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The transformation of industrial policies in Turkey within the framework of industrial ecology and circular economy

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Abstract

Since the 1980s, sustainability has become a central theme in industrial and environmental policies, with growing criticism of linear production systems and increasing emphasis on circular production. Unlike linear systems, which rely on one-way resource flows and generate waste, circular models promote reuse, repair, and recycling, aiming to preserve materials and reduce ecological impact. Within this framework, industrial ecology proposes a closed-loop approach that combines economic growth with environmental sustainability and has laid the conceptual foundation for the circular economy. Highlighted in EU industrial policies, this paradigm seeks to minimize waste and extend the life cycle of raw materials. This study examines the transformation of industrial policies in Turkey within the framework of "industrial ecology" and the "circular economy". Since 2010, initiatives centered on industrial symbiosis have been introduced in Turkey, strengthening awareness of a production model based on by-product exchange among producers. During this period, practices were implemented in two main categories: the development of regional industrial symbiosis schemes and the transformation of existing Organized Industrial Zones into Eco-Industrial Parks. After 2020, under the influence of the EU Green Deal, the circular economy discourse has become the dominant narrative in policy documents. By analyzing policy documents over the past 15 years, the study demonstrates both the growing institutionalization of circularity and its structural weaknesses. Notably, insufficient attention to spatial dimensions and the risk of reducing circularity to bureaucratic waste trading emerge as critical challenges. Achieving genuine environmental sustainability requires reframing the circular economy beyond technical or economic efficiency, integrating ecological principles, and embedding it holistically within spatial, social, and governance contexts.

Keywords: circular economy, industrial ecology, industrial symbiosis, sustainability, Türkiye

1. Introduction

Environmental problems have emerged in parallel with industrial development and have increasingly been addressed at a global scale since the 1970s. In response, efforts have focused on developing systems that maintain industrial productivity while minimizing environmental damage, avoiding the overuse of natural resources, and preventing pollution. The concept of sustainability, which emerged in this context, has been a dominant theme in industrial and environmental policies since the 1980s. Following the publication of the United Nations Sustainable Development Goals, the concept of sustainability also gained considerable traction in the business world. As a result, the limitations of linear production systems have increasingly come under scrutiny, and the necessity of transitioning to circular production has become a common theme in both policy frameworks and academic literature. While linear systems are based on a one-way flow of resources that generates waste and environmental pressure, circular production emphasizes reuse, repair, and recycling, aiming to preserve materials and reduce ecological impact. This shift reflects a move from efficiency-oriented improvements toward a more systemic approach to production and consumption.

Within this evolving discourse, it becomes necessary to critically evaluate the actual outcomes of policies built around widely used concepts such as "circularity" and "sustainability," as well as

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the concrete practices they generate. The frequent use of these terms in policy documents, corporate strategies, and public statements often serves to promote a greener image; however, this alone does not suffice to address the underlying issues. Consequently, the development of industrial policies capable of sustaining economic productivity while simultaneously tackling environmental challenges has become a pressing need. Many countries are now taking tangible steps toward this goal.

This study aims to contribute to the discussion on evolving industrial policies in Turkey by extending the debate to the "industrial ecology" (IE) approach, which laid the foundation for the concept of the circular economy. For this purpose, an evaluation and criticism at the conceptual level are presented by examining application examples and policy documents. The second chapter presents the conceptual background, beginning with ecological approaches developed in response to the environmental issues brought about by industrialization. This is followed by an exploration of the IE approach, with particular attention to concepts such as industrial symbiosis (IS) and eco-industrial parks (EIPs). Finally, the concept of the circular economy, which emerged from this foundation, is examined. The third chapter focuses on Turkey's experience, addressing the search for circularity in industry and the changes observed in policy documents. It discusses regional IS practices and projects aimed at transforming existing organized industrial zones (OIZs) into EIPs. The fourth chapter reviews national policy and strategy documents shaped around circularity. The final chapter presents the concluding remarks.

2. Conceptual Background

2.1. Environmental Movement

Despite the rise in environmental awareness throughout history, the capitalist system has continued to treat and consume nature as if it were an unlimited resource. This assumption was analytically challenged by the Limits to Growth report, published by the Club of Rome in 1972, which demonstrated the ecological limits of growth-oriented development (Aşıcı, 2012). Scholars have argued that development must also incorporate human and social dimensions, especially in underdeveloped countries (Adelman & Morris, 1973; Myrdal, 1974). Over time, indicators such as wealth distribution, access to education and healthcare, democratic rights, and gender equality have increasingly been considered part of the broader definition of development.

As environmental problems grew too significant to ignore, certain economic regulations became necessary. Environmental economics emerged as a field that evaluates the costs associated with the excessive use of natural resources, which are often deemed "ownerless" and outside traditional market structures. However, this approach tends to treat nature not as something inherently valuable, but merely as a "resource" (Zengin Taşdemir, 2021). It frames environmental damage as an external cost to be priced and charged for (Smith, 2001), but it does not necessarily promote environmental protection or equitable access to resources (Sagoff, 1988).

Considering these limitations, more radical environmental movements began to offer critiques that targeted not just consumption but the broader production system itself. "Deep ecology," for example, emerged as a critique of the dominant economic and social value systems. It positioned humans as part of nature rather than above it and called for a fundamental shift in social paradigms (Naess, 1973; Devall, 1979). This perspective laid the groundwork for discourses centered on principles such as equality, diversity, symbiosis, class opposition, holism, autonomy, and decentralization (Sessions, 1987; Keller, 2008). Throughout the 1970s and 1980s, related approaches, such as radical ecology and feminist ecology, explored various dimensions of the human–nature relationship.

