Planlama 2025;Supp(1):18–34 | doi: 10.14744/planlama.2025.55798

ARTICLE / ARAŞTIRMA

Integrated and Sustainable Food Systems in the Context of the WEF Nexus Approach: An Assessment of Istanbul, Ankara, and Izmir

WEF Nexus Yaklaşımı Bağlamında Entegre ve Sürdürülebilir Gıda Sistemleri: İstanbul, Ankara ve İzmir Üzerine Bir Değerlendirme

Ebru Ala,[1] Gülden Demet Oruç Ertekin[2]

[1]Department of Urban and Regional Planning, Süleyman Demirel University Faculty of Architecture, Isparta, Türkiye
[2]Department of Urban and Regional Planning, İstanbul Technical University Faculty of Architecture, İstanbul, Türkiye

ABSTRACT

Urbanization, climate change, population growth, and resource limitations create significant challenges for sustainability and security in food systems. Despite advancing technology, the increasing number of people who cannot access safe food and the likelihood that this number will continue to rise due to global challenges necessitates a new approach in policy decisions related to food systems. In this context, terms like integration, interrelatedness, and Nexus have become central in the literature, as they are crucial for ensuring the resilience and sustainability of food systems in the face of negative externalities. Given the current food crisis, it is essential to evaluate these limited resources, which are directly or indirectly interconnected, in planning and implementation processes. The WEF Nexus approach, which explains the relationships between water, energy, and food components and aims to optimize them, is a concept that can respond to the sustainability framework. This study aims to explain the impact of the WEF Nexus on the sustainability of food systems. In this research, which examines urban policy decisions in the context of the WEF Nexus and specifically in food systems, Istanbul, Ankara, and Izmir, Türkiye's three largest metropolises, were selected for evaluation. Policy decisions affecting food systems and addressed by local governments have been analyzed qualitatively and quantitatively within the context of the WEF Nexus approach. These analyses highlight the need to ensure policy coherence in areas such as "waste management," "climate change," "education/awareness," "disaster management," and "logistics/IT" to achieve sustainable food systems.

Keywords: Integrated planning; sustainable food systems; Türkiye; WEF nexus.

ÖZ

Kentleşmenin yol açtığı arazi tahribatı, iklim değişikliği, nüfus artışı ve kaynakların kısıtlılığı gıda sistemlerinde sürdürülebilirlik ve güvenlik açısından çeşitli zorluklar yaratmaktadır. Gelişen teknolojiye rağmen güvenli gıdaya ulaşamayan insan sayısının artması ve bu sayının küresel zorlukların etkisiyle giderek artacak olması, gıda sistemlerine ilişkin politika kararlarında yeni bir yaklaşımı zorunlu kılmaktadır. Bu doğrultuda literatürde entegrasyon, ilişkisellik ve Nexus terimleri öncelikli hale gelmektedir. Bu terimler, olumsuz dışsallıklar karşısında gıda sistemlerinin dayanıklılığını ve sürdürülebilirliğini sağlama açısından önemlidir. Çünkü gıda krizinin gündemde olduğu bu dönemde, planlama ve uygulama süreçlerinde doğrudan veya dolaylı ilişkide olan bu kısıtlı kaynakların birlikte değerlendirilmesi gerekmektedir. WEF Nexus yaklaşımı ise; su, enerji ve gıda bileşenleri arasındaki ilişkileri açıklayarak ve optimize etmeyi hedefleyerek sürdürülebilirlik çerçevesine yanıt verebilecek bir kavramdır. Bu çalışma, WEF Nexus yaklaşımının gıda sistemlerinin sürdürülebilirliği üzerindeki etkisini açıklamayı amaçlamaktadır. Kentsel politika kararlarının WEF Nexus yaklaşımı bağlamında ve gıda sistemleri özelinde incelendiği bu araştırmada, değerlendirmek üzere Türkiye'nin en büyük üç metropolü olan İstanbul, Ankara ve İzmir seçilmiştir. Yerel yönetimler tarafından ele alınan ve gıda sistemlerini etkileyen veya etkileme potansiyelinde olan politika kararları, WEF Nexus yaklaşımı çerçevesinde nitel ve nicel olarak analiz edilmiştir. Bu analizler üç metropol özelinde, sürdürülebilir gıda sistemlerine ulaşmak için "atık yönetimi", "iklim değişikliği", "eğitim/farkındalık", "afet yönetimi" ve "lojistik/BT" gibi alanlarda politika tutarlılığı sağlama gerekliliğini vurgulamaktadır.

Anahtar sözcükler: Bütünleşik planlama; sürdürülebilir gıda sistemleri; Türkiye; WEF nexus.

Received: 22.08.2024 Revised: 06.03.2025
Accepted: 29.03.2025 Available online date: 18.08.2025
Correspondence: Ebru Ala
e-mail: ebruala@sdu.edu.tr

TMMOB Şehir Plancıları Odası

Introduction

In the 21st century, various internal and external factors such as pandemics, wars, earthquakes, land degradation, climate change, and population growth, which significantly impact urban areas, are leading to the scarcity of natural resources, thereby jeopardizing the sustainability of food systems. Food systems are heterogeneous systems that establish direct or indirect relationships with water and energy components during production, distribution, consumption, and post-consumption processes, and they involve many internal and external factors. The continuity of these relationships, and thus the sustainability of food systems, are put at risk due to the depletion of natural resources. This is because these global challenges not only have negative effects on the supply of clean water and energy production, but also disrupt the balance between supply and demand, thereby affecting the sustainability of food systems (de Andrade Guerra et al., 2021).

According to United Nations (UN) reports, the world population could reach up to 8.5 billion by 2030. By 2030, urban areas are expected to house approximately 60% of the global population, and due to global population growth, demands for water, energy, and food are predicted to increase by approximately 35%, 40%, and 50%, respectively (UN, 2018, 2022; National Intelligence Council, 2012). In addition, although global food production strives to keep up with this rapid population growth and demand, it is known that nearly 750 million people, making up approximately 10% of the global population, were exposed to severe food insecurity in 2023 (FAO, 2024). Given the various global challenges faced today and the pressure these challenges place on natural resources, it is inevitable that this rate will rapidly increase over the years. Therefore, it should be understood that food systems cannot be addressed in isolation when responding to the food demand of the current and future population, and they must be integrated into a holistic planning process together with water and energy resources. Ringler and others support this view, arguing that resources and their usage are interconnected in terms of environmental outcomes for present and future generations, and that a rigorous theoretical framework is necessary to balance the costs of trade-offs and identify synergies to ensure sustainability (Ringler et al., 2013). Considering the natural resources that food systems are directly or indirectly connected with, the Water, Energy and Food Security Nexus concept/approach (WEF Nexus) corresponds to this theoretical framework. Therefore, the primary objective of this study is to qualitatively and quantitatively assess the sustainability of the urban food systems in terms of the level of integration among water, energy, and food components. This assessment is conducted through a systematic review, content analysis, and comparative analysis of the planning and policy decisions found in the plans prepared or commissioned by the local governments of Istanbul, Ankara, and Izmir—Türkiye's three largest metropolitan cities—using the MAXQDA 2024 software. In this regard, the study focuses respectively on the sustainability of food systems, the WEF Nexus, the relationship this approach establishes with sustainability, and finally the sustainability of food systems in the context of the WEF Nexus approach. Because this approach is recognized in the literature for explaining the connections between water, energy, and food components, aiming to optimize these components, and contributing to the sustainability of food systems. Additionally, it is regarded as a tool that optimizes the resource use of society and cities, and consequently, food systems.

Additionally the WEF Nexus approach has generally been a subject of study in the fields of engineering, economics, environmental sciences, and policy in the literature. These studies have addressed factors such as the design of systems, the use of innovative technologies, the standardization of economic investments, and the analysis of costs (Rasul, 2014; Bazilian et al., 2011; Smajgl & Ward, 2013; Hoff, 2011; Simpson & Jewitt, 2019; Ali & Acquaye, 2024). When examining plans at various scales, it becomes apparent that there are deficiencies in the visions of establishing intersectoral relationships and serving a network-connected planning approach for the future. The fragmentation of planning decisions and policies between sectors, along with the lack of integrated governance, leads to undesirable outcomes in terms of sustainability (Weitz et al., 2017; Childers et al., 2015). Despite the growing awareness in recent times, the integrated design and implementation of WEF components (water, energy, food) in planning processes, which have not yet been adequately addressed, also bring important legal and administrative issues to the forefront (Olawuyi, 2020). In other words, the lack of effective incorporation of the WEF Nexus approach into policy agendas from legal and administrative perspectives creates a significant gap between science and policy, affecting the sustainability of food systems.

While the WEF Nexus approach has been previously applied to food system planning, this study represents the first attempt in Türkiye to 'urbanize' and 'systematize' the concept, specifically within the context of food systems. It does so by examining the governance tools and power dynamics that shape interactions between water, energy, and food components in urban areas. Therefore, the findings of the study, derived from Türkiye's three largest metropolitan cities, are expected to shed light on the key points of convergence and divergence between sustainable food system goals and the criteria based on the WEF Nexus approach for policymakers and researchers.

Sustainable Food Systems

According to the literature, systems theory addresses the interactions between components aimed at maintaining the stability and integrity of a system in the face of various externalities, the problems arising from these interactions, and the effective management of resources (Eakin et al., 2017; Ericksen, 2008).

