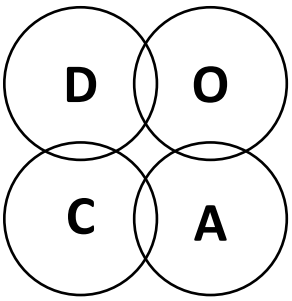
Why This Study Matters Beyond Tabriz?

While this research focuses on Tabriz, the lessons learned here are relevant to many other cities facing similar challenges. Urban areas in the Global South, in particular, often deal with rapid population growth, limited resources, and outdated infrastructure. By studying urban metabolism, we can better understand how cities can transition toward more sustainable and efficient systems.

This research also highlights how global ideas about urban sustainability need to be adapted to fit the specific needs of each city. What works in one part of the world may not work in another, so it's important to find local solutions that take into account geography, culture, and economic conditions. By applying these insights, cities like Tabriz can move toward a future that is not only more sustainable but also more resilient to environmental and economic challenges.



Water
Food
Energy
Waste



3+1 Flows
Setting flows as a base for metabolism research.

[DOCA] Methodology
Collecting data, opportunities, challenges and anecdotes for each flow.

Mapping Data
Mapping available data on national level for each flow.

2.3. Methodology

Working on metabolism

Cities function like living systems. They take in resources, use them, and produce waste. This process, known as urban metabolism, determines how a city grows, sustains itself, and interacts with its environment. Understanding this metabolism helps reveal the hidden connections between different urban flows and shows where challenges and opportunities exist. In this research, four key flows in Tabriz are studied: energy, water, food, and waste. These flows are essential to daily life, shaping everything from how people live and work to how the city can plan for a more sustainable future.

To study these flows, multiple methods were used. First, data was collected to understand how energy, water, and food system work in city. This data was then analyzed to identify patterns and trends. Mapping was an important step in visualizing how these resources move through different parts of the city, showing where they are concentrated, where shortages exist, and how they connect to each other. Diagrams were created to simplify complex relationships, making it easier to see how energy, water, food, and waste interact. Beyond data and maps, direct fieldwork was essential in capturing the real experience of these flows in the city. Visits were made to power plants, water facilities, markets, and waste collection sites to observe how these systems operate in practice. Photographs and on-site documentation helped record these findings, showing both the visible and hidden aspects of urban metabolism. Seeing these flows firsthand provided deeper insights into how they impact daily life in Tabriz.

Each flow plays a different role in the city's metabolism. Energy powers homes, businesses, and transportation, but its production and consumption affect the environment and economy. Water is essential for drinking, sanitation, agriculture, and industry, but its availability and management determine how efficiently it can be used. Food comes from local and imported sources, moving through supply chains that influence its accessibility and cost. Waste, often seen as the end of the cycle, is actually a continuous flow—what is discarded can sometimes be reused, recycled, or transformed into energy, but if not managed properly, it can harm .the environment

By studying these four flows together, this research sees Tabriz not just as a collection of roads, buildings, and people, but as a living system where resources constantly move and change. Understanding these flows helps identify challenges, such as resource shortages, inefficiencies, and environmental impacts, while also revealing opportunities for improvement. A better understanding of urban metabolism can help create strategies for a more sustainable, resilient, and efficient city—one that balances its resource use with the .well-being of its people and environment

Thinking in FLows

There are many flows that shape a city's metabolism, but this research aims to focus on four key ones: water, energy, food, and waste. These flows are essential to the functioning of Tabriz and directly impact its sustainability. Water is a critical issue in Tabriz due to its semi-arid climate and growing demand, making the city increasingly vulnerable to shortages. Energy use is another key flow, as the city still relies heavily on fossil fuels, which creates inefficiencies and environmental concerns. Food, tied to agriculture, is vital for the local economy, but its future is threatened by the ongoing water scarcity. Finally, waste management is a significant challenge, with the city's current system unable to keep up with the growing population, leading to pollution and health risks. By focusing on these four flows, this research aims to identify the major challenges and explore solutions that can guide Tabriz toward a more sustainable urban future. Tabriz faces challenges in each flow that make them much more important to investigate. Some points listed below:

Tabriz is in a semi-arid region, so water is already limited. The city depends a lot on external water sources, and local groundwater is running low. As more people move in and industries grow, the need for water keeps increasing. This makes the situation even more serious. If solutions aren’t found, water shortages could affect daily life, farming, and the city’s future. Using water wisely, improving irrigation, and recycling water could help. More advanced methods like rainwater harvesting, desalination, and fixing leaks in the city’s water pipes can also help reduce waste and make better use of available resources. Educating people about water conservation and enforcing laws to prevent overuse will be key to managing this crisis.

The city has access to energy, but it is not used efficiently. Most of it still comes from fossil fuels, which cause pollution and make the city dependent on changing prices. Unlike some cities that are using more clean energy, Tabriz has not made big progress with solar or wind power. Using energy-saving technology, better public transport, and cleaner energy could help reduce these problems. Adding solar panels to homes and businesses, improving insulation in buildings, and encouraging people to use public transportation instead of cars could make a big difference. Government support for renewable energy projects and better energy storage solutions would also help the city rely less on fossil fuels.

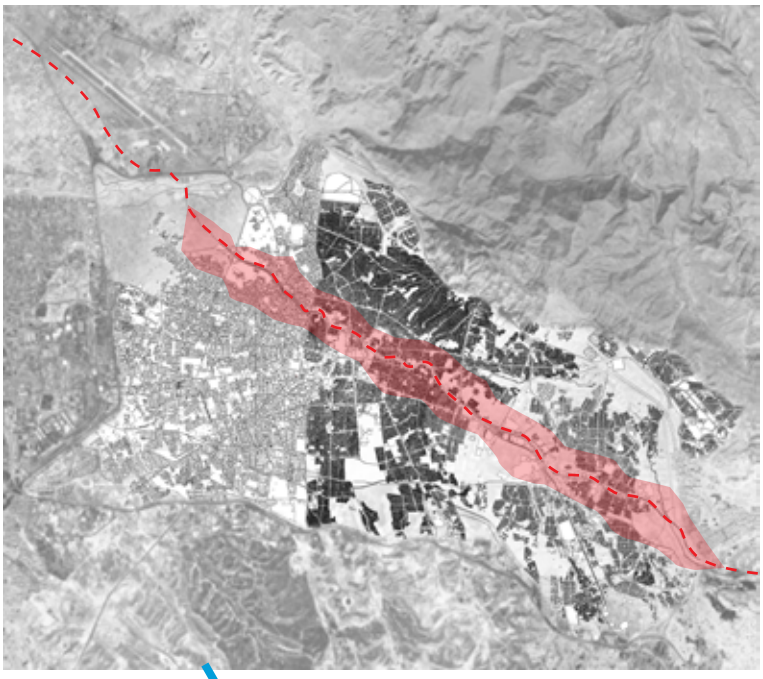
As the population grows, more waste is being produced. But the waste system has not kept up. Landfills are filling up, illegal dumping is increasing, and pollution is a problem. Without better waste management, these issues will get worse. Recycling, composting, and waste-to-energy methods could help. Teaching people about waste and making rules stricter could also improve the situation. Setting up more recycling stations around the city, promoting biodegradable packaging, and encouraging companies to reduce plastic waste could help cut down on garbage. Waste separation at home and in businesses should also be encouraged so that reusable materials do not end up in landfills.

Agriculture is very important for Tabriz. The farmlands around the city provide food and jobs. But farming depends on water, and if shortages continue, it will suffer. Many farms still use old irrigation methods, which waste water. Soil is also getting worse, and climate change makes things harder. If farmers don’t use better techniques, it will be difficult to keep farming strong. More efficient watering, modern farming methods, and support for farmers could help. Crop rotation, drought-resistant plants, and hydroponic farming could reduce the pressure on water supplies. Helping farmers access better tools and techniques, along with financial support from the government, can help secure the future of agriculture in the region.

To solve these problems, Tabriz needs to change the way it uses resources. One good idea is urban metabolism, which looks at how cities use and recycle resources, like a living organism. By studying water, energy, and waste, experts can find better ways to manage them. Smarter policies, green projects, and teamwork between the government, businesses, and people can help Tabriz become a more sustainable city. Investing in green spaces, encouraging eco-friendly industries, and improving public transportation can make the city more livable. A long-term plan for resource management and stronger environmental policies will ensure that Tabriz grows in a way that protects its resources for future generations.

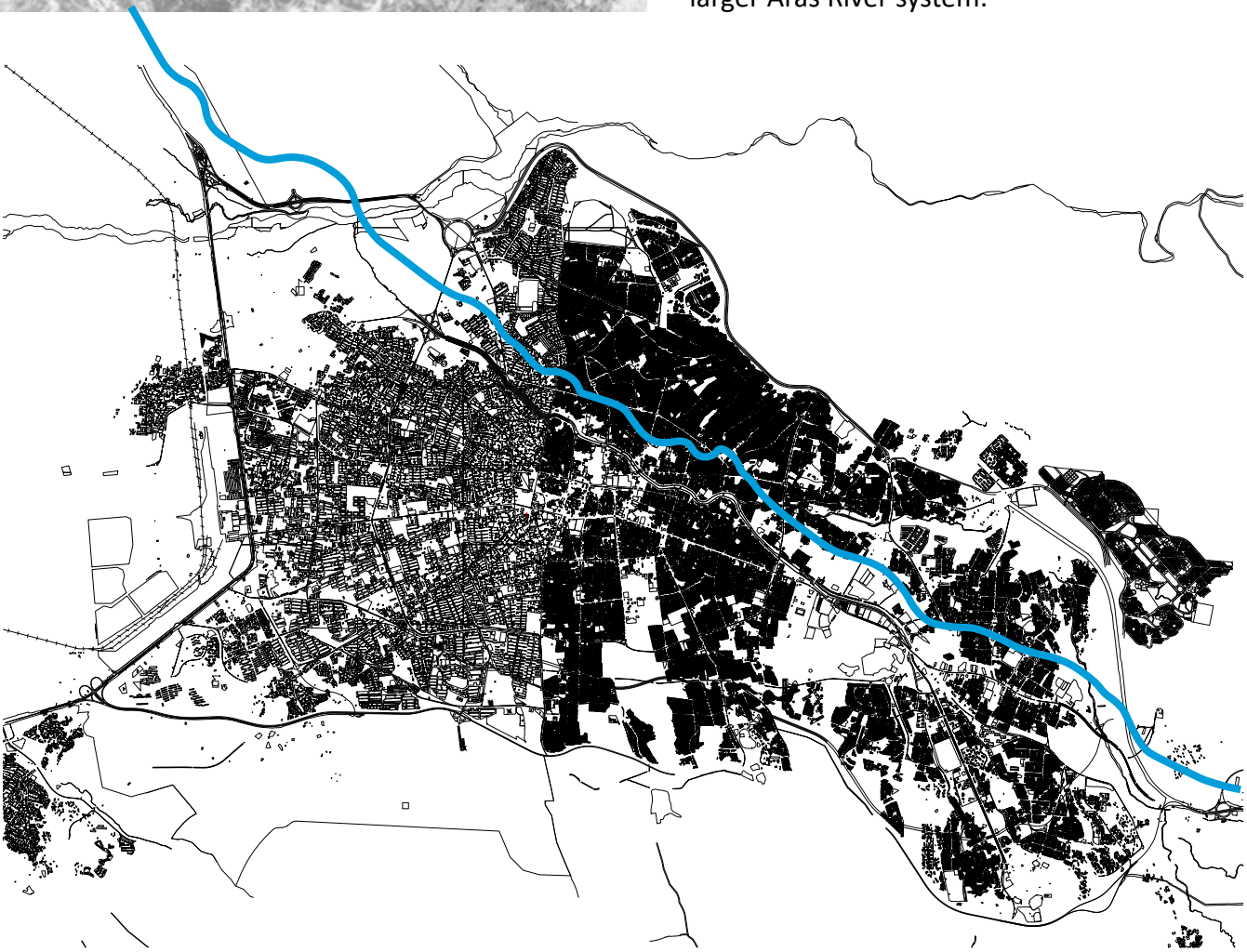
2.4. Flows

2.4.1. Water flow

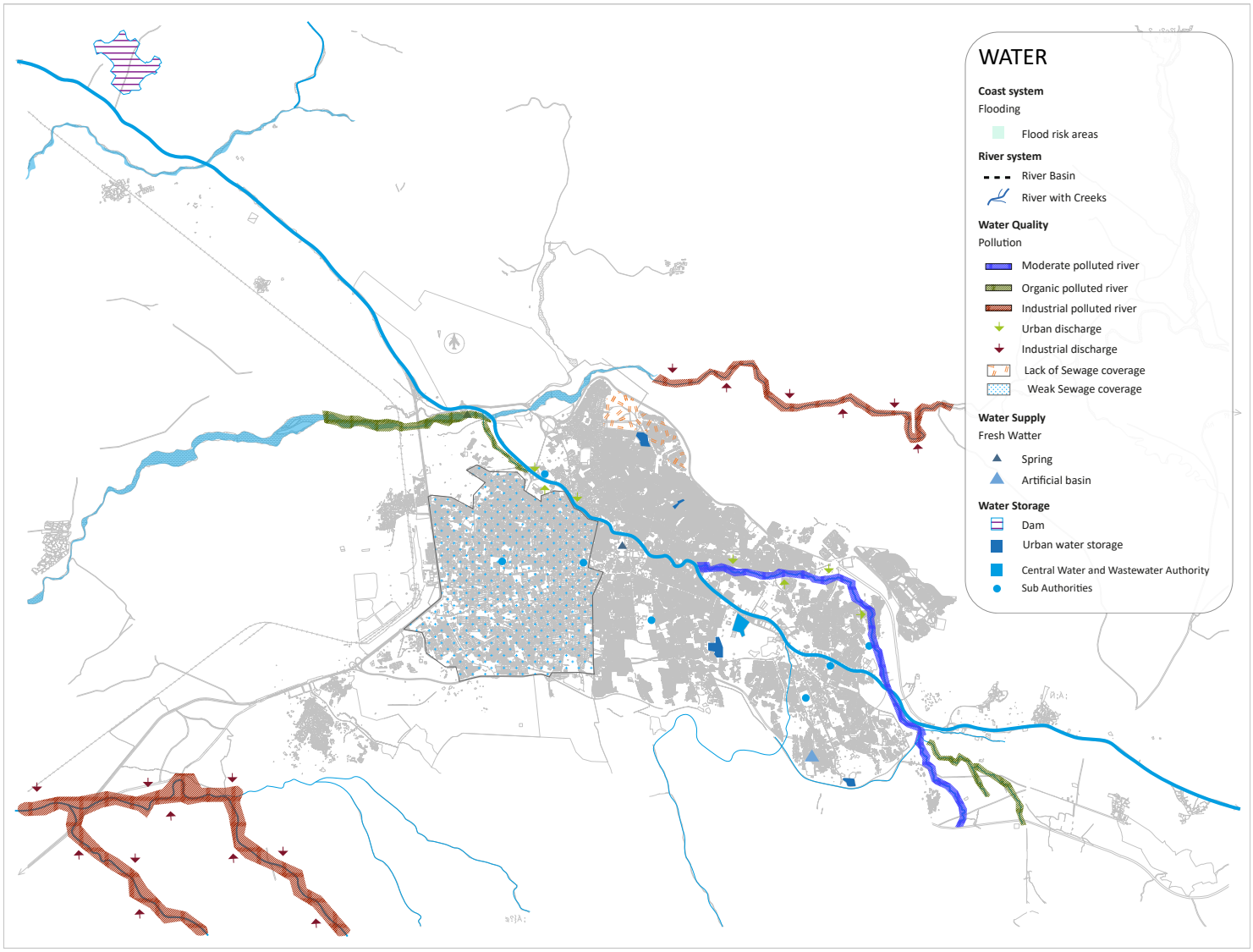


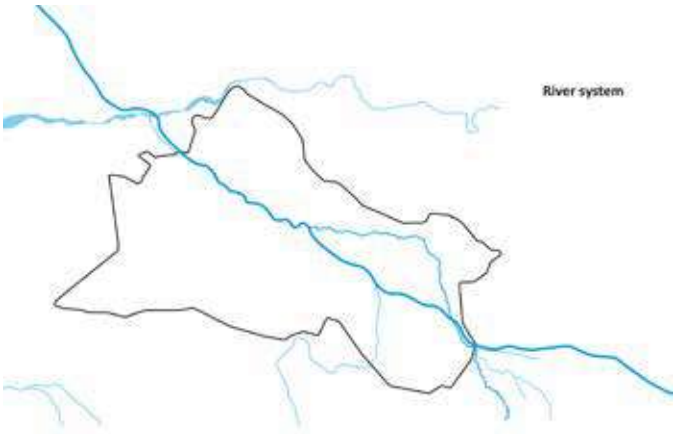
TABRIZ METROPOLITAN AREA
— QURI CHAY RIVER

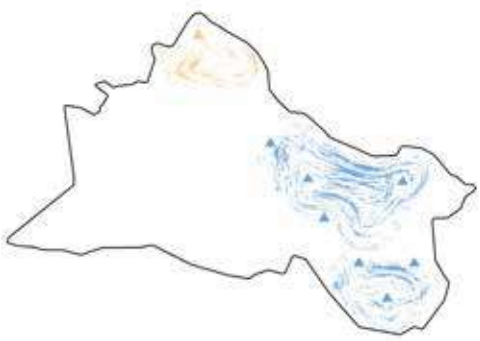
Length: About 100 km (62 miles) long.
Average flow rate: The river is often dry or with low water levels. In its more active state, it may have an average flow rate of 2-5 cubic meters per second.
Basin: It is part of the larger Urmia Basin, which drains into Lake Urmia.
Origin elevation: The river originates in the foothills of the mountains near Tabriz, at approximately 1,500 meters (4,920 feet) above sea level.
Mouth type: The river eventually empties into the Aji Chay River, which is a tributary of the larger Aras River system.



The Quri Chay, also known as the Quru Chay or Quri River, divides Tabriz into northern and southern sections, connected by several bridges, including the historic Qari Bridge. The name "Quri Chay" translates to "dry river," reflecting its tendency to have minimal or no flow, especially in recent decades. Efforts are underway to restore a permanent flow to the river.



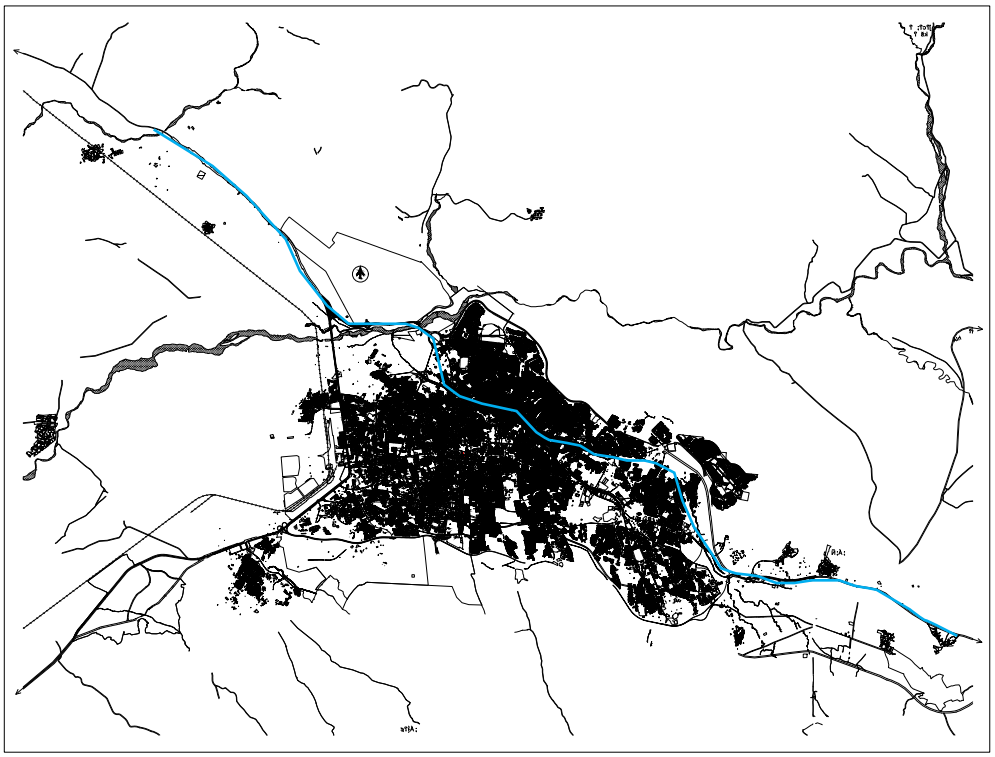




Waterland Tabriz

Water is very important for Tabriz. The city is in a dry area, so water has always been a challenge. In the past, people used qanats (underground water channels) and rivers to bring water to the city. One of the biggest water sources nearby is Lake Urmia, but it is shrinking because of less rainfall and too much water use. Inside the city, the Aji Chay River and Mehran River help provide water, but they do not always have enough. As the city grows, water use is increasing. Factories, farms, and homes all need water, but sometimes it is not used efficiently. Groundwater is being taken too quickly, and some rivers are getting polluted. Many old water systems also need repairs to stop leaks and waste. Even with these problems, water is still a big part of life in Tabriz. People and the government are working to save water, clean polluted areas, and find better ways to use it. Protecting water is important for the future of the city and its people.

Water flow statistical analysis



In the context of urban metabolism, water plays a crucial role in the functioning and sustainability of cities. This section of the thesis focuses on the water flow dynamics in Tabriz, analyzing key statistics related to total water supply, consumption patterns, wastewater generation, and sewage treatment processes. Understanding the intricacies of these elements is essential for evaluating the efficiency of water distribution systems and the overall environmental impact. By examining these figures, the study aims to highlight both the challenges and opportunities for improving water management in Tabriz, contributing to a more sustainable urban future.

Total Water Supply & Sources

Category	value
Total Water Supplied (per year)	~400-300 million m^3/year
Main Sources of Water	%60 Groungwater, %30 Surfacewater, %10 Other

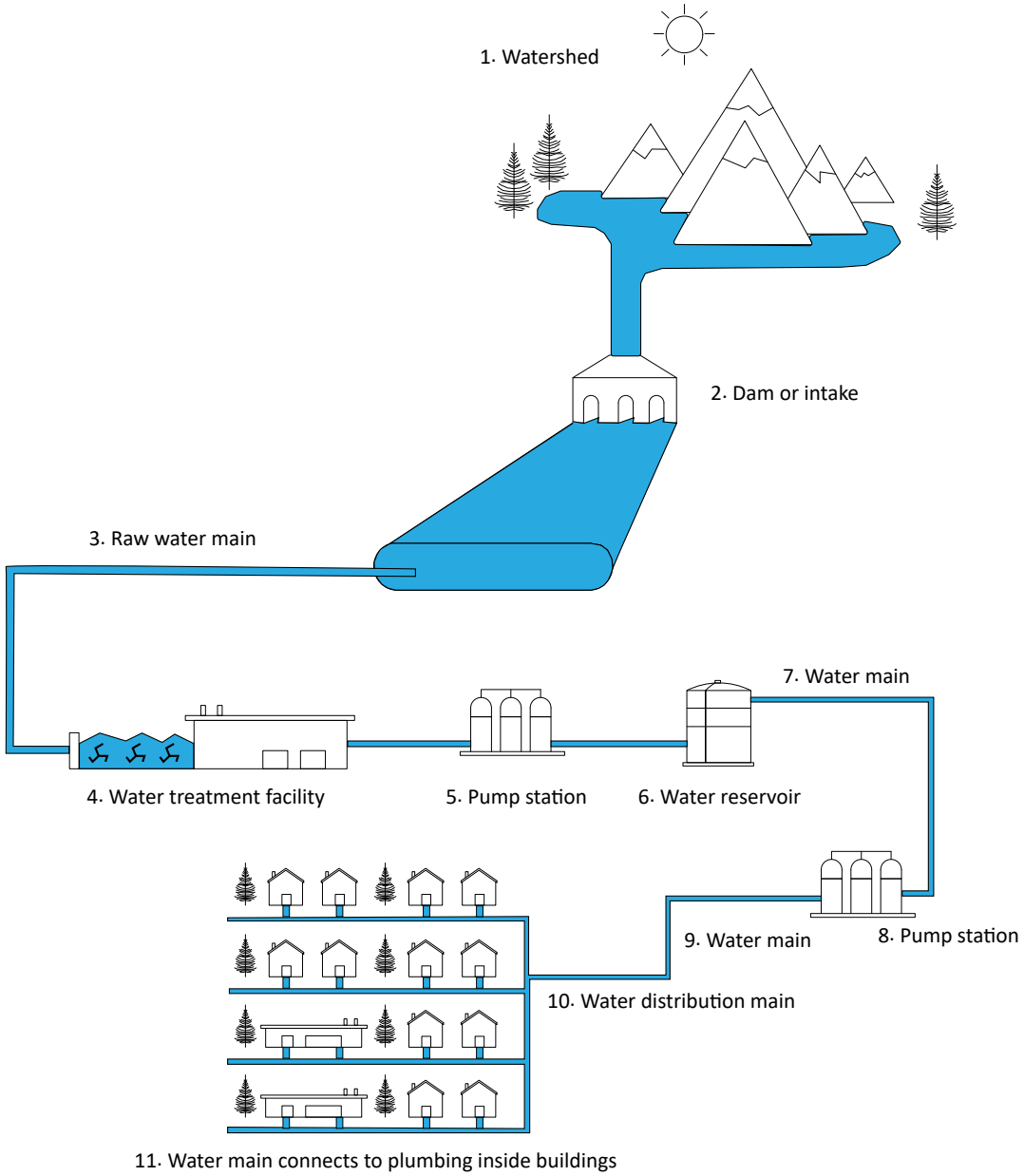
Water Consumption & Demand

Category	value
Per Capita Water Consumption	200-150 liters/day per person
Total Water Demand (per year)	~255-340 million m^3/year
Water Consumption by Sector (Household)	%50 of total water use
Water Consumption by Sector (Industry)	%30 of total water use
Water Consumption by Sector (Agriculture)	%20 of total water use

Wastewater & Sewage Treatment

Category	value
Total Wastewater Generated (per year)	~220-300 million m^3/year
Percentage of Wastewater Treated	~60-70% of wastewater treated
Number of Wastewater Treatment Facilities	2 facilities
Breakdown of Wastewater (Household)	~70% of total wastewater
Breakdown of Wastewater (Industrial)	~20% of total wastewater
Breakdown of Wastewater (Agricultural Runoff)	~10% of total wastewater

Water Distribution & Infrastructure

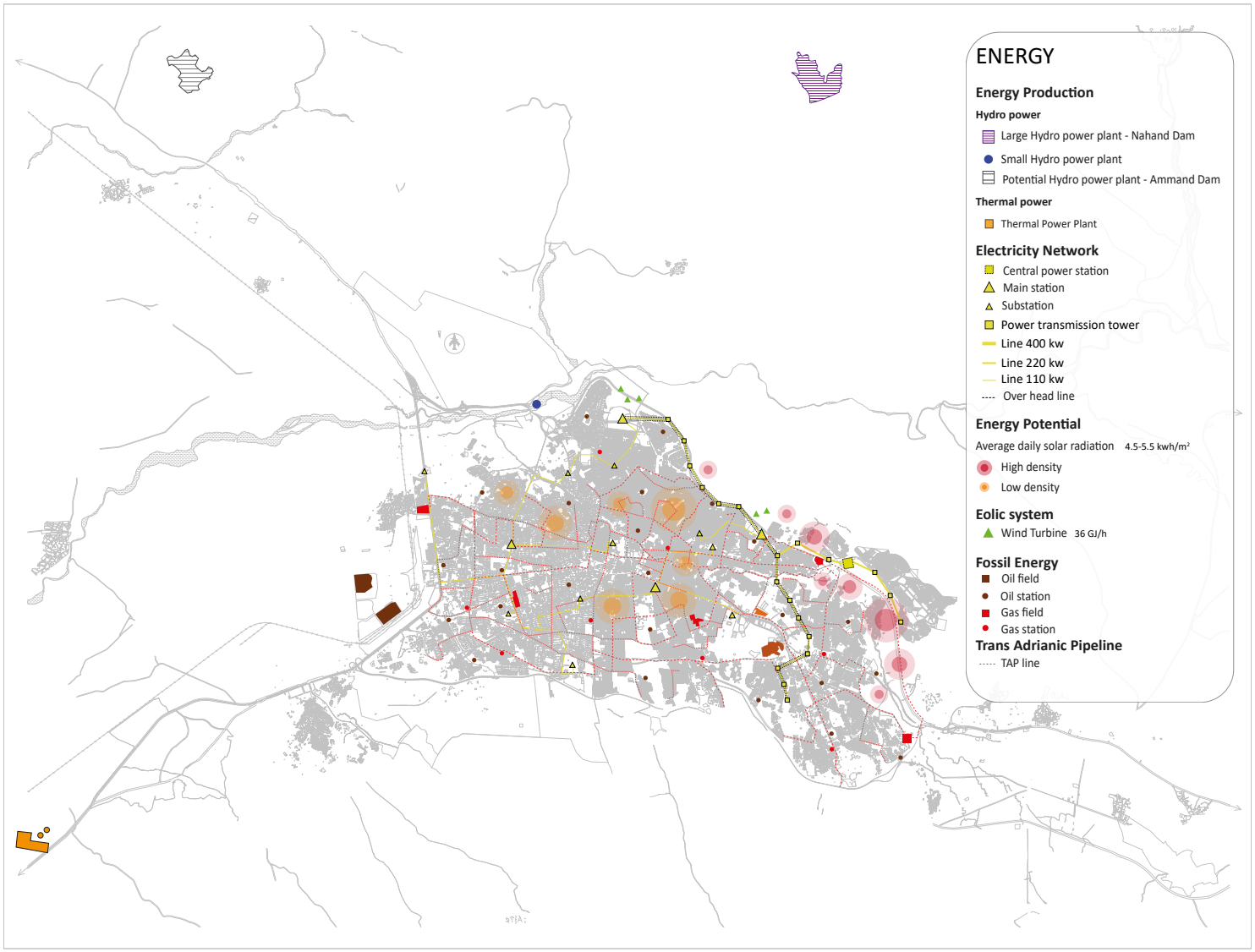


Water Distribution & Infrastructure

Category	value
Water Loss During Distribution	~15-25% of total water supplied
Length of Water Distribution Network	~4000-5000 km
Water Treatment Plants	2-4 facilities

- While Tabriz's water supply is diverse, its over-reliance on groundwater may pose challenges in the long run. More focus on surface water management and potential renewable water sources could help in ensuring a more balanced water supply.
- Water conservation efforts, such as reducing consumption in households and industries, could contribute significantly to reducing the growing water demand.
- Improving water distribution infrastructure and reducing water loss will be essential for maintaining the city's ability to provide sufficient water to its residents.
- Expanding wastewater treatment capacity and ensuring better management of industrial and agricultural runoff will reduce the environmental impact and improve water quality in the long term.