Within this spectrum, the "green economy" approach gained prominence with the rise of sustainable development as a policy goal (Allen, 2012). This approach, more compatible with the existing economic order, advocates for environmental solutions rooted in labor-intensive sectors and renewable energy (Aşıcı, 2012). However, dominant environmental approaches have been

criticized for overlooking the dynamics of industrialization and economic growth, thereby creating tensions with the socio-economic requirements of societies. (Graedel & Allenby, 1995). These debates have led to a reassessment of industrial production models and the development of alternative frameworks. Among them, IE stands out with its emphasis on circularity.

2.2. Industrial Ecology and Circularity

IE suggests that it is possible to achieve economic growth without compromising environmental sustainability. For industrialized countries to maintain their current living standards without environmental degradation, and for developing countries to reach similar levels, consumers and producers must adopt behaviors modeled on natural ecosystems (Frosch & Gallopoulos, 1989). Its five core principles include a systems approach, the analysis of material and energy flows, interdisciplinary collaboration, biomimicry, and a transition from linear to circular production models (Garner & Keoleian, 1995; Erkman, 1997; Graedel, 1997; Lombardi & Laybourn, 2012). This holistic approach seeks to transform industry into a "closed-loop system" where materials are continually reused, minimizing waste and environmental harm (Lowe, 1993).

A key mechanism for implementing IE is IS, which involves the cooperative use of resources, energy, and by-products among firms. The benefits of IS extend to companies, local communities, and the environment. Chertow (1998) defines five forms of symbiotic relationships: One-way waste exchanges, intra-organizational changes, intra-regional exchanges, localized exchanges and regional-scale collaborations. These collaborations can lead to the development of EIPs, where companies operate in clusters to share resources and optimize their collective performance (Lowe, 1997). For IS to emerge, proximity and interaction between firms are crucial (Chertow, 1998; Christensen, 2006; Dai et al., 2021). Supporting infrastructure, such as shared treatment facilities or logistics systems, is also essential for enabling waste and energy loops across firms.

The network structure of IS, when guided by a systems approach, integrates multiple actors, disciplines, and spatial scales (Richards & Frosch, 1997). In this regard, EIPs represent the most prominent application of industrial ecology principles. As businesses collaborate, they create shared value that exceeds individual gains (PCSD, 1997). EIPs aim to replicate natural ecosystems within industrial settings, promoting minimal use of raw materials and energy while creating closed cycles of materials and water (Graedel, 1997; Bai et al., 2014). The components of EIP design are grouped under six headings: natural systems, energy cycle, material cycle, water cycle, park management and support services, and sustainable design and construction (Lowe et al., 1997).

The Kalundborg EIP in Denmark is widely recognized as the first successful industrial symbiosis model (Chertow, 1998). Developed organically over several decades, it demonstrates how firms across different sectors can voluntarily collaborate to achieve both economic and environmental benefits. Its success highlights the role of voluntary cooperation, resource sharing, and mutual trust (Grann, 1997; Ehrenfeld & Gertler, 1997; Ditlevsen, 2014).

Initially widespread in Europe and North America, EIPs are now being adopted as part of industrial and environmental policies in numerous countries, particularly in Korea and China (Park et al., 2016; Chertow et al., 2021). The EIP concept has also been promoted globally through UNIDO's EIP and eco-city projects. Following the United Nations Industrial Development Organization (UNIDO)'s first pilot initiative in India in 2010, two additional projects were launched in Tunisia. In 2012, through growing collaboration with United Nations Environment Programme (UNEP), the Resource Efficient and Cleaner Production (RECP) program was introduced as a joint initiative (UNIDO, 2017). The program emphasizes reducing industrial impacts on nature and promoting social advancement. Thus, EIPs have begun to be implemented as an environmentally friendly industrial model in developing countries under pressure for industrialization. In many countries, such as Egypt, Brazil, and Taiwan, EIP practices have been found to provide both environmental and economic benefits (Pai et al, 2018; Susur et al. 2019; Nessim et al. 2023).

2.3. Circular Economy

The development of IE made it possible to analyze and model closed systems, leading to a broader understanding of circularity beyond production, extending it to the entire economy (Gomez et al., 2018). This conceptual evolution has been enriched by various approaches such as cradle-to-cradle design, industrial metabolism, green accounting, biomimicry, and the blue economy. With the popularization of the term by the Ellen MacArthur Foundation, the circular economy has gained wide acceptance in both business strategies and policymaking. Defined as an industrial system that is restorative or regenerative by design (EMF, 2013), the circular economy aims to minimize resource input, waste, emissions, and energy leakage (Geissdoerfer et al., 2017). Through long-lasting design, reuse, remanufacturing, renewal, and recycling, it offers a business model where waste is reintegrated at the start of the value chain—extending product lifespans and improving resource efficiency (Ekins et al., 2019; EMF, 2013).

The influence of the circular economy on national policies initially emerged through regulations focused on waste recycling and disposal. One of the earliest examples is Japan's "Resource Efficient Law", enacted in 1991, which was followed by several other legal frameworks aimed at waste recovery and product life extension (Ghisellini et al., 2016; Ji et al., 2012). In Germany, circularity was introduced into legislation with the "Closed Substance Cycle and Waste Management Act" of 1996, which notably emphasized producer responsibility (Ogunmakinde, 2019).