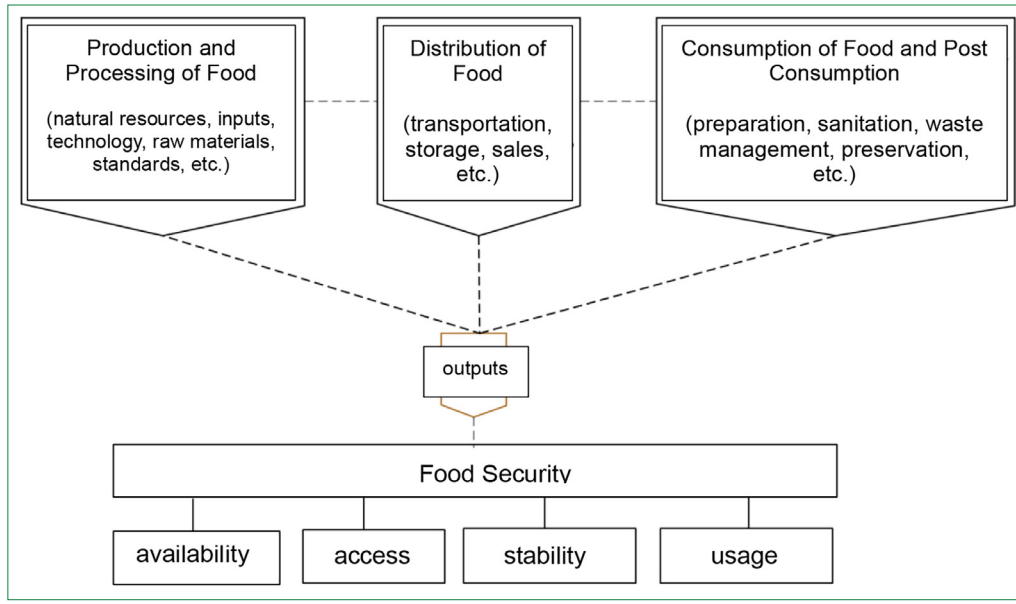

Figure 1. Processes and steps in food systems (Ericksen, 2018; FAO, 2014).

Food systems are considered to be complex and heterogeneous systems that integrate social, environmental, and economic processes extending from production to consumption in order to meet vital needs (Ericksen, 2008; Sobal et al., 1998; Bilali et al., 2021). The discussion of the sustainability of these systems, which face the challenge or necessity of providing safe, adequate, and healthy food and encompass many processes, has gained importance in recent years among experts from different disciplines (Béné et al., 2019; Kneen, 1993; Chopra et al., 2005). It can be said that food systems, which are responsible for the vital continuity of the rapidly growing global population, face various challenges that require structural changes in order to become sustainable (Weber et al., 2020).

Making food systems sustainable and optimizing them are directly affected by how the supply-demand balance among various natural resources is established. Karan and others indicate that decisions related to meeting the food demands of the population directly impact water and energy demand (Karan et al., 2018). In this context, within the framework of systems theory and food systems sustainability, achieving an optimal balance in food systems depends directly on maintaining a well-regulated supply-demand relationship between water and energy components. Therefore, in policy or planning decisions aimed at ensuring the sustainability of food systems, it is necessary to consider the pressure and demand created on other natural resources and cities.

According to Eriksen and the Food and Agriculture Organization of the United Nations (FAO) report, food systems include three fundamental processes and various steps (Ericksen, 2008; FAO, 2014). These fundamental processes and their corresponding steps are illustrated in Figure 1.

As can be seen in Figure 1, food systems have three fundamental processes: food production, food distribution, and food consumption. These processes involve various steps and inputs.

Firstly, in the food production and processing stage, there is a need for various natural resource inputs, the use of technology, the procurement and preparation of raw materials, and the establishment of standards. In the food distribution process, steps include transportation and logistics, the safe and secure storage of food, and the execution of sales. Finally, in the food consumption and post-consumption stages, various steps such as preparation for consumption, sanitation processes, waste management, and storage are involved. If optimization of these processes and the steps within them can be achieved, food security can be ensured. This allows for sustainable responses to the demands of both current and future populations at the fundamental components of food security: "availability," "access," "stability," and "utilization" (Ericksen, 2008; FAO, 2014).

Therefore, the sustainability of food systems is essentially dependent on natural resources; this dependence and reliance inevitably lead to various impacts on the fundamental processes of food systems like production, processing, transportation, and retail (Béné et al., 2019). These impacts can threaten the availability of natural resources and the right/need of future populations to access food. This is because it is known that food systems account for approximately 34% of total greenhouse gas emissions, about 30–35% of global energy consumption, and about 70% of global water use, stemming from land use, storage, transportation, packaging, processing, retail, and consumption (International Food Policy Research Institute, 2022). In other words, the sustainability of food systems and their processes is in a bidirectional

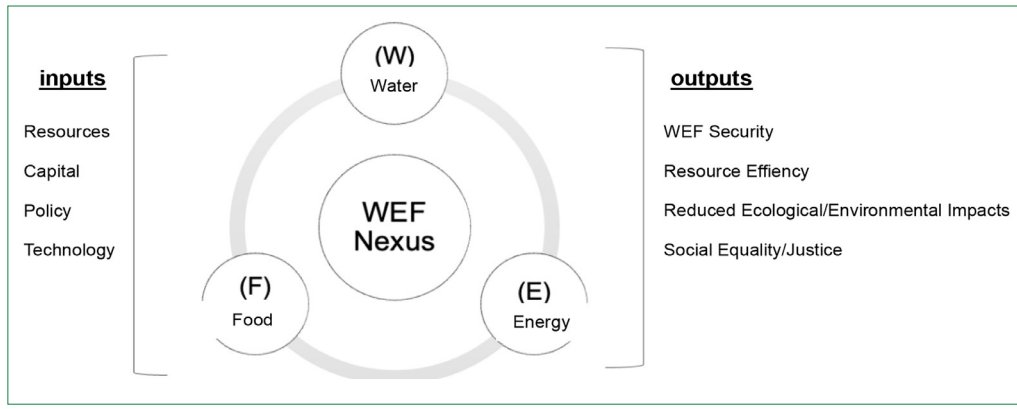

Figure 2. Bonn 2011 Nexus framework (Hoff, 2011).

relationship with unsustainable resources. Singh and Tayal state that one of the biggest barriers to urban policy efforts is the difficulty in understanding the holistic resource issues and interconnections within the food system (Singh & Tayal, 2022). From this perspective, understanding that the sustainability of food systems is directly related to other resources is crucial. It is necessary to approach the sustainability of this heterogeneous system, which is both directly affected by and has the potential to directly affect these resources, from the "Nexus" perspective. Because the fundamental purpose of the Nexus approach is to draw attention to three essential resources—water, energy, and food—that are at risk due to environmental changes and human interventions. The relationship among these resources is crucial for the survival of both humans and the biosphere (Farmandeh et al., 2024).

WEF Nexus Approach

The term "Nexus," derived from Latin meaning "to connect," generally refers to the concept of examining the interrelationships between two or more things (De Laurentiis et al., 2016). The WEF Nexus approach, aimed at ensuring water, energy, and food security for current and future populations, has particularly gained momentum in recent years. It focuses on enhancing inter-resource synergies and providing integrated governance for water, energy, and food security (Srigiri & Dombrowsky, 2021; Hoff, 2011). In this context, it can be stated that examining the mutual interconnections between water, energy, and food components forms the core idea of this approach (Orimoloye, 2022). Some of the main reasons for the increasing interest and importance in this approach in recent years are its multi-centric nature and the equal consideration of each sector within the approach's context (Simpson & Jewitt, 2019). In this context, the balance of supply and demand for water, energy, and food components is established, and any planning decisions made for one resource that could threaten the sustainability of the other two resources are prevented.

According to the literature, the emergence of this concept is known to be based on the increasing issues of water scarcity and insecurity that arose with the 2007–2008 food and energy crisis (Estoque, 2022; Chirisa & Bandauko, 2015). Additionally, this inter-resource connection and relationship was first brought to attention with the landmark report titled "Water Security: The Water-Food-Energy-Climate Nexus," published during the World Economic Forum in 2011 (World Economic Forum, 2011). In this forum, it was discussed that water security is a global concern and creates threats/opportunities for the business world, and solutions for the efficient use of resources were discussed (Pahl-Wostl , 2019). The Bonn 2011 Nexus Conference, organized by the German government in 2011, is considered a significant initial step in the development of the core concept and approach of the WEF Nexus (Leck et al., 2015). During the Bonn Conference in 2011, the term "Nexus" was coined for this relational situation supporting sustainability and sustainable development, through the background document titled "Understanding the Nexus," prepared by Hoff (Hoff, 2011). At the conference, the term "Nexus" was described as a network-focused approach necessary for addressing unsustainable growth patterns and emerging resource insecurities, while enhancing access security to essential services (Bonn 2011 Nexus Conference, 2011). In addition to the World Economic Forum and the Bonn Conference, which played significant roles in the emergence of this approach in 2011, organizations such as the World Water Forum, Planet Under Pressure, Future Earth, Rio+20, Nexus 2014, and Stockholm Water Week, held in 2012 and 2014, also played crucial roles in shaping the approach (Al-Saidi & Elagib, 2017). To summarize, following the food and energy crises of 2007 and 2008, this concept gained momentum particularly in the business world. With the World Economic Forum and the Bonn Conference in 2011, it took shape as the WEF Nexus approach. Today, it is seen as a managerial understanding necessary for the sustainability of all urban systems and systems in general.

Figure 2 shows the Nexus framework from the background document titled "Understanding the Nexus," presented by Hoff (2011) during the Bonn Conference in 2011, which was instrumental in the emergence of the WEF Nexus approach.

According to the framework in Figure 2, the WEF Nexus approach involves various inputs and outputs. Factors such as resources, capital, policies, and technology constitute the "inputs," while the outcome of a system addressing water, energy, and food components through this approach results in ensuring resource security, increasing resource efficiency, reducing environmental/ecological impacts, and promoting social justice/equality. In other words, the WEF Nexus supports integrated and sustainable resource planning and management, and optimizes resource use to ensure fundamental and universal rights related to water, energy, and food security (Kurian, 2017; World Economic Forum, 2011).

To anticipate potential risks of future resource insecurity and protect against them, this approach, which addresses key issues in food, water, and energy components through a sustainability lens, focuses on the security of the three resources. It offers simultaneous global assessment solutions for developing and implementing different approaches (Salem et al., 2022; Biggs et al., 2015). In this context, it is possible to state that the approach provides a common foundation for researchers, policymakers, practitioners, and stakeholders in managing the production, use, and security of water-energy-food systems in an interconnected manner (Cai et al., 2018).