2.4.2. Energy flow



Understanding energy flow is essential for sustainable urban development. Cities rely on energy for transportation, industry, and daily life, making it a key factor in environmental impact and economic stability. Analyzing energy consumption and production helps identify inefficiencies, reduce waste, and promote cleaner energy alternatives. A well-planned energy system can improve resilience, lower emissions, and support long-term urban sustainability.

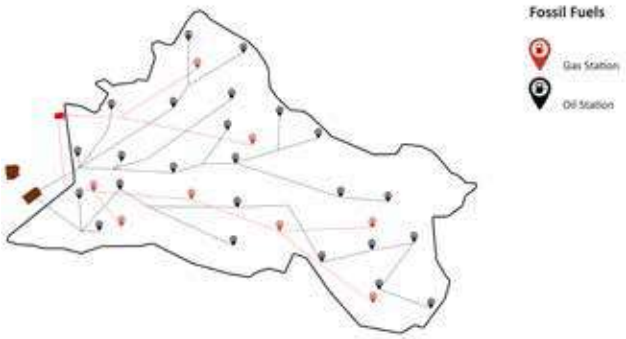
Energy Challenges in Tabriz

Tabriz faces several energy-related challenges that impact sustainability and efficiency. One of the main issues is the city's heavy reliance on fossil fuels, particularly natural gas, which contributes to air pollution and greenhouse gas emissions. Despite the presence of renewable energy potential, the transition to cleaner energy sources has been slow due to infrastructure limitations and economic constraints.

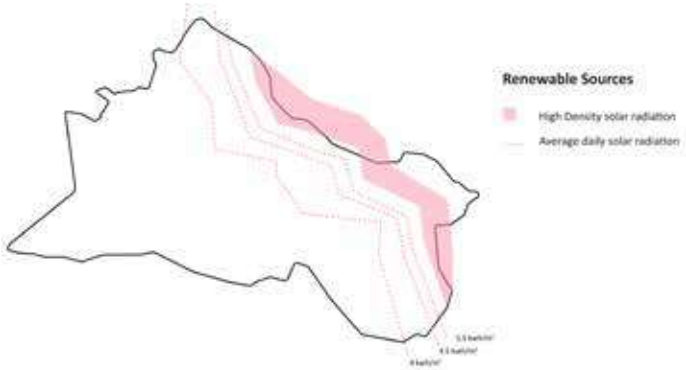
Energy distribution is another critical challenge. The electricity grid experiences inefficiencies, leading to energy losses during transmission. Additionally, rapid urbanization and population growth increase energy demand, putting pressure on existing infrastructure. Ensuring a stable and efficient energy supply requires investment in modernization and smart grid technologies.

Moreover, seasonal variations affect energy consumption patterns. Cold winters lead to higher demand for heating, while hot summers increase electricity use for cooling. Managing these fluctuations effectively is necessary to prevent shortages and improve energy resilience.

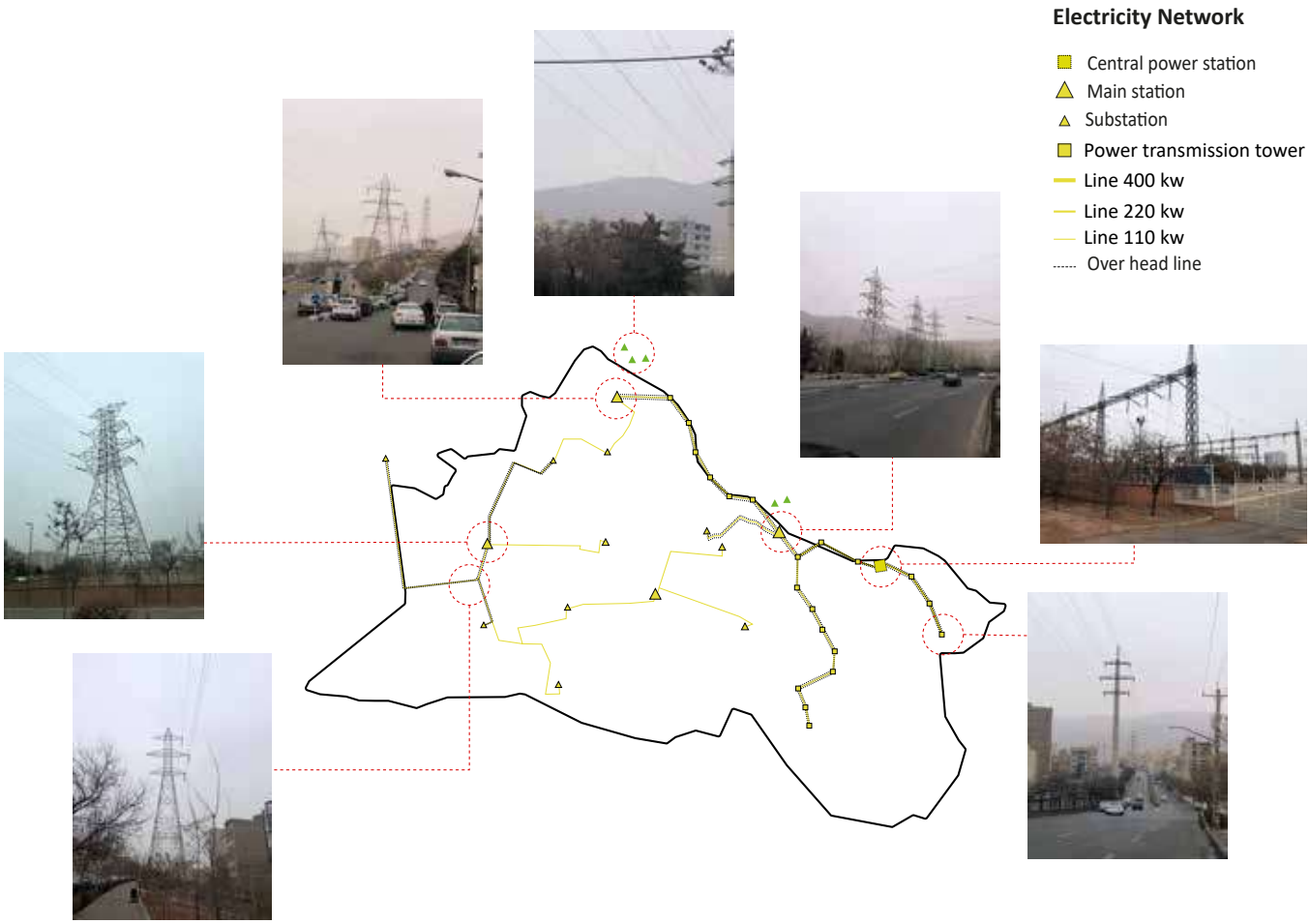
This research investigates the energy flow in Tabriz, focusing on electricity and natural gas. The city's energy system is analyzed based on its electricity network, energy production sources, and overall consumption patterns. A map has been prepared to illustrate the electricity grid, energy production sites, and key energy sources. It includes fossil fuel-based power plants, wind (eolic) energy systems, and areas with potential for renewable energy development. This visual representation helps to understand the distribution and connectivity of energy infrastructure across the city.



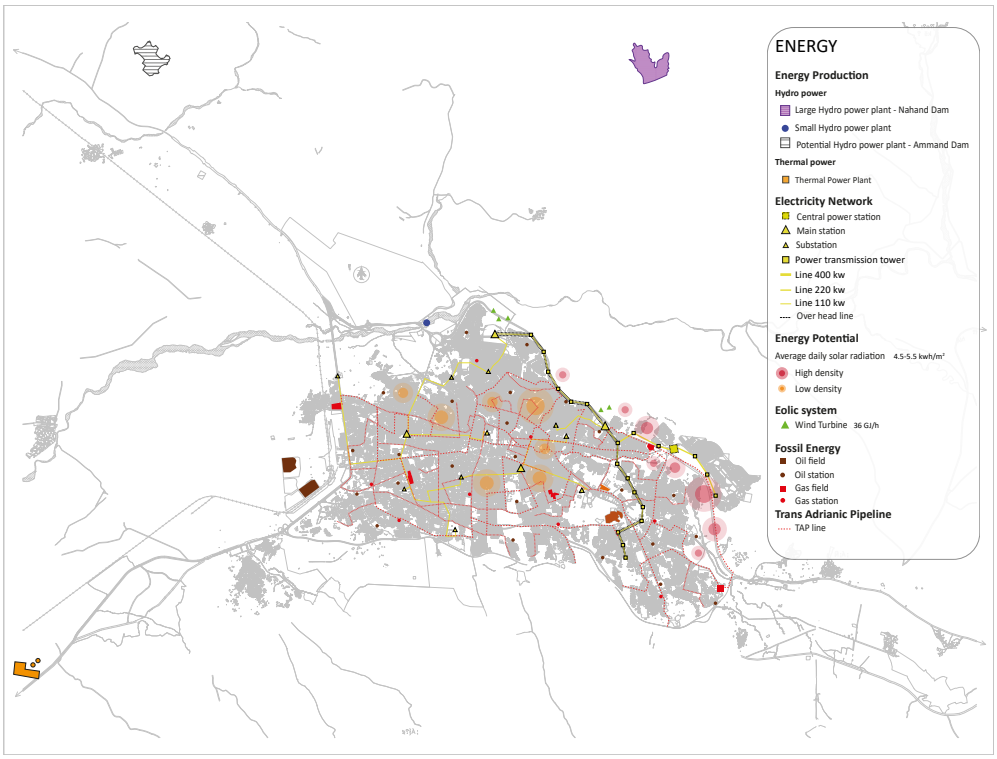
By examining these energy flows, the study aims to assess the efficiency of the current system and explore opportunities for a more sustainable energy future. Reducing dependence on fossil fuels and integrating renewable energy sources are key considerations for improving urban sustainability.



These three maps provide a detailed visualization of the electricity network with real photos, highlight the most suitable areas for solar systems like photovoltaic cells based on daily solar radiation, and show the distribution of oil and gas stations across the city.



Energy flow statistical analysis



Energy is a vital component of urban metabolism, influencing the economic, environmental, and social dynamics of a city. This section examines the energy flow in Tabriz, focusing on key aspects such as energy production, consumption patterns, and the efficiency of energy distribution systems. By analyzing data on energy integration, the study seeks to assess the city's energy efficiency and its environmental impact. This analysis provides valuable insights into the opportunities for optimizing energy use, reducing waste, and transitioning towards more sustainable energy practices in Tabriz's urban system. In this part some data about different aspects of Energy Flow are collected.

Total Energy Supply & Sources

Category	value
Total Energy Supplied (per year)	~3.5-4.5 million MWh/year
Primary Sources of Energy	50-60% Fossil Fuels (Natural Gas, Oil), 10-20% Hydro, 10-20% Renewable (solar, wind)

Energy Consumption by Sector

Category	value
Household Energy Consumption (per year)	~2000-2500 kWh/year
Total Household Energy Consumption (per year)	~3.4-4.3 million MWh/year
Energy Consumption by Sector (Industrial)	~30-40% of total energy consumption
Energy Consumption by Sector (Transport)	~20-30% of total energy consumption
Energy Consumption by Sector (Commercial)	~10-20% of total energy consumption

Energy Distribution & Infrastructure

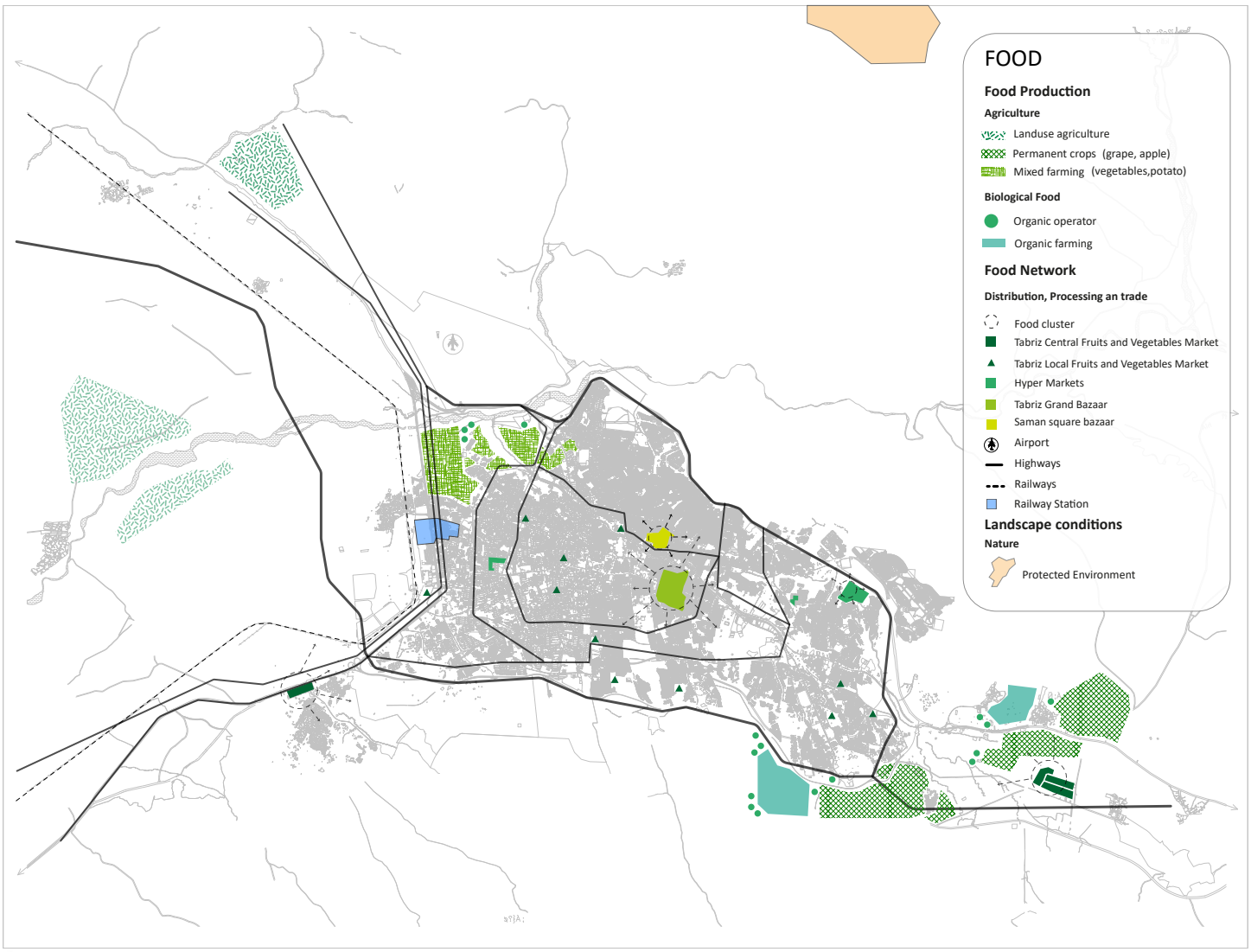
Category	value
Energy Loss During Distribution	~5-15% of total energy distributed
Length of Energy Distribution Network	~3500-4500 km (electricity, gas pipelines)
Energy plants	~5-8 plants (mostly thermal, few renewable)

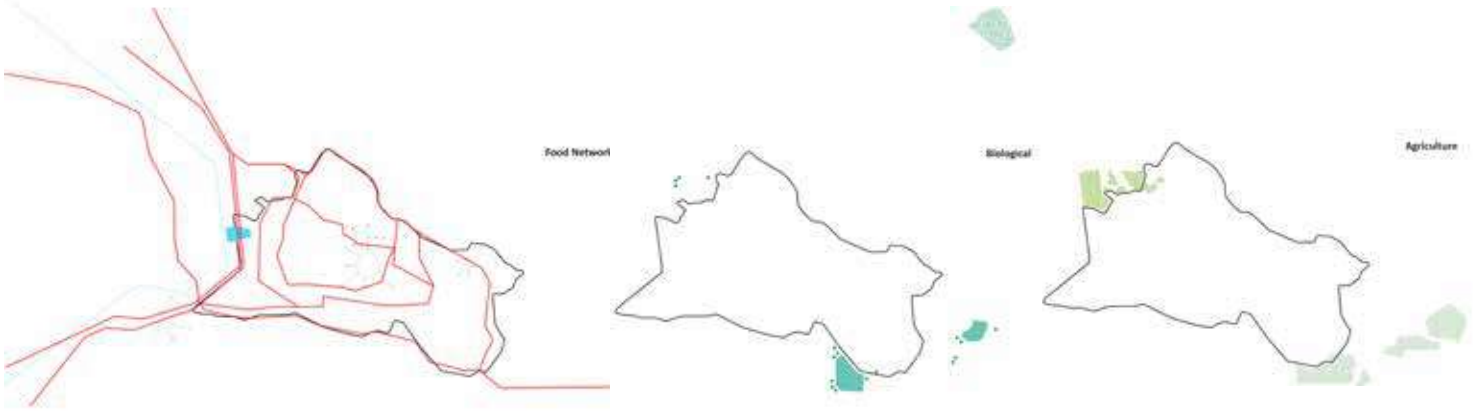
Renewable Energy

Category	value
Total Renewable Energy Generated (per year)	~350000-700000 MWh/year
Share of Renewable Energy in Total Supply	~10-20% of total energy supply
Types of Renewable Energy Used	Solar,Wind, Hydropower
Number of Renewable Energy Facilities	~2-5 facilities (solar farms, wind turbines)

* Renewable energy share has been estimated based on Iran's ongoing push toward renewable energy and may be more limited in Tabriz.

2.4.3. FOOD FLOW

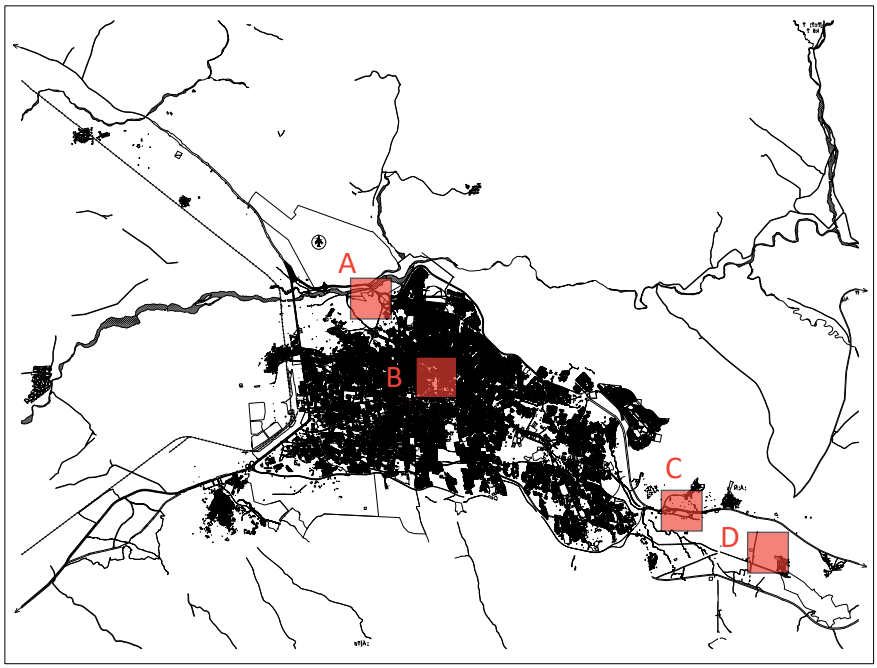




Food flow plays a crucial role in urban metabolism, influencing sustainability, resource management, and food security. Understanding how food is produced, distributed, and consumed helps identify inefficiencies and opportunities for a more resilient food system.

This research examines the food production and distribution network in Tabriz, highlighting key food sources, markets, and agricultural areas. The study maps out major agricultural zones, including regions dedicated to organic and biological food production. Additionally, the food distribution network is analyzed, showing the connections between production sites, storage facilities, wholesale markets, and retail outlets. By visualizing these food flows, the research aims to assess the efficiency of the current system and explore ways to improve accessibility, reduce food waste, and support sustainable agricultural practices. Strengthening local food networks and promoting environmentally friendly farming methods can contribute to a more resilient and self-sufficient urban food system.

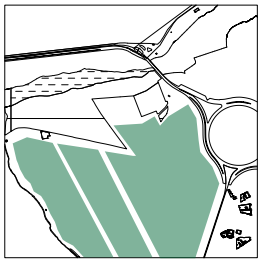
Anallyzing current system

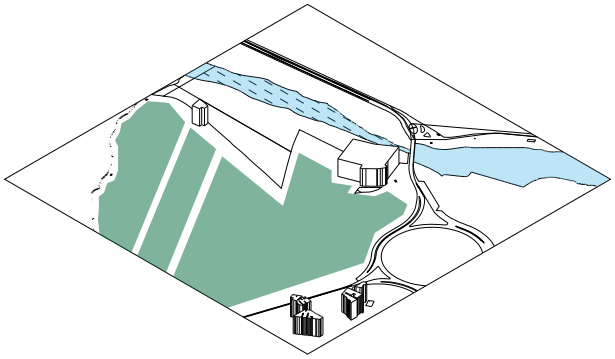


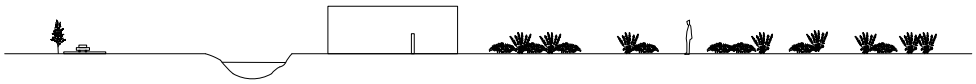
For analyzing current food flow system, four area have been chosen based on the type of production. Area A refers to Mixed Farming area producing mainly vegetables, Area B refers to main local markert of citiy, Tabriz Bazaar, Area C refers to Organic Farming and Permanent Crops and finally Area D refers to main local market of selling Fruits and Vegetabels. In the following part, plans, sections, xonometric views have been collected.

Understanding the point that how food flow works in Tabriz can be useful for detecting the weaknesses of system and getting into possible solutions for incresing the quality of system.

Area A: Mixed Farming - Vegetables, Potato

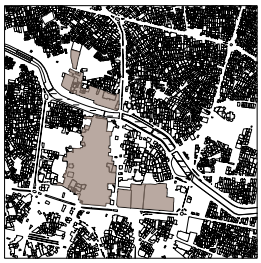


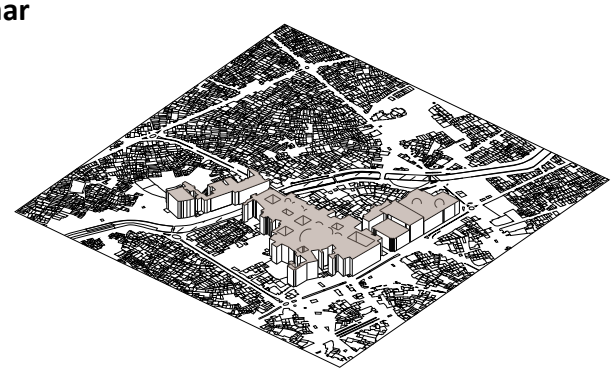




Mixed cropping is a cropping technique in which different types of crops are cultivated together on the same field or land so that nutrient requirements are shared. This reduces risk and gives some insurance against the failure of one of the crops.
Hokm Abad district is the name of this area which mainly produce different types of fresh vegetables for urban use.