In China, significant advancements were made in areas such as cleaner production, pollution and waste management, and energy conservation, starting with the "Cleaner Production Promotion Law" in 2002 and continuing with the "Circular Economy Promotion Law" in 2009. At the micro level, the circular economy is approached through cleaner production practices targeting firms; at the meso level, the development of IS and EIPs is encouraged; and at the macro level, policies promote symbiotic and circular structures across cities and regions (Zhijun & Nailing, 2007). Despite the establishment of numerous EIPs (Lin et al., 2004; Hong & Gasparatos, 2020) and the implementation of various IS initiatives (Bellantuono et al., 2017), critics argue that China's comprehensive approach to the circular economy has not been fully integrated into market mechanisms or public engagement strategies (Liu et al., 2009).

The European Union (EU) introduced its first Circular Economy Strategy in 2015. However, the foundations for this shift were laid earlier, as the EU began reorganizing its policies in the 2000s in response to climate change. In line with this transition, a growth strategy centered on industrial transformation was adopted. The publication of the European Green Deal in 2019 and the declaration of the goal to become the first climate-neutral continent by 2050 marked the beginning of a new era in industrial policy. Anchored in the principles of a circular economy, the strategy aims not only to address the climate crisis but also to transform the economic model from a linear to a circular structure. Its core objectives include achieving net-zero greenhouse gas emissions by 2050, decoupling economic growth from resource use, and ensuring that no person or region is left behind (European Comission, 2019). In this context, the European Commission's 2020 report, A New Industrial Strategy for Europe, highlights key priorities such as climate-neutral industry, circular economy practices, and innovation (European Comission, 2020).

Although the concept of the circular economy has gained widespread attention, it continues to face criticism due to the ambiguity surrounding its practical application. The tendency to conceptualize it primarily through engineering and business case studies has led to a fragmented understanding, further obscuring the core meaning of circularity (Blomsma & Brennan, 2017; Corvellec et al., 2022). Moreover, as circular economy regulations often center on carbon trading, broader environmental concerns are, to some extent, overlooked. While border carbon taxes are seen as environmentally beneficial, they are also criticized for potentially exacerbating global inequalities (Douenne & Fabre, 2022). Another major critique concerns the neglect of social dynamics and consumer behavior (Fellner et al., 2017). In this regard, when the circular economy is detached from everyday lifestyles and embedded solely in policy documents, it tends to offer

unfulfilled promises and result in policy packages that risk misleading industrial stakeholders and consumers by oversimplifying the principles of IE (Corvellec et al., 2022).

3. Industrial Ecology Applications and Adoption of Circularity in Turkey

When industrial zones and industrial policies in Turkey are examined from an environmental perspective, it becomes evident that global and European trends have influenced Turkey's environmental approach. The earliest initiatives related to circularity in Turkish industry were projects focused on IS. Following these projects, concepts such as green industry, symbiosis, and circularity began to appear in national policy documents. In this context, the first notable IS applications emerged around 2010. Over time, framework documents were developed, and especially after 2020, more comprehensive strategy documents focused on the circular economy began to be published (Figure 1).

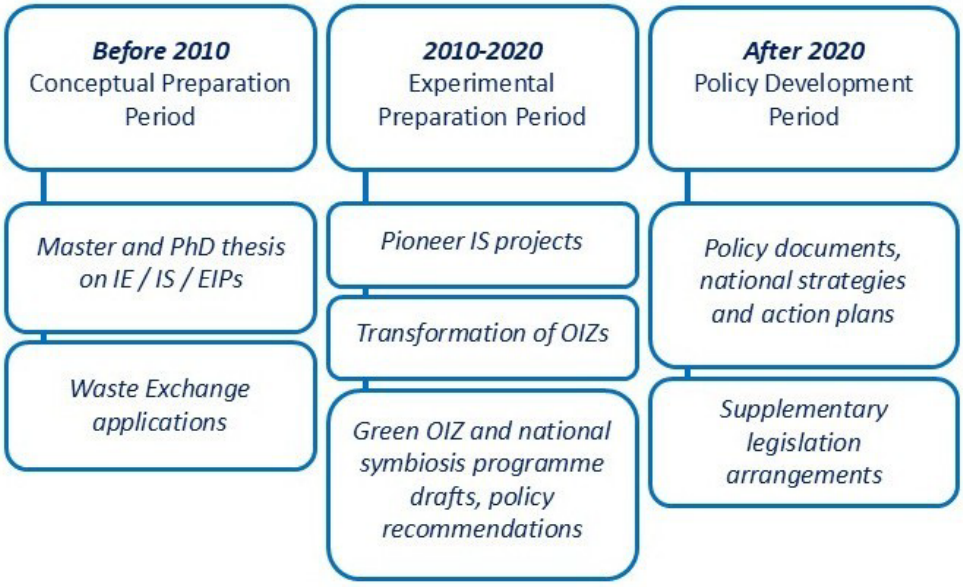

Figure 1 IS based industrial periods in Turkey (Prepared by the author)

The first IS example in Turkey was the BTC İskenderun Bay Industrial Symbiosis Project (2010–2014), developed as part of the Baku-Tbilisi-Ceyhan (BTC) Pipeline Project. The main partners of the symbiosis project were the BTC Company, the Ministry of Development, and TTGV (Technology Development Foundation of Turkey). The project was initiated in 2008–2009 with the support of UNDP and under the coordination of the Adana Chamber of Industry (ADASO). The Middle East Technical University and International Synergies also contributed to the implementation process. While the project primarily aimed to address soil pollution caused by the pipeline, it also identified a variety of industrial relationships, including interactions with agricultural and forested areas in the region (Figure 2).