Additionally, it has been determined that 2.2 billion people worldwide lack access to safe drinking water, approximately 789 million people were without electricity in 2018, and about 25.9% of the global population was affected by moderate to severe food insecurity in 2019 (Carmona-Moreno et al., 2021). In its 2012 report, the United States National Intelligence Council identified the WEF Nexus approach as one of four mega-trends for 2030. It highlighted that due to global population growth, demands for water, energy, and food are expected to increase by approximately 35%, 40%, and 50%, respectively. The report emphasized that policymakers and stakeholders need to be proactive to avoid resource constraints (National Intelligence Council, 2012). The European Union's (EU) 2011–2012 Development Report focused on water, energy, and land issues, and examined the importance of integrating these resources in promoting sustainable development (EU, 2012). In other words, the increase in shortages of water and food resources, along with supply crises and failures of fragmented management strategies, are considered driving forces behind the emergence of this approach. The approach aims to create synergies between water, energy, and food to ensure resource efficiency and sustainability as a solution to climate change and resource scarcity caused by various factors (Al-Saidi & Elagib, 2017; Conway et al., 2015).

In the context of the approach, the interconnections and relationships between sectors are paramount. Simply put, water is needed to produce energy, energy is needed to supply water, food is needed to produce energy, and energy is needed to produce food. Considering these interconnections can enhance mutual benefits and minimize negative impacts on the sectors (Bielicki et al., 2019; Stringer et al., 2014). Understanding the interactions between the components of the WEF Nexus approach and addressing policy decisions while balancing costs can enhance the efficient use of resources and ensure resource security (Hoff, 2011; World Economic Forum, 2011). Because most resource management policies in many countries remain sectoral and fragmented, they lead to various medium- and long-term challenges on a global scale in the process of resource management and climate change adaptation (de Andrade Guerra et al., 2021). In other words, the WEF Nexus approach (water-energy-food connection), which promotes synergistic integration between sectors, aims to reduce global risks by avoiding the negative externalities of treating each sector in isolation and focuses on increasing efficiency by optimizing resources.

The Relationship between WEF Nexus and Sustainability

The fulfilment of essential human activities is related to the sustainability of water, energy, and food systems (Biggs et al., 2015). These resources and systems, while having various activity areas and processes, can create both positive and negative effects on each other. For example, according to the FAO's 2018 report, about one-third of the food produced in food supply and consumption processes is lost, which accounts for 20% of freshwater and 38% of energy consumption (FAO, 2018). By 2030, it is estimated that there will be a 40% water deficit in meeting global drinking water demand, food, and energy needs (Bizikova et al., 2013). In this context, considering the interconnections between systems and the loss of natural resources resulting from these interconnections, it is possible to state that vital issues such as food security, nutrition, and sustainability are under threat in the future. As a result, there is a need to focus on ensuring the "safety" of sustainability and examining the positive and negative impacts of the resources or systems discussed within the approach (Simpson & Jewitt, 2019). Additionally, sustainability is directly connected to the concept of "security," but it is not solely related to the existence or availability of resources; it also requires focusing on ensuring universal access and distributive justice (Biggs et al., 2015; Leese & Meisch, 2015). In this context, the WEF Nexus approach is an approach that aims to focus on resource security and equal/fair distribution of resources, and it directly contributes to sustainability. This approach, which explains the interdependencies or dependencies between these resources or systems, can also significantly affect future urban growth (Kurian & Ardakanian, 2015). Additionally, it is suggested that integrating water, energy, and food within a "nexus" framework is a necessary path to achieving a holistic sustainability vision that aims to balance the various goals, interests, and needs of people and the envi-

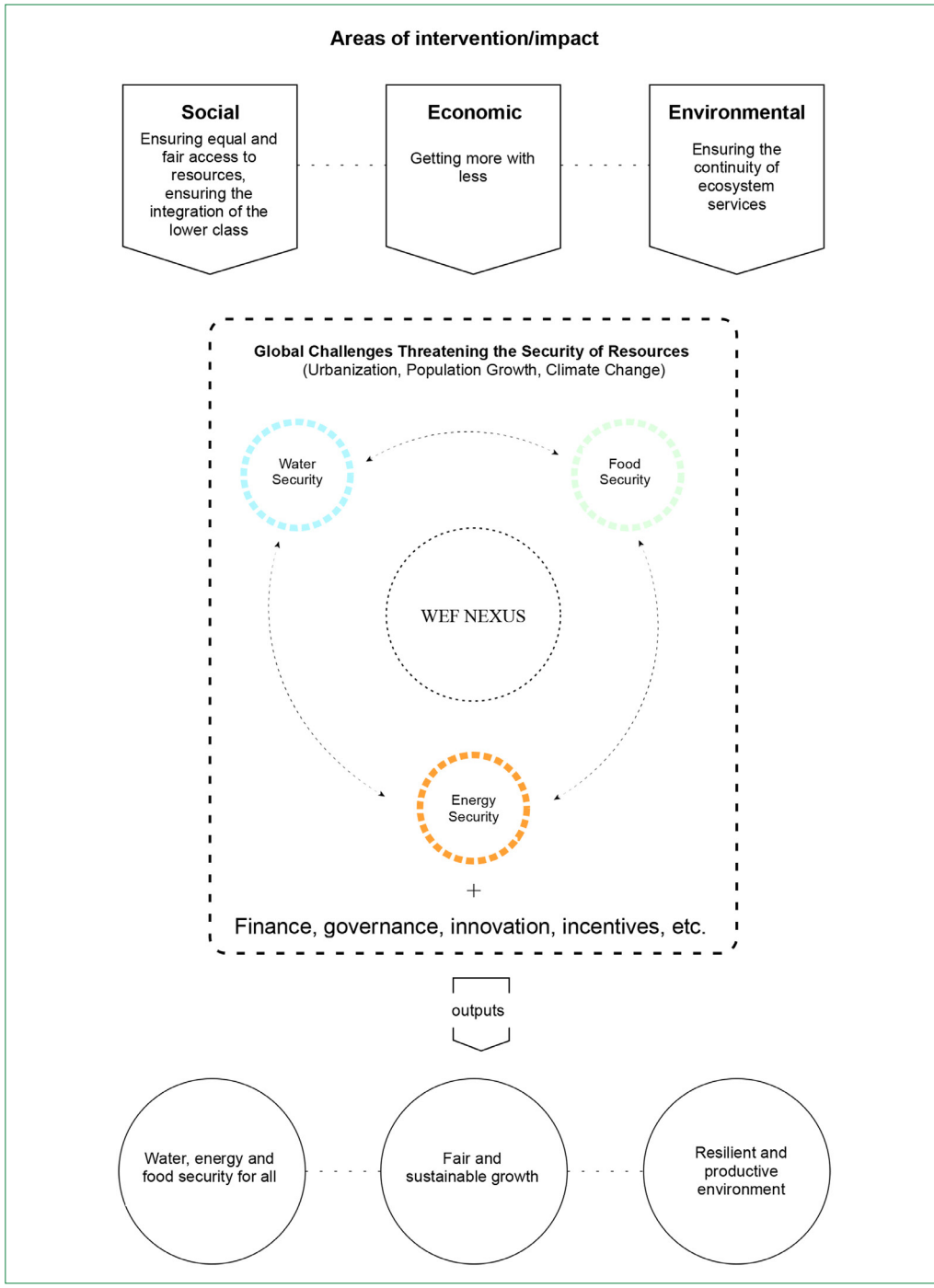

Figure 3. Outcomes of the approach that contribute to the sustainability vision (Hoss, 2011).

ronment (Salam et al., 2017; Chang et al., 2016). According to Hoff (2011), a key figure in conceptualizing the approach, the outputs and conceptual expression of the approach that contribute to the sustainability vision are illustrated in Figure 3.

When examining the expression shown in Figure 3, global challenges such as urbanization, population growth, and climate change are first identified. As a result of these challenges and various constraints, the components of water, energy, and food, which are under threat to sustainability, are integrated within the WEF Nexus approach. This framework defines the security of these resources and their interrelationships. Subsequently, intervention areas necessary for ensuring the fundamental concept of sustainability—"resource security"—are identified and classified into social, economic, and environmental categories.

Table 1. The level of relevance of WEF (water, energy, food) components to the sustainable development goals (Rockström & Sukhdev, 2016; Bhaduri, et al., 2016; United Nations, 2015)

	Sustainable development goals																
	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 8	SDG 9	SDG 10	SDG 11	SDG 12	SDG 13	SDG 14	SDG 15	SDG 16	SDG 17
	No poverty	Zero hunger	Good health and well-being	Quality education	Gender equality	Clean water and sanitation	Affordable and clean energy	Decent work and economic growth	Industry, innovation, and infrastructure	Reduced inequalities	Sustainable cities and communities	Responsible consumption and production	Climate action	Life below water	Life on land	Peace, justice, and strong institutions	Partnerships for the goals
W (water)	●●	●●	●●	●	●	●●●	●●	●●	●	●	●●	●●	●●	●●	●●	●	●
E (energy)	●●	●●	●●	●	●	●●	●●●	●●	●●	●	●●	●●	●●	●●	●●	●	●
F (food)	●●	●●●	●●	●	●	●●	●●	●●	●	●	●●	●●	●●	●●	●●	●	●

Evaluating these intervention areas, the need to ensure equitable and fair access to resources for the population at the base of the societal pyramid emerges. Secondly, from an economic perspective, the ability to achieve more output with fewer inputs is highlighted to increase efficiency. Lastly, it is noted that various investments are required to ensure the sustainability of ecosystem services and the protection of resources. Summarizing these three intervention areas within the scope of sustainability: ensuring equitable/fair access to resources, protecting the natural environment and resources to secure ecosystem continuity, and implementing practices that achieve economic efficiency all require referencing concepts such as finance, management, and innovation. Finally, Figure 3 shows that managing resource security equitably/fairly in these three intervention areas and with the required concepts of finance, management, and innovation will contribute to sustainable growth.