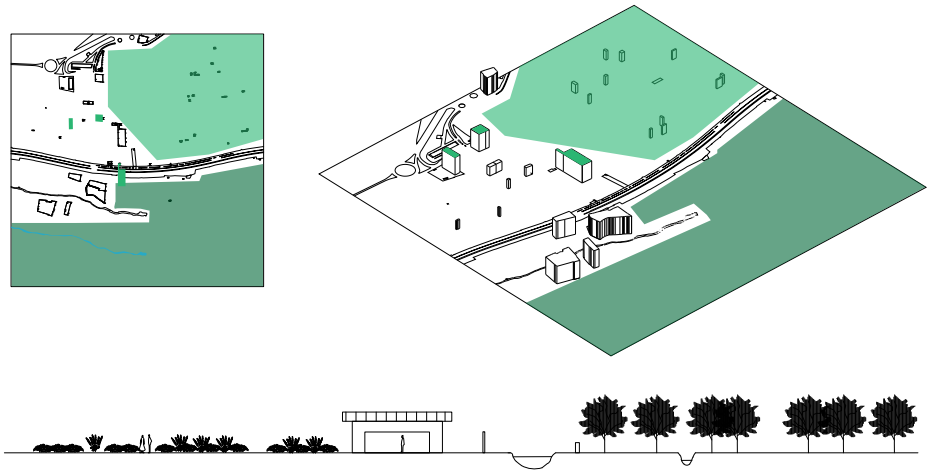
Area B: Tabriz Grand Bazaar





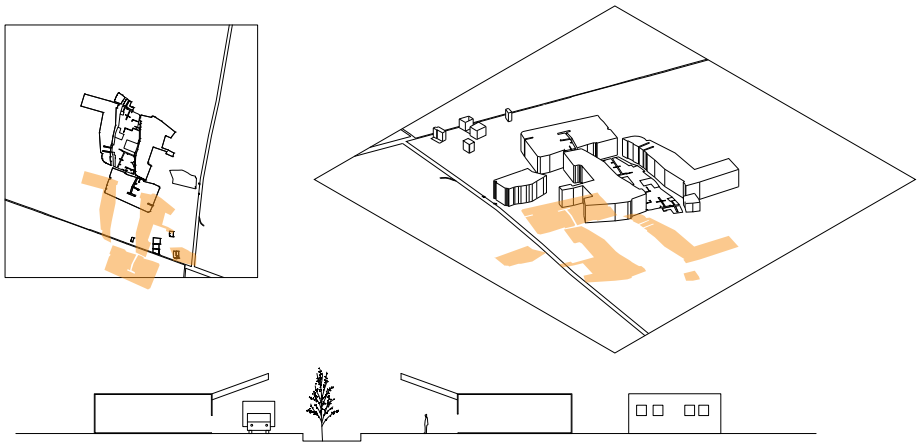
The Bazaar of Tabriz is a historic market in central Tabriz, Iran. It is one of the oldest bazaars in the Middle East and the largest covered bazaar in the world. It is one of Iran's UNESCO World Heritage Sites.
In this bazzar you can find different edible products, nuts, spice. On one side of the bazaar, you will be amazed by the astonishing gold and on another side, you can find handicrafts.

Area C: Organic Farming - Permanent Crops (apple)



Organic farming, also known as organic agriculture or ecological farming or biological farming, is an agricultural system that emphasizes the use of naturally occurring, non-synthetic inputs, such as compost manure, green manure, and bone meal and places emphasis on techniques such as crop rotation, companion planting, and mixed cropping. In this area mainly, organic vegetables and egg are produced.

Area D: Main Local Market of Fruits and Vegetables



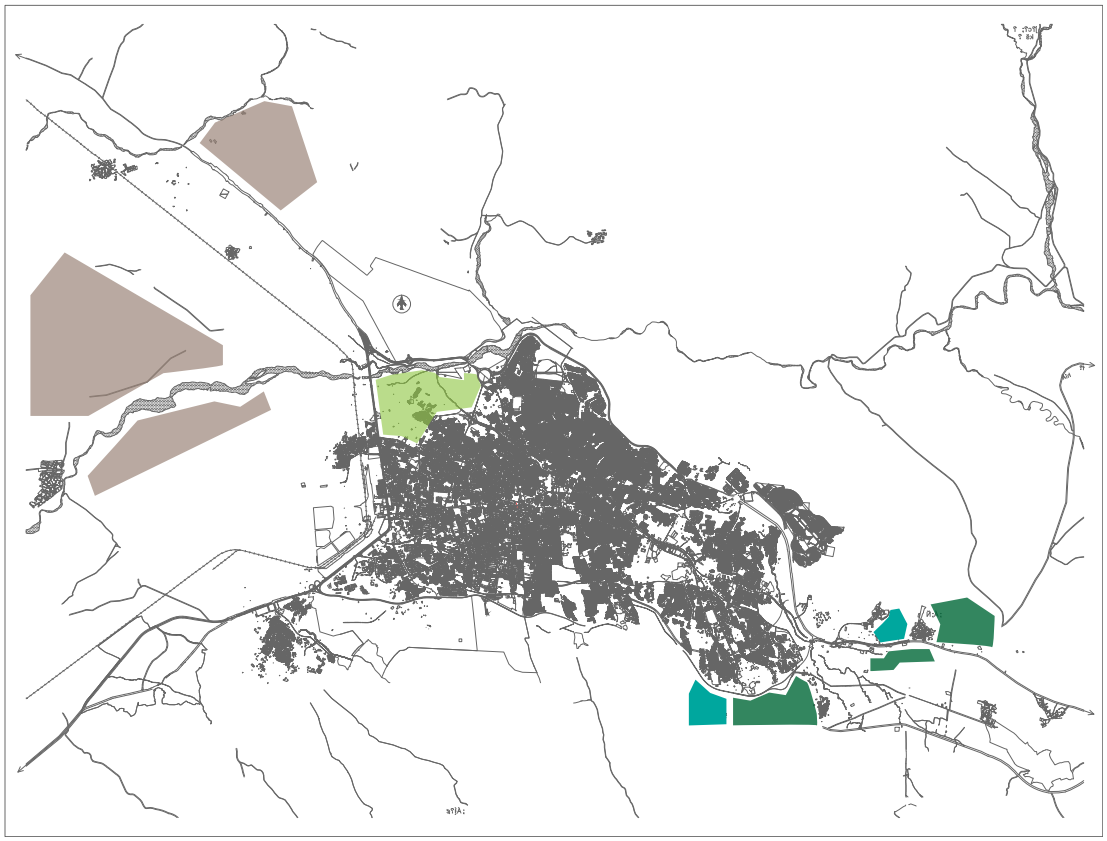
This area, named Khavaran market of fruits and vegetables, is one of the main spots to distribute vegetables and fruits to Tabriz. Being a very bid local market, this area consists of many little friut shops.

Food Flow Analysis and Its Importance in Urban Metabolism

Food flow analysis plays a critical role in understanding the urban metabolism of a city. In the case of Tabriz, there are several key spots that contribute to the production and distribution of food. These include areas such as mixed farming, organic farming, and permanent crops, particularly the apple orchards, which are vital for food production. For food distribution, important hubs like shopping centers, the Grand Bazaar of Tabriz, fruit and vegetable markets, and local grocery stores play a significant role.

If the food production and distribution system is thoroughly analyzed and evaluated, it can help in identifying the strengths and weaknesses within the system. A comprehensive understanding of food flow dynamics allows city planners to pinpoint areas where improvements can be made to enhance efficiency, sustainability, and resilience. By examining this flow in detail, it becomes possible to optimize resource allocation, reduce food waste, and increase the overall food security of the city. Furthermore, this approach can highlight critical gaps in supply chains, logistical bottlenecks, and underperforming sectors that may require attention. A deeper understanding of the food flow system can also contribute to enhancing the city's environmental sustainability by optimizing transportation routes and reducing the carbon footprint associated with food supply. Ultimately, food flow analysis helps us to build a more robust, resilient, and efficient food system in Tabriz, benefiting both its residents and the broader urban ecosystem.

Food flow statistical analysis
Food Production



Landuse Argriculture
(Mainly wheat)

Mixed Farming
(Mainly Leaf Vegetables)

Permanent Crops
(Mainly Apple, Grape)

Organic Farming
(Tomato, strawberry, mushroom,cucumber,...)

Total production rate of TABRIZ CITY / Annually

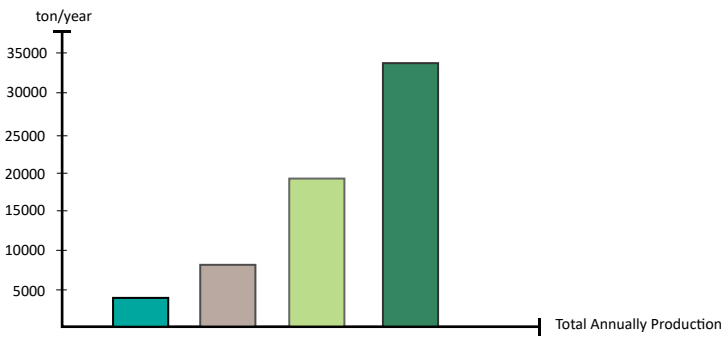
Area: 20 km² = 2000 hectares.
Average yield per hectare: 4 tons per hectare annually.
Annual production: 8,000 ton/y

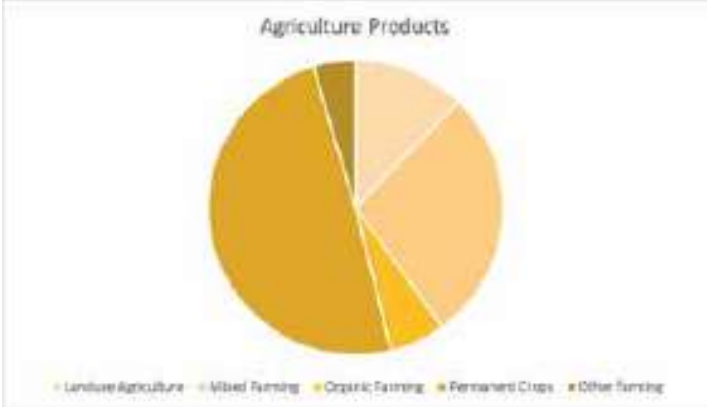
Area: 6 km² = 600 hectares.
Average yield per hectare: 30 tons per hectare annually.
Annual production: 18,000 ton/y

Area: 8 km² = 800 hectares.
Average yield per hectare: 40 tons per hectare annually.
Annual production: 32,000 ton/y

Area: 4 km² = 400 hectares.
Average yield per hectare: 10 tons per hectare annually.
an average organic yield for mixed crops
Annual production: 4,000 ton/y

Tabriz County (consisting of Tabriz city, 3 other cities and 90 villages) have 110 hectares of pastures, 3600 hectares of gardens and 44 thousand hectares of agricultural land in Tabriz, including 22 thousand hectares of rainfed lands and 22 thousand hectares of irrigated lands.
According to the announcement of the Agricultural Jihad, the annual production of agricultural products in Tabriz city is 267 thousand tons, of which approximately 65 thousand tons are related to the production of Tabriz city itself.





Resource: SCI (Statistic Center of Iran), Ministry of Agriculture Jihad, IFDA (Iran Food and Drug administration

Food Distribution and Retail

- Number of food markets, supermarkets, and grocery stores
- Percentage of food sold in traditional vs. modern markets
- Food supply chains and logistics

1. Number of Food Markets, Supermarkets, and Grocery Stores

In Tabriz, as in many large cities in Iran, there's a mix of traditional markets (bazaars) and modern retail outlets. Here's a breakdown:
Traditional Markets (Bazaars)
- Tabriz is known for its historic bazaar, which is one of the largest and most important in Iran
- The Tabriz Grand Bazaar serves as a central hub for various products, including fresh produce, spices, dairy, and meat
- There are likely dozens of smaller traditional food markets throughout Tabriz, catering to local neighborhoods.
- Supermarkets: The larger supermarkets in Tabriz typically include well-known national chains, such as Shahrvand (a major chain in Iran), Hyperstar, and Refah, Ofogh Koorosh. There are probably around 40 large supermarkets across the city, particularly in urban areas.
- Hyper markets: Known as HyperMe, tabriz has three main hyper markets in Lale park, Atlas and Setareh malls

2. Percentage of Food Sold in Traditional vs. Modern Markets

- Traditional Markets (Bazaars): Around 50-60% of total food sales, especially in terms of local produce and traditional foods.
- Modern Markets (Supermarkets and Grocery Stores): Around 40-50% of food sales. This includes processed foods, packaged goods, imported products, and more convenience-oriented food options.

3. Food Supply Chains and Logistics

- Agricultural Production: Tabriz is located in a major agricultural zone of Iran, so a significant portion of the city's food supply is sourced locally from nearby farms. These include fruits (apples, pomegranates), vegetables (tomatoes, lettuce), grains, dairy, and livestock (cattle, sheep).
- Farmers' Markets and Wholesale Markets: Local farmers and producers often sell their goods to wholesalers or directly at traditional markets. Some of the larger wholesale markets might operate near Tabriz's main bazaars or on the outskirts of the city.

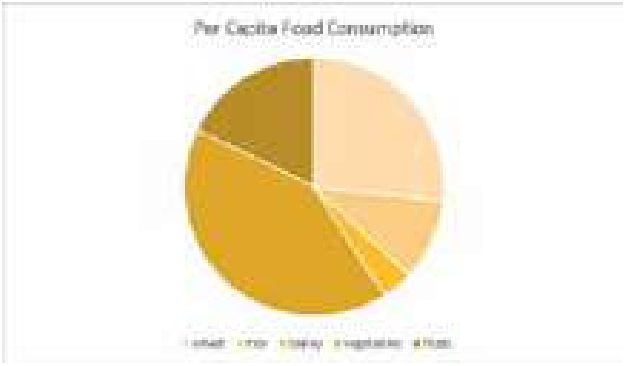
Transportation and Logistics
- Trucks and Distribution Centers: Food products are typically transported via trucks, and there are likely distribution centers on the outskirts of Tabriz where fresh produce, dairy, and packaged foods are stored before being distributed to local markets and supermarkets.
- Cold Chain: For perishable goods like dairy, meat, and certain fruits and vegetables, the cold chain logistics system is crucial. Modern supermarkets and stores usually have refrigerated transport to ensure the freshness of these items.
- Import and Export: Tabriz's proximity to international borders (such as with Turkey and Armenia) means that imported food products, particularly grains, processed foods, and packaged goods, can enter through regional border crossings and be distributed to supermarkets and wholesale markets.
Processing and Packaging
- Food Processing Industries: As Tabriz has a number of food processing industries (such as for dairy, canned fruits, juices, and other food products), processed foods also play a key role in the food supply chain. Products from local food processing plants (such as dairy or canned fruit) are distributed both within Tabriz and to other regions of Iran.

Resource: SCI (Statistic Center of Iran), Ministry of Agriculture Jihad, IFDA (Iran Food and Drug administration

Food Consumption

- Per capita food consumption (grains, meat, dairy, vegetables, etc.)
- Dietary habits and nutritional intake in Tabriz
- Food expenditure per household

1. Per Capita Food Consumption (in Tabriz)



Grains (Wheat, Rice, Barley)
Wheat: 80-100 kg/year
Rice: 30-40 kg/year
Barley: B 10-15 kg/year

Vegetables and Fruits
Vegetables: 100-150 kg/year
Fruits: 50-70 kg/year

2. Dietary Habits and Nutritional Intake

Traditional Diet: The diet is rich in fruits, vegetables, grains, dairy products, meat and chicken.
Fruits and Vegetables: Fresh seasonal fruits like apples, grapes and green leafy vegetables.

3. Food Expenditure per Household

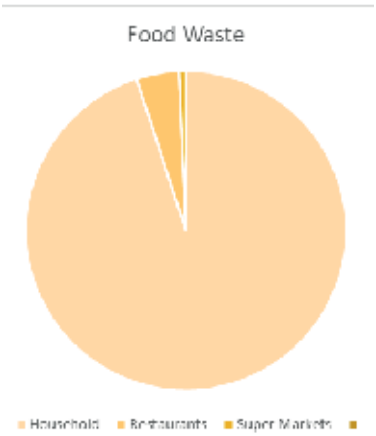
According to Iranian data, around 30-40% of a typical household's budget is spent on food
Average Monthly Household Food Expenditure: In Tabriz, the average monthly expenditure on food might range from 150,000,000 IRR to 200,000,000 IRR (Iranian Rials) per month for a family of 4.
This converts to around 150-200 USD monthly for food per household (depending on exchange rates).

Number of food processing industries: Around 50 to 100 (small, medium-sized businesses as well as larger ones)

Food Waste and Loss

- Amount of food waste generated per capita
- Waste from households, restaurants, and supermarkets

Households:
- Waste per capita: 30-40 kg/year per person.
- Total household waste: For a population of 1.8 million, assuming 60% of the population generates food waste consistently, this would amount to: 1.08 million people × 30-40 kg = 30,600 to 40,800 tons per year.



Restaurants:
- With about 1,500 restaurants in Tabriz (a rough estimate), each generating 600-1200 kg/year of food waste, we can estimate:
1,500 × 600-1200 kg = 900 to 1800 tons per year

Supermarkets:
- Assuming 50 large supermarkets generate an average of 3600 kg/year of food waste:
50 supermarkets × 3600 kg = 180 tons per year

Resource: SCI (Statistic Center of Iran), Ministry of Agriculture Jihad, IFDA (Iran Food and Drug administration

2.4.4. Waste flow

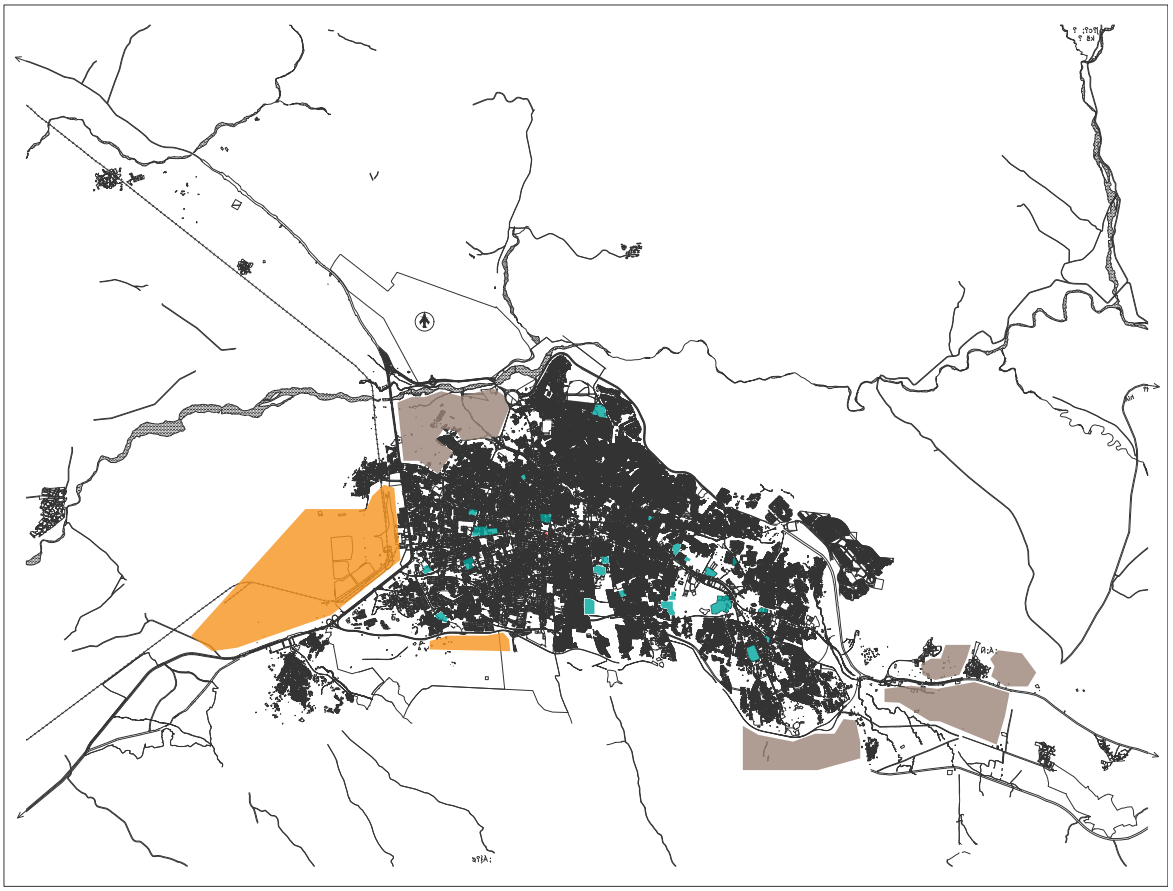
Importance of Studying Waste Flow in Tabriz

Waste management is a crucial aspect of urban sustainability, directly impacting public health, environmental quality, and resource efficiency. In a growing city like Tabriz, where urban expansion, population increase, and industrial activities continuously generate large amounts of waste, understanding the waste flow is essential for developing effective strategies to reduce pollution, improve recycling rates, and enhance the overall livability of the city. This research will focus on a comprehensive analysis of waste flow in Tabriz by examining the current waste management system, identifying existing challenges, and exploring potential opportunities for improvement. The study will first assess the existing situation, including the volume of waste produced, the types of waste generated, and the efficiency of collection, transportation, and disposal methods. It will also investigate the role of different stakeholders, including municipal authorities, private sector participants, informal waste collectors, and the general public, in shaping waste management practices. Additionally, this research will analyze the key challenges associated with waste flow in Tabriz. These challenges include inadequate waste sorting at the source, limited recycling infrastructure, the prevalence of illegal dumping, and the lack of public awareness regarding proper waste disposal practices. By highlighting these issues, the study aims to provide a clear picture of the gaps in the current system that need to be addressed.

On the other hand, opportunities for improving waste flow will also be explored. Tabriz already has some strengths, such as an existing municipal waste collection system, a composting facility, and a strong informal recycling sector. By leveraging these opportunities and implementing innovative policies and technological advancements, the city can move towards a more efficient and sustainable waste management system.

Waste flow statistical analysis

Waste Production



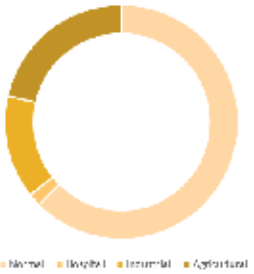
Types of waste

Normal waste
Household waste and construction debris

Hospital waste
Infectious and harmful waste from hospitals

Agricultural waste
Produced by activities in the agricultural sector

Industrial waste
Produced by industrial and mining activities



Waste Management in Iran:

Compost production in Iran started in 1967 in Isfahan. In 1969, Tehran built its first compost factory in Saleh Abad with help from an English company. After the 1979 revolution, the Fertilizer Headquarters planned compost factories in five major cities (Isfahan, Rasht, Tabriz, Mashhad, and Shiraz) by 1982. In 1991, Tehran Municipality created an organization to manage waste. The most important legal step in waste management was the approval of the Waste Management Law in 2004.

Waste Composition in Tabriz (By source)

Waste Type	Per Day (tons)	Per Month (tons)
Normal Waste (MSW)	1020-1360	30600-40800
Hospital Waste	20-27	600-810
Agricultural Waste	275-415	8300-12500
Industrial Waste	204-272	6120-8160
Total Waste	1519-2074	45620-62270

Key Insights:
Municipal solid waste (MSW) is the largest waste source (~60-70% of total).
Agricultural waste is significant but seasonal.
Industrial waste is growing due to urbanization and industrial expansion.
Hospital waste is smaller but hazardous, requiring special treatment.

Waste Composition in Tabriz (By type)

Waste Type	Percentage (٪)	Estimated Daily Waste (Tons)
Organic Waste (Food, Green Waste, etc.)	55-60%	561-816
Plastics	10-15%	102-204
Paper & Cardboard	10-12%	102-163
Glass	3-5%	30-68
Metals	2-4%	20-54
Other Waste (E-waste, textiles, hazardous waste, etc.)	5-10%	51-136

Resources: Tabriz Municipality, Iranian Department of Environment (DOE), Iranian Ministry of Waste Management Office, Materials Recycling and Conversion Organization

Waste Collection and Transportation

1. Number of Waste Collection Trucks Operating in Tabriz

~150 - 200 trucks are likely operating in Tabriz, based on the city's size and waste management needs.

2. Total Waste Collected per Day (Tons)

Total Municipal Solid Waste (MSW) per day is: 1,020 - 1,360 tons/day

3. Collection Efficiency (% of Total Waste Collected vs. Generated)

Typically, 85-95% of generated waste is collected in cities with relatively well-developed waste management systems. However, in some cases, inefficiencies may cause lower collection rates.

4. Frequency of Waste Collection

In Tabriz, waste collection is likely daily in residential areas. In commercial and industrial zones, it may be more frequent, possibly multiple times per day. Street cleaning and public spaces may have less frequent collection, such as every other day or bi-weekly.

5. Percentage of Waste Improperly Disposed of (Dumped in Open Areas, Littering)

Typically, in many cities, the percentage of waste improperly disposed of can range between 5-20%, especially in areas without strong waste management enforcement. For Tabriz, a reasonable estimate is 10% of the total waste being improperly disposed of, due to issues like littering, illegal dumping, or lack of access to proper waste bins in some areas.

Summary of Waste Collection Data for Tabriz

Waste Management Factor	Estimated Value
Number of Waste Collection Trucks	150-200 trucks
Total Waste Collected per Day	1020-1360 tons per day
Collection Efficiency	90%
Frequency of Waste Collection	Daily (residential); more frequent for commercial/industrial zones
Improper Waste Disposal	10% (illegal dumping, littering, etc.)

Waste Treatment and Recycling

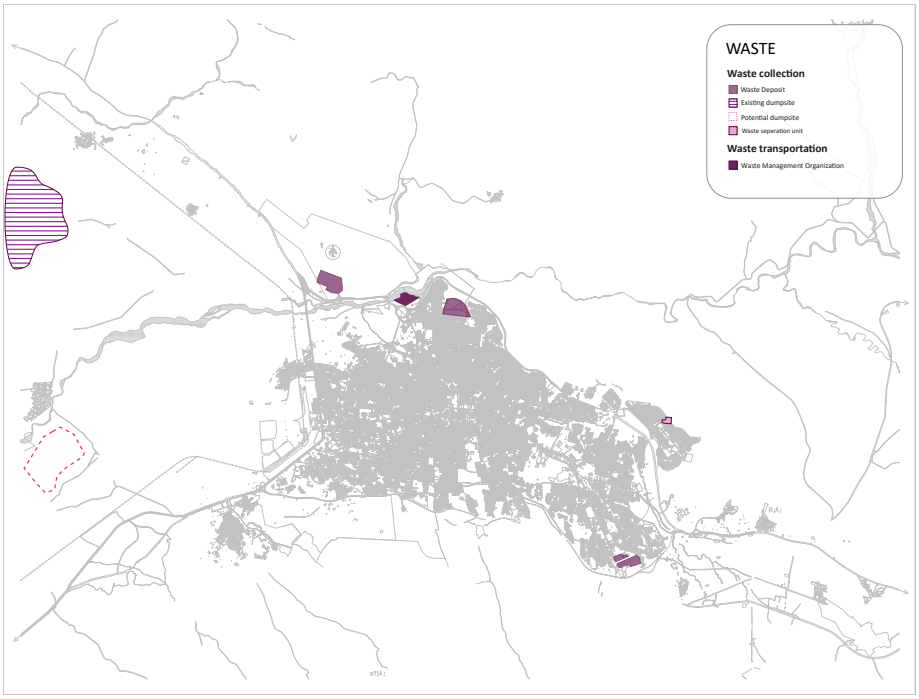
Recycling in Tabriz is inefficient, with only 10-20% of waste recycled. Public awareness is low, and waste separation at the source is rare, making recycling difficult. The city also lacks proper equipment and infrastructure, with few specialized bins and outdated facilities. As a result, most waste ends up in landfills, increasing pollution. Better waste collection, modern equipment, and public awareness programs are needed to improve recycling. Here's the waste treatment & recycling data in a table format:

Category	Value
Total Waste Recycled Per Year	~37,000 tons (10% of total waste)
Number of Recycling Facilities	5-10 facilities (paper, plastic,glass,organic waste...)
Recycling Programs	Government initiatives + private sector involvement
Organic Waste Composted	~20,000 tons per year (15% of organic waste)
Plastic Waste Recycled	~7,400 tons per year (25% of plastic waste)
E-Waste Recycled *	~340 tons per year (10% of total e-waste)

*E-waste recycling is limited in Iran, and collection is not fully organized.