Following the project, 420 potential synergies were identified within the IS network of 51 member companies from 28 sectors (Dolgen & Alpaslan, 2020). A significant environmental gain has been achieved through the IS process (Özkan et al., 2018). In addition to environmental benefits, the project also provided social and economic gains (Demircioğlu & Ever, 2020). As a result, it was calculated that the investment in IS was recovered within 1.1 years (Yıldız, 2019).

The experience gained from the İskenderun Bay IS project has contributed to building knowledge and capacity for other national-level projects. Realizing the potential identified in theoretical studies through concrete implementation paved the way for the design of new initiatives. This experience has been transferred to other projects through Development Agencies and TTGV; complementary academic publications have been produced, and new IS potentials have been

identified in existing industrial zones with the support of the Ministry of Industry and Technology (MoIT) (Yıldız, 2019). During this process, the transformation of existing OIZs into EIPs also came onto the agenda. IS projects in Turkey are designed at two main scales: (1) regional-scale IS projects coordinated by Development Agencies, and (2) local-scale projects focusing on transforming existing OIZs into EIPs.

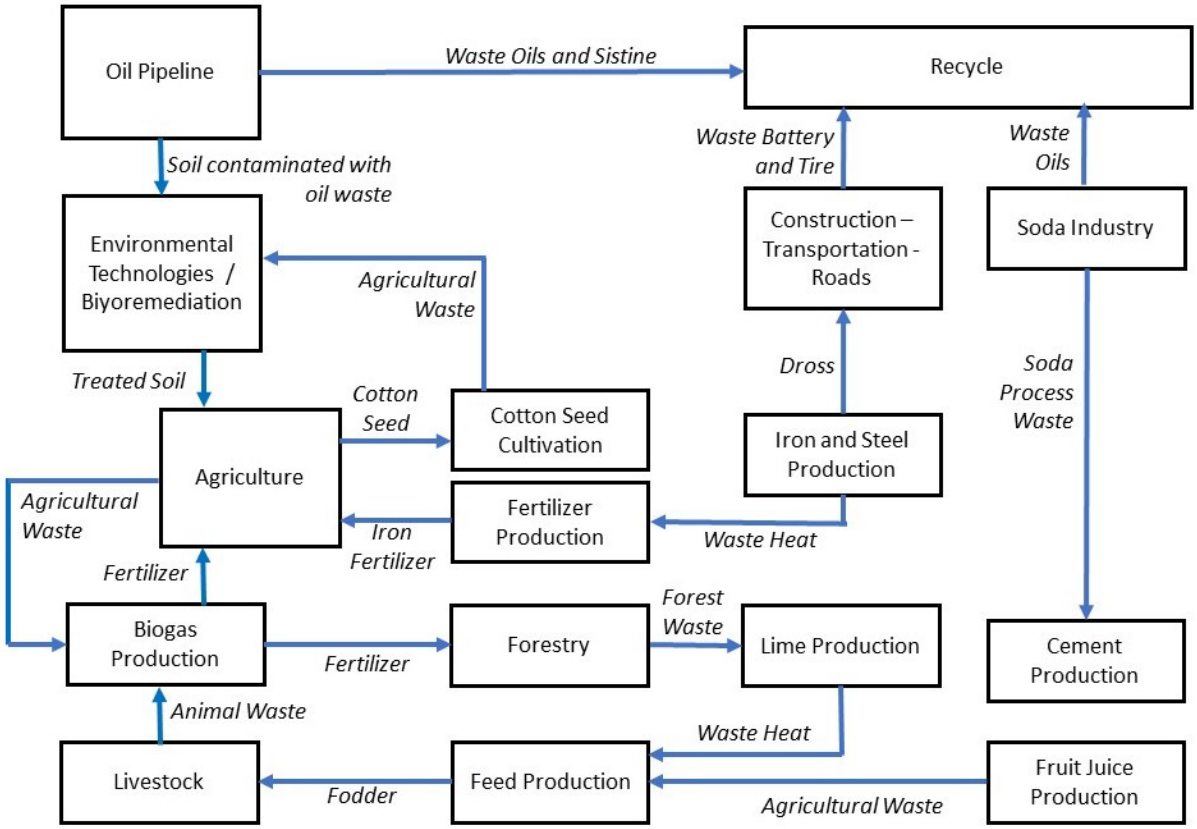

Figure 2 BTC İskenderun Bay IS scheme (Drawn by the author)

3.1. Regional IS Projects

The involvement of Development Agencies as the main actors in IS projects has ensured that these projects are positioned as part of regional development goals. The gains defined by the projects have revealed that economically efficient systems can be designed in addition to ecological benefits, and studies have begun for IS applications and cyclical systems in the economy (Genç et al., 2019; Genç et al., 2020).

The Bursa Eskişehir Bilecik Industrial Symbiosis Program was developed as a feasibility study for the TR41 Region. This initiative was launched in line with the regional policy objective under the heading 'Balanced Spatial Development and Sustainable Environment,' which called for the implementation of IS practices that deliver both environmental and economic benefits by enhancing cooperation among companies. According to the feasibility report, the program aimed to raise awareness of IS in the region, identify existing potential and strategic directions through regional and sectoral analyses, carry out feasibility assessments, conduct communication activities, and establish the infrastructure needed for the long-term implementation and dissemination of IS practices (BEBKA, 2014). The report focused on OIZs characterized by multi-sectoral structures and high manageability. As part of the program, each province in the region was evaluated separately. For instance, in the case of Eskişehir, potential transformation projects were identified at the company and sector levels within the Eskişehir OIZ (BEBKA, 2020).