Additionally, this approach advocates for an integrated system with specified interrelationships, rather than an independent and isolated system. It also plays a significant role in achieving the Sustainable Development Goals (Wang et al., 2021). Although the Sustainable Development Goals refer to many policy areas, the interconnections and indirect relationships between the goals are often weak. For example, the lack of clear specification of the interconnections between food security goals and the water and energy sectors is indicative of this issue (Boas et al., 2016). However, interconnections between sectoral goals are quite important; it is known that a policy decision in one sector can lead to inconsistencies in policy goals in another area (Howells et al., 2013). In this context, a comprehensive approach to fundamental planning principles, management, evaluation, and implementation is required to overcome various challenges related to sustainability (Estoque, 2022). Therefore, it is important to understand the interactions between the Sustainable Development Goals and to assess them from the "Nexus" perspective, which has been widely supported over the past decade as a framework that promotes the coordinated implementation of these goals (Olawuyi, 2020). This is because all the Sustainable Development Goals are interconnected or dependent on each other directly or indirectly; the WEF Nexus plays a crucial role in achieving these goals in a holistic manner (Saladini et al., 2018; Biggs et al., 2015). Salem and others argue that this approach represents a holistic sustainability vision that addresses long-term sustainability challenges by protecting natural, human, and social capital, and promotes sustainable development by conserving natural resources and the environment (Salem et al., 2022). In this regard, this approach and vision provide a systematic perspective to overcome the pressures that global risks place on resources and require effective management to achieve the UN Sustainable Development Goals (de Andrade Guerra et al., 2021; Hoff, 2011).

When evaluating the Sustainable Development Goals in relation to the components addressed by the WEF Nexus approach, Sustainable Development Goal 2 (zero hunger), Sustainable Development Goal 6 (clean water and sanitation), and Sustainable Development Goal 7 (affordable and clean energy) are directly related to food, water, and energy secu-

rity, respectively (UN, 2015). The approach also establishes indirect connections with all other goals, as all Sustainable Development Goals are interconnected in various ways, similar to the interrelationships among food, water, and energy systems. However, there is still no consensus on a framework that encompasses all Sustainable Development Goals. Nevertheless, it is argued that integrating water, energy, and food within a nexus framework can be considered a necessary path to achieving the Sustainable Development Goals (Estoque, 2022; Salam et al., 2017). In this regard, Table 1 presents the levels of direct or indirect relationships between the components of the WEF Nexus approach—water, energy, and food—and all Sustainable Development Goals.

As stated in Table 1, the goals directly related to the components of the WEF Nexus approach—water, energy, and food—are Sustainable Development Goal 2, Sustainable Development Goal 6, Sustainable Development Goal 7, Sustainable Development Goal 14, and Sustainable Development Goal 15. For instance, when examining the water component specifically, it is seen to be directly and fundamentally related to Sustainable Development Goal 6, but also to have interconnections and overlaps with all other goals. In other words, failing to achieve water-related goals increases the risk of not achieving other interconnected goals (Bhaduri et al., 2016). In other words, achieving Sustainable Development Goal 6 will significantly contribute to achieving Sustainable Development Goal 14, titled "Life Below Water," and Sustainable Development Goal 15, titled "Life on Land." Conversely, failing to achieve Sustainable Development Goal 6 will negatively impact all interconnected Sustainable Development Goals (Bhaduri et al., 2016).

Therefore, analyzing the complex relationships within the water-energy-food nexus is critical for ensuring sustainability at national, regional, and urban levels. Establishing a balance between the direct and indirect relationships among the components will help create resilient urban areas against resource limitations and inequities in access.

Sustainable Food Systems in the Context of the WEF Nexus

According to a 2014 report by FAO, it is expected that by 2050, the global population will require more than 60% additional food to meet the rising demand (FAO, 2014). According to a 2021 report by the UN, approximately 760 million people (10% of the population) experienced food insecurity in 2019, and this number increased with the impact of COVID-19 starting in 2020 (UN, 2021). In addition, there are many adverse global externalities today that have the potential to significantly impact these projections, such as urbanization, population growth, political instability, pandemics, natural disasters, wars, and climate change. These factors jeopardize the sustainability and security of food systems and necessitate major transformations in management or governance systems (Hassen et al., 2025; Daher et al., 2021). This is because it is known that the destructive effects of economic growth, globalization, or urbanization have a negative impact on ecosystems, dietary patterns, and the availability of resources (De Laurentiis et al., 2016). In the context of the WEF Nexus approach, the negative trend towards the unsustainability of all resources makes the concept of "security" crucial in food systems.

Firstly, the concept of food security generally emphasizes ending hunger worldwide (Pahl-Wostl, 2019). This concept was first expressed at the World Food Summit in 1996 as "the state of people's physical, economic and social access to healthy, sufficient and safe food that meets their body needs to be productive and have a sane lifestyle" (FAO, 1996). Ericksen defines food security as a dynamic situation resulting from the interaction of multiple factors or components (Ericksen, 2008). In addition, FAO also states that food security has four basic dimensions: availability, access, stability and utilization; and adopts an integrated management framework/approach in order to ensure balance between these dimensions (FAO, 2014). The integrated approach adopted and emphasized by FAO is the WEF Nexus (water-energy-food nexus) approach. This is because the approach takes into account the impact of water and energy resources on food security and the sustainability of food systems. Considering the effects of water, energy, and food on each other and the interrelationship among these resources, the WEF Nexus approach is crucial for ensuring food security and achieving the four specified dimensions. Furthermore, FAO states that the adoption of the WEF Nexus approach is based on a vision of "sustainability," and that ensuring the sustainability of resources is essential for achieving and maintaining the dimensions of food security (Pahl-Wostl, 2019; FAO, 2014). The four dimensions or components defined by FAO for achieving food security—"food availability," "food access," "food stability," and "food utilization"—along with other interacting sub-components, are shown in Figure 4.

According to Figure 4, the first fundamental dimension of food security, "food availability," is addressed along with four sub-components. These sub-components collectively contribute to the availability of food in terms of both quantity and quality and are categorized as "production," "consumption," "import," and "export." The other fundamental dimension, "food access," is influenced by resources, resource management, infrastructure, and transportation factors. Additionally, the level of "access" to food is determined by how well people can convert their various financial, political, and other assets into food, making it closely related to inequalities in food availability and distribution (Ericksen, 2008). Thus, these fundamental dimensions and sub-components encompass the necessary policy and physical processes for ensuring that

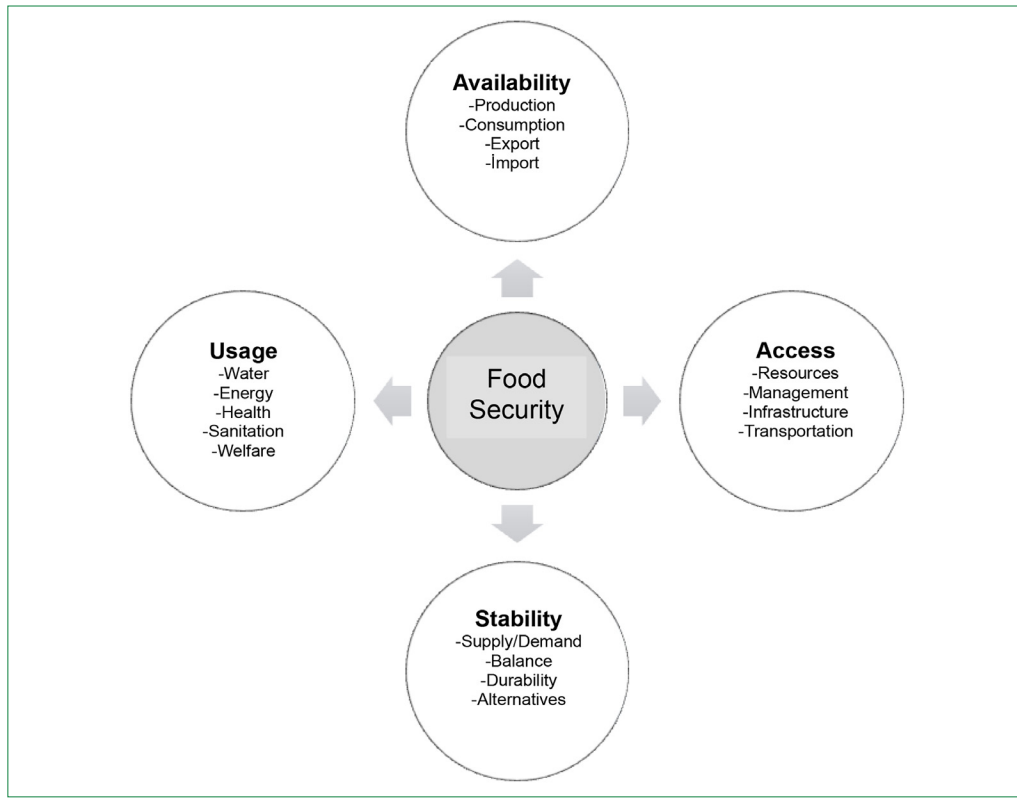

Figure 4. Dimensions and compenents of food security (FAO, 2014).

both current and future populations have access to secure food. The third fundamental dimension, "stability," plays a crucial role in maintaining stability while meeting food supply and demand, enhancing the resilience of food systems, and increasing alternatives. The final fundamental dimension, "utilization," focuses on preventing developments that could jeopardize the sustainability of the resources addressed within the WEF Nexus approach. In this phase, the primary goal is to ensure that all segments of the population have access to safe and healthy food by minimizing or optimizing the amounts of water and energy required in food systems.

On the other hand, when considering food security dimensions and sustainable food systems within the context of the WEF Nexus approach, the literature provides fundamental solutions for balancing food demand sustainably and ensuring universal access to food. These solutions include "using sustainable and clean methods in production stages," "enhancing education/awareness to promote changes in dietary patterns", and "reducing waste" (De Laurentiis et al., 2016; Dogliotti et al., 2014; Godfray et al., 2010; Herrera-Franco et al., 2024). In light of these recommendations, it can be stated that the primary goal is to optimize inputs and resource use within food systems, and that the WEF Nexus approach can support this objective through policies and regulations that enhance efficiency and infrastructure resilience (De Laurentiis et al., 2016; Hogeboom et al., 2021; Romero-Lankao et al., 2018).

