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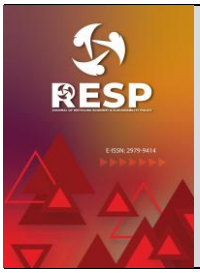

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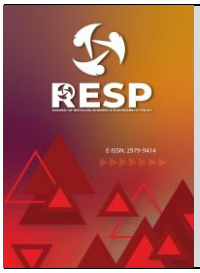

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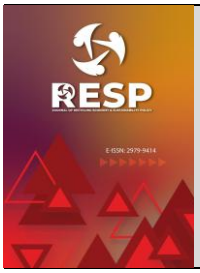

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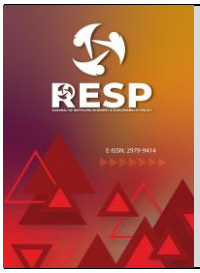

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Araştırma Makalesi ● Research Article

Chinese Electric Vehicle (Ev) Financial Performance – Is The Market Supporting It?

Çin Elektrikli Araç (Ev) Finansal Performansi - Piyasa Destekliyor Mu?

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ANAHTAR KELİMELER

Elektrikli Araçlar (EA)
Borsa Performansı
Devlet Desteği
Finansal Göstergeler
Rekabet Ortamı

ÖZ

Çin'in elektrikli araç (EV) endüstrisi, güçlü devlet desteği, teknolojik gelişmeler ve değişen tüketici tercihlerinin etkisiyle küresel bir lider olarak ortaya çıkmıştır. Bu özet, aralarında BYD, NIO, Li Auto ve XPeng'in de bulunduğu başlıca Çinli elektrikli araç üreticilerinin finansal performanslarının ve borsa eğilimlerinin derinlemesine bir analizini sunmaktadır. Çalışma, gelir artışı, kârlılık, araştırma ve geliştirme (Ar-Ge) harcamaları ve borç-özsermaye oranları gibi temel finansal göstergeleri inceleyerek sektörün ekonomik sağlığı hakkında fikir vermektedir. Sonuç olarak, Çin elektrikli araç sektörü önemli yatırım fırsatları sunarken, aynı zamanda düzenleyici belirsizlikler, sermaye harcaması gereklilikleri ve teknolojik aksaklıklarla ilişkili riskler de taşımaktadır. Gelecekteki hisse senedi performansı, sürekli inovasyona, maliyet verimliliğine ve giderek daha rekabetçi ve dinamik hale gelen bir pazarda üretimi kârlı bir şekilde ölçeklendirme becerisine bağlı olacaktır.

KEYWORDS

Electric Vehicles (EVs)
Stock Market Performance
Government Support
Financial Indicators
Competitive Landscape

ABSTRACT

China's electric vehicle (EV) industry has emerged as a global leader, driven by strong government support, technological advancements, and shifting consumer preferences. This abstract provides an in-depth analysis of the financial performance and stock market trends of major Chinese EV manufacturers, including BYD, NIO, Li Auto, and XPeng, among others. While the Chinese EV sector presents substantial investment opportunities, it also carries risks associated with regulatory uncertainties, capital expenditure requirements, and technological disruptions. Future stock performance will depend on continued innovation, cost efficiency, and the ability to scale production profitably in an increasingly competitive and dynamic market.

1. Introduction

The electric vehicle (EV) industry has grown exponentially during the last decade. The growth is driven by environmental concerns, technological advancements, and favourable regulatory policies. Globally, the transition from carbon fuel vehicles to EVs is reshaping the automotive sector, impacting energy markets, supply chains, and national economies. This article explores the economics of EVs, analyzing key drivers, cost factors, market dynamics, and future trends with a China focus. The global EV market has grown exponentially, with sales increasing from a few thousand units in 2010 to over 10 million in 2022. China's EV market has seen a year-on-year steady growth of 20%, reaching 40% of the total market share in 2024.

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Key factors influencing this expansion include favourable regulatory policies and financial incentives. Most countries are looking to reduce carbon emissions through EV-incentivized subsidies, tax breaks, and regulatory mandates to encourage wider EV adoption. The decreasing cost of lithium-ion batteries has shown a reduction of 90% over the last decade. The nascent EV battery technologies have made EVs more affordable for consumers. Another crucial factor is the growing consumer awareness of climate change and EVs' environmental benefits contributing to an increasing global demand. Electrical power infrastructure development, with expanding EV charging networks globally, has helped address one of the key barriers to EV adoption. These measures promote EVs as a viable option for a wider market for affordability.