One notable regional IS initiative is the Trakya Industrial Symbiosis Program (2014–2016), developed for the TR21 Region, which includes the provinces of Edirne, Kırklareli, and Tekirdağ, located in the European part of Turkey, west of Istanbul. The Trakya Regional Plan emphasized the

importance of integration and cooperation in production and expressed a commitment to implementing IS practices at the regional level. These studies revealed that OIZs with sectoral diversity hold significant potential for IS, and key focus areas for implementation were identified (Trakya KA, 2016).

Unlike other regional IS efforts, the Gaziantep Industrial Symbiosis Project (2015–2016) was initiated under the leadership of the Gaziantep Chamber of Industry, with the İpekyolu Development Agency acting as a project partner. The project explored IS opportunities within Gaziantep OIZ, analyzing 1,305 companies across 57 sectors and identifying 104 potential IS ties (Demirer, 2015; Dolgen & Alpaslan, 2020).

Another similar initiative is the Filyos Eco-Industrial Park Project, completed in 2016. This project was developed by the Western Black Sea Development Agency (BAKKA) in collaboration with TTGV. It aimed to leverage the regional development potential of the Filyos Port and its hinterland production zones by integrating them with the advantages of IS (Arslan & Öztürk, 2023).

As of the end of 2024, Development Agencies have issued their third-generation regional development plans for the 2024–2028 period. The visions articulated in these plans prominently feature concepts such as “green transformation,” “green economy,” “green growth,” “sustainable development,” “sustainable value,” and “sustainability.” An analysis of the strategic axes of the plans reveals that the Istanbul Regional Plan (TR10) integrates themes such as “IS,” “circular economy,” “green economy,” “sustainability,” and “digital transformation.” Similarly, the concept of “green transformation” is embedded within the strategic frameworks of other industrially significant regions, including TR31 (İzmir), TR41 (Bursa, Eskişehir, Bilecik), and TR42 (Kocaeli, Sakarya, Yalova, Bolu, Düzce). These developments indicate a continued institutional commitment by Development Agencies to support initiatives related to IS and the establishment of EIPs at the regional level in the near future.

3.2. Transformation of OIZs into EIPs

The second prominent model in Turkey’s IS practices involves enhancing the environmental standards of existing OIZs and integrating IS principles into their operations. OIZs have served as a foundational model for industrialization in Turkey since 1962. From the outset, the approach emphasized developing industry within designated zones while simultaneously implementing measures to prevent environmental pollution. As a result, numerous OIZs have been established, contributing to the spread of planned industrial areas across the country.

These zones incorporate a range of practices aligned with IE principles, such as controlled production, wastewater treatment facilities, energy generation from natural gas, rainwater harvesting, and green-certified buildings. Additionally, local Chambers of Industry have facilitated waste exchange programs that allow companies to reuse each other's by-products. Given these features, OIZs have increasingly been seen as viable starting points for ecological transformation in Turkish industry (Albayrak, 2000; Şenlier & Albayrak, 2011).

One notable initiative was the transformation project carried out in the Antalya OIZ under the title “Industrial Symbiosis and Eco-efficiency” (2015–2016). The project aimed to reduce resource consumption and enhance ecological production efficiency (Dolgen & Alpaslan, 2020). Other transformation efforts include pilot projects developed under the Green OIZ Framework Development for Turkey (2016–2018), launched at the national level. Technical analyses were conducted in four selected OIZs—İzmir Atatürk OIZ, Bursa OIZ, Adana Hacı Sabancı OIZ, and Ankara ASO I. OIZ—to assess their potential for conversion into EIPs. Among them, İzmir Atatürk OIZ has continued its transformation under the Eco-Industrial Park Transformation in İzmir: Green IAOSB project, in collaboration with the İzmir Development Agency (IZKA). Within this framework, action plans focusing on resource efficiency and green infrastructure were implemented, including

centralized wastewater treatment, enhanced water circularity, and industrial symbiosis applications. (Dolgen & Alpaslan, 2020).

These efforts have laid the groundwork for broader ecological and environmental priorities in Turkish industry. Starting from OIZs, initiatives that promote waste transformation and sustainable production practices are becoming increasingly widespread.

4. Industrial Ecology and Circularity in Policy Documents in Turkey

While feasibility studies and pilot projects are currently underway to support implementation, efforts have also commenced to develop a national policy framework aimed at promoting IS practices and EIPs. The concept of a “green industry” was first introduced in the Industrial Strategy Document published in 2013. A significant milestone in this regard was the “Green OIZ Framework Development for Turkey (2016–2018)” Project, initiated by the Ministry of Industry and Technology in collaboration with the World Bank and the International Finance Corporation. The project addressed key thematic areas such as eco-efficiency and cleaner production, green infrastructure (including renewable energy, wastewater treatment, and recycling systems), and circularity opportunities, particularly through IS (General Directorate of Industry and Productivity, 2019). Technical analyses were carried out in four selected OIZs to assess their potential for conversion into EIPs.

One of the key indicators demonstrating the national-level adoption of the IS approach is the inclusion of the statement in the 2019 Industrial Strategy Document–2023 that, “Within the framework of the Green OIZ Framework Development for Turkey Project, efforts to expand IS practices across the country will continue in collaboration with relevant stakeholders, including the Ministry of Environment and Urbanization, Organized Industrial Zones (OIZs), and industrial estates.” The strategy document further outlines commitments to green production, the modernization of OIZ infrastructure and enterprises through technology-intensive solutions, and the promotion of new investments aligned with cleaner production principles (MoIT, 2019, p. 49). These elements reflect a sustained policy direction and signal the initiation of systemic reforms designed to support the operationalization of circularity at the national level.