Additionally, it is well known that food waste and losses at various stages of food systems have a significant environmental impact. This issue was highlighted in a study prepared by FAO, which documented the environmental damage caused by waste in food system processes. The study noted that reducing food waste would significantly decrease the need to increase food production by 60% to meet the food demand of the population in 2050 (FAO, 2013). Kummu and others have addressed this environmental damage and negative impacts, noting that approximately one-quarter of the food produced is lost in food supply chains (Kummu et al., 2012). Additionally, when considered within the context of the WEF Nexus approach, it has been found that food waste also impacts other limited resources. The production of wasted food crops constitutes approximately 24% of the total freshwater used in crop production, and about 23% of the total global cultivated land area and global fertilizer use (Kummu et al., 2012). It is inevitable that these results will have negative consequences on the natural environment and resources, endangering the sustainability of food systems and food security.

Finally, when considering the sustainability of food systems in the context of the Sustainable Development Goals, the UN's 2030 Sustainable Development Goals are directly or indirectly related to global food systems and their performance. It is known that these goals, while global in scope, also require adaptation efforts at national, regional, and local levels (Chaud-

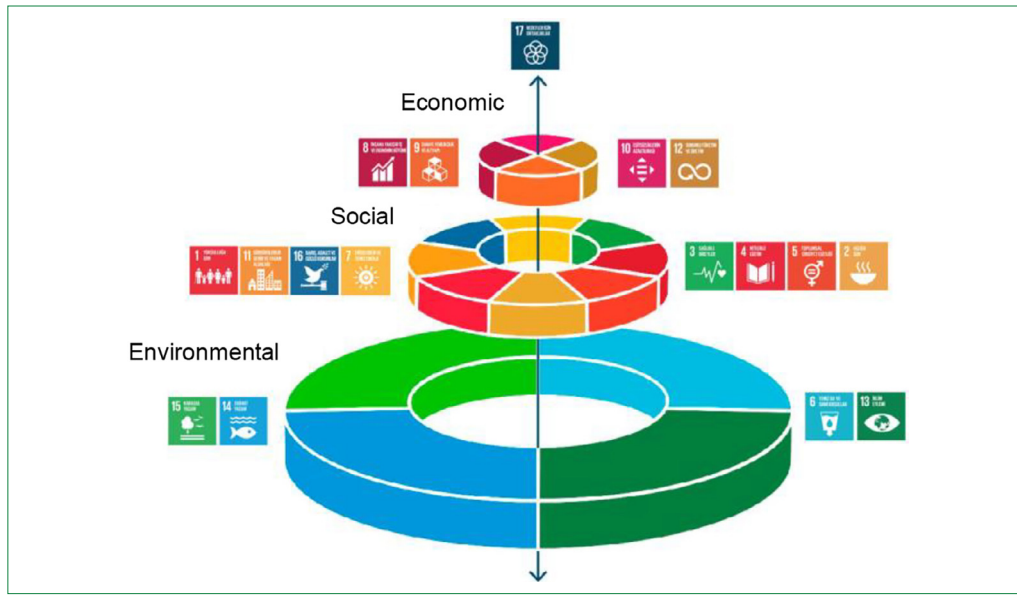

Figure 5. The connection between the sustainable development goals (SDGs) and food (Rockström & Sukhdev, 2016).

hary et al., 2018; Kanter et al., 2016; UN, 2015). The UN also emphasized the critical role of food systems in achieving the Sustainable Development Goals by 2030, at the Food Systems Summit (UNFSS) in September 2021, emphasizing the transition to a "system" view encompassing all processes in food systems (International Food Policy Research Institute, 2022). Rockström and Sukhdev also defended this idea and stated that the role of food systems should be taken into consideration in achieving the Sustainable Development Goals and meeting the requirements of these goals, and that all Sustainable Development Goals are interrelated and directly or indirectly affect food systems (Rockström & Sukhdev, 2016). Figure 5 shows that all Sustainable Development Goals are directly or indirectly linked to food and food systems.

As seen in Figure 5, achieving sustainability requires the advancement of economic, social, and environmental development, with these three dimensions being interconnected. At the EAT Food Forum, Johan Rockström and Pavav Sukhdev offered a new perspective on the economic, social, and environmental aspects of the Sustainable Development Goals, stating that all Sustainable Development Goals are directly or indirectly linked to sustainable and secure food (Rockström & Sukhdev, 2016). Considering that food systems are complex and heterogeneous systems integrating social, environmental, and economic processes from production to consumption, according to Ericksen, it is inevitable that all Sustainable Development Goals serving these three dimensions are related to food systems and the processes they encompass (Ericksen, 2008).

In summary, as indicated in Figure 3, which outlines the outputs contributing to the vision of sustainability, the WEF Nexus approach affects the dimensions of sustainability: social, environmental, and economic processes. Additionally, as shown in Table 1, which explains the direct or indirect relationships between the WEF Nexus components of water, energy, and food with all Sustainable Development Goals, and Figure 5, which states that all Sustainable Development Goals are connected to food, it is argued that the WEF Nexus approach can be considered a necessary pathway for achieving the Sustainable Development Goals and the sustainability of food systems (Estoque, 2022; Salam et al., 2017; Ericksen, 2008).

Methodology

Istanbul, Ankara, and Izmir, Türkiye's three largest metropolitan cities located in the Marmara, Central Anatolia, and Aegean regions, respectively, have distinct yet interconnected food systems shaped by their geographic, economic, and demographic characteristics. Türkiye's economic hub, Istanbul, possesses a highly complex and dynamic food system, whereas the capital, Ankara, serves as a crucial center for grain, meat, and dairy production due to its proximity to the country's central agricultural regions. Meanwhile, Izmir has a food system closely linked to agricultural and marine resources (Izmir Metropolitan Municipality, 2019; AMM, 2019; IMM, 2020).

In this study, Istanbul, Ankara, and Izmir have been selected to evaluate and analyze policy decisions within the WEF Nexus framework, focusing on their impact on local food systems. The analyzed resources, prepared or commissioned by local governments, are listed in Table 2.

The study examines strategies, objectives, actions, and sub-actions influencing food system processes—production, distribution, consumption, and post-consumption—across the finalized plans listed above (Table 2). These plans prepared for urban sustainability, were evaluated within the WEF Nexus framework.

Table 2. Cities and resources to be evaluated in the study

Cities	No	Resources	
Istanbul	1	Istanbul Regional Plan (2014–2023)	(Istanbul Development Agency, 2014)
	2	IMM Strategic Plan (2020–2024)	(IMM, 2020)
	3	ISKI Strategic Plan (2021–2025)	(ISKI, 2020)
	4	Istanbul Climate Change Action Plan	(IMM, 2021a)
	5	Istanbul Sustainable Urban Mobility Plan	(ARUP, 2022)
	6	Local Equality Action Plan (2021–2024)	(IMM, 2021b)
Ankara	7	Ankara Regional Plan (2014–2023)	(Ankara Development Agency, 2015)
	8	Ankara Strategic Plan (2020–2024)	(AMM, 2019)
	9	ASKİ Strategic Plan (2020–2024)	(ASKI, 2019)
	10	Ankara Province Local Climate Change Action Plan	(AMM, 2022)
	11	Local Equality Action Plan (2021–2024)	(AMM, 2021)
Izmir	12	Izmir Regional Plan (2014–2023)	(IZKA, 2015)
	13	Izmir BB Strategic Plan (2020–2024)	(Izmir Metropolitan Municipality, 2019)
	14	IZSU Strategic Plan (2020–2024)	(IZSU, 2019)
	15	Izmir Sustainable Energy and Climate Action Plan - Izmir Green City Action Plan	(Izmir Metropolitan Municipality, 2020a)
	16	Izmir Sustainable Urban Logistics Plan (2030)	(Izmir Metropolitan Municipality, 2020b)
	17	Local Equality Action Plan (2022–2024)	(Izmir Metropolitan Municipality, 2022)

Within the framework of the WEF Nexus approach and its components (water, energy, and food), a systematic review of the 17 selected plans was conducted using MAXQDA 2024 software in accordance with the key reference concepts identified in Table 3. As a result of the review conducted based on the key reference concepts identified within the framework of the literature, key objectives, strategies, actions, or sub-actions addressing food systems and their various processes were identified. In other words, the study is confined to policy decisions specifically related to WEF components that have the potential to influence food systems and processes. Within this scope, plans prepared or commissioned by local governments were analyzed in accordance with Table 3, where the reference concepts were identified within the framework of the literature in the context of the WEF Nexus approach and specifically for food systems. The purpose of identifying these key concepts/domains in Table 3 is to categorize and analyze the strategies, objectives, goals, actions, and sub-actions related to food systems in the plans. Based on these findings, both quantitative and qualitative analyses were conducted for the three selected cities.

According to Table 3, the key common concepts referenced in the analysis of policy/plan decisions related to the components of water (W), energy (E), and food (F) that have direct or indirect effects on the processes within food systems include waste management, climate change, clean production, technology/innovation, resilient infrastructure, fundamental planning principles (inter-plan coherence, transparency, intersectoral coordination), air quality, quality of educational curricula, awareness, and disaster management.

Additionally, in the analysis of policy and plan decisions related to the water (W) component, other concepts such as biodiversity, sensitive ecological areas, wastewater management processes (recycling, reuse, and chemical disposal) also emerged.

For the energy (E) component, the concepts analyzed include transportation connections, logistics, and information/communication technology (ICT).

Lastly, in the analysis of policy decisions related to the food (F) component, concepts not shared with the three components include biodiversity, sensitive ecological areas, transportation connections, logistics, ICT, organic waste management, organic fertilizers, rural development, food management, food security, and sustainable consumption.

In summary, the strategies, objectives, actions, or sub-actions that influence various processes within the food systems (production, distribution, consumption/post-consumption) in Istanbul, Ankara, and Izmir, and primarily aim for sustainability, have been systematically reviewed via MAXQDA 2024 based on the different scales of plans presented in Table 1, within the context of the WEF Nexus approach and its components.