Resources: Tabriz Municipality, Iranian Department of Environment (DOE), Iranian Ministry of Waste Management Office, Materials Recycling and Conversion Organization

Landfills & Waste Disposal



Number of Landfills in Tabriz

1 major landfill - 1 proposed

Total Waste Sent to Landfills Per Year

Waste that is not recycled, composted, or recovered goes to landfills.
Estimated landfill disposal rate: ~70-80% of total waste.
Waste sent to landfills per year: (70-80%) × (394200-525600)* = ~270000-400000 tons per year

* The total waste generated per year (372,300 – 496,400 tons) comes from estimating per capita waste generation based on:
Population of Tabriz → ~1.8 million people
Per capita waste generation → 0.6 – 0.8 kg per person per day (a typical range for Iranian cities)

Percentage of Waste Going to Landfills vs. Recycling/Composting

Waste Management Method	Percentage of Total Waste
Landfills	70-80%
Recycling	10-20%
Composting (Organic Waste)	10-15%

Capacity & Lifespan of Existing Landfills

~20-30 years before full capacity.

Key Takeaways

Recycling & composting efforts exist but are limited (most waste goes to landfills).
Plastic & e-waste recycling rates are low, requiring better collection programs.
Landfills are the main disposal method, with growing environmental concerns.

Environmental Impact Metrics (Methane Emissions & Groundwater Contamination)

Landfills generate methane (CH_4) from decomposing organic waste. Methane capture systems are not widespread in Iran, leading to emissions.
Groundwater contamination risk: Older landfills without proper lining can leak pollutants into groundwater.

2.5. OPPORTUNITIES AND CHALLENGES

Investigating Opportunities and Challenges in DOCA Methodology

A key part of the DOCA methodology is identifying the opportunities and challenges within a city's resource flows. Every urban system has strengths that can be expanded and weaknesses that need solutions. By studying these factors, we can gain insights into how cities use water, energy, food, and waste, and how they can improve these systems for long-term efficiency, sustainability, and resilience. In the case of Tabriz, this analysis helps us understand how natural resources, infrastructure, and policies interact in shaping the city's metabolism. It also provides a foundation for improving urban planning, governance, and environmental management to create a more sustainable future.

Why Investigating Tabriz's Opportunities and Challenges is Important

Tabriz, as one of Iran's largest and most industrialized cities, faces both advantages and limitations in managing its resource flows. Understanding these aspects is crucial for several reasons:

- Water Management: Tabriz relies on multiple water sources, including Ammand Dam, Nahand Dam, and underground water reserves. However, the city faces water shortages, with an increasing gap between water supply and demand. Identifying opportunities such as water recycling and efficiency programs, as well as challenges like over-extraction and pollution, can help improve long-term water security.

- Energy Supply & Consumption: Tabriz is home to key energy infrastructure, including Tabriz Power Plant and a strong natural gas distribution network. However, high energy consumption in industries and households, along with limited renewable energy adoption, presents a challenge. Finding solutions such as solar energy expansion and energy efficiency programs could help balance supply and demand.

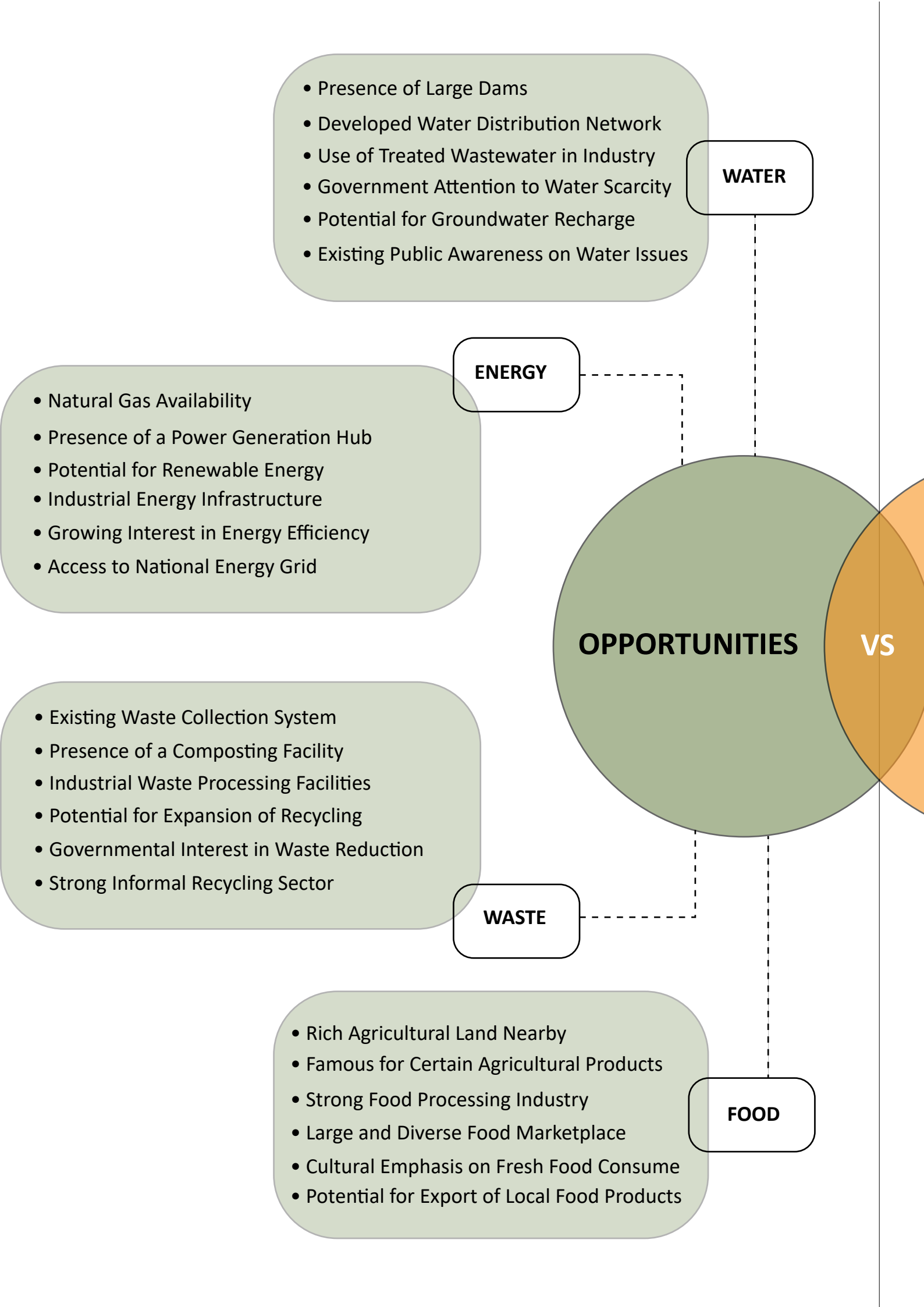
- Waste Management: Tabriz generates over 1,200 tons of municipal solid waste per day, but only a small percentage is recycled or composted. The city has some waste processing facilities, but informal waste collection and illegal dumping remain issues. Strengthening recycling programs and public awareness on waste separation could improve waste management outcomes.

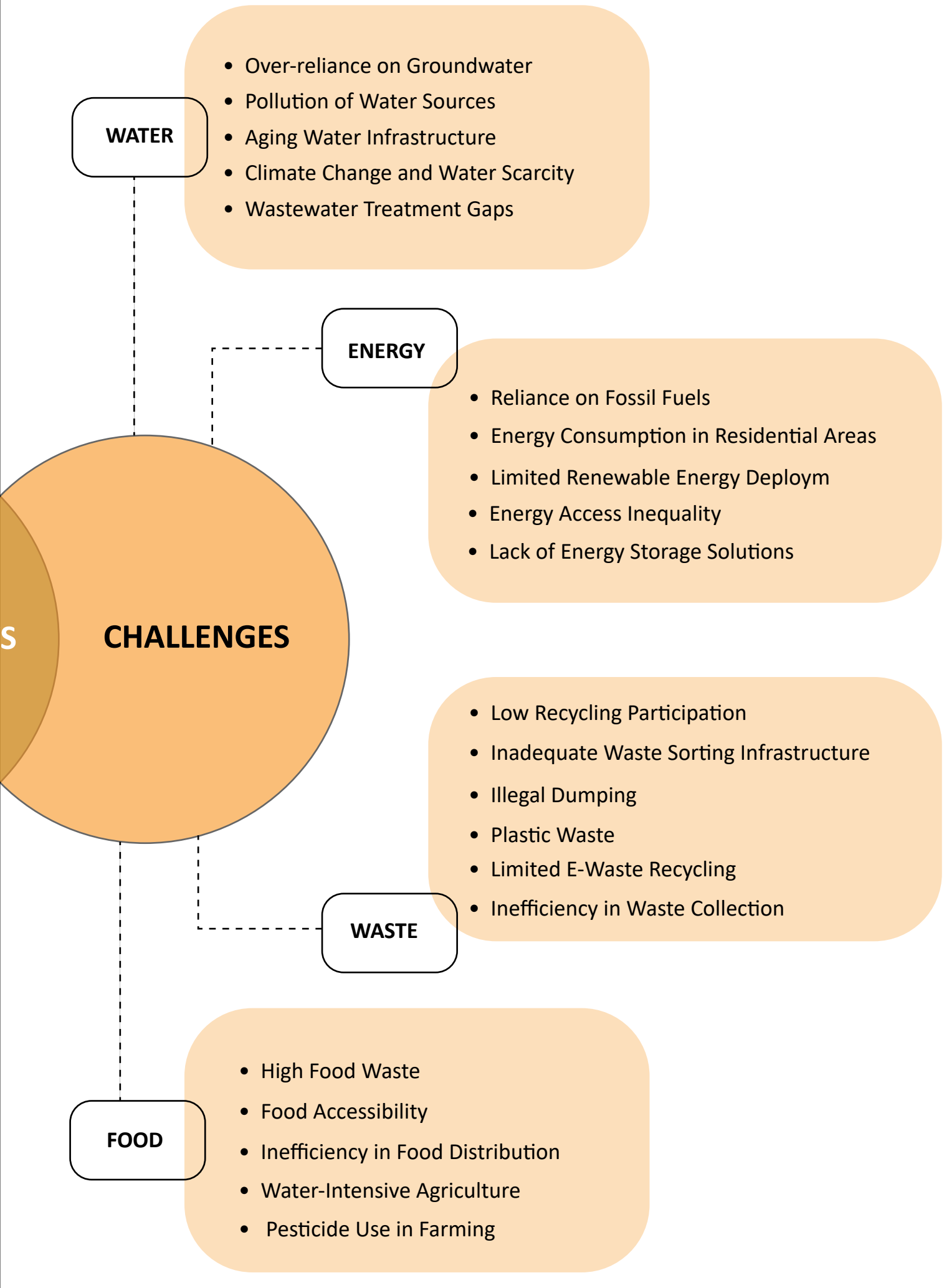
- Food System & Distribution: Tabriz benefits from strong agricultural production in nearby regions, such as Marand and Shabestar, which supply fruits, vegetables, and dairy. However, food waste remains a concern, and the efficiency of food supply chains and markets needs improvement.

By analyzing these factors, we can identify where the city is performing well and where action is needed, leading to better policies, improved infrastructure, and more balanced urban metabolism.

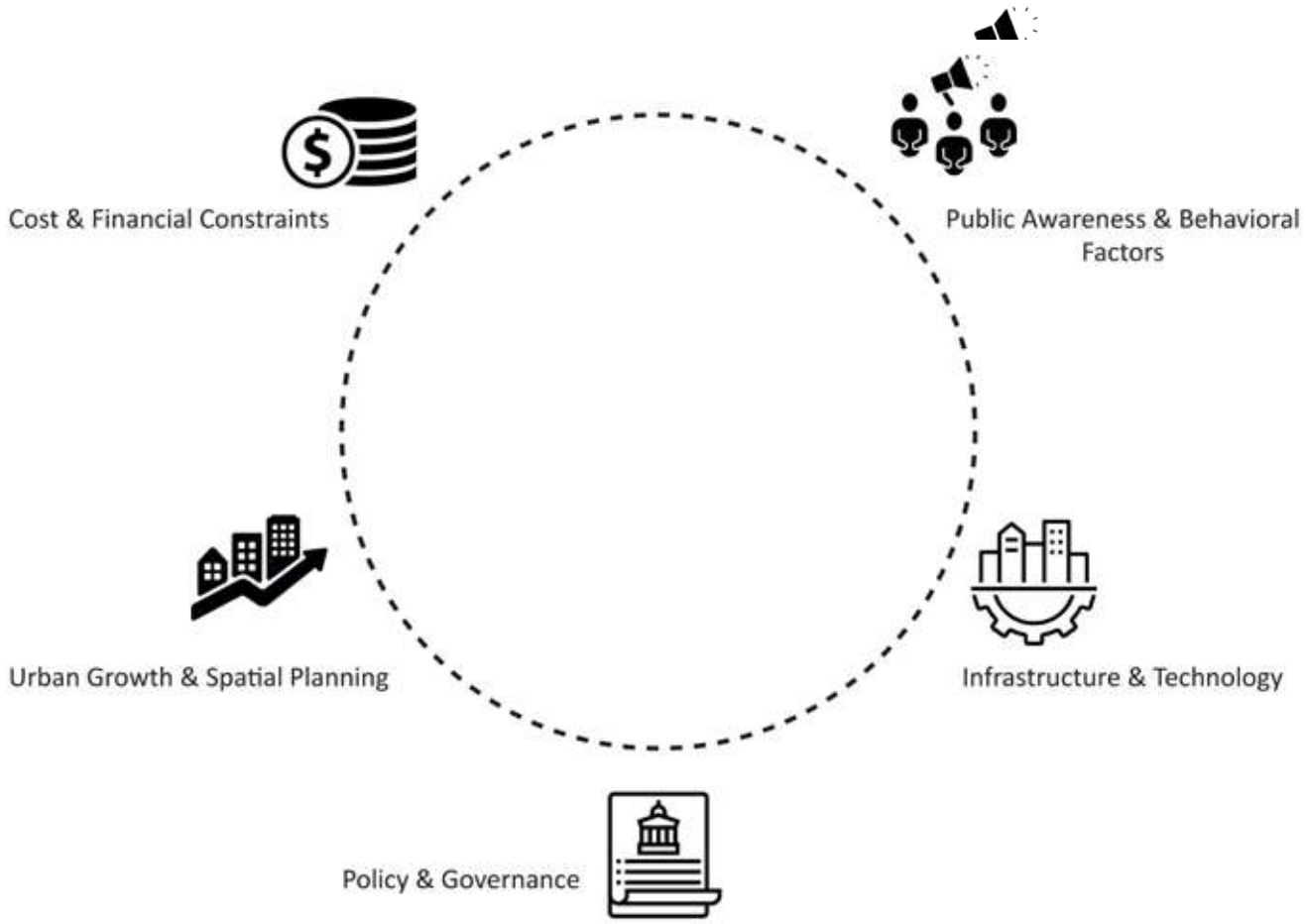
To identify the key opportunities and challenges in Tabriz's resource flows, a multi-faceted research approach was undertaken. First, field observations were conducted across different urban areas to assess how water, energy, food, and waste are managed in everyday life. Interviews with local residents provided insights into their consumption habits, concerns, and challenges they face regarding resource accessibility and efficiency. Additionally, discussions with experts, including urban planners, environmental specialists, and municipal officials, helped in understanding systemic issues, policy gaps, and potential areas for improvement. These qualitative findings were further supported by statistical data and reports from municipal offices and environmental organizations, allowing for a more comprehensive analysis of inefficiencies and opportunities.

Beyond individual behaviors and expert perspectives, spatial differences in resource management were also analyzed, particularly by comparing zones with contrasting socioeconomic conditions. This helped reveal how factors such as infrastructure, governance, and public awareness influence sustainability efforts in different parts of the city. By integrating direct observations, expert knowledge, and quantitative data, a holistic understanding of Tabriz's urban metabolism was developed. The following diagram visually presents the key opportunities and challenges identified across the four resource flows.


• Presence of Large Dams
• Developed Water Distribution Network
• Use of Treated Wastewater in Industry
• Government Attention to Water Scarcity
• Potential for Groundwater Recharge
• Existing Public Awareness on Water Issues
WATER
ENERGY
• Natural Gas Availability
• Presence of a Power Generation Hub
• Potential for Renewable Energy
• Industrial Energy Infrastructure
• Growing Interest in Energy Efficiency
• Access to National Energy Grid
OPPORTUNITIES
VS
• Existing Waste Collection System
• Presence of a Composting Facility
• Industrial Waste Processing Facilities
• Potential for Expansion of Recycling
• Governmental Interest in Waste Reduction
• Strong Informal Recycling Sector
WASTE
• Rich Agricultural Land Nearby
• Famous for Certain Agricultural Products
• Strong Food Processing Industry
• Large and Diverse Food Marketplace
• Cultural Emphasis on Fresh Food Consume
• Potential for Export of Local Food Products
FOOD


WATER
Over-reliance on Groundwater
Pollution of Water Sources
Aging Water Infrastructure
Climate Change and Water Scarcity
Wastewater Treatment Gaps
ENERGY
Reliance on Fossil Fuels
Energy Consumption in Residential Areas
Limited Renewable Energy Deploym
Energy Access Inequality
Lack of Energy Storage Solutions
CHALLENGES
WASTE
Low Recycling Participation
Inadequate Waste Sorting Infrastructure
Illegal Dumping
Plastic Waste
Limited E-Waste Recycling
Inefficiency in Waste Collection
FOOD
High Food Waste
Food Accessibility
Inefficiency in Food Distribution
Water-Intensive Agriculture
Pesticide Use in Farming

Prospective Glossary of the Tabriz Methabolism



Introduction to Key Categories for Analyzing Opportunities and Challenges

In order to systematically assess the opportunities and challenges in Tabriz's resource flows—water, energy, food, and waste—five key categories have been selected: Cost & Financial Constraints, Infrastructure & Technology, Public Awareness & Behavioral Factors, Policy & Governance, and Urban Growth & Spatial Planning. These categories provide a comprehensive framework for understanding the factors influencing resource management and sustainability in the city. Cost & Financial Constraints determine the feasibility of implementing new solutions, as economic limitations can hinder infrastructure upgrades and sustainability projects. Infrastructure & Technology focuses on the physical systems and innovations available to improve efficiency and reduce waste. Public Awareness & Behavioral Factors highlight the role of community engagement and everyday habits in resource consumption and waste generation. Policy & Governance examines the effectiveness of regulations and institutional while Urban Growth & Spatial Planning addresses how the city's expansion and land use impact resource flows. By analyzing opportunities and challenges through these five lenses, this study aims to highlight both the existing strengths of Tabriz and the barriers that must be overcome for sustainable urban metabolism. This approach is particularly useful in identifying which challenges arise due to financial or technological constraints, which are linked to governance inefficiencies, and which require cultural or behavioral shifts. Additionally, it allows for a targeted assessment of opportunities, such as leveraging existing infrastructure or policy support, to improve resource efficiency. Understanding these dynamics will provide actionable insights for policymakers, urban planners, and stakeholders, helping them prioritize interventions based on what is feasible, necessary, and impactful in different urban contexts

OPPORTUNITIES

Presence of Large Dams	○	●	○	○	●
Developed Water Distribution Network	○	○	○	●	●
Use of Treated Wastewater in Industry	●	○	○	○	●
Government Attention to Water Scarcity	●	○	●	○	○
Potential for Groundwater Recharge	○	●	○	○	●
Existing Public Awareness on Water Issues	●	○	●	○	○
Natural Gas Availability	○	●	○	○	●
Presence of a Power Generation Hub	●	○	○	○	●
Potential for Renewable Energy	○	○	●	○	●
Industrial Energy Infrastructure	○	○	○	●	●
Growing Interest in Energy Efficiency	●	○	●	○	○
Access to National Energy Grid	●	○	○	○	●
Existing Waste Collection System	●	○	○	○	●
Presence of a Composting Facility	○	○	○	●	●
Industrial Waste Processing Facilities	○	●	○	○	●
Potential for Expansion of Recycling	●	●	○	○	○
Governmental Interest in Waste Reduction	●	○	○	○	●
Strong Informal Recycling Sector	●	○	●	○	○
Rich Agricultural Land Nearby	○	○	○	●	●
Famous for Certain Agricultural Products	○	●	●	○	○
Strong Food Processing Industry	●	○	○	○	●
Large and Diverse Food Marketplace	○	●	○	●	○
Cultural Emphasis on Fresh Food Consume	●	○	●	○	○
Potential for Export of Local Food Products	●	●	○	○	○

Presence of Large Dams (Ammand and Nahand Dams)

Tabriz benefits from large water reservoirs like the Sahand and Nahand dams, which play a crucial role in regulating water supply. These dams are essential in meeting the city's water demand, particularly in the face of water scarcity due to the semi-arid climate of the region. Their strategic location ensures that water can be stored and released when needed, providing a buffer for agricultural and industrial needs, as well as residential consumption.

Relation to Key Factors:
- Cost & Financial Constraints: While maintaining dams requires significant financial investment, their existence reduces the need for expensive alternative water sources or extensive water importation.

- Infrastructure & Technology: The infrastructure for dam management and water distribution is already in place, enhancing efficiency in resource allocation.

Ammand Dam

Developed Water Distribution Network

Tabriz has a relatively developed water distribution network, making it easier for most residents to access clean potable water. The city's existing infrastructure has been built up over the years, and it covers a large part of the urban area, ensuring reliable service to homes and businesses. The network includes pipelines, reservoirs, and pumping stations, all working in tandem to deliver water efficiently.

Relation to Key Factors:

- Infrastructure & Technology: The presence of a developed water distribution network is an important factor that makes Tabriz's water management efficient.

Policy & Governance: Effective water governance can further optimize the system and ensure equitable water distribution across the city.

Tabriz water distribution network

Use of Treated Wastewater in Industry

Some of Tabriz's industrial facilities, particularly in the petrochemical sector, already use treated wastewater in their operations. This reduces the demand for freshwater, which is vital in a region facing water scarcity. Wastewater reuse for industrial purposes not only conserves water but also presents a potential opportunity for expanding sustainable practices within other sectors.

Relation to Key Factors:

Infrastructure & Technology: The use of wastewater treatment technology is a critical component that can be expanded further to other industries.

Policy & Governance: Government policies promoting wastewater reuse could incentivize more industries to adopt these practices.

Government Attention to Water Scarcity

Due to the region's semi-arid climate, the government has implemented policies to address water scarcity. These policies focus on water conservation, efficient distribution, and developing new sources of water, ensuring long-term water sustainability in Tabriz. This governmental attention helps mobilize resources and create awareness among residents and industries about the importance of water conservation.

Relation to Key Factors:

Policy & Governance: Government actions are essential in creating policies that promote water-saving behaviors and the implementation of sustainable water management practices.

Public Awareness & Behavioral Factors: Government initiatives that educate the public about water conservation increase community involvement in managing the resource.

Potential for Collect surfacewatr and Groundwater Recharge

Tabriz is investing in groundwater recharge projects to counteract over-extraction. These projects aim to replenish underground water reserves, ensuring that future water needs are met sustainably. Groundwater recharge is a key strategy in addressing the imbalances caused by excessive water extraction for agricultural, industrial, and domestic use.

Relation to Key Factors:

Infrastructure & Technology: Implementing groundwater recharge requires the development of suitable infrastructure to facilitate the process.

Cost & Financial Constraints: These projects may require substantial investment, but the long-term benefits far outweigh the costs by ensuring water security.

Surfacewater management project - city outskirts

Surface water management project - deprived areas

Existing Public Awareness on Water Issues

Tabriz has a relatively high level of public awareness regarding water scarcity and its associated issues. Many residents and businesses are already conscious of the challenges related to water supply, and as a result, there have been voluntary efforts to reduce water consumption. This awareness can drive changes in consumer behavior, encourage more sustainable water use, and increase support for water conservation initiatives. Public engagement can be a key factor in the city's efforts to manage its water resources efficiently.

Relation to Key Factors:

Public Awareness & Behavioral Factors: The city's public awareness campaigns and community engagement have contributed to a culture of water conservation. This opportunity hinges on maintaining and strengthening these efforts to further reduce water consumption.

Policy & Governance: Government policies can support public awareness efforts by creating regulations that encourage responsible water use and backing educational campaigns with clear policies and incentives.

Tabriz municipality poster for water consumption management

Energy Flow in Tabriz – Opportunities

Natural Gas Availability

Tabriz benefits from a stable natural gas infrastructure that provides a consistent energy source to households and industries. This extensive natural gas network ensures that the city's energy needs are met without relying on external sources, providing a reliable energy supply for residential, commercial, and industrial use.

Relation to Key Factors:

Cost & Financial Constraints: Natural gas is relatively inexpensive compared to other energy sources, providing a cost-effective solution for the city's energy needs.

Infrastructure & Technology: The natural gas infrastructure is a strong foundation for energy supply and can support future energy efficiency measures.

Presence of a Power Generation Hub (Tabriz Power Plant)

The Tabriz Power Plant is an important energy provider, ensuring stable electricity supply for the city and surrounding areas. This hub plays a vital role in meeting the growing demand for electricity, which is expected to increase with urbanization and industrial growth.

Relation to Key Factors:

Infrastructure & Technology: The presence of a power generation hub indicates the city's capability to meet its energy demands, with potential for further technological upgrades.

Policy & Governance: Strong governance is needed to maintain and upgrade the power plant to meet future energy demands.

Tabriz Power Plant

Potential for Renewable Energy (Solar and Wind Energy)

Tabriz's geographical location offers great potential for the development of renewable energy sources, such as solar and wind. With high sunshine hours throughout the year and favorable wind conditions, the city is well-positioned to harness clean energy, reducing reliance on fossil fuels.

Relation to Key Factors:

Infrastructure & Technology: The development of renewable energy infrastructure requires investments in new technologies and grid integration.

Public Awareness & Behavioral Factors: Promoting the benefits of renewable energy can encourage public participation in energy-saving efforts.

Wind turbine on OnebnAli mountain - North of Tabriz

Solar cells - Tabriz Sahand University of Technology

Industrial Energy Infrastructure

Tabriz is home to several large industries that already have established energy networks, including petrochemical plants and automotive manufacturers. This provides a foundation for optimizing energy use within the industrial sector, which could result in significant energy savings and reduced emissions.

Relation to Key Factors:
Cost & Financial Constraints: Optimizing energy usage within industries reduces operational costs, offering financial savings.
Infrastructure & Technology: The existing industrial energy infrastructure can be upgraded to incorporate more energy-efficient technologies.