To draw upon international experiences for advancing applications at the national level, the document titled “A Roadmap for a National Industrial Symbiosis Programme for Turkey” was developed in 2019 in collaboration with the consultancy firm International Synergies. This document proposes a national framework inspired by the UK’s National Industrial Symbiosis Programme (NISP-UK) system, emphasizing the government's role as both a regulatory authority and a provider of financial resources. According to the project, TUBITAK-MAM is responsible for conducting scientific studies that will inform the implementation and coordination among the stakeholders involved. The framework suggests that an Organized Industrial Zone (OIZ) or a chamber of industry should serve as the nucleus of the regional IS system, with surrounding chambers, OIZs, and free zones forming an integrated network. Moreover, it recommends the establishment of a technological monitoring and reporting system alongside a program advisory group composed of representatives from various sectors to ensure the system’s effective operation.

Following the preparatory initiatives, a new phase in the incorporation of the “circular economy” into Turkey’s policy agenda was initiated with the announcement of the European Green Deal in 2019. The introduction of carbon trading regulations in Europe had significant implications not only for EU member states but also for countries with close trade relations with the Union, including Turkey. In response, Turkey launched its Green Deal Action Plan in 2021, coordinated by the Ministry of Trade, aiming to align its policies with Europe’s environmental objectives. This action plan, developed in accordance with the “Livable Cities, Sustainable Environment” priority of the 11th Development Plan, articulated the goal of transitioning towards a “green and circular economy.” The strategy seeks to simultaneously ensure trade compatibility with the EU and enhance the environmental sustainability of Turkey’s production structure. The 12th Development

Plan has further developed this approach in a more integrated manner. While it does not provide a detailed roadmap for the transformation of the existing industrial landscape, it does reaffirm the commitment to aligning with the European Green Deal and highlights the intention to establish the necessary infrastructure for green transformation. Under the main objective titled "Competitive Production with Green and Digital Transformation," sector-specific targets are outlined; however, no concrete benchmarks for green transformation are provided, with the focus primarily placed on raising awareness.

Thus, the process initiated through EIP transformation and IS projects in Turkey has evolved significantly under the influence of the EU. Although the term IE is rarely mentioned in policy documents, its key component, IS, has increasingly been included. Despite this, the term "EIP" has been largely avoided in policy discourse, with preference given instead to terms such as "green industry" and "green OIZ." In line with this thematic shift, the transformation of OIZs has been framed around the concept of "green," and Green OIZ Certification Standards have been developed collaboratively by the Turkish Standards Institute and the Ministry of Industry and Technology.

To qualify for certification, OIZs must first meet several preliminary criteria, including possession of TS EN ISO 14001 and TS EN ISO certifications, a "zero waste" certificate, the establishment of a dedicated unit for climate change and sustainability monitoring, the implementation of wastewater treatment within the OIZ, and the exclusion of coal usage. Once these prerequisites are fulfilled, OIZs are assessed according to economic, environmental, and social performance indicators. These include metrics such as the percentage of firms engaged in industrial symbiosis, reductions in energy and water consumption and waste generation, training initiatives, and geographic location. Based on their performance, OIZs may be awarded certification levels such as platinum, gold, silver, or bronze. As of 2025, it has been mandated that all newly established OIZs obtain a Green OIZ Design Certificate. Complementing this framework, the Türkiye Carbon Market Development Project was launched in 2024. With the finalization of operating rules for the carbon market, it is anticipated that the Turkish Environment Agency, established under Law No. 7261, will assume a more active and functional role in facilitating this transition.

Within the framework of the Technical Support Project for Assessing Turkey's Transition to a Circular Economy (2022–2025), supported by the EU, the National Circular Economy Strategy and Action Plan (UDESEP) was published in September 2024. The strategy outlines legislative measures aimed at ensuring product and economic circularity and identifies priority sectors in which product life cycles will be systematically addressed. These sectors include Packaging, Electronics and Information-Communication Technologies (ICT), Food and Biomass, Construction, Batteries and Vehicles, Plastics, and Textiles.

In parallel, the Climate Change Adaptation Strategy and Action Plan (2024–2030), published in 2024, incorporates circular economy considerations, albeit to a limited extent, under the thematic area of circular economy and industry. Among the listed actions, measures such as "strengthening the technical knowledge and capacity of industrial enterprises, particularly SMEs, for adaptation to climate change" and "disseminating information on the integration of adaptation elements into voluntary green procurement updates in the industrial sector" suggest an indirect connection to circular economy objectives.

By contrast, the Climate Law reflects a more explicit emphasis on the circular economy, although predominantly from the perspective of carbon market regulation. The legislation is largely structured around the establishment of an emissions trading system, indicating a shift away from the holistic perspective of IE toward a market-oriented regulatory framework. While the law devotes substantial attention to emissions trading mechanisms, it provides limited clarity regarding the implementation of adaptation strategies or the integration of Local Climate Change Action Plans into the existing planning framework. Nevertheless, amendments to zoning regulations have been initiated to enhance environmental standards and promote circularity.

5. Concluding Remarks

This study has examined the evolution of the concept of circularity, which has gained increasing prominence in Turkey's industrial policies and practices over the past 15 years, by addressing approaches shaped by both IE and circular economy perspectives (Figure 3). The initial efforts in Turkey were inspired by international examples of IE, with feasibility studies focusing on the transformation of OIZs into EIPs and the identification of potential IS schemes at the regional level. These early projects, launched in the absence of a formal legal framework, primarily aimed to map out possible collaboration opportunities, highlight circularity potential, and encourage producer participation in emerging IS systems.