Table 3. Key concepts/areas referenced in the analysis of policy decisions related to WEF components effective in food systems processes

	WEF nexus components			
	W (water)	**E (energy)**	**F (food)**	**References from literature**
Key concepts related to components	Waste management	Waste management	Waste management	(De Laurentiis, Hunt, & Rogers, 2016; Kummu, et al., 2012)
	Climate change	Climate change	Climate change	(Goodarzi, Mohtar, Piryaei, Fatehifar, & Niazkar, 2022; Al-Saidi & Elagib, 2017; Conway, et al., 2015; Hassen, Bilali, Daher, & Burkart, 2025)
	Clean production	Clean production	Clean production	(Herrera-Franco, Bravo-Montero, Caicedo-Potosí, & Carrión-Mero, 2024)
	Technology, innovation	Technology, innovation	Technology, innovation	(Hoff, 2011; Karnib & Alameh, 2020; Kurian, 2017)
	Resilient infrastructures	Resilient infrastructures	Resilient infrastructures	(Hogeboom, et al., 2021; Romero-Lankao, Bruns, & Wiegleb, 2018)
	Basic planning principles	Basic planning principles	Basic planning principles	(Kurian, 2017; Estoque, 2022)
	Air quality	Renewable energy, air quality	Air quality	(Herrera-Franco, Bravo-Montero, Caicedo-Potosí, & Carrión-Mero, 2024)
	Education, awareness	Education, awareness	Education, awareness	(Kurian, 2017; De Laurentiis, Hunt, & Rogers, 2016)
	Disaster management	Disaster management	Disaster management	(Daher, Hamie, Pappas, Karim, & Thomas, 2021; Hassen, Bilali, Daher, & Burkart, 2025)
	Pressure on resources		Pressure on resources	(Hoff, 2011; Salem, Pudza, & Yihdego, 2022)
	Biodiversity, precision ecology		Biodiversity, precision ecology	(Hoff, 2011)
		Logistics, ICT	Logistics, ICT	(FAO, 2014)
	Wastewater management		Organic waste management	(Kurian, 2017)
			Rural development	(FAO, 2024; FAO, 2014)
			Food management	(FAO, 2024; FAO, 2014)

ICT: Information/communication technology.

This systematic review was conducted in accordance with the key concepts and domains identified in Table 3, followed by qualitative and quantitative analyses.

Findings

Table 4 includes the qualitative and quantitative analysis of the relationship between policy decisions effective in food system processes within the plans of the three cities and the WEF components and identified key concepts. The numbers presented in Table 4 indicate the number of policy decisions that are effective in food system processes and are associated with the key concepts identified within the scope of WEF components.

According to Table 4, the relationship between policy decisions affecting food systems and processes and the WEF components and identified key concepts shows some differences across the three cities, both quantitatively and qualitatively.

Firstly, Ankara's plans demonstrate a higher potential for development and alignment in the area of "wastewater management" compared to Istanbul and Izmir. However, in areas such as "waste management", "climate change", "education/awareness", "disaster management," and "logistics/ICT," Ankara lags behind the other two cities. Istanbul and Izmir exhibit similar quantitative tendencies in these aspects. This situation indicates that Ankara needs to develop a more comprehensive sustainability strategy for its food systems. Although Ankara's food system management is strong in terms of wastewater management, there is a need for broader integration in terms of overall sustainability. In particular, deficiencies in education and awareness, disaster management, and logistics processes have the potential to weaken the resilience of the food system (AMM, 2019, 2021, 2022; ASKI, 2019; Ankara Development Agency, 2015). Disaster management and logistics are concepts that must be coor-

Table 4. Qualitative and quantitative analysis of the relationship between planning decisions effective in food systems processes and WEF components and key concepts

WEF nexus components	Key concepts related to components	Cities and the number of policy decisions		
		Istanbul	Ankara	Izmir
W (water)	Waste management	16	4	12
	Climate change	5	1	6
	Wastewater management	13	15	8
	Clean production	3	1	2
	Technology, innovation	8	10	8
	Resilient infrastructures	2	7	8
	Basic planning principles	6	3	6
	Air quality	7	1	2
	Education, awareness	11	2	9
	Pressure on resources	5	6	6
	Disaster management	8	0	5
	Biodiversity, precision ecology	2	1	8
E (energy)	Waste management	9	3	10
	Climate change	3	2	3
	Clean production	2	1	3
	Technology, innovation	7	6	10
	Renewable energy, air quality	7	4	10
	Resilient infrastructures	1	3	3
	Education, awareness	8	2	8
	Basic planning principles	7	4	7
	Logistics, ICT	2	1	13
	Disaster management	6	0	1
F (food)	Waste management	11	4	14
	Climate change	4	3	6
	Clean production	1	1	2
	Technology, innovation	7	7	12
	Resilient infrastructures	1	3	4
	Basic planning principles	6	2	6
	Air quality	7	1	2
	Education, awareness	11	8	9
	Pressure on resources	5	6	4
	Disaster management	5	0	5
	Biodiversity, precision ecology	4	1	7
	Logistics, ICT	2	0	13
	Organic waste management	0	3	0
	Rural development	6	3	3
	Food management	8	5	3

Sources: Authors. ICT: Information/communication technology.

dinated with each other. In addition to the direct impact of disasters on food systems due to the pressure they exert on natural and limited resources, operating in an unstable infrastructure/logistics environment during disasters, combined with a lack of operational knowledge or low awareness, will lead to significant deficiencies, particularly in food supply systems (Kovács & Spens, 2007).

Secondly, Table 4 indicates that Istanbul's plans have a higher potential for development and alignment, quantitatively, in policy decisions related to the water component, particularly in "waste management", and in the areas of "education and awareness", "rural development", and "food management" compared to Ankara and Izmir. However, Istanbul is relatively behind Ankara and Izmir in "resilient infrastructure" across all WEF components, specifically in the area of "logistics/ICT." Istanbul's strengths in food systems may be based on water management and education processes; however, infrastructure deficiencies increase the system's vulnerability. In other words, while Istanbul's food system policies provide advantages in water management and rural development, deficiencies in logistics and resilient infrastructure may lead to vulnerabilities in the food supply chain. To enhance food security, it is essential to focus on infrastructure investments and resilient systems (Istanbul Development Agency, 2014; IMM, 2020, 2021a, 2021b; ISKI, 2020; ARUP, 2022). Infrastructures are the means through which water, energy, and food are transformed or transmitted for urban use, determining the availability and utilization of resources. As they can either mitigate or exacerbate the vulnerability of cities and populations to threats, they represent a fundamental source of dependency, particularly in the context of food systems (Romero-Lankao et al., 2018).

Lastly, as to Izmir, the policy decisions affecting food systems and their processes show a higher potential for development quantitatively in the areas of "waste management," "logistics/ICT" related to energy and water components, "technology/innovation," "biodiversity," "sensitive ecology," and "renewable energy" compared to the other two cities. The focus of these areas is generally on increasing efficiency, conserving resources, and ensuring effective implementation. Considering the impact of all processes in food systems from production to consumption on sustainability, resource efficiency, conservation, and the presence of innovative practices, these factors inevitably contribute to the sustainability of food systems. In other words, Izmir's policy decisions regarding food systems and within the framework of the WEF Nexus approach adopt a more environmentally friendly and innovative perspective by focusing particularly on renewable energy, logistics, and ecological sustainability. Its ability to develop integrated solutions, especially in the areas of renewable energy, sensitive ecology, and logistics, positions it as the strongest city in terms of the WEF Nexus (IZKA, 2015; IZSU, 2019; Izmir Metropolitan Municipality, 2019, 2020a, 2020b, 2022). Considering that most food loss and waste in developing countries stem from inadequate infrastructure, limitations in traditional harvesting techniques, deficiencies in storage and refrigeration technologies, and lack of market access, the ability to develop integrated solutions in renewable energy, precision ecology, and logistics is of critical importance (De Laurentiis et al., 2016).

Conclusion

Today, the food crisis is driven by multiple factors, including climate change, urbanization, poor economic investments, political upheavals, and conflicts. As a result, ensuring sustainable food systems and food security has become a critical priority. However, food systems cannot be addressed in isolation within policy decisions and implementation processes, as they rely on complex interactions across multiple sectors. Their continuity—from production to consumption—depends on the availability of essential natural resources. To effectively address this challenge, the WEF Nexus framework provides a holistic approach, balancing interactions, trade-offs, and resource constraints between water, energy, and food systems. It aims to optimize resource use, manage scarcity sustainably, and develop integrated response strategies across sectors.

This study aims to analyze the impact of the WEF Nexus approach on food system sustainability. Focusing on Istanbul, Ankara, and Izmir—Türkiye's largest metropolitan areas facing significant external challenges—local policy decisions were examined using MAXQDA 2024. Targets, strategies, and actions affecting food systems were systematically reviewed within the WEF Nexus framework (water, energy, and food) and key literature-derived domains. The qualitative and quantitative analyses highlight policy gaps and emphasize the need for integrated governance, offering insights into urban policy deficiencies and planning inefficiencies.

The findings highlight that urban food system sustainability challenges vary significantly across Istanbul, Ankara, and Izmir. In Ankara, it is possible to state that prioritizing issues such as "waste management," "climate change," "education/awareness," "disaster management," and "logistics/IT" in policy-making, planning, or implementation efforts in Ankara's plans is critically important for ensuring the sustainability of food systems and addressing urban sustainability challenges. In this regard, urban planning policies or practices should place more emphasis on sustainable waste management and the creation of necessary infrastructures, clearly address interventions to reduce the impacts of climate change, increase education and awareness efforts, take measures against various disasters that affect the sustainability of WEF components such as water, energy, and food, and develop efficient and effective logistics frameworks.

In the case of Istanbul, it is necessary to give more consideration to the resilience of infrastructures and the logistics framework in the processes of producing or implementing urban planning policies. This is because the components of energy and water have significant impacts on various processes such as food production, processing, and distribution. The advancement, resilience, and overall logistics framework of infrastructures are critical for steps like minimizing environmental impacts, and ensuring the delivery and supply of food through the effective provision and utilization of water and energy.

In the plans determined by local authorities in İzmir that will affect the sustainability of food systems, it is possible to state that there is a focus on increasing resource efficiency in areas such as "waste management," "logistics/IT," and "technology/innovation." However, there are deficiencies in "disaster management" related to the protection of energy and water resources. Overall, it can be expressed that İzmir is showing progress toward a vision that can adapt modern planning approaches to current conditions, compared to the other two cities, in terms of urban policy decisions that could impact food systems and processes.

Overall, this study demonstrates that there is no integrated vision for the water-energy-food relationship in policy decisions shaping food systems across Türkiye's three largest metropolitan areas. Instead, these components are treated in a fragmented manner in urban planning.