Growing Interest in Energy Efficiency

There has been a noticeable shift in Tabriz toward more energy-efficient practices. This growing interest is reflected in some local companies and public institutions starting to implement energy-saving measures.

Such initiatives include using more efficient appliances, improving building insulation, and adopting better lighting systems. As energy efficiency becomes more widely embraced, it can significantly reduce the overall energy consumption in the city and make the use of energy more sustainable.

Relation to Key Factors:

Public Awareness & Behavioral Factors: The growing interest in energy efficiency reflects a shift in consumer behavior, driven by awareness campaigns and a collective recognition of the need for sustainable energy use.

Policy & Governance: Energy efficiency policies and incentives at the local and national levels can support this shift by encouraging businesses and households to adopt energy-saving practices.

Access to National Energy Grid

Tabriz is well connected to Iran's national electricity grid, ensuring a stable and reliable supply of electricity to the city. This connection facilitates the city's energy distribution and ensures that energy demands can be met efficiently. Being part of the national grid also provides Tabriz with the opportunity to diversify its energy sources and draw from the country's larger energy mix, which includes both conventional and renewable sources.

Relation to Key Factors:

Infrastructure & Technology: The national grid provides a robust infrastructure for energy distribution. This can be upgraded to accommodate more renewable energy sources, allowing for greater diversification in energy supply.

Energy Access Inequality: Connection to the national grid helps ensure that energy access is distributed more equally across Tabriz, reducing disparities between different areas of the city.

Waste Flow in Tabriz – Opportunities

Existing Waste Collection System

The municipal waste collection system in Tabriz provides an essential foundation for waste management. An efficient collection network reduces environmental pollution, improves hygiene, and enables waste sorting at the source. However, despite its advantages, gaps remain in waste separation, recycling integration, and system expansion to informal settlements.

Relation to key factors:

Infrastructure & Technology: Investment in collection vehicles, digital tracking, and waste sorting stations can enhance operational efficiency.

Policy & Governance: Stronger regulations and incentives for recycling-based collection can enhance waste diversion rates.

Waste collection system of Tabriz municipality

Presence of a Composting Facility

Tabriz already has a composting facility, which presents an opportunity to reduce landfill waste by processing organic materials. Composting supports soil fertility and reduces methane emissions from landfills. However, scaling up this initiative requires better infrastructure and public participation.

Relation to key factors:

Infrastructure & Technology: Expanding composting facilities with modern technology can process larger volumes of organic waste efficiently.

Urban Growth & Spatial Planning: Integrating composting facilities into urban waste management plans will help accommodate population growth.

Potential for Expansion of Recycling

Recycling programs in Tabriz, although limited, offer a strong opportunity for expansion. With proper investment and policies, the city can increase recycling rates and reduce reliance on landfills.

Relation to key factors:

Cost & Financial Constraints: Expanding recycling can generate revenue by selling recyclable materials and reducing landfill costs.

Policy & Governance: Stronger enforcement of recycling policies and incentives for businesses to recycle can enhance waste management.

Strong Informal Recycling Sector

Tabriz has an active informal recycling sector, consisting of waste pickers and small businesses. Formalizing this sector can improve efficiency and ensure fair labor practices.

Relation to key factors:

Public Awareness & Behavioral Factors: Recognizing the role of informal recyclers can encourage cooperation with the formal system.

Policy & Governance: Government regulations to integrate informal waste pickers into official recycling programs can enhance productivity.

Small-Scale Waste Recycling Plant - Private Sector

Governmental Interest in Waste Reduction

The Iranian government and Tabriz Municipality are increasingly prioritizing waste management through new policies and infrastructure development.

Relation to key factors:

Infrastructure & Technology: Investments in advanced sorting and recycling plants will improve waste management capacity.

Policy & Governance: Stronger policies on waste reduction and recycling will drive long-term improvements.

Food Flow in Tabriz – Opportunities

Rich Agricultural Land Nearby

Tabriz benefits from fertile agricultural land in nearby areas like Marand and Shabestar, ensuring a steady supply of fresh produce.

Relation to key factors:

Infrastructure & Technology: Efficient distribution networks, cold storage facilities minimize food waste.

Urban Growth & Spatial Planning: Preventing urban sprawl from encroaching on agricultural land is essential for long-term food security.

Agricultural Lands - Shabestar province

Strong Food Processing Industry

Tabriz hosts food processing industries such as dairy and confectionery plants, adding value to agricultural products.

Relation to key factors:

Infrastructure & Technology: Investments in modern processing equipment enhance efficiency and reduce food waste.

Policy & Governance: Government incentives for food industries encourages sustainable processing practices.

Shirin Asal Factory - Confectionery

Sutchilar Factory - Dairy

Famous for Certain Agricultural Products

Tabriz is known for apples, tomato, grapes, potato, and dairy products, which provide economic and food security benefits.

Relation to key factors:

Cost & Financial Constraints: Exporting high-value agricultural products boosts the local economy.

Public Awareness & Behavioral Factors: Marketing local products encourages consumption and supports local agriculture.

Potato Farm - Tabriz

Apple Garden - Marand

Tomato Farm - Laleh, Tabriz

Large and Diverse Food Marketplaces

Tabriz has a well-established marketplace network, including the historic Tabriz Bazaar, which ensures fresh food availability.

Relation to key factors:

Cost & Financial Constraints: Traditional markets offer affordable food options for residents.

Urban Growth & Spatial Planning: Expanding market infrastructure will be necessary as the city's population increases.

Cultural Emphasis on Fresh Food Consumption

Tabriz residents have a strong preference for fresh products which supports the demand for locally sourced food. This cultural habit reduces reliance on processed and imported food, contributing to better health and a more sustainable local food system.

Relation to key factors:

Public Awareness & Behavioral Factors: The preference for fresh food encourages sustainable consumption habits, reducing processed food dependency.

Policy & Governance: Government support for local farmers and markets can reinforce this cultural tradition and improve food accessibility.

Potential for Export of Local Food Products

Tabriz is well-known for its high-quality agricultural products which have strong export potential, offering economic benefits for local farmers and producers. Expanding exports can boost the regional economy and encourage agricultural investment.

Relation to key factors:

Cost & Financial Constraints: Exporting local food products increases revenue for farmers and food businesses, making the agricultural sector more profitable.

Policy & Governance: Government support, trade agreements, and streamlined export regulations can facilitate access to foreign markets.

CHALLENGES

Over-reliance on Groundwater	○	○	○	●	●
Pollution of Water Sources	●	○	●	○	○
Aging Water Infrastructure	○	●	○	○	●
Climate Change and Water Scarcity	●	○	○	●	○
Wastewater Treatment Gaps	○	●	○	○	●
Reliance on Fossil Fuels	○	●	●	○	○
Energy Consumption in Residential Areas	○	○	○	●	●
Limited Renewable Energy Deployment	○	●	○	○	●
Energy Access Inequality	●	○	○	●	○
Lack of Energy Storage Solutions	○	●	○	○	●
Low Recycling Participation	●	○	●	○	○
Inadequate Waste Sorting Infrastructure	○	●	○	○	●
Illegal Dumping	●	○	●	○	○
Plastic Waste	●	○	●	○	○
Limited E-Waste Recycling	○	●	○	○	●
Inefficiency in Waste Collection	●	○	○	○	●
High Food Waste	●	○	●	○	○
Food Accessibility	○	●	○	●	○
Inefficiency in Food Distribution	○	●	○	○	●
Water-Intensive Agriculture	●	○	○	○	●
Pesticide Use in Farming	●	○	●	○	○

Over-Reliance on Groundwater

Tabriz heavily depends on groundwater as a primary water source, especially for agricultural and industrial use. Excessive groundwater extraction has led to declining water tables, land subsidence, and reduced water availability in the long run. Over-extraction can cause wells to dry up, making it harder to meet water demands. Without alternative water sources or stricter regulations, this trend could pose severe risks to long-term water security.

Relation to Key Factors:

Infrastructure & Technology: Limited infrastructure for rainwater harvesting or desalination forces reliance on groundwater.

Urban Growth & Spatial Planning: Urban expansion increases water demand, accelerating groundwater depletion.

Pollution of Water Sources

Contamination of water sources from industrial waste, agricultural runoff, and untreated sewage is a major issue in Tabriz. Polluted water not only harms ecosystems but also reduces the availability of clean drinking water. Industrial zones discharge pollutants into rivers, and improper wastewater management further exacerbates the issue.

Relation to Key Factors:

Policy & Governance: Weak regulations on industrial discharge worsen pollution.

Public Awareness & Behavioral Factors: Improper disposal of chemicals and household waste contributes to contamination.

Talkhe Rood River - North of Tabriz

Aging Water Infrastructure

Much of Tabriz's water infrastructure, including pipelines and distribution networks, is outdated. Leakage and inefficiencies result in water loss before it even reaches consumers. A deteriorating system means higher maintenance costs and potential contamination risks.

Relation to Key Factors:

Cost & Financial Constraints: Repairing and replacing old infrastructure requires high investment.
Infrastructure & Technology: Limited funding for modernization results in continued inefficiencies.

Water leakage due to wear and rusting of Tabriz water pipes

Climate Change and Water Scarcity

Rising temperatures and decreasing rainfall threaten water availability in Tabriz. Droughts are becoming more frequent, making it difficult to sustain current water consumption levels. Agriculture, drinking water supply, and industry all face serious risks due to climate variability.

Relation to Key Factors:

Policy & Governance: Lack of proactive climate adaptation policies hinders response efforts.

Urban Growth & Spatial Planning: Continued expansion increases water demand despite declining resources.

Wastewater Treatment Gaps

Tabriz lacks sufficient wastewater treatment facilities, leading to untreated sewage discharge into the environment. This not only pollutes water sources but also reduces the potential for water reuse, which could help alleviate shortages.

Relation to Key Factors:

Cost & Financial Constraints: High costs prevent investment in new treatment plants.

Infrastructure & Technology: Insufficient wastewater processing infrastructure results in untreated discharge.

Energy Flow in Tabriz – Challenges

Reliance on Fossil Fuels

Tabriz's energy system still heavily depends on natural gas and other fossil fuels, leading to environmental pollution and carbon emissions. This reliance limits the city's ability to transition to a more sustainable energy future.

Relation to Key Factors:

Cost & Financial Constraints: Transitioning to renewable energy requires significant investment.

Public Awareness & Behavioral Factors: Consumers may not prioritize clean energy due to low awareness.

Tabriz CNG and Oil Station

Energy Consumption in Residential Areas

Tabriz experiences high energy demand, especially in residential buildings, due to inefficient insulation and outdated heating systems. During cold seasons, energy consumption spikes, putting stress on the electricity and gas supply network.

Relation to Key Factors:

Infrastructure & Technology: Limited use of smart grids and energy-saving appliances increases waste.

Urban Growth & Spatial Planning: Rapid expansion of new housing increases energy demand

Limited Renewable Energy Deployment

Despite having significant solar energy potential, Tabriz has not fully integrated renewable sources into its energy mix. Investments in solar and wind energy remain low, keeping the city reliant on conventional power generation.

Relation to Key Factors:

Cost & Financial Constraints: High initial costs of solar and wind energy installations.

Infrastructure & Technology: Lack of advanced energy storage solutions limits renewable energy use.

Energy Access Inequality

Some areas in Tabriz experience unreliable electricity or heating, particularly lower-income neighborhoods. Energy disparities lead to discomfort, economic burdens, and social inequalities.

Relation to Key Factors:

Policy & Governance: Unequal resource allocation leads to energy access gaps.

Urban Growth & Spatial Planning: Poor planning leaves certain areas with weaker infrastructure.

Lack of Energy Storage Solutions

A major limitation in Tabriz's energy system is the lack of large-scale battery storage, making it difficult to store renewable energy for later use. This limits the efficiency of solar and wind energy.

Relation to Key Factors:

Cost & Financial Constraints: Energy storage systems require large investments.

Infrastructure & Technology: Limited research and implementation of advanced battery storage.

Waste Flow in Tabriz – Challenges

Low Recycling Participation

Although some recycling initiatives exist in Tabriz, overall participation remains low. Many residents and businesses do not separate recyclables from general waste, and there are limited incentives to do so. Additionally, the informal waste sector remains dominant, making it harder to implement structured recycling programs.

Relation to Key Factors:

Public Awareness & Behavioral Factors: Many people are unaware of the importance and benefits of recycling.

Policy & Governance: Weak government support for structured recycling programs.

Inadequate Waste Sorting Infrastructure

One of the biggest barriers to efficient recycling in Tabriz is the lack of a well-organized waste sorting system. Households and businesses generally do not separate waste, leading to contamination of recyclable materials and reducing their processing efficiency.

Relation to Key Factors:

Cost & Financial Constraints: Waste sorting facilities and collection systems require significant investment.

Infrastructure & Technology: The city lacks modern waste sorting and recycling plants.

Illegal Dumping

Illegal waste dumping occurs in some areas of Tabriz, particularly on the outskirts and in low-income neighborhoods. This issue arises due to inadequate waste collection services, lack of enforcement, and the cost of proper waste disposal. Illegal dumping creates environmental and health risks, polluting soil and water sources.

Relation to Key Factors:

Public Awareness & Behavioral Factors: Some residents and businesses lack knowledge or concern about proper disposal methods.

Policy & Governance: Weak enforcement of waste disposal regulations.

Plastic Waste

Plastic waste is a major environmental concern in Tabriz, with plastic bags, bottles, and packaging materials contributing to pollution. A lack of strong recycling programs means much of this waste ends up in landfills or, worse, in natural areas. Single-use plastics remain widely used in markets and businesses, further worsening the problem.

Relation to Key Factors:

Public Awareness & Behavioral Factors: Low awareness about the negative environmental effects of plastic.

Policy & Governance: Weak regulations limiting single-use plastics.

Limited E-Waste Recycling

Electronic waste (e-waste) disposal remains a significant challenge in Tabriz. Many discarded electronic devices contain hazardous materials like lead and mercury, which can contaminate soil and water if not handled properly. Currently, there are very few specialized recycling centers for e-waste, leading to improper disposal or informal recycling, which can pose health risks.

Relation to Key Factors:

Cost & Financial Constraints: Establishing proper e-waste recycling facilities requires investment.

Infrastructure & Technology: Lack of specialized recycling plants and collection points.

Inefficiency in Waste Collection

Tabriz faces irregular waste collection, leading to illegal dumping and environmental pollution. Some neighborhoods receive better waste management services than others, creating disparities.

Relation to Key Factors:

Infrastructure & Technology: Insufficient waste trucks and collection systems reduce efficiency.

Policy & Governance: Weak waste management policies contribute to inefficiencies.

Food Flow in Tabriz – Challenges

High Food Waste

A significant portion of food in Tabriz is wasted at the household, retail, and restaurant levels. Poor portion control, lack of awareness about expiration dates, and cultural habits contribute to food waste. Additionally, there are no strong food recovery programs to redirect edible food to those in need.

Relation to Key Factors:

Public Awareness & Behavioral Factors: Lack of awareness about food waste reduction strategies.

Policy & Governance: Weak enforcement of food waste reduction laws.

Food Accessibility

While Tabriz has strong food markets, food accessibility is not equal across all socioeconomic groups. Low-income residents, especially in informal settlements, may struggle to afford fresh and nutritious food. Additionally, some areas lack sufficient grocery stores or markets, making food access difficult.

Relation to Key Factors:

Cost & Financial Constraints: Rising food prices make access difficult for lower-income groups.

Urban Growth & Spatial Planning: Poorly planned neighborhoods may lack essential food supply infrastructure.

Inefficiency in Food Distribution

The food supply chain in Tabriz faces inefficiencies, including long transportation times, poor storage conditions, and lack of coordinated logistics. This leads to food loss before reaching consumers, especially for perishable items like fruits, vegetables, and dairy. The lack of modern distribution centers and cold chain logistics exacerbates the issue.

Relation to Key Factors:

Cost & Financial Constraints: High costs of modernizing storage and distribution systems.

Infrastructure & Technology: Limited cold storage and inefficient transportation networks.

Apple tree rotting due to frost on the distribution route

Water-Intensive Agriculture

Agriculture in Tabriz heavily relies on water-intensive crops, such as rice and some fruit varieties, which require significant water resources. Given the city's semi-arid climate, this places additional stress on already limited water supplies. With growing water scarcity, this type of agriculture is increasingly unsustainable. Over-reliance on surface water from dams and groundwater extraction for irrigation contributes to the depletion of local water sources, exacerbating the issue.

Relation to Key Factors:

Infrastructure & Technology: Modern water-saving technologies are not widely adopted.

Policy & Governance: Lack of incentives for water-efficient farming prevents change.

Pesticide Use in Farming

Pesticide use in farming in Tabriz, especially in surrounding rural areas, is widespread and often unregulated. While pesticides help in controlling pests and increasing crop yields, their overuse can lead to environmental pollution, health issues, and soil degradation. The lack of effective monitoring and enforcement of safe pesticide use exacerbates these problems, negatively affecting local ecosystems and potentially harming public health.

Relation to Key Factors:

Public Awareness & Behavioral Factors: Farmers and consumers may lack sufficient knowledge about the risks of pesticide overuse and the benefits of alternatives.

Policy & Governance: Weak regulations and insufficient government oversight regarding pesticide use and agricultural practices.

Improper pesticide spraying without safety equipment - Tabriz

2.6. Case Studies

Case Study: Two Urban Zones in Tabriz

To gain a deeper understanding of how urban conditions impact resource flows, this study focuses on two different areas of Tabriz:

1. Valiasr Zone (Higher Urban Quality, Wealthier Population)

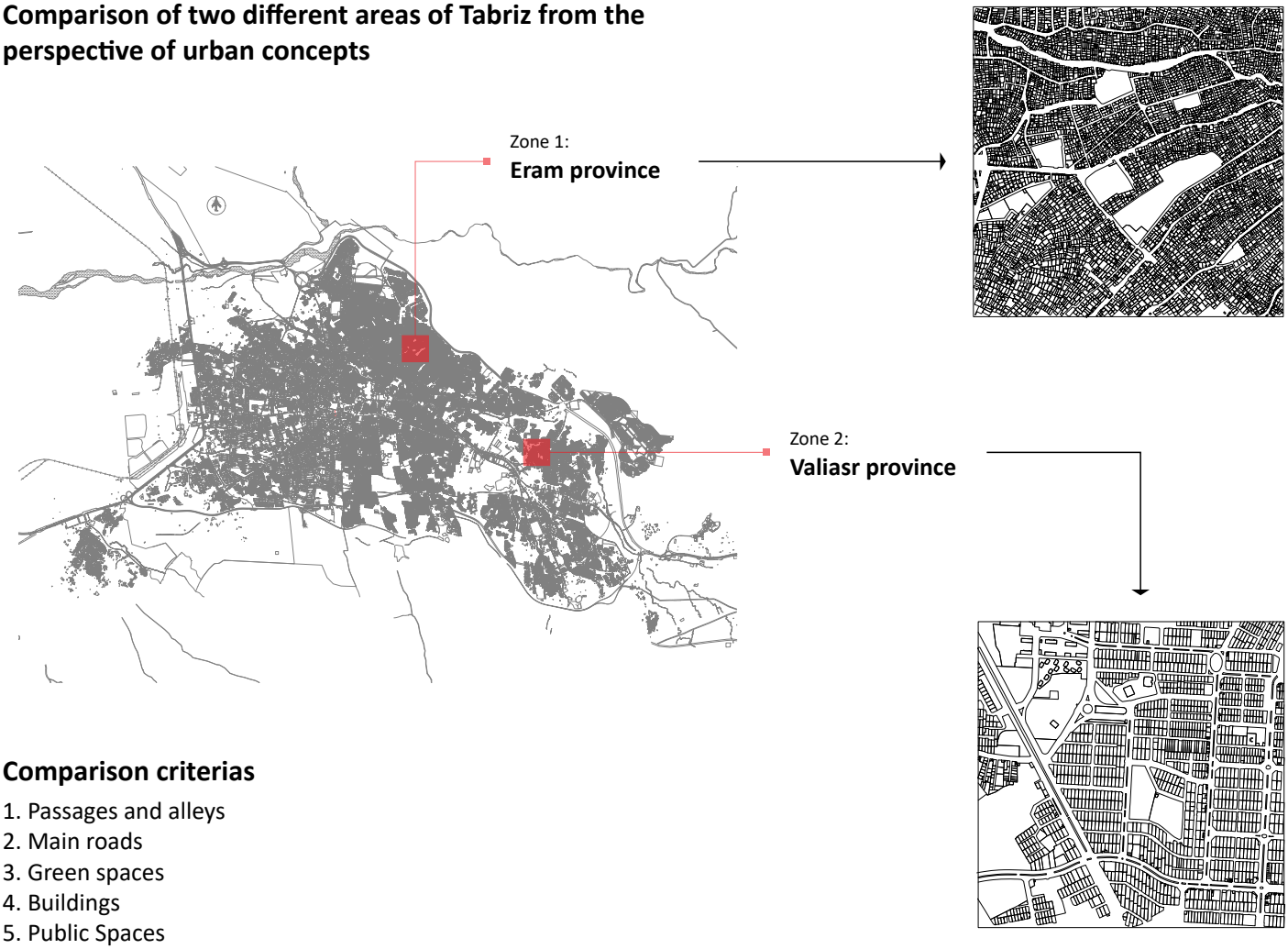
Located in the east part of Tabriz, Valiasr is known for modern infrastructure, better services, and higher-income residents. The area has better access to clean water, reliable electricity, and waste collection services. Energy and water consumption tend to be higher due to larger homes, green spaces, and modern appliances. Waste generation is higher per capita. Food consumption includes higher quality.

2. Eram Zone (Lower Urban Quality, Lower-Income Population)

Located in the north part of Tabriz, Eram is characterized by poorer infrastructure, lower living standards, and high population density. Residents often experience water supply issues, and some areas rely on water storage tanks due to intermittent service. Energy use is lower per capita, but inefficient housing conditions lead to higher energy waste in winter. Waste collection is less frequent. Food access relies more on local markets and street vendors, with a higher percentage of low-cost staple foods in daily consumption.

The selection of Valiasr and Eram as case study areas is based on their contrasting urban characteristics, which provide valuable insights into how different socioeconomic conditions affect resource flows in Tabriz. By comparing these two zones, we can see how income levels, infrastructure, and urban planning affect the use of resources, and we can develop targeted strategies for different parts of the city to improve overall sustainability.

Comparison of two different areas of Tabriz from the perspective of urban concepts



Comparison criterias

1. Passages and alleys
2. Main roads
3. Green spaces
4. Buildings
5. Public Spaces

Case Studies

Passages and alleys

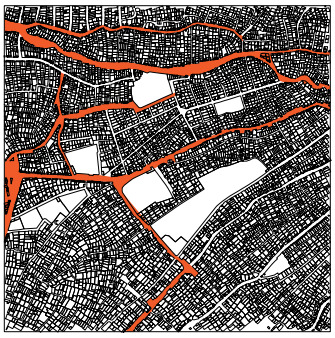
Zone 1: Eram province

Alleys and passages are narrow, sloping, generally human-oriented and irregular

Zone 2: Valiasr province

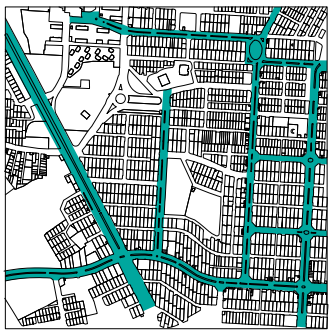
Alleys and passages are wide, flat, linear and regular

Main Roads



Zone 1: Eram province

- Narrow roads
- Streets are without proper marking and tabulation
- Roads have non-geometric pattern
- Streets are curved and irregular

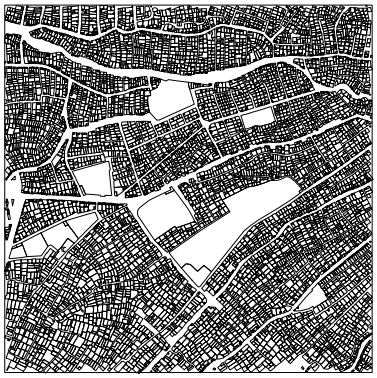


Zone 2: Valiasr province

- Wide oads
- Appropriate marking and tabulation
- Roads have geometric pattern
- Liner roads

Case Studies

Green spaces



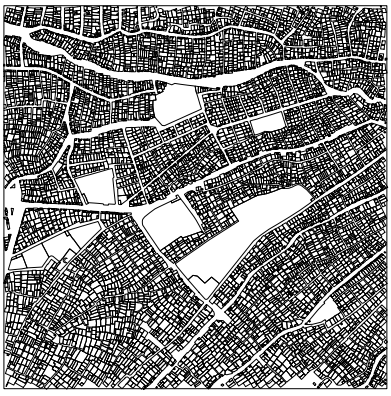
Zone 1: Eram province

Lack of any green space for public use

Zone 2: Valiasr province

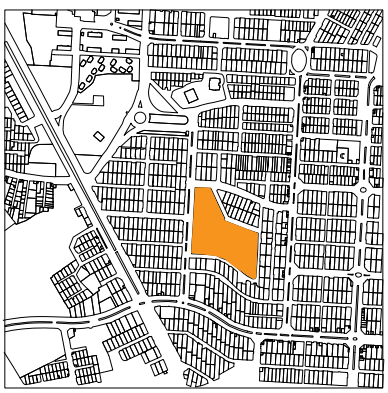
Appropriate green space for the public use as Park, outdoor sport area, kids playing area

Public spaces



Zone 1: Eram province

Lack of any appropriate public space



Zone 2: Valiasr province

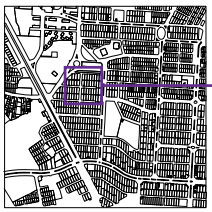
Appropriate public gathering space for the public use as shopping mall, cinema, gym, hyper market

Case Studies

Buildings

Zone 1: Eram province

- Non-geometric and irregular plans
- Confusion in the arrangement of buildings
- Inconsistent and different infrastructure size in plans
- Old buildings with no facade
- Very dense and compact construction texture



Zone 2: Valiasr province

- Single, regular and geometric plans
- Fine order in the arrangement of buildings
- Almost the same size in plans
- New buildings with modern facade
- Cohesive and regular construction texture

The comparison between Eram and Valiasr highlights key differences in urban quality, infrastructure, and resource management in Tabriz. Valiasr, with wider roads, better infrastructure, and more green spaces, provides higher living standards and efficient resource access, while Eram, with denser housing, fewer public spaces, and limited services, faces greater challenges in urban sustainability. These differences directly impact water, energy, food, and waste flows. Water access is more reliable in Valiasr, while Eram faces greater risks of shortages and lower water quality. Energy consumption is higher in Valiasr due to modern appliances and better infrastructure, whereas Eram struggles with inefficient housing and affordability issues. Food availability is better in Valiasr, with greater access to fresh and diverse products, while Eram residents may face limited options and affordability constraints. Waste management is more effective in Valiasr, whereas Eram experiences inefficient collection and lower recycling participation. Understanding these variations provides valuable insights for improving urban resource management and developing targeted interventions for a more sustainable Tabriz.