The global socio-economic disparities, especially in the global south, impact EV adoption a challenge. China currently dominates global EV sales. In 2023, over 60% of all new EV registrations were in China, followed by 25% in Europe, 10% in the US/Canada, and 5% in the rest of the world. The stringent domestic content requirements for EV and battery manufacturing are the potential bottlenecks for Europe and North America to keep up with the EV growth in China. In 2023, China exported over 1.2 million EVs, mainly to Europe and Asia. The increasing tariffs on Chinese EVs by Europe and North America are seen as a protectionist response against more advanced and cheaper Chinese EVs. Governments worldwide play a crucial role in shaping the EV market through various policies to accelerate adoption and reduce carbon emissions. Subsidies and tax incentives have been implemented in countries such as Norway, China, and the U.K. to lower the upfront cost of EVs, making them more accessible to consumers. Additionally, stringent emission standards, such as the EU's strict CO2 emission targets, have pushed automakers to ramp up EV production to comply with emission regulations. Many nations have also announced future bans on internal combustion engine (ICE) vehicles, further encouraging the transition to EVs. Increased public and private investments in nascent charging infrastructure have facilitated greater EV adoption by addressing range anxiety and improving accessibility to charging stations, making EVs a more practical choice for consumers worldwide.

The economics of EVs are closely tied to production costs, which are influenced by several key factors. Battery costs, the most expensive component of an electric vehicle, have been steadily decreasing due to advancements in battery chemistry and improvements in production efficiency, making EVs more affordable over time. Manufacturing costs also play a crucial role, as EV production generally requires fewer moving parts than traditional internal combustion engine vehicles, leading to lower long-term maintenance costs. However, the initial investment in EV manufacturing remains high due to the need for specialized production facilities and supply chain adjustments. Additionally, charging and energy costs impact overall affordability, with electricity generally being cheaper than gasoline in most markets, though regional variations exist based on energy sources and electricity pricing structures. As these factors evolve, electric vehicles' cost-effectiveness and widespread adoption will be shaped. Price parity between EVs and gasoline vehicles is expected by 2025 in many markets, driven by continued technological improvements and economies of scale. The EV industry relies on a complex global supply chain, with key components sourced from different regions to support the growing demand for electric vehicles. Battery production is primarily dominated by China, where companies such as CATL and BYD lead the market in manufacturing lithium-ion batteries, a critical component of EVs. The supply of essential raw materials, including lithium, cobalt, and nickel, is concentrated in regions like Australia, Chile, and the Democratic Republic of Congo, making these countries vital players in the EV ecosystem. Established and emerging automakers compete to capture market share, with traditional giants like Tesla, Volkswagen, and General Motors facing increasing competition from newer entrants such as Rivian, NIO, and XPeng. As the industry continues to evolve, the efficiency and resilience of this global supply chain will play a crucial role in determining the pace of EV adoption and innovation (Geng, et al., 2016). Geopolitical factors, trade restrictions, and resource scarcity challenge stable supply chains, influencing EV pricing and production capabilities.

The widespread adoption of electric vehicles (EVs) is closely linked to the expansion and availability of charging infrastructure, which continues to evolve in response to growing demand. A key trend is the rapid expansion of charging networks, as governments and private companies make substantial investments in fast-charging stations to alleviate range anxiety and encourage consumer confidence. Additionally, innovative charging solutions are crucial in optimizing energy use; technologies such as bidirectional charging enable EVs to consume energy and supply power back to the grid, while smart grids facilitate better integration with renewable energy sources, reducing dependency on fossil fuels. However, the disparity between urban and rural charging infrastructure remains a significant challenge. While major cities are witnessing a surge in charging stations, remote and less populated areas still struggle with inadequate access, which could slow EV adoption in those regions. Addressing these gaps through targeted policies, incentives, and innovative charging solutions—such as mobile or solar-powered stations—will be crucial in ensuring equitable EV accessibility and supporting the global transition to sustainable transportation (Xia, Wu, Wu, & Ma, 2023).

The transition to electric vehicles (EVs) carries profound economic and environmental implications, shaping industries, labour markets, and energy consumption patterns. One of the most significant benefits is reducing carbon emissions, as EVs produce little to no tailpipe emissions, helping to mitigate climate change, particularly in countries that rely on renewable energy sources for

electricity generation. As EV adoption grows, the oil demand is expected to decline, leading to disruptions in global energy markets. Major oil-producing nations and fossil fuel companies are already adapting by diversifying into renewable energy, battery technologies, and EV charging solutions to stay relevant in the evolving landscape. At the same time, the shift to EVs is reshaping the job market. While traditional automotive manufacturing jobs, especially those related to internal combustion engines—may decline, new employment opportunities are emerging in battery production, software development, and the expansion of charging infrastructure. The need for skilled workers in battery recycling, energy grid management, and autonomous vehicle technology is also growing, further transforming the workforce. As governments and businesses navigate this transition, policies supporting workforce retraining and sustainable energy development will ensure a smooth and equitable shift toward an electrified future (Qiu & Li, 2012).