To address these issues, local governments should prioritize integrated governance frameworks that align water, energy, and food policies. This includes:

- Establishing multi-sectoral working groups to improve inter-agency coordination,
- Enhancing data-sharing mechanisms between municipalities,
- Implementing adaptive policy strategies that dynamically respond to environmental and economic changes.

Given these findings, urgent action is needed to systematically embed WEF Nexus considerations in urban planning and policy frameworks. Without such efforts, the sustainability and resilience of Türkiye's urban food systems will remain at risk, potentially exacerbating resource shortages and environmental vulnerabilities in the coming decades.

Future research could further investigate the institutional and political factors influencing the degree of WEF Nexus integration in urban planning. Understanding the underlying governance structures and decision-making processes may provide deeper insights into why certain elements are prioritized while others remain overlooked.

References

Ali, S. M., & Acquaye, A. (2024). An examination of water-energy-food nexus: From theory to application. *Renewable and Sustainable Energy Reviews, 202*, 114669.

Al-Saidi, M., & Elagib, N. A. (2017). Towards understanding the integrative approach of the water, energy and food nexus. *Science of the Total Environment, 574*, 1131-1139.

AMM (Ankara Metropolitan Municipality). (2019). *Ankara strategic plan (2020-2024)*. Retrieved from https://s.ankara.bel.tr/files/2022/04/06/c2dd96f266679134a44d544972fd36dc.pdf

AMM (Ankara Metropolitan Municipality). (2021). *Ankara local equality action plan (2021-2024)*. Retrieved from https://www.ankara.bel.tr/kadin-calismalari/yerel-esitlik-eylem-plani

AMM (Ankara Metropolitan Municipality). (2022). *Ankara local climate change action plan*. Retrieved from https://www.ankara.bel.tr/files/2022/06/22/0b663954d523bfee1d1e1d5fa66a082f.pdf

Ankara Development Agency. (2015). *Ankara regional plan (2014-2023)*. Retrieved from https://www.kalkinmakutuphanesi.gov.tr/assets/upload/dosyalar/35_ankara-bolge-plani-2014-2023.pdf

ARUP. (2022). *Istanbul sustainable urban mobility plan*. Retrieved from https://surdurulebilirulasim.istanbul/wp-content/uploads/2022/08/271487-60-IS-IMP-M9REP-Arup-001_TR-10-rs_compressed.pdf

ASKI (Ankara Water and Sewerage Administration). (2019). *Strategic plan (2020-2024)*. Retrieved from https://www.aski.gov.tr/Yukle/Dosya/faaliyetperformans/2020-24stratejikplan28kasim.pdf

Bazilian, M., Rogner, H., Howells, M., Hermann, S., Arent, D., Gielen, D., . . . Yumkella, K. K. (2011). Considering the energy, water and food nexus: Towards an integrated modelling approach. *Energy Policy, 39*(12), 7896-7906.

Béné, C., Oosterveer, P., Lamotte, L., Brouwer, I. D., de Haan, S., Prager, S. D., . . . Khoury, C. K. (2019). When food systems meet sustainability – Current narratives and implications for actions. *World Development, 113*, 116-130.

Bhaduri, A., Bogardi, J., Siddiqi, A., Voigt, H., Vörösmarty, C., Pahl-Wostl, C., . . . Osuna, V. R. (2016). Achieving Sustainable Development Goals from a Water Perspective. *Frontiers in Environmental Science, 4*, 64.

Bielicki, J. M., Beetstra, M. A., Kast, J. B., Wang, Y., & Tang, S. (2019). Stakeholder perspectives on sustainability in the food-energy-water nexus. *Frontiers in Environmental Science, 7*, 7.

Biggs, E. M., Bruce, E., Boruff, B., Duncan, J. M., Horsley, J., Pauli, N., . . . Imanari, Y. (2015). Sustainable development and the water–energy–food nexus: A perspective on livelihoods. *Environmental Science & Policy, 54*, 389-397.

Bilali, H. E., Strassner, C., & Hassen, T. B. (2021). Sustainable agri-food systems: environment, economy, society, and policy. *Sustainability, 13*(11), 6260.

Bizikova, L., Roy, D., Swanson, D., Venema, H. D., & McCandless, M. (2013). The water-energy-food security nexus: Towards a practical planning and decision-support framework for landscape investment and risk management. Winnipeg: International Institute for Sustainable Development.

Boas, I., Biermann, F., & Kanie, N. (2016). Cross-sectoral strategies in global sustainability governance: towards a nexus approach. *International Environmental Agreements: Politics, Law and Economics, 16*, 449-464.

Bonn 2011 Nexus Conference. (2011). *Bonn 2011 Nexus Conference: The water, energy and food security nexus—solutions for a green economy*. Retrieved February 22, 2023, from https://www.water-energy-food.org/

Cai, X., Wallington, K., Shafiee-Jood , M., & Marston, L. (2018). Understanding and managing the food-energy-water nexus – opportunities for water resources research. *Advances in Water Resources, 111*, 259-273.

Carmona-Moreno, C., Crestaz, E., Cimmarrusti, Y., Farinosi, F., Biedler, M., Amani, A., . . . Carmona-Gutierrez, A. (Eds.). (2021). *Implementing the water-energy-food-ecosystems nexus and achieving the sustainable development goals*. IWA Publishing.

Chang, Y., Li, G., Yao, Y., Zhang, L., & Yu, C. (2016). Quantifying the water-energy-food nexus: Current status and trends. *Energies, 9*(2), 65.

Chaudhary, A., Gustafson, D., & Mathys , A. (2018). Multi-indicator sustainability assessment of global food systems. *Nature Communications, 9*(1), 1-13.

Childers, D. L., Cadenasso, M. L., Grove, J. M., Marshall, V., McGrath, B., & Pickett, S. T. (2015). An ecology for cities: A transformational nexus of design and ecology to advance climate change resilience and urban sustainability. *Sustainability, 7*(4), 3774-3791.

Chirisa, I., & Bandauko, E. (2015). African cities and the water-food-climate-energy nexus: An agenda for sustainability and resilience at a local level. *Urban Forum, 26*, 391-404.

Chopra, K., Leemans, R., Kumar, P., & Simons, H. (2005). *Ecosystems and human well-being: Policy responses* (Vol. 3). Island Press. Retrieved from https://edepot.wur.nl/95364

Conway, D., Garderen, E. A., Deryng, D., Dorling, S., Krueger, T., Landman, W., . . . Dalin, C. (2015). Climate and southern Africa's water–energy–food nexus. *Nature Climate Change, 5*(9), 837–846.

Daher, B., Hamie, S., Pappas, K., Karim, M. N., & Thomas, T. (2021). Toward resilient water-energy-food systems under shocks: Understanding the impact of migration, pandemics, and natural disasters. *Sustainability, 13*(16), 9402.

de Andrade Guerra, J., Berchin, I., Garcia, J., da Silva Neiva, S., Jonck, A., Faraco, R., . . . Ribeiro, J. (2021). A literature-based study on the water–energy–food nexus for sustainable development. *Stochastic Environmental Research and Risk Assessment volume, 35*(1), 95-116.

De Laurentiis, V., Hunt, D. V., & Rogers, C. D. (2016). Overcoming food security challenges within an energy/water/food nexus (EWFN) approach. *Sustainability, 8*(1), 95.

Dogliotti, S., Giller, K. E., & Ittersum, M. K. (2014). Achieving global food security whilst reconciling demands on the environment: report of the First International Conference on Global Food Security. *Food Security, 6*, 299–302.

Eakin, H., Connors, J. P., Wharton, C., Bertmann, F., Xiong, A., & Stoltzfus, J. (2017). Identifying attributes of food system sustainability: emerging themes and consensus. *Agriculture and Human Values, 34*(3), 757-773.

Ericksen, P. J. (2008). Conceptualizing food systems for global environmental change research. *Global Environmental Change, 18*(1), 234-245.

Estoque, R. C. (2022). Complexity and diversity of nexuses: A review of the nexus approach in the sustainability context. *Science of The Total Environment, 854*, 158612.

EU (European Union). (2012). *The 2011/2012 European report on development, confronting scarcity: managing water, energy and land for inclusive and sustainable growth*.

FAO (Food and Agriculture Organization of the United Nations). (1996). *The state of food and agriculture, 1996*. Retrieved June 11, 2023

FAO (Food and Agriculture Organization of the United Nations). (2013). *Food wastage footprint: Impacts on natural resources, summary report*. Retrieved March 8, 2023, from https://www.fao.org/3/i3347e/i3347e.pdf

FAO (Food and Agriculture Organization of the United Nations). (2014). *The water-energy-food nexus—A new approach in support of food security and sustainable agriculture*. Retrieved February 8, 2023, from https://reliefweb.int/report/world/water-energy-food-nexus-new-approach-support-food-security-and-sustainable-agriculture.

FAO (Food and Agriculture Organization of the United Nations). (2018). *Food loss and waste and the right to adequate food: making the connection*. Retrieved October 18, 2022, from https://www.fao.org/3/CA1397EN/ca1397en.pdf

FAO (Food and Agriculture Organization of the United Nations). (2024). *The state of food security and nutrition in the Wworld 2024*. Retrieved January 11, 2025, from https://www.fao.org/documents/card/en/c/ca9692en

Farmandeh, E., Choobchian, S., & Karami, S. (2024). Conducting water-energy-food nexus studies: what, why, and how. *Scientific Reports, 14*(1), 27310.

Godfray, H. C., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., . . . Toulmin, C. (2010). Food security: The challenge of feeding 9 billion people. *Science, 327*(5967), 812-818.

Goodarzi, M. R., Mohtar, R. H., Piryaei, R., Fatehifar, A., & Niazkar, M. (2022). Urban WEF nexus: an approach for the use of internal resources under climate change. *Hydrology, 9*(10), 176.

Hassen, T. B., Bilali, H. E., Daher, B., & Burkart, S. (2025). Editorial: Sustainable and resilient food systems in times of crises. *Frontiers in Nutrition, 12*, 1564950.