After identifying the spatial and socioeconomic contrasts between different urban areas, the next step in this research is to explore the opportunities and challenges within the four key resource flows: water, energy, food, and waste. Investigating these factors is essential for understanding how existing strengths can be leveraged and what obstacles need to be addressed to enhance urban sustainability. Opportunities highlight positive aspects, such as available infrastructure, local policies, or natural resources, that can contribute to a more efficient and resilient city metabolism. On the other hand, challenges reveal limitations, inefficiencies, and systemic gaps that hinder effective resource management. By examining both, this research aims to provide practical recommendations for improving resource efficiency, environmental sustainability, and urban resilience in Tabriz.

— DESIGN

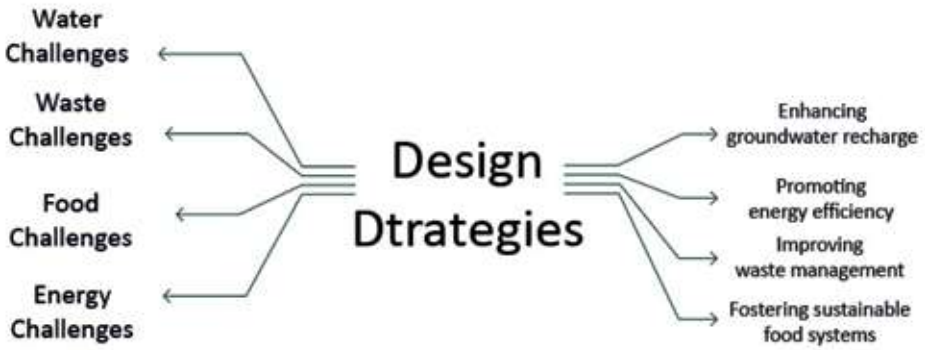
Strategies and Solutions

Strategies towards Metabolic city ——
Strategies on Tabriz

DESIGN STRATEGIES

3.1. Design strategies for being a metabolic city

In this section, design strategies aimed at addressing the challenges faced by Tabriz will be introduced to transform the city into a more metabolic and sustainable urban environment. By focusing on key resource flows such as water, energy, waste, and food, the strategies will aim to improve efficiency, reduce waste, and enhance the city's overall resilience. These strategies will incorporate solutions that address the city's specific challenges, such as enhancing groundwater recharge, promoting energy efficiency, improving waste management, and fostering sustainable food systems. The goal is to align the city's urban systems with natural processes, enabling a circular metabolism where resources are used efficiently, waste is minimized, and the city becomes more self-sustaining. Through careful planning and implementation of these strategies, Tabriz can move towards a more integrated and regenerative urban model, benefiting both its residents and the environment.



3.1.1. Water Strategies

Enhancing Groundwater Recharge:

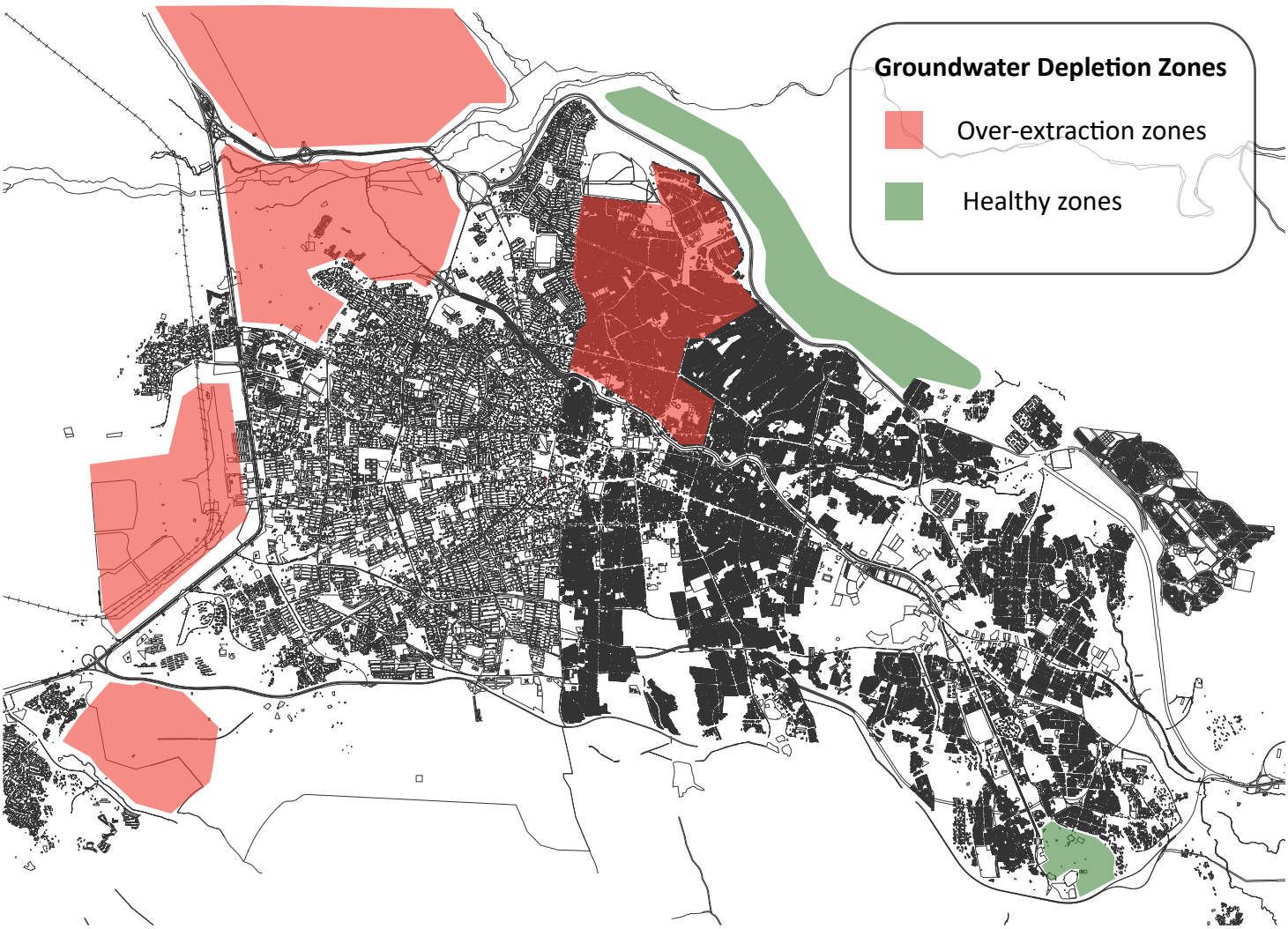
- Construct artificial recharge basins in selected areas to allow rainwater to seep into underground aquifers.
- Use permeable pavements and green infrastructure to reduce surface runoff and increase infiltration.
- Identify areas with the highest groundwater depletion and implement controlled water extraction policies.

Definition & Importance

Groundwater recharge is the process by which water from the surface infiltrates into the groundwater system, replenishing aquifers that are often used as a primary source of drinking water and irrigation. In a city like Tabriz, which is located in a semi-arid region, groundwater is a crucial resource for sustaining agriculture, industry, and urban life. However, over-extraction, along with limited natural recharge, has led to the depletion of local aquifers, which poses significant challenges for water sustainability. To address this issue, strategies like constructing artificial recharge basins, using permeable pavements, and green infrastructure (e.g., green roofs, rain gardens) are essential. These strategies enhance the natural process of water infiltration, reducing surface runoff and promoting the movement of water into underground aquifers. This approach not only helps restore depleted groundwater levels but also mitigates the risks of flooding, which can be exacerbated by impervious surfaces in the city.

How It Helps Tabriz Become a Metabolic City: In Tabriz?

Enhancing groundwater recharge is key to ensuring long-term water security. The implementation of recharge basins in areas with significant groundwater depletion would allow the city to sustainably manage its water resources, making it less dependent on external water sources. Additionally, using permeable pavements and green infrastructure can create a more sustainable urban landscape that mimics natural water cycles, promoting a healthier balance between water extraction and replenishment. By identifying areas where groundwater depletion is most critical, Tabriz can take a more targeted approach to water management, ensuring that resources are used efficiently and are replenished naturally.



Over-Extraction Zones in Tabriz

Agricultural Zones: Outskirts of Tabriz (e.g., Marand, Shabestar): These areas have intensive agricultural activities. Over-reliance on groundwater for irrigation can lead to significant depletion.

Irrigated Agricultural Areas: Areas with heavy reliance on underground water resources for irrigation (due to lack of sufficient surface water resources).

Urban Expansion Areas: As Tabriz expands, especially in suburban areas and newly developed parts of the city, urban growth often leads to increased demand for water. Areas such as Eram and other peripheral neighborhoods could face over-extraction as water is pumped for urban needs.

Industrial Zones: Industrial districts like the Tabriz Petrochemical Complex or the industrial parks may contribute to over-extraction.

Green Zones for Healthy Environments in Tabriz

Existing Parks and Green Spaces: El Goli Park (Shahgoli) is one of the largest parks in Tabriz and serves as an important green area for recreational activities and environmental improvement. Expanding similar parks and integrating more green spaces within urban settings can help mitigate the effects of air pollution and support groundwater recharge.

Possible Suggestions for improvement

Community Gardens and Urban Farming Projects: These can be encouraged in both residential and commercial areas to support local food production and reduce reliance on distant agricultural resources.

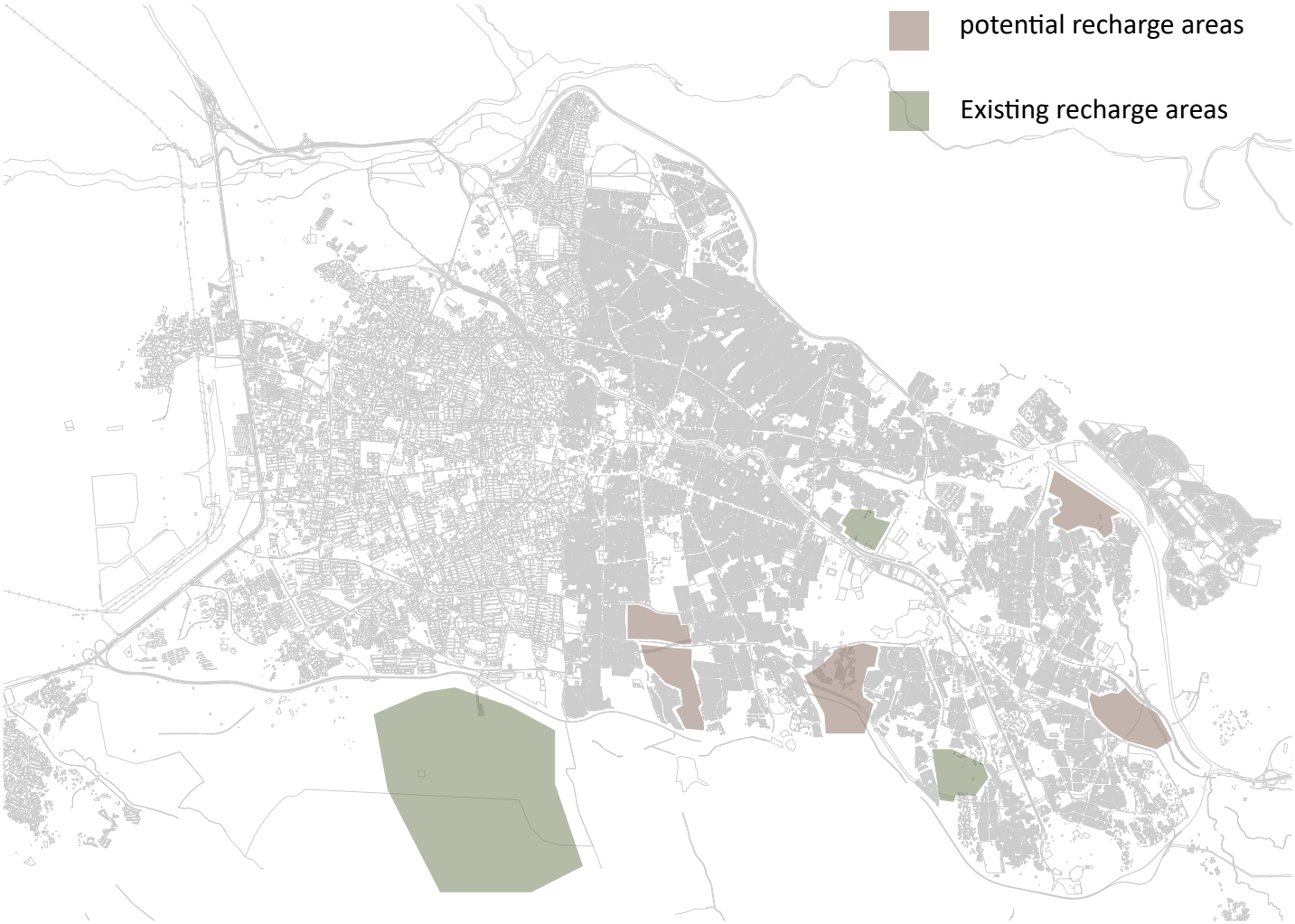
Green Corridors and Ecological Networks:

Riverbanks of Qareh Sou: The areas surrounding Tabriz's river systems can be revitalized into green corridors. These zones can increase biodiversity, support local ecosystems, and act as recreational spaces for residents.

Connecting Green Spaces: Create a network of green corridors that link parks and natural areas, enhancing the overall urban ecological structure and making it easier for people to access nature.

Rehabilitation of Degraded Urban Areas:

Rehabilitation Projects in Peripheral Zones: Some of the peripheral or older urban areas in Tabriz have limited green spaces or poorly maintained parks. Investing in the regeneration of these spaces could help to rejuvenate the local environment and improve the quality of life for residents.



Challenges and Solutions for "Enhancing Groundwater Recharge" in Tabriz

1. Limited Availability of Suitable Land for Recharge Basins

Identifying and securing land for constructing artificial recharge basins can be challenging in a city like Tabriz, especially with urban expansion and competing land uses. Urban areas are becoming more densely populated, and land for environmental projects may be limited.

Solution:
Integration into Urban Planning: Incorporate recharge basins into new urban development projects. In new residential or commercial zones, urban planners can allocate spaces specifically for groundwater recharge.

2. Public Resistance or Lack of Awareness

Public resistance or lack of understanding about the importance of groundwater recharge projects may hinder efforts to implement recharge basins or other green infrastructure measures.

Solution:
- Community Engagement: Raise public awareness through community campaigns about the importance of groundwater recharge for sustainable water management. Workshops, social media campaigns, and educational programs in schools could help spread knowledge.
- Demonstration Projects: Implement pilot projects in visible areas to show the effectiveness of recharge systems, helping to gain public support.

3. Inadequate Maintenance of Recharge Infrastructure

After the construction of recharge basins or permeable pavements, maintaining the infrastructure to ensure its continued effectiveness can be a challenge due to lack of funding, poor planning, or insufficient resources.

Solution:
- Regular Monitoring and Maintenance Plans: Establish clear maintenance schedules for recharge basins and permeable pavements, ensuring they are kept free of debris and are functioning as designed.
- Use of Local Workforce: Involve local communities or job creation programs to provide the necessary workforce for maintenance, which can help to reduce costs and increase engagement.

4. Pollution of Rainwater or Stormwater

Rainwater and stormwater that enters recharge basins may carry pollutants from streets, industrial areas, or residential zones. This contamination can affect the quality of groundwater and make it unsafe.

Solution:
- Stormwater Filtration Systems: Incorporate filtration systems such as bioswales, sand filters, or vegetated swales before the water enters the recharge basins to remove contaminants and ensure that only clean water recharges the aquifers.
- Regular Water Quality Testing: Establish a monitoring system to regularly check the quality of water entering the recharge basins, identifying any contaminants early to prevent negative impacts.

5. Climate Variability and Reduced Rainfall

Tabriz's semi-arid climate means that the city experiences periods of low rainfall, which can make it difficult to rely on rainwater for groundwater recharge during certain seasons.

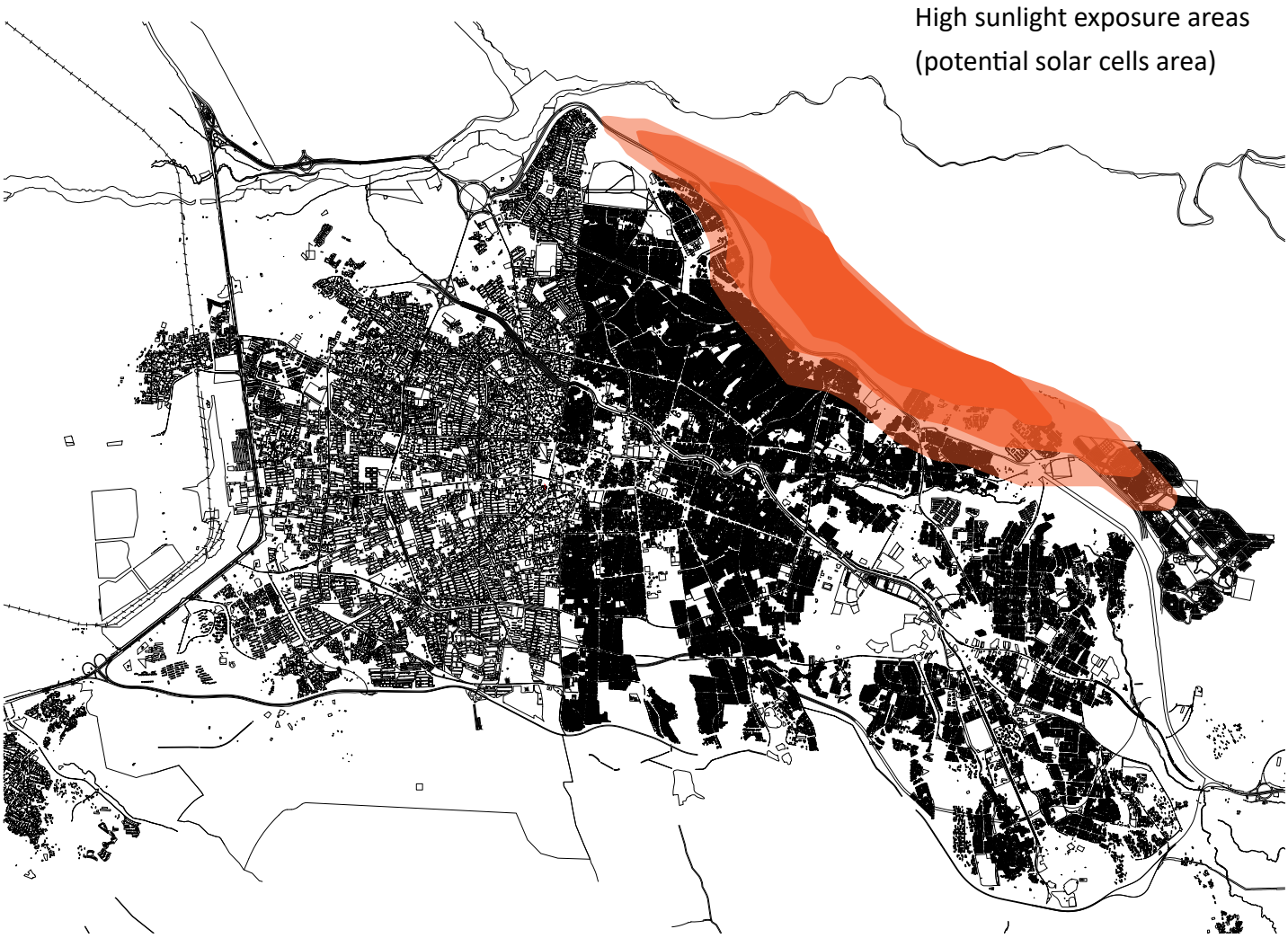
Solution:
- Rainwater Harvesting: In addition to artificial recharge basins, encourage the harvesting of rainwater from rooftops and other surfaces, which can then be used to supplement groundwater recharge efforts during dry periods.
- Climate-Resilient Infrastructure: Integrate climate-resilient infrastructure, such as water storage systems, to capture water during periods of excess rainfall, helping to store it for later use in recharge during dry spells.

6. Over-extraction of Groundwater

Over-extraction of groundwater, especially in agricultural or industrial sectors, can reduce the effectiveness of recharge initiatives by lowering the water table.

Solution
- Water Use Efficiency Measures: Implement water-efficient technologies in agriculture, industry, and urban areas. Encourage the use of treated wastewater for non-potable purposes to reduce dependence on groundwater.
- Water Allocation Policies: Develop and enforce policies that regulate groundwater extraction, limiting usage in over-extracted areas while encouraging sustainable practices.

3.1.2. Energy Strategies



Solar Energy Expansion

- Install solar panels on public buildings, industries, and residential rooftops.
- Provide subsidies for small-scale solar energy installations.

Definition & Explanation:

Expanding solar energy in Tabriz involves utilizing the city's high solar potential by installing photovoltaic (PV) panels on public facilities, industrial sites, and private residential buildings. This includes converting underused rooftops into energy-generating surfaces and offering subsidies or incentives for households and businesses to invest in solar technology. It also includes integrating solar systems into urban infrastructure—like bus stops, schools, and municipal buildings—reducing reliance on fossil fuels.

Why It's Important for a Metabolic City:

In an urban metabolism model, the city functions like a living system—inputs (like energy) should be clean, renewable, and efficiently used. Solar energy provides a renewable, decentralized input to Tabriz's energy flow, reducing pressure on the national grid and cutting down emissions from fossil fuels. It also diversifies energy sources, helping the city become more self-reliant and sustainable.

Why It Matters for Tabriz?

Tabriz receives a significant amount of sunlight annually, making it geographically ideal for solar power. Additionally, as electricity demands rise—especially for heating in winter and cooling in summer—solar energy can offer a stable and clean supplement. For neighborhoods with irregular power access, solar panels can improve energy equity.

How Solar Energy Expansion Supports Tabriz as a Metabolic City

A metabolic city treats energy, water, food, and waste like flows within a living organism—each input and output must be managed sustainably. Solar energy supports this idea by creating a clean, local, and renewable input to the urban system. In the case of Tabriz, which traditionally relies on fossil fuels and centralized power generation, expanding solar energy helps by:

- Reducing Dependence on Non-renewable Inputs: Fossil fuels are limited and polluting. Solar power introduces a clean, endless energy source that doesn't deplete natural resources.
- Decentralizing Energy Production: Rooftop solar systems allow each neighborhood or even household to produce its own energy, lowering transmission loss and creating resilience during shortages or blackouts.
- Closing the Energy Flow Loop: By using renewable energy at the source (like on buildings), the city can minimize waste (like emissions and transmission loss), keeping the system more circular and efficient.
- Lowering Environmental Impact: Less reliance on fossil fuels means less air pollution and CO_2 emissions, improving overall environmental quality—essential in a metabolic urban model.
- Boosting Urban Self-sufficiency: A metabolic city aims to be less dependent on external systems. Solar energy enables Tabriz to sustain part of its own energy needs, increasing urban autonomy.

Challenges:

1. Cost & Financial Constraints:
- High initial investment for equipment and installation, especially for low-income households.
- Limited financial incentives currently available for widespread adoption.

2. Infrastructure & Technology:
- Lack of skilled labor and local companies to install and maintain solar systems.
- Need for smart grid infrastructure to efficiently manage and distribute solar power.

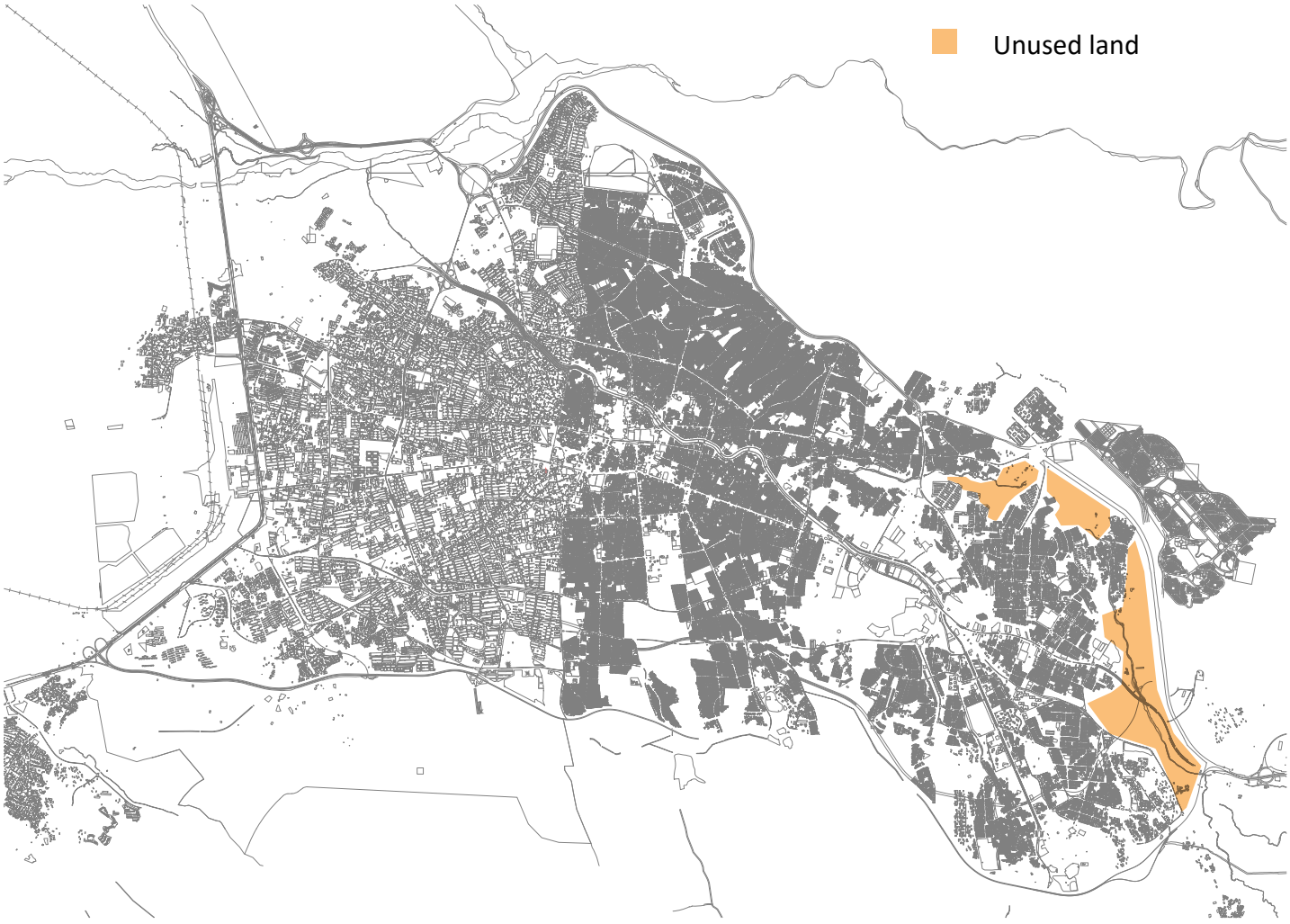
3. Public Awareness & Behavioral Factors:
- Limited understanding among citizens about the long-term economic and environmental benefits.
- Hesitancy to invest in new technology without visible success examples.

4. Policy & Governance:
- Absence of strong policies or municipal programs promoting solar integration.
- Regulatory hurdles and lack of clear guidelines for residential solar systems.