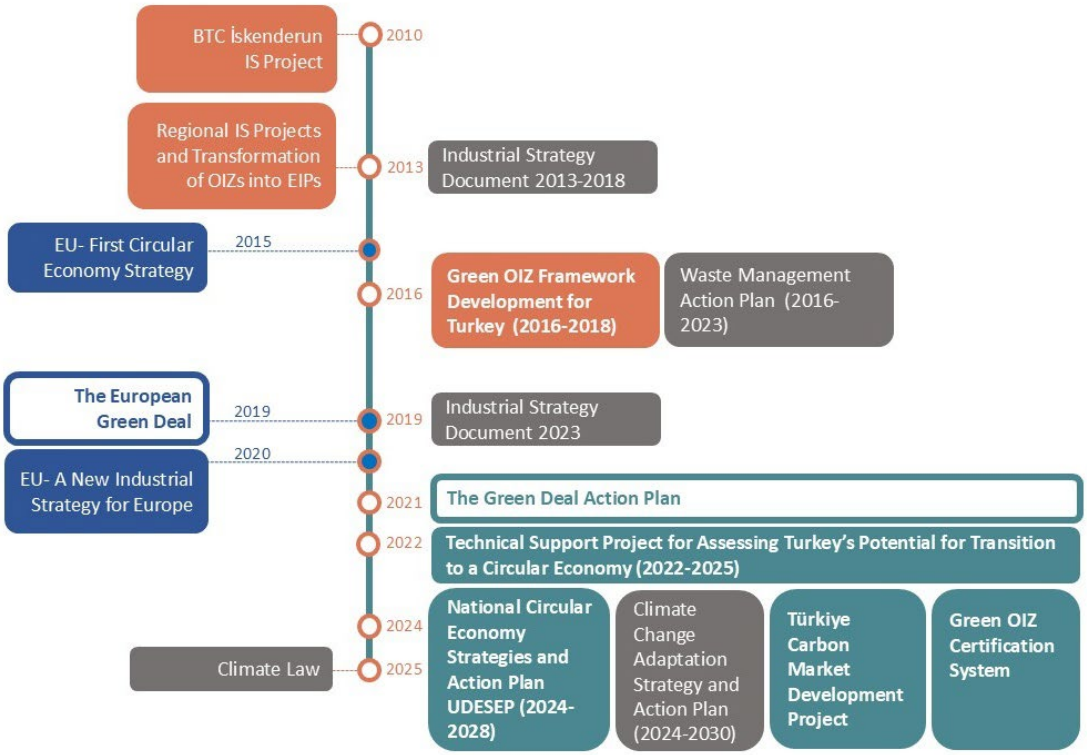

Figure 3 From industrial ecology practices to the circular economy: The evolution of policy frameworks in Turkey (Prepared by the author)

However, there remains no nationally recognized or standardized success criterion to evaluate the effectiveness or outcomes of these IS initiatives. Additionally, the fact that many of these regionally focused projects are limited to short-term (typically two-year) timelines and are designed through top-down approaches by centrally governed institutions may undermine their ability to accurately reflect local IS potential. The regional scale of these schemes, often encompassing multiple provinces and large geographic areas, also poses challenges to fostering the interaction and cooperation necessary for successful symbiosis. Since 2010, numerous initiatives aimed at assessing IS potential and facilitating the transformation of OIZs into EIPs have been launched. Nevertheless, no comprehensive evaluation has been conducted to assess the outcomes or effectiveness of these efforts. While the lack of systematic assessment limits broader conclusions, some academic studies, most notably those focusing on the İskenderun Bay Industrial Symbiosis Project, have reported significant realized or potential environmental benefits (Alkaya et al., 2014).

While the discourse of IE has gradually diminished in the formulation of policy documents, the concept of the circular economy has emerged as the dominant paradigm, particularly under the influence of the European Green Deal. This change, which has increased especially after 2020, can also be seen in Table 1.

Table 1 Concepts in Policy Documents (Prepared by the Author)

	Years	Policy Document	Main Concepts*					
			IE	EIP	IS	CE	GI	GOIZ
2010--2020	2013	Industrial Strategy Document					■	
	2016	Green OIZ Framework Development for Turkey (2016-2018)	■	■	■			■
	2019	Industrial Strategy Document -2023			■			■
	2019	A Roadmap for a National Industrial Symbiosis Programme for Turkey	■	■	■			
After 2020	2021	The Green Deal Action Plan 2021			■	■		
	2022	Technical Support Project for Assessing Turkey's Potential for Transition to a Circular Economy (2022-2025)			■	■		
	2024	National Circular Economy Strategies and Action Plan UDESEP (2024-2028)			■	■		
	2024	Türkiye Carbon Market Development Project			■	■		
	2024	Climate Change Adaptation Strategy and Action Plan (2024-2030)					■	
	2024	Green OIZ Certification System			■	■		■
	2025	Climate Law				■		

IE-Industrial Ecology, EIP-Eco-Industrial Park, IS-Industrial Symbiosis, CE-Circular Economy, GI-Green Industry, GOIZ-Green Organized Industry Zone

Within this emerging policy landscape shaped by themes such as "circularity," "circular economy," and "green industry," references to ecological foundations have progressively receded. As a result, the focus has narrowed to mechanisms such as "emissions trading" and "carbon markets," thereby reducing the holistic scope of earlier ecological frameworks. In this context, policy instruments such as the Industrial Strategy Documents, the National Circular Economy Strategy and Action Plan (UDESEP), and the Climate Law constitute the institutional and legal infrastructure grounded in the concept of the circular economy. However, within this emerging framework, the influence of IE appears to have been largely eclipsed.