Herrera-Franco, G., Bravo-Montero, L., Caicedo-Potosí, J., & Carrión-Mero, P. (2024). A sustainability approach between the water–energy–food nexus and clean energy. *Water, 16*(7), 1017.

Hoff, H. (2011). Understanding the nexus. *Background Paper for the Bonn 2011 Conference: The Water, Energy and Food Security Nexus*. Stockholm Environment Institute.

Hogeboom, R. J., Borsje, B. W., Deribe, M. M., Meer, F. D., Mehvar, S., Meyer, M. A., . . . Nelson, A. D. (2021). Resilience meets the water–energy–food nexus: Mapping the research landscape. *Frontiers in Environmental Science, 9*, 630395.

Howells, M., Hermann, S., Welsch, M., Bazilian, M., Segerström, R., Alfstad, T., . . . St. (2013). Integrated analysis of climate change, land-use, energy and water strategies. *Nature Climate Change, 3*(7), 621-626.

IMM (Istanbul Metropolitan Municipality). (2020). *Strategic plan (2020-2024)*. Retrieved from https://www.ibb.istanbul/Uploads/2020/2/iBB-STRATEJIK-PLAN-2020-2024.pdf

IMM (Istanbul Metropolitan Municipality). (2021a). *Istanbul climate change action plan*. Retrieved from https://cevre.ibb.istanbul/wp-content/uploads/2022/01/ist_iklim_degisikligi_eylem_plani.pdf

IMM (Istanbul Metropolitan Municipality). (2021b). *Local equality action plan (2021-2024)*. Retrieved from https://www.ibb.istanbul/Uploads/2021/3/Yerel-Esitlik-Eylem-Plani.pdf

International Food Policy Research Institute. (2022). Global food policy report: Climate change and food systems. Washington. DC: International Food Policy Research Institute (IFPRI). Retrieved Ocak 12, 2023, from https://doi.org/10.2499/9780896294257

ISKI (Istanbul Water and Sewerage Administration). (2020). *Strategic plan (2021-2025)*. Retrieved from https://www.iski.gov.tr/web/assets/SayfalarDocs/faaliyetraporlari/faaliyetraporu/pdf/Stratejik%20Plan%20(2021-2025).pdf

Istanbul Development Agency. (2014). *Istanbul regional plan (2014-2023)*. Retrieved from https://www.istka.org.tr/media/1063/2014-2023-%C4%B0stanbul-b%C3%B6lge-plan%C4%B1.pdf

IZKA (Izmir Development Agency). (2015). *Istanbul regional plan (2014-2023)*. Retrieved from https://izka.org.tr/wp-content/uploads/pdf/01_bolgeplani_1.pdf

Izmir Metropolitan Municipality. (2019). *Strategic plan (2020-2024)*. Retrieved from https://www.izmir.bel.tr/CKYuklenen/Dokumanlar_2020/Stratejik%20Plan2024.pdf

Izmir Metropolitan Municipality. (2020a). *Izmir sustainable energy and climate action plan*. Retrieved from https://skpo.izmir.bel.tr/Upload_Files/FckFiles/file/2020/WEB_SAYFASI_SECAP-Turkce.pdf

Izmir Metropolitan Municipality. (2020b). *Izmir sustainable urban logictics plan*. Retrieved from https://www.izmirlojistikplan.com/_files/ugd/a65054_6927ace2f26d4b1dbea1883133d5cfe0.pdf

Izmir Metropolitan Municipality. (2022). *Local equality action plan (2022-2024)*. Retrieved from https://www.izmir.bel.tr/tr/Dokumanlar/23/66

IZSU (Izmir Water and Sewerage Administration). (2019). Strategic plan (2020-2024). Retrieved from https://www.izsu.gov.tr/YuklenenDosyalar/Dokumanlar/03012020_095712_sp_2020-2024.pdf

Kanter, D. R., Schwoob, M. H., Baethgen, W. E., Bervejillo, J. E., Carriquiry, M., Dobermann, A., . . . de Lima, J. M. (2016). Translating the Sustainable Development Goals into action: A participatory backcasting approach for developing national agricultural transformation pathways. *Global Food Security, 10*, 71-79.

Karan, E., Asadi, S., Mohtar, R., & Baawain, M. (2018). Towards the optimization of sustainable food-energy-water systems: A stochastic approach. *Journal of Cleaner Production, 171*, 662-674.

Karnib, A., & Alameh, A. (2020). Technology-oriented approach to quantitative assessment of water–energy–food nexus. *International Journal of Energy and Water Resources, 4*, 189–197.

Kneen, B. (1993). *From land to mouth*. Toronto: University of Toronto Press.

Kovács, G., & Spens, K. M. (2007). Humanitarian logistics in disaster relief operations . *International Journal of Physical Distribution & Logistics Management*, 99-114.

Kummu, M., Moel, H. d., Porkka, M., Siebert, S., Varis, O., & Ward, P. (2012). Lost food, wasted resources: Global food supply chain losses and their impacts on freshwater, cropland, and fertiliser use. *Science of The Total Environment, 438*, 477-489.

Kurian, M. (2017). The water-energy-food nexus: Trade-offs, thresholds and transdisciplinary approaches to sustainable development. *Environmental Science & Policy, 68*, 97-106.

Kurian, M., & Ardakanian, R. (Eds.). (2015). *Governing the nexus: Water, soil and waste resources considering global change*. Switzerland: Springer International Publishing.

Leck, H., Conway, D., Bradshaw, M., & Rees, J. (2015). Tracing the Water–Energy–Food Nexus: Description, Theory and Practice. *Geography Compass, 9*(8), 445-460.

Leese, M., & Meisch, S. (2015). Securitising sustainability? Questioning the'water, energy and food-security nexus'. *Water Alternatives, 8*(1).

National Intelligence Council. (2012). *Global Trends 2030: Alternative Worlds*.

Olawuyi, D. (2020). Sustainable development and the water-energy-food nexus: Legal challenges and emerging solutions. *Environmental Science & Policy, 103*, 1-9.

Orimoloye, I. R. (2022). Water, energy and food nexus: Policy relevance and challenges. *Frontiers in Sustainable Food Systems, 5*, 824322.

Pahl-Wostl , C. (2019). Governance of the water-energy-food security nexus: A multi-level coordination challenge. *Environmental Science & Policy, 92*, 356-367.

Rasul, G. (2014). Food, water, and energy security in South Asia: A nexus perspective from the Hindu Kush Himalayan region☆. *Environmental Science & Policy, 39*, 35-48.

Ringler, C., Bhaduri, A., & Lawford, R. (2013). The nexus across water, energy, land and food (WELF): potential for improved resource use efficiency? *Current Opinion in Environmental Sustainability, 5*(6), 617-624.

Rockström, J., & Sukhdev, P. (2016). *How food connects all the SDGs*. Retrieved February 13, 2023, from https://www.stockholmresilience.org/research/research-news/2016-06-14-how-food-connects-all-the-sdgs.html.

Romero-Lankao, P., Bruns, A., & Wiegleb, V. (2018). From risk to WEF security in the city: The influence of interdependent infrastructural systems. *Environmental Science & Policy, 90*, 213-222.

Saladini, F., Betti, G., Ferragina, E., Bouraoui, F., Cupertino, S., Canitano, G., . . . Bastianoni, S. (2018). Linking the water-energy-food nexus and sustainable development indicators for the Mediterranean region. *Ecological Indicators, 91*, 689-697.

Salam, P. A., Pandey, V. P., Shrestha, S., & Anal, A. K. (2017). The need for the nexus approach. *Water-Energy-Food Nexus: Principles and Practices, 1*, 3-10.

Salem, H. S., Pudza, M. Y., & Yihdego, Y. (2022). Water strategies and water–food Nexus: challenges and opportunities towards sustainable development in various regions of the World. *Sustainable Water Resources Management, 8*(4), 114.

Simpson, G. B., & Jewitt, G. P. (2019). The development of the water-energy-food nexus as a framework for achieving resource security: a review. *Frontiers in Environmental Science, 7*, 8.

Singh, S., & Tayal, S. (2022). Managing food at urban level through water–energy–food nexus in India: A way towards holistic sustainable development. *Environment, Development and Sustainability, 24*(3), 3640-3658.

Smajgl, A., & Ward, J. (2013). *The water-food-energy nexus in the Mekong region*. New York, NY: Springer New York.

Sobal, J., Khan, L. K., & Bisogni, C. (1998). A conceptual model of the food and nutrition system. *Social Science & Medicine, 47*(7), 853-863.

Srigiri, S. R., & Dombrowsky, I. (2021). Governance of the water-energy-food nexus for an integrated implementation of the 2030 Agenda: Conceptual and methodological framework for analysis. *Discussion Paper*.

Stringer, L. C., Quinn, C. H., Berman, R. J., Le, H. T., Msuya, F. E., Orchard, S. E., & Pezzuti, J. C. (2014). Combining nexus and resilience thinking in a novel framework to enable more equitable and just outcomes., 73.

UN (United Nations). (2015). *Transforming our rorld: The 2030 agenda for sustainable development*. Retrieved December 1, 2022, from https://documents-dds-ny.un.org/doc/UNDOC/GEN/N15/291/89/PDF/N1529189.pdf?OpenElement

UN (United Nations). (2021). *The United Nations world water development report 2021: Valuing water.* Retrieved January 12, 2023, from https://www.unwater.org/publications/un-world-water-development-report-2021.

Wang, X.-C., Jiang, P., Yang, L., Fan, Y. V., Klemeš, J. J., & Wang, Y. (2021). Extended water-energy nexus contribution to environmentally-related sustainable development goals. *Renewable and Sustainable Energy Reviews, 150*, 111485.

Weber, H., Poeggel, K., Eakin, H., Fischer, D., Lang, D. J., Wehrden, H. V., & Wiek, A. (2020). What are the ingredients for food systems change towards sustainability?—Insights from the literature. *Environmental Research Letters, 15*(11), 113001.

Weitz, N., Strambo, C., Kemp-Benedict, E., & Nilsson, M. (2017). Closing the governance gaps in the water-energy-food nexus: Insights from integrative governance. *Global Environmental Change, 45*, 165-173.

World Economic Forum. (2011). Water Security: The Water-Food-Energy-Climate Nexus. Washington, DC: Island Press