Solutions:

- Subsidies & Incentives: Government or municipal subsidies for installation, especially in low-income or high-energy-use areas.
- Awareness Campaigns & Pilot Projects: Showcase successful installations on public buildings to build trust and understanding. Host community workshops on solar energy benefits.
- Training & Local Workforce Development: Support training programs for local technicians to build a skilled solar workforce in Tabriz.
- Streamlined Regulations: Develop clear municipal guidelines for rooftop installations and simplify permitting processes.
- Public-Private Partnerships (PPP): Encourage partnerships between the municipality and private solar companies for funding and scaling up installations.

3.1.3. Food Strategies



Urban Farming & Community Gardens

Convert unused land into urban farms and greenhouses.

Reducing Food Waste at the Source

Establish food donation programs.

Eco-Friendly Agricultural Practices

Reduce pesticide use and encourage organic farming.

Definition

Urban farming and community gardens, the reduction of food waste at the source, and the promotion of eco-friendly agricultural practices are interconnected strategies aimed at improving food systems in Tabriz, making them more sustainable and metabolic. Urban farming involves converting unused urban spaces, such as vacant lots, rooftops, or public parks, into productive agricultural areas for growing food. These spaces can be used for community gardens or small-scale farming projects. Reducing food waste at the source includes initiatives like food donation programs, where surplus food from households or businesses is redirected to those in need instead of being discarded. Eco-friendly agricultural practices focus on encouraging organic farming and reducing pesticide use, which is better for both the environment and human health. These three strategies can be implemented together to reduce the city's overall food waste, promote local food production, and improve the resilience of the food system in Tabriz.

Importance

These strategies are key to transforming Tabriz into a metabolic city because they not only support local food production but also reduce the environmental impact of food waste. Urban farming can help to reduce the city's dependence on external food sources, cutting down on transportation emissions and promoting local food security. The reduction of food waste at the source directly addresses one of the city's major challenges—waste management—by diverting organic materials from landfills and reducing methane emissions from waste decomposition. By promoting eco-friendly agricultural practices, the city can reduce harmful chemicals that pollute the environment and help preserve soil quality for future generations. Together, these strategies contribute to a more sustainable, self-sufficient, and resilient city, where food production and consumption become more balanced and integrated into the urban environment.

Challenges & Solutions

Urban Farming & Community Gardens:

Challenges:

- Limited available space in dense urban areas may make it difficult to implement large-scale urban farming projects.
- Lack of access to necessary tools and resources for individuals or communities to start farming.
- Potential resistance from local authorities due to zoning laws or urban planning regulations.

Solutions:

- Prioritize underutilized land, such as abandoned buildings or vacant lots, which can be easily converted into community gardens.
- Provide support programs that offer tools, seeds, and educational materials to local residents.
- Advocate for policy changes that allow urban farming on public lands and provide incentives for green infrastructure.

Reducing Food Waste at the Source:

Challenges:

- Lack of awareness about the importance of food waste reduction and how to implement simple changes at the household or business level.
- Insufficient infrastructure to handle the redistribution of surplus food.
- Social or cultural resistance to donating food due to fears about food safety or stigmatization.

Solutions:

- Launch public awareness campaigns about the environmental and social benefits of food waste reduction.
- Set up food donation networks that connect businesses with charitable organizations.
- Educate the public and businesses on how to safely and efficiently donate food, with clear guidelines to ensure food safety standards are met.

Eco-Friendly Agricultural Practices:

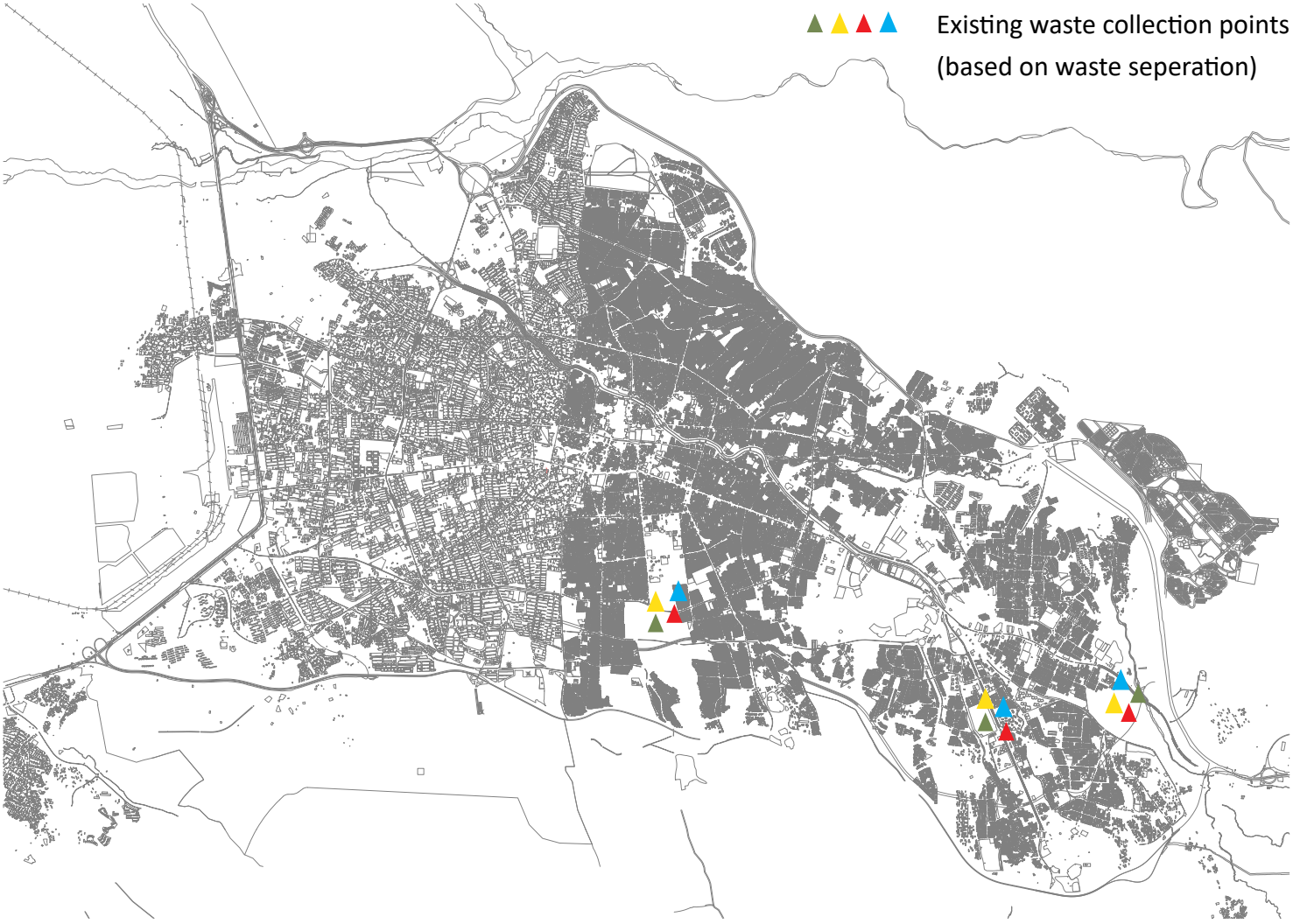
Challenges:

- Resistance from traditional farmers who are accustomed to conventional farming practices.
- Higher upfront costs for organic farming inputs or eco-friendly equipment.
- Limited knowledge about organic farming techniques in the local agricultural community.

Solutions:

- Provide training and certification programs for farmers in organic farming methods.
- Offer financial incentives such as subsidies or tax breaks to encourage farmers to adopt sustainable practices.
- Partner with local agricultural experts or universities to provide technical support and knowledge on sustainable farming practices.

3.1.4. Waste Strategies



Comprehensive Waste Sorting Program

- Establish waste separation bins in residential and commercial zones.
- Educate people on recycling habits.

Strengthening Recycling Infrastructure

- Build specialized recycling plants for e-waste, plastics, and organic waste.

Expansion of Composting Facilities

- Encourage composting at the household and municipal levels.

Integrated Waste Management: Waste Sorting, Recycling, and Composting

Definition: This strategy involves developing a city-wide waste system where materials are efficiently separated, recovered, and reused. It includes three interlinked components:
- Comprehensive Waste Sorting Program – introducing color-coded bins and awareness campaigns to encourage people to separate recyclables, organics, and landfill waste at the source.
- Strengthening Recycling Infrastructure – investing in specialized facilities to process e-waste, plastics, metals, and other recyclable materials efficiently.
- Expansion of Composting Facilities – promoting composting at both the household and municipal levels, converting organic waste into usable compost for agriculture or green spaces.

Importance

Integrated waste management—through sorting, recycling, and composting—is a cornerstone of creating a metabolic city, where urban systems function more like natural ecosystems: efficiently circulating resources, minimizing waste, and reusing what would otherwise be discarded. In Tabriz, where waste-related challenges such as unsorted garbage, high plastic consumption, and underutilized organic material are prevalent, this strategy offers a transformative path forward. By implementing these systems, Tabriz can reduce the pressure on landfills and decrease environmental pollution, particularly in its peripheral and lower-income neighborhoods where waste is often mismanaged. Composting diverts biodegradable waste from landfills, reducing methane emissions and producing valuable compost that can nourish local agriculture or urban green spaces. Recycling cuts down on the need for raw material extraction and supports local industries with cheaper, reusable resources. From a metabolic lens, this approach closes the loop between input (resource consumption) and output (waste), turning outputs into new inputs for other systems. Organic waste becomes compost for food production, recycled materials return to manufacturing, and the city consumes fewer virgin resources. It not only improves resource efficiency, but also boosts resilience, supports environmental equity, and reduces the ecological footprint of Tabriz. Furthermore, these changes build a cultural and behavioral shift among citizens toward more sustainable lifestyles. Residents become part of the solution, actively contributing to waste reduction and system improvement. Over time, this shifts the identity of Tabriz from a consumer-driven city to a resource-conscious, self-regulating, and circular urban metabolism.

Challenges

- Cost & Financial Constraints:
Establishing and maintaining advanced recycling and composting infrastructure requires high initial investment. Also, incentivizing public participation may need financial support schemes.
- Infrastructure & Technology:
Tabriz lacks widespread, efficient recycling centers, composting facilities, and collection mechanisms. There's also limited technology for sorting at source and waste tracking.
- Public Awareness & Behavioral Factors:
Many residents are unfamiliar with correct sorting methods or lack motivation. Cultural habits, convenience, and skepticism toward institutional efforts can hinder participation.
- Policy & Governance:
Weak enforcement of waste separation regulations and limited inter-agency coordination slow progress. There’s a need for updated legislation and long-term waste reduction policies.
- Urban Growth & Spatial Planning:
Informal settlements and rapidly growing areas in the city’s periphery may lack formal waste services, making uniform system rollout difficult. Space constraints in dense neighborhoods can also limit composting efforts.

Sollutions

-Cost & Financial Constraints: Public-private partnerships (PPP) can fund infrastructure development. Subsidies and tax incentives can encourage businesses and residents to participate. Recycling fees and eco-taxes on non-recyclable waste can help generate funds.
- Infrastructure & Technology: Invest in modern waste management technology like smart bins and automated sorting systems. Introduce decentralized systems like mobile recycling units and community composting stations to handle waste efficiently in densely populated areas.
Public Awareness & Behavioral Factors: Launch educational campaigns via schools, media, and community centers to promote waste sorting. Offer incentives like rewards or discounts for residents who recycle correctly. Conduct workshops and training programs to build awareness.
- Policy & Governance: Implement strong waste management policies with penalties for non-compliance. Set up a waste management task force to ensure coordination between government bodies and businesses. Incentivize waste reduction programs for companies.
- Urban Growth & Spatial Planning: Incorporate waste management infrastructure into urban planning. Promote community-based initiatives for composting and recycling in growing areas. Use zoning laws to allocate space for waste facilities in expanding neighborhoods and support informal recyclers with training and equipment.

3.2. Pilot Project

Introduction to Spatial Implementation of Metabolic Strategies in Tabriz

As cities around the world grow more complex and resource-dependent, the need for new urban planning approaches becomes increasingly urgent. Traditional development models often treat cities as linear systems — where resources are consumed, used, and discarded — resulting in wasteful and unsustainable outcomes. In contrast, the metabolic city framework proposes a more circular and regenerative model, one in which cities function like living organisms: absorbing resources efficiently, distributing them wisely, and recycling or reusing what remains. This perspective shifts the focus toward sustainability, integration, and systemic thinking in urban design.

In the case of Tabriz, the metabolic approach offers a practical and visionary path forward. Tabriz faces a range of environmental and infrastructural challenges, from groundwater depletion and inefficient waste management to rising energy demand and urban food insecurity. At the same time, the city also possesses significant opportunities — including public awareness, renewable energy potential, and a culture of local food production — that can be leveraged to create a more resilient and self-sustaining urban environment. Through a series of research phases including field observation, expert interviews, public engagement, and analysis of existing flows, this study has identified a tailored set of strategies designed to help Tabriz evolve into a more metabolic city. These strategies aim to reduce resource waste, close environmental loops, and enhance urban livability while aligning with five core factors essential to successful implementation:

Cost & Financial Constraints, Infrastructure & Technology, Public Awareness & Behavioral Factors, Policy & Governance, and Urban Growth & Spatial Planning.

The strategies are categorized into four key urban systems — Water, Energy, Waste, and Food — which represent the essential flows within any urban metabolism. Below is a categorization of the selected strategies, grouped under the four primary urban flows:

WATER FLOW
- Artificial Recharge Basins – to replenish groundwater resources.
- Permeable Pavements & Green Streets – to increase infiltration and reduce runoff.
- Rainwater Harvesting Systems – for capturing and reusing rainwater.
- Dual Water Supply Lines (Potable + Recycled) – for efficient and safe reuse of treated wastewater.

ENERGY FLOW
- Solar Rooftop Panels on Public Buildings – to tap into renewable energy sources.
-Solar Farms in Urban Fringe Areas – for large-scale solar energy production.
- Urban Wind Turbines – to generate clean energy from local wind patterns.
- Energy-Efficient Building Retrofits – to minimize energy loss and consumption.

WASTE FLOW
- Waste Sorting Bins in Public Spaces – to improve separation at the source.
- Neighborhood Recycling Centers – to facilitate local material recovery.
- Composting Stations in Parks – to transform organic waste into useful compost.
- Underground Waste Collection System – for cleaner and more efficient waste handling.

FOOD FLOW
- Community Gardens on Vacant Lots – for local food production and green space.
- Urban Greenhouses – to support year-round urban agriculture.
- Local Farmer's Market in Public Squares – to strengthen local food systems.
- Food Bank Collection Points – to reduce food waste and address food insecurity.

Selected Pilot Areas for Implementation

To test the effectiveness and adaptability of these strategies, three specific urban locations in Tabriz have been chosen for detailed design interventions:

1. Tarbiat Street
A historic and commercial pedestrian zone in the heart of the city, Tarbiat Street was selected due to its symbolic urban role, visibility, and dense public use. It offers a strategic opportunity to implement urban water and energy strategies such as solar panels, green infrastructure, and rainwater harvesting in a high-impact setting.

2. Shahgoli Park
One of the largest and most visited green spaces in Tabriz, Shahgoli Park serves as an ideal environment for ecological and water management strategies. Its natural setting makes it suitable for artificial recharge basins, decentralized wastewater reuse, and educational engagement with sustainable practices.

3. Vacant Urban Areas
Numerous underutilized plots and vacant lots scattered across Tabriz offer immense potential for revitalization. These areas were chosen to implement food flow strategies such as community gardens, urban greenhouses, and local markets. Their transformation can support food security, foster community, and bring life back to idle spaces.

These three distinct urban contexts reflect the spatial diversity of Tabriz and serve as living laboratories to demonstrate how metabolic urbanism can be adapted and implemented in real-world conditions. The following maps and diagrams illustrate the proposed interventions in each area, emphasizing how these strategies can interact with existing structures and contribute to a more sustainable urban metabolism.

3.2.1. TARBIAT street, Tabriz

Introduction to Tarbiat Street
Tarbiat Street is one of the most iconic and historically significant pedestrian thoroughfares in the heart of Tabriz, Iran. Stretching through the city's central business and cultural district, this street has long served as a key urban axis, linking commercial, social, and architectural landmarks. Originally developed during the Pahlavi era, it was among the first modern urban interventions in Tabriz, and over time, it has evolved into a vibrant pedestrian corridor, attracting both locals and tourists.

The street is distinguished by its blend of modern retail activity and historical architecture, with elements of Qajar-era buildings still visible alongside contemporary storefronts. As a car-free zone, it offers a unique urban experience where people can walk, shop, socialize, and enjoy the public space. Key landmarks such as the Tabriz Bazaar, Saat Tower, and several cultural institutions are within walking distance, making Tarbiat Street an important node in the city's spatial and social network.

Due to its centrality, accessibility, and symbolic significance, Tarbiat Street represents an ideal site for testing urban strategies aimed at transforming Tabriz into a more metabolic, sustainable, and people-centered city. Its pedestrian-friendly nature, high foot traffic, and adjacency to mixed-use developments provide a strong foundation for implementing solutions related to urban agriculture, water reuse, energy efficiency, and waste management.

Why Tarbiat Street is Suitable for Metabolic Urban Strategies?

Tarbiat Street presents a unique opportunity for demonstrating sustainable and metabolic urban interventions due to its central role in the life of Tabriz. Its pedestrian nature reduces vehicular pollution and creates a more controlled environment for testing strategies related to resource cycles such as water, energy, food, and waste. The presence of commercial, cultural, and social functions along the street means that any design intervention can reach a wide audience and generate visible impact.

In addition, the high density of activity and the mix of traditional and modern elements make it possible to apply both bottom-up and top-down strategies. The street's existing infrastructure—such as underground services, lighting, and open space design—can be adapted or upgraded to incorporate technologies like solar panels, water recycling units, composting stations, and community gardens. This makes Tarbiat a flexible laboratory for applying the principles of urban metabolism in a localized and tangible manner.

By focusing on Tarbiat Street, the aim is not only to improve the sustainability of this key public space but also to create a replicable model for similar interventions across other parts of the city.

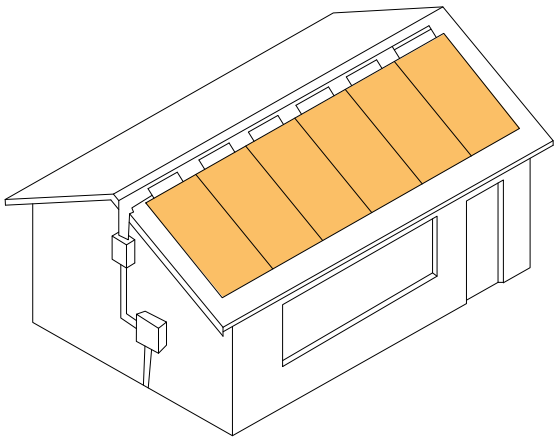
Tarbiat Street Entrance Gate

Tarbiat Street

Proposed Strategies in Tarbiat Street

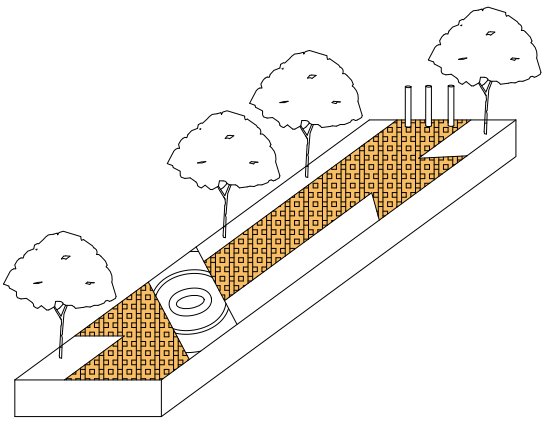
1. Solar Rooftop Panels on Public Buildings and Solar Panels on Street Lamps

Applicability:
Tarbiat Street hosts several public and semi-public buildings such as municipal offices, cultural centers, shopping complexes, and historical structures with adequate roof space. Many of these rooftops receive ample sunlight throughout the year, making solar energy a viable renewable option.



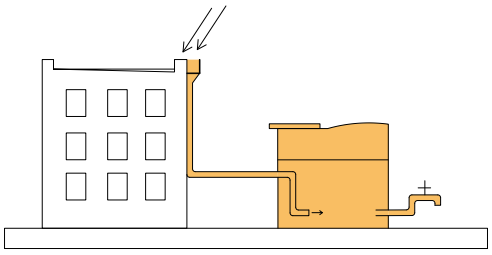
Why it works here:
- Tabriz has a good solar potential due to its geographic location.
- Public buildings can set an example for broader adoption across the city.
- Helps reduce dependency on fossil-fuel-based electricity in a high-footfall zone.

2. Permeable Pavements & Green Streets
Applicability:
Tarbiat Street is a pedestrian-priority area with wide walking spaces, plazas, and landscaped sections. Replacing or modifying existing pavements with permeable materials is feasible and can be phased in gradually.



Why it works here:
- Tarbiat Street's walkability offers a great testbed for low-impact development.
- Helps manage stormwater locally instead of overwhelming the urban drainage system.
- Green corridors can also provide shade, reduce heat, and enhance urban aesthetics.

3. Rainwater Harvesting Systems
Applicability:
Rainwater harvesting systems can be integrated into the roofs of commercial and public buildings along the street. Collected water can be reused for cleaning the pedestrian paths, irrigating urban greenery, and even for use in nearby buildings after treatment.



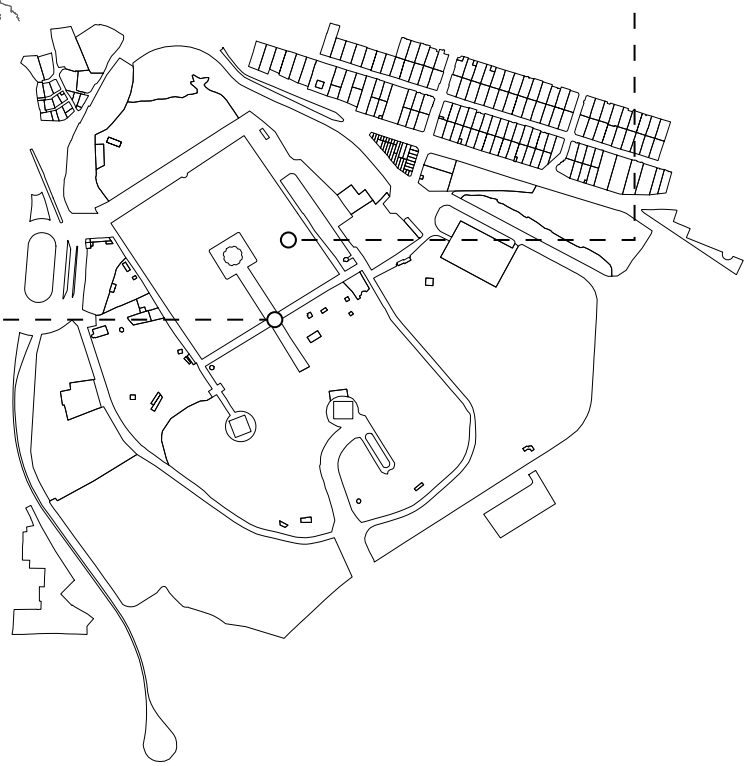
Why it works here:
- Tabriz faces water stress; urban water conservation is essential.
- Tarbiat Street has multiple buildings close together, allowing for networked collection systems.
- Promotes environmental awareness through visible, functional infrastructure.

3.2.2. SHAHGOLI Park, Tabriz

Introduction to Shahgoli Park (El Goli Park), Tabriz
Shahgoli Park, also known as El Goli, is one of Tabriz's most iconic and historically rich urban green spaces. Located in the southeastern part of the city, the park features a large central artificial lake with a historic pavilion-turned-restaurant at its heart, surrounded by expansive lawns, tree-lined paths, and recreational zones. As a well-loved public destination, it serves both locals and tourists as a place for leisure, walking, sports, and family gatherings.

Due to its size, landscape character, and existing infrastructure, Shahgoli offers unique potential as a demonstration site for ecological and sustainable urban interventions. Its blend of built and natural environments creates a balanced testing ground for water, energy, food, and waste strategies that align with the vision of a metabolic city.

Beyond its recreational value, the park plays an essential role in urban microclimate regulation, air purification, and public well-being. This makes it a prime location for implementing strategies that enhance urban metabolism while also engaging citizens directly with ecological thinking through visible, functional systems embedded in daily life.



Why Shahgoli Park is Suitable for Metabolic Urban Strategies

Shahgoli Park, one of the most iconic and historic public spaces in Tabriz, presents an exceptional opportunity for applying metabolic urban design strategies. Known for its lush greenery, central lake, and continuous public use, Shahgoli serves not only as a recreational destination but also as a cultural and ecological landmark. The park's large open spaces, diverse landscape features, and high foot traffic make it an ideal testbed for introducing integrated environmental solutions that enhance both ecological performance and public experience.

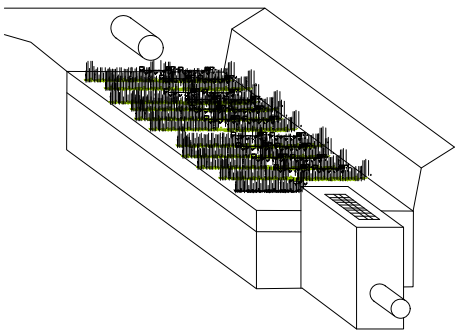
Unlike denser urban areas, Shahgoli provides spatial flexibility for experimenting with infrastructure improvements, including water reuse systems, solar installations, and waste processing zones. Its existing natural elements—such as trees, gardens, and water bodies—already support a degree of ecological function, which can be significantly enhanced through targeted interventions. Moreover, the park's visibility and accessibility make it a strategic site for engaging citizens in sustainability, education, and behavioral change.

From a planning perspective, Shahgoli acts as a green lung within the growing urban fabric of Tabriz. As the city expands and faces pressures related to resource scarcity, Shahgoli can be positioned not just as a passive recreational area, but as an active urban metabolism node—where flows of water, energy, food, and waste are managed locally and visibly. These features make Shahgoli Park not only an appropriate site for sustainable innovation, but also a powerful platform to demonstrate the possibilities of a metabolic city in action.

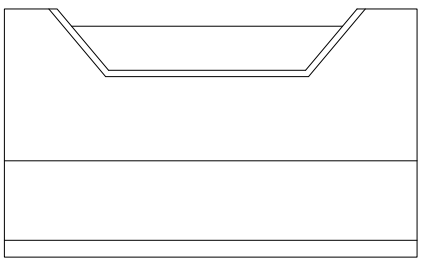
Proposed Strategies in Shahgoli Park

Given Shahgoli Park's expansive green spaces, existing landscape infrastructure, and public visibility, it offers fertile ground for introducing metabolic design strategies that align with both ecological goals and public engagement.

1. Rainwater Harvesting Systems:
Shahgoli Park, with its wide green areas, walkways, and built elements, is highly suitable for implementing rainwater harvesting strategies. By installing underground storage tanks, bioswales, and collection channels along the park's topography, rainwater can be captured and reused for irrigation. This reduces dependency on municipal water supply and contributes to more resilient water management. The park's open layout allows these systems to be subtly integrated without disrupting the user experience.