At the core of the circular economy lies the objective of establishing business models that extend product life cycles through reuse and waste valorization. Although IS, a key component of IE, continues to be embedded within this model, EIPs have been increasingly sidelined. Instead, a market-driven approach has been proposed, in which symbiotic exchanges are monetized through instruments such as carbon and emissions trading systems (EMF, 2013). This situation has been the subject of criticism in terms of EU environmental policies (Corvellec et al., 2022) and has also been the starting point for research on improving and regulating the environmental contributions of the carbon trading system (Douenne & Fabre, 2022). Following the European Green Deal, this paradigm has become prominent not only in Turkey's national policy documents but also in certain regional plans reflecting the country's strong economic ties with the EU. While the circular economy has contributed to raising awareness of waste reuse and emission reduction, it also contains some weaknesses that require discussion.

Difficulties in Designing a Circular System:

Defining IS models based on the number of connections or the volume of waste exchanged can create rigid and difficult-to-manage systems. Consequently, such systems may guarantee waste production rather than reducing it. Quantitative criteria alone should not be taken as indicators of success, as they may offer a distorted view of system performance. However, within circular economy frameworks, prioritizing the recycling of economically valuable waste risks neglecting materials with little or no economic value but with significant environmental consequences. These wastes must be included in the system first.

Operational Challenges and Responsibilities:

Building production chains on the by-products of other firms is a fragile strategy under uncertain economic conditions. IS requires transparent rules, stable economic frameworks, and open communication among actors. While short-term cooperation may yield economic gains, sudden government decisions or an unstable business environment can easily undermine long-term sustainability. Furthermore, managing waste through top-down mechanisms may create bureaucratic obstacles, reducing the flexibility of companies in adapting to market dynamics. Another important challenge lies in clarifying legal responsibilities when waste in IS schemes fails to meet quality standards or cannot be utilized. Technical and legal capacities must be developed not only for system design and management but also for effective monitoring and enforcement.

Green Labeling and Greenwashing:

The widespread labeling of OIZs as "Green OIZs" risks concealing significant environmental deficiencies. Even with a tiered certification system (bronze, silver, gold), companies that neither participate meaningfully in waste cycles nor demonstrate progress in environmental practices may still benefit from the reputational advantages of certification. This raises questions about the fairness and credibility of such schemes. Additionally, the use of "green" tags may obscure environmental negligence. For instance, a zone causing harm in one area may still be labeled green due to limited positive practices elsewhere, misleading the public. Similarly, a company may improve circularity in some streams while continuing pollution in others, thus distorting the overall environmental picture. The certification and labeling mechanisms of OIZs therefore require critical reconsideration.

Governance:

At the regional scale, centralization and standardized approaches to IS schemes may restrict the development of innovative, locally adapted models. In Turkey, policy processes are typically hierarchical and top-down, whereas internationally recognized examples such as Kalundborg evolved through bottom-up initiatives shaped by local actors and their interactions. The technical complexity of the Emissions Trading System (ETS), combined with limited public engagement in its development, has hindered the identification of potential weaknesses in these mechanisms. While waste recycling is a visible indicator of circularity, the role of carbon markets and emissions trading in achieving actual emission reductions remains uncertain. Critical debates on the choice between emissions trading and carbon taxes, as well as the ethical implications of commodifying emissions, remain underexplored but warrant further study.

Spatial Dimension:

Circular systems should not be reduced to waste exchanges between companies but should be approached as comprehensive processes that also encompass urban functions. This requires linking industrial strategies with spatial planning. Recent regulatory changes in zoning laws, such as those related to waste recycling and rainwater use, represent positive steps toward integrating circularity into urban and industrial development. However, an economy cannot truly be considered circular if natural areas are not preserved, ecological systems are degraded, and mineral resources are extracted without adequate control. Protecting ecosystems and regulating resource extraction are therefore essential prerequisites for achieving genuine circularity.

This study provides a comprehensive assessment of current practices and highlights the conceptual shift in Türkiye's discourse, evolving from IE toward a circular economy. Future research is expected to focus more on the local and regional impacts of circularity-based industrial policies, as well as their implementation at the organizational level. Advancing this field requires further interdisciplinary studies. A more robust empirical discussion depends on the establishment of databases on circularity-oriented practices and the production of reliable regional and national statistics. In addition, the dissemination of case studies during this process would be highly beneficial for both policymakers and the industrial sector.

The circular economy should be regarded as a philosophical framework rather than reduced to a mere "commercial bureaucracy." Institutions need to internalize this perspective in a way similar to the mainstreaming of sustainability. At this stage, strengthening institutional capacity for monitoring legal regulations, managing carbon markets, and overseeing emission trading processes is essential to ensure environmental accountability. Although the circular economy has not yet fully met its environmental promises, its central role in Türkiye's industrial and regional development policies requires critical re-evaluation. Such a reassessment should be guided by participatory approaches that integrate spatial planning and place ecological priorities above superficial forms of "greenwashing." The future of circularity ultimately depends on embedding it not only in industrial strategies but also in broader urbanization policies.

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Ayşe Nur Albayrak: Writing – review & editing, Writing – original draft, Methodology, Investigation, Analysis, Data curation, Conceptualization, Data visualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

Ethics Committee Approval

Ethics committee permission is not required.

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