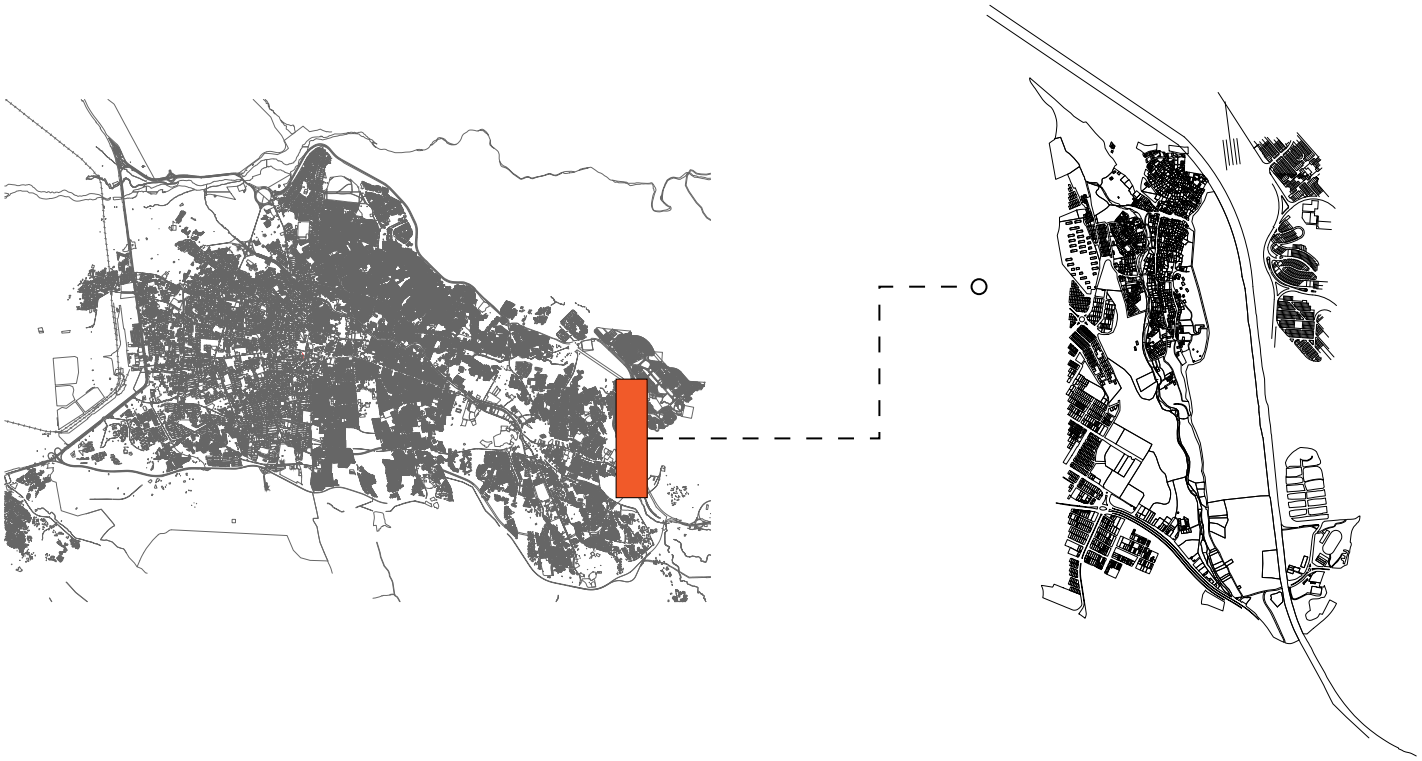
2. Artificial Recharge Basins:
Shahgoli Park's extensive open green areas and natural topography make it highly compatible with the installation of artificial recharge basins. The park already handles significant volumes of irrigation and surface water runoff, especially during rainy seasons. By redirecting some of this water into recharge zones, the park can contribute to replenishing Tabriz's overdrawn aquifers. Additionally, Shahgoli's educational and touristic appeal offers a chance to showcase the importance of sustainable water practices in a highly visible public space.



3. Urban Agriculture Demonstration Gardens:
Portions of the park's peripheral or underused areas can be transformed into educational urban farms or community gardens. These would serve as living labs to promote sustainable food practices and reconnect citizens with local food production. As a family-oriented space, Shahgoli is ideal for interactive green education through seasonal planting, gardening workshops, and food-growing exhibitions.

3.2.3. Tabriz Vacant Areas

Tabriz, like many rapidly expanding cities, contains numerous vacant and underutilized urban spaces—ranging from empty plots between buildings to disused industrial lands and neglected corners of neighborhoods. These areas, often overlooked or considered as urban voids, hold significant potential for reactivation and sustainable transformation. Rather than leaving them idle, these spaces can be strategically repurposed to support urban agriculture, green infrastructure, community-based services, and circular systems. By converting vacant lots into community gardens, local markets, or greenhouses, and by installing food bank collection points, Tabriz can simultaneously address food insecurity, promote local economies, reduce environmental pressure, and foster a more connected and self-sustaining urban metabolism. Embracing these forgotten spaces as catalysts for ecological and social regeneration aligns closely with the city's transition toward a more metabolic and resilient future.



Proposed Design Strategies for Vacant Areas in Tabriz

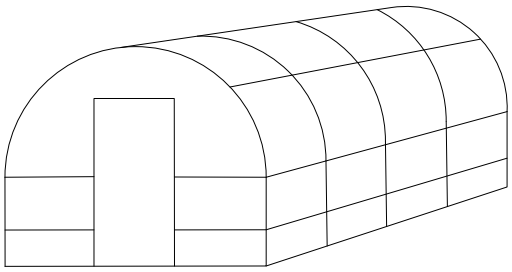
1. Community Gardens on Vacant Lots

Explanation:
Community gardens involve transforming unused or underutilized vacant land into shared plots where local residents can grow fruits, vegetables, and herbs. These spaces encourage collaboration, urban agriculture, and green space creation in otherwise lifeless zones. They can be managed by neighborhood groups, schools, or NGOs and often incorporate composting, rainwater collection, and biodiversity elements.

How It Helps Tabriz Become a Metabolic City:
Community gardens close the loop on organic waste by turning food scraps into compost, reduce reliance on long food supply chains, and bring local food production into the urban core. They create socially and ecologically productive areas that improve microclimates, promote community engagement, and contribute to food resilience—all critical aspects of a metabolic city.

2. Urban Greenhouses

Explanation:
Urban greenhouses are enclosed farming structures built in cities, often using hydroponic or aquaponic systems to grow crops with minimal water and land use. These can be installed on vacant land, rooftops, or integrated into existing buildings. They provide a controlled environment that ensures high-yield, pesticide-free food production throughout the year.



How It Helps Tabriz Become a Metabolic City:
Urban greenhouses reduce food transportation emissions, optimize land use, and introduce high-efficiency water and nutrient cycles into the urban ecosystem. They support technological innovation, reduce urban heat islands, and can be paired with renewable energy systems—making them a high-impact metabolic solution for food and resource management in Tabriz.

3. Local Farmer's Market in Public Squares

Explanation:
Creating local farmers' markets in accessible vacant or public spaces provides a platform for small-scale farmers and producers to sell directly to consumers. These markets can be regular (weekly or monthly) and serve as community gathering places centered on local food, handmade goods, and sustainable lifestyles.

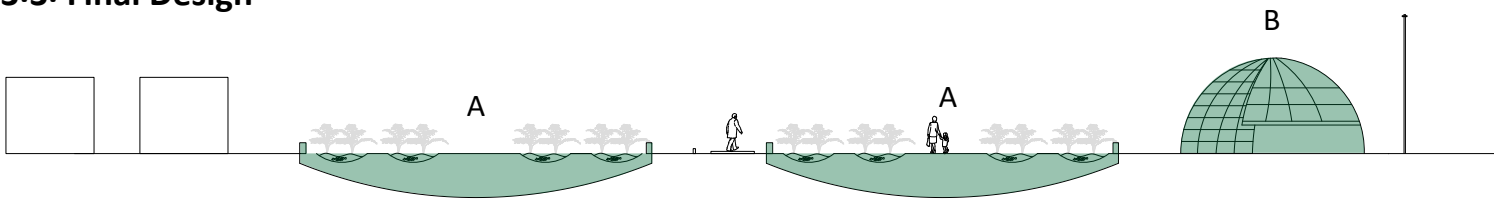
How It Helps Tabriz Become a Metabolic City:
By shortening the food supply chain, local markets reduce energy use, food loss, and packaging waste. They stimulate the local economy and promote seasonal, local diets. Farmers' markets help create resilient food systems and culturally rich urban nodes, both of which align with the metabolism of a self-sustaining and low-impact city.

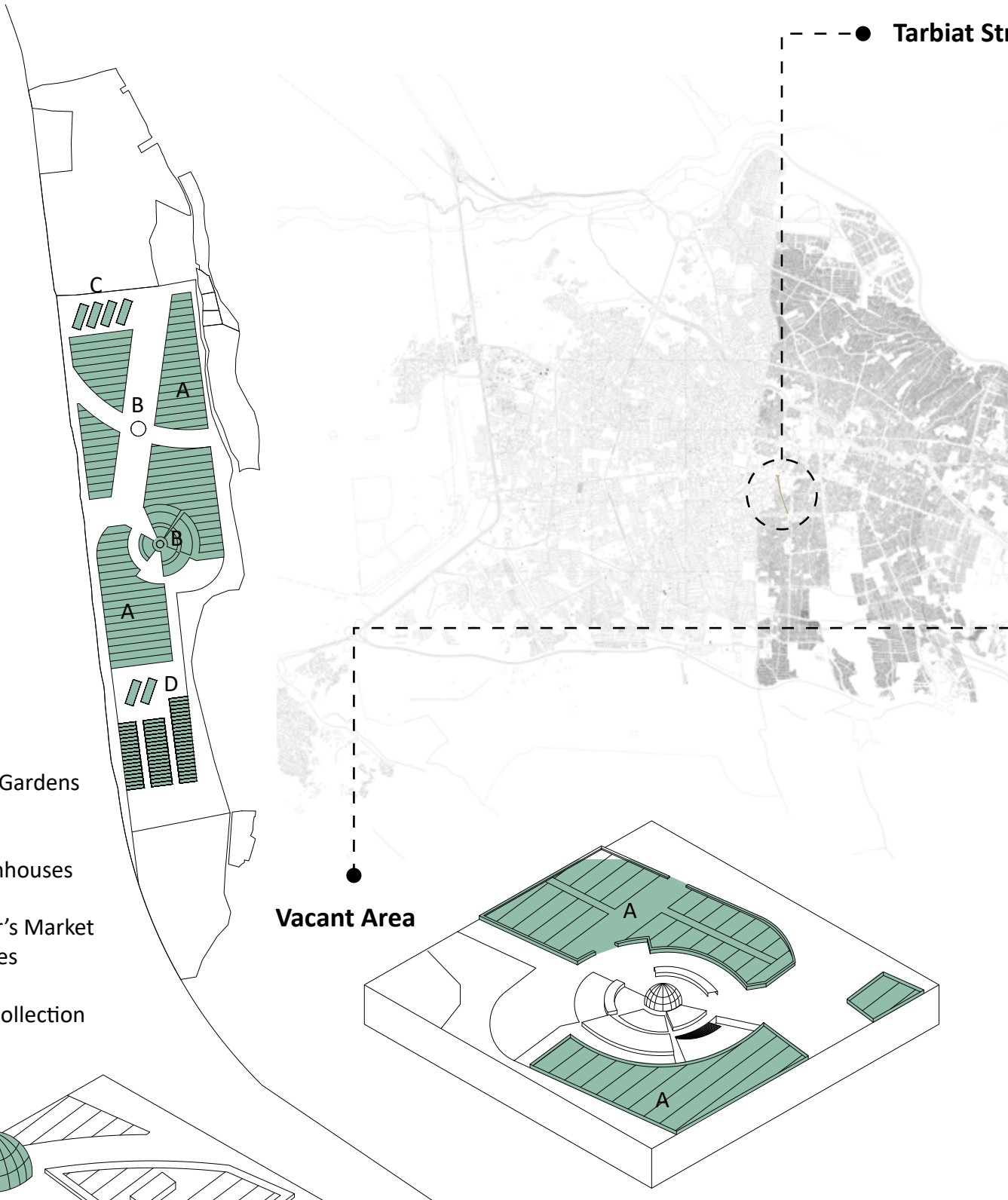
4. Food Bank Collection Points

Explanation:
Food bank collection points are designated drop-off and pick-up zones where surplus food from restaurants, homes, and markets can be redistributed to vulnerable populations. These points can be integrated into community centers, markets, or even placed within residential neighborhoods.

How It Helps Tabriz Become a Metabolic City:
Food banks prevent edible food from becoming waste, supporting circularity within the urban food system. They address food inequality and waste simultaneously, turning excess into resource. This not only minimizes landfill contributions but strengthens social sustainability, an often overlooked yet essential layer of metabolic urban planning.

3.3. Final Design



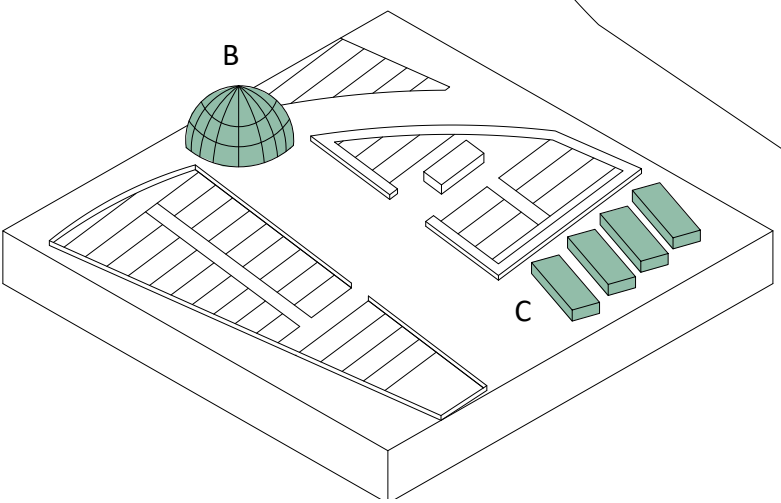


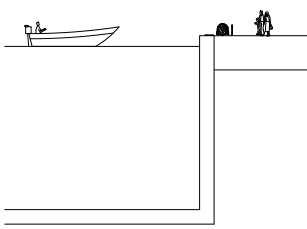
A) Community Gardens on Vacant Lots

B) Urban Greenhouses

C) Local Farmer's Market in Public Squares

D) Food Bank Collection Points





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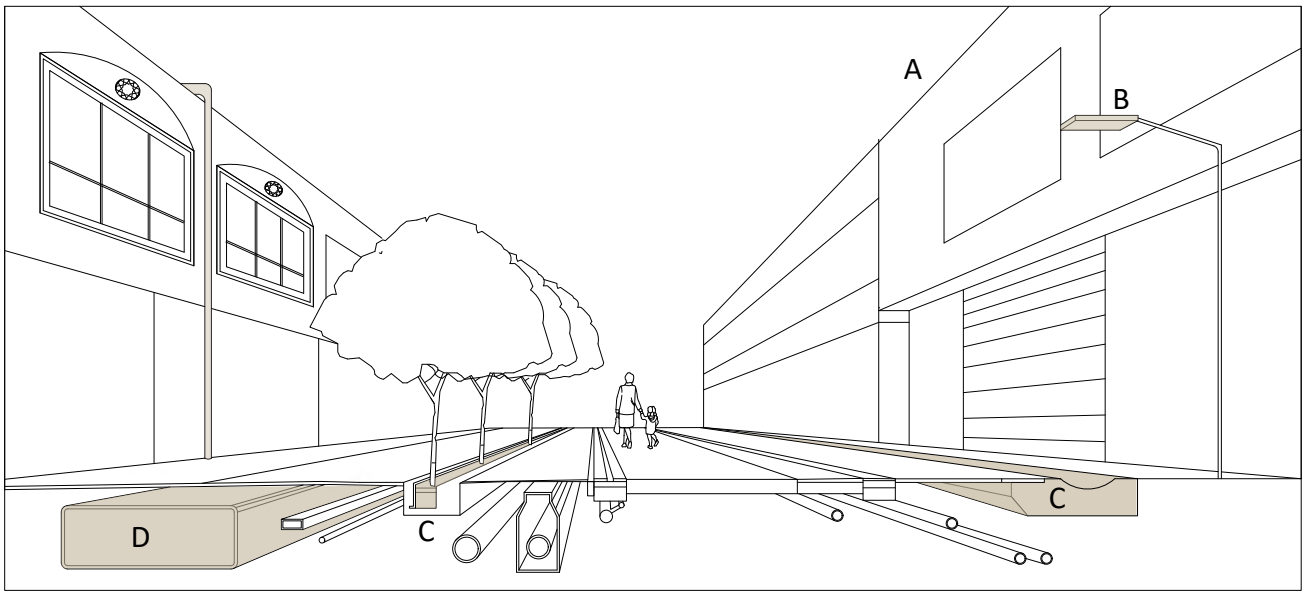
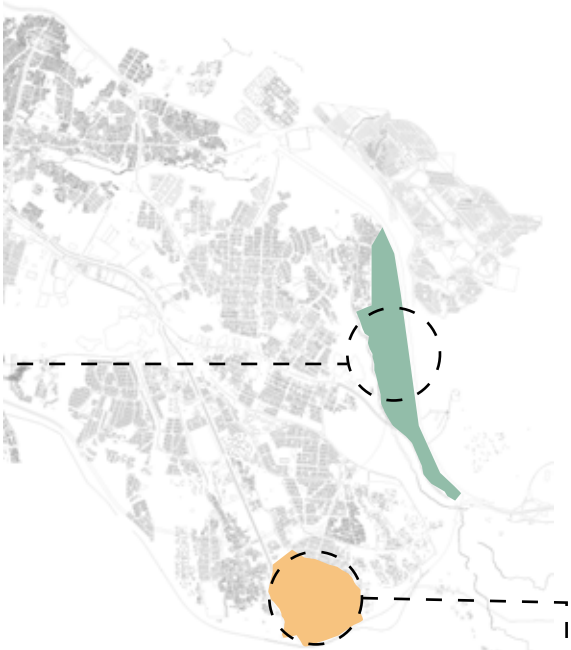
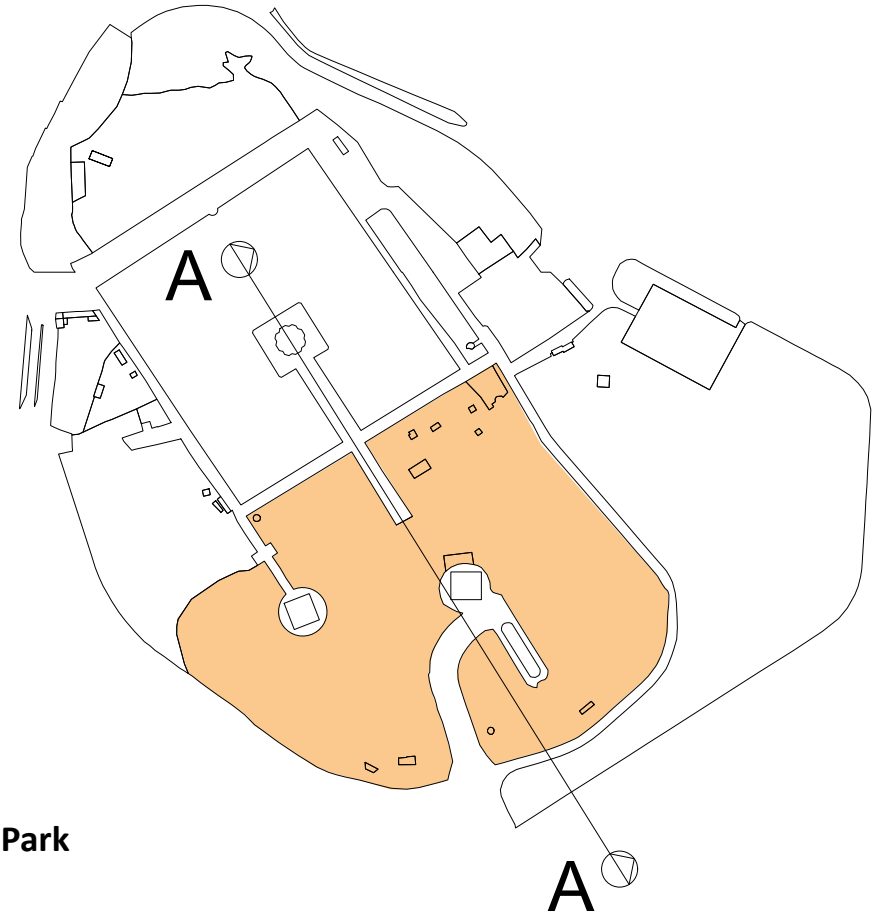
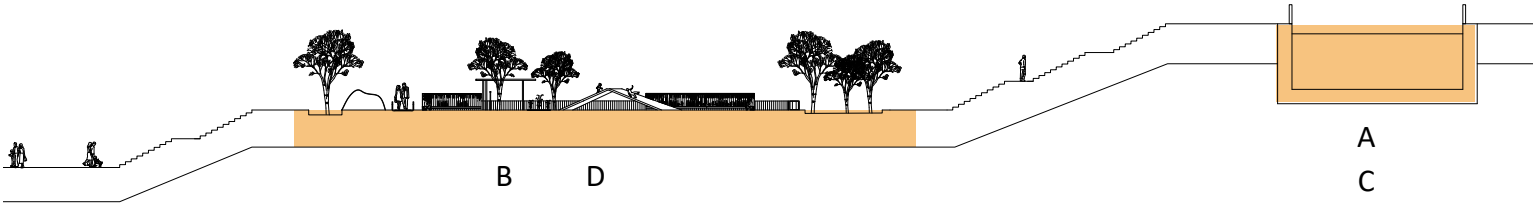


A) Solar Rooftop Panels on Public Buildings
B) Solar Panels on Street Lamps
C) Permeable Pavements & Green Streets
D) Rainwater Harvesting Systems





Shah-Goli Park



A) Artificial Recharge Basins
B) Decentralized Wastewater Treatment Units
C) Treated Water for Irrigation & Urban Landscaping
D) Green walls in Public spaces

Visualizing the Transformation

In this section, a series of collages has been prepared to illustrate how the proposed strategies can be implemented in three selected areas of Tabriz: Tarbiat Street, Shahgoli Park, and a vacant urban lot. These visual compositions combine real photographs of existing conditions with imagined scenarios showing the integration of sustainable features. By presenting both "before" and "after" views, the collages aim to clearly demonstrate how each intervention can reshape the urban environment—not only visually, but also functionally—towards a more metabolic and resilient future for the city.

Existing Situation

Tarbiat Street: A Step Toward Sustainability

This collage shows how simple design strategies can improve Tarbiat Street and support a more sustainable Tabriz.

1. Rain Garden: Collects and filters rainwater through soil and plants, reducing flooding and adding greenery.
2. Permeable Pavement: Lets water soak into the ground, helping recharge groundwater and prevent surface runoff.
3. Underground Water Tank: Stores rainwater for later use, like watering plants or cleaning, reducing demand on the main water supply.
4. Solar Street Lamp: Uses sunlight to power lights at night, saving energy and lowering emissions.

Existing Situation

Vacant Area: Turning Empty Spaces into Productive Land

This collage shows how unused land in Tabriz can be transformed into active, productive spaces that benefit both people and the environment—creating small hubs of sustainability within the urban fabric.

1. Urban Greenhouses: These enclosed, controlled environments allow for growing fresh vegetables and herbs throughout the year, regardless of weather conditions. By using efficient irrigation and vertical planting systems, they help conserve water and space—making them especially valuable in a city like Tabriz, where water resources can be limited. Beyond food production, they can serve educational purposes and introduce modern farming techniques into the city.
2. Community Gardens: These are small plots shared and managed by local residents, where they can grow their own fruits, vegetables, and medicinal plants. Community gardens not only promote healthier diets but also build stronger social bonds between neighbors. They give people a sense of ownership, offer a green escape within the city, and encourage more sustainable food habits.

Together, these ideas turn neglected land into sources of food, community, and learning—helping Tabriz take a step closer to becoming a more metabolic and resilient city.

Existing Situation

Shahgoli Park: Nature-Based Solutions in Action

This collage explores how Shahgoli Park can support sustainability through simple but powerful changes, turning an already beloved public space into a model for ecological responsibility.

1. Green Walls: By adding vertical gardens to the park's built structures—such as rest areas, cafés, or walls near pathways—Shahgoli can benefit from improved air quality, natural insulation, and a more comfortable microclimate. These living walls help absorb heat, reduce dust and noise pollution, and provide a visually calming experience for visitors, making the park both more beautiful and environmentally functional.

2. Waste Separation Units: Installing clearly labeled, color-coded bins throughout the park makes it easy for people to sort their waste—separating recyclables, organics, and general trash. This simple yet impactful step not only reduces landfill use but also raises public awareness about the value of proper waste management. Over time, it encourages a culture of responsibility and participation in keeping shared spaces clean and sustainable.

Together, these elements show how even modest, well-placed changes can create a park that supports a more metabolic city—where nature, people, and systems work in harmony.

Existing Situation

3. Artificial Recharge Basins:

These are specially designed, shallow landscaped areas that collect and hold rainwater during wet periods. Instead of letting the water run off into drains or flood streets, these basins let it slowly seep into the soil, where it can naturally refill underground aquifers. This process helps restore groundwater levels, which is especially important in cities like Tabriz that face water scarcity. Besides their functional role, recharge basins can be integrated into public parks or green spaces, adding both beauty and ecological value to urban areas. By using natural systems to manage water, they support a more balanced and sustainable urban environment.

Conclusion

This thesis explored how the concept of urban metabolism can guide sustainable development in the city of Tabriz. By analyzing the flows of water, energy, waste, and food, it became clear that urban systems are deeply interconnected, and their efficiency depends on how well these flows are managed. Tabriz, like many growing cities, faces a number of environmental and infrastructural pressures, but it also holds many untapped opportunities for change.

The research began by studying the city's current conditions, identifying key challenges such as groundwater depletion, limited renewable energy use, inefficient waste separation, and reliance on imported food. At the same time, local behaviors, community awareness, and interest in sustainability pointed to areas of potential. These insights shaped the development of practical design strategies that respond directly to the city's specific needs and characteristics.

Strategies were introduced for each of the four flows. For water, solutions like artificial recharge basins and rainwater harvesting were proposed to improve water balance. In the energy sector, expanding solar energy use on rooftops and street lamps offered a renewable and accessible path forward. Waste strategies focused on sorting, recycling, and composting systems that could be integrated into public spaces and neighborhoods. For food, urban farming, local markets, and food redistribution programs were suggested to create a more localized and resilient food system.

To show how these strategies might work in practice, three locations in Tabriz were selected as potential implementation sites. These areas represent different urban conditions—from dense commercial zones to large public parks and vacant lots—and together demonstrate how metabolic principles can be adapted across the city. Each space was matched with strategies that suit its physical context and social function.

Looking to the future, these interventions are not one-time solutions, but stepping stones toward a broader transformation. With continued investment, policy support, and community involvement, Tabriz can become a model for sustainable urban development in Iran and beyond. A metabolic approach encourages cities to reduce waste, reuse resources, and plan with long-term balance in mind—principles that are essential for adapting to environmental challenges and improving quality of life.

This work highlights the importance of seeing cities as living systems, where every flow counts and every space can contribute to a healthier, more efficient, and more sustainable urban life.

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