Despite the promising outlook for electric vehicles (EVs), several significant challenges must be addressed to ensure sustained growth and widespread adoption. One of the primary concerns is the availability of raw materials such as lithium, cobalt, and nickel, which are essential for battery production. As global demand for EVs increases, securing a stable and ethical supply chain for these critical minerals is becoming increasingly complex, with geopolitical tensions and environmental concerns adding further complications. Developing efficient battery recycling systems mitigates battery disposal's ecological impact, reduces reliance on newly mined materials, and creates a more sustainable supply loop. Another pressing issue is affordability—although EV costs are gradually declining due to advancements in battery technology and economies of scale, price remains a barrier for lower-income consumers. Expanding government incentives, improving financing options, and investing in lower-cost battery chemistries could help make EVs more accessible to a broader audience (Dixon, 2023).

Meanwhile, ongoing technological advancements hold the potential to reshape the industry. Innovations such as solid-state batteries promise greater energy density and faster charging times, while wireless charging could enhance convenience for consumers. Additionally, integrating autonomous driving technology with EVs may revolutionize mobility by enabling self-driving fleets, increasing efficiency, and reducing transportation costs. Addressing these challenges through strategic investments, policy support, and innovation will be key to unlocking the full potential of EVs and accelerating the transition to a cleaner, more sustainable transportation future. The global EV industry is pivotal, with strong growth prospects and economic transformations underway. While challenges remain, continued policy support, technological innovation, and investment in infrastructure will determine the speed and scale of global EV adoption. As the world moves toward a greener future, EVs will play a crucial role in shaping sustainable transportation and energy systems.

2. China’s EV industry

China has emerged as the world's largest market for electric vehicles (EVs), accounting for more than half of global EV sales. This dominance results from strategic government policies, aggressive industrial investments, and a robust supply chain for battery production. As the world shifts towards sustainable transportation, the economics of EVs in China provide a fascinating case study in industrial policy, market forces, and technological progress (Geng, et al., 2016). China's remarkable success in the electric vehicle (EV) market is primarily attributed to decisive government intervention, which has created a highly supportive policy environment for manufacturers and consumers. The Chinese government has implemented a combination of subsidies, tax incentives, and regulatory measures to accelerate EV adoption, making China the world's largest EV market. One of the most influential policies has been direct subsidies, which were in place from 2009 to 2020 and covered a significant portion of EV costs—sometimes up to 60%—making EVs more affordable for consumers while boosting domestic production. Another key initiative is the New Energy Vehicle (NEV) credit system, which requires automakers to produce a certain percentage of EVs or purchase credits from compliant manufacturers, ensuring that EV production remains a priority for the industry. Additionally, restrictive policies on traditional gasoline cars have further encouraged EV adoption; in cities like Beijing and Shanghai, strict license plate quotas, high auction prices, and driving restrictions for gasoline vehicles make EVs the more practical and accessible choice. Beyond consumer incentives, China has made significant investments in infrastructure, developing one of the world's most extensive EV charging networks, which surpassed 6 million charging points by 2023. This large-scale infrastructure push reduces range anxiety and ensures that EV adoption remains convenient even in densely populated urban areas. These policies have positioned China as a global leader in EV technology and adoption, influencing other nations to consider similar policy-driven approaches to accelerate their transitions to electric mobility. These policies have led to a rapid increase in EV sales, but the phase-out of subsidies since 2022 has raised concerns about the sustainability of growth (Harkavy, 2024).

China’s EV industry benefits from a vertically integrated supply chain, particularly in battery production. Chinese companies like CATL and BYD dominate global lithium-ion battery manufacturing, benefiting from raw materials and large-scale production cost advantages. China's electric vehicle (EV) supply chain dominance is driven by several key factors that provide it with a significant competitive edge in global markets. One of the most critical advantages is its control over the refining and processing of essential raw materials such as lithium, cobalt, and nickel—key components for EV battery production. While China does not have the largest reserves of these minerals, it has

invested heavily in securing global supply chains, particularly in countries like the Democratic Republic of Congo (for cobalt) and Australia (for lithium), ensuring a steady and cost-effective supply for its battery manufacturers. Another major strength lies in economies of scale; China's massive domestic demand for EVs allows manufacturers to achieve lower per-unit costs, making EVs more affordable domestically and for export. This scale advantage extends to battery production, where leading Chinese companies like CATL and BYD produce batteries at a lower cost than many of their international competitors.

Furthermore, China is at the forefront of technological advancements in battery innovation, particularly lithium iron phosphate (LFP) batteries. Unlike traditional nickel-manganese-cobalt (NMC) batteries, LFP batteries are cheaper to produce, have a longer lifespan, and offer improved safety due to their lower risk of overheating. These innovations have allowed Chinese manufacturers to enhance battery performance while decreasing costs, further strengthening their position in the global EV market. As a result, China has established itself as a leader in EV production and the critical supply chains that underpin the industry, making it difficult for other countries to compete without significant investment in domestic production capabilities (Zhang, Luo, Zhang, Shu, & Shao, 2024).

China's electric vehicle (EV) market is one of the most dynamic and competitive in the world, featuring a mix of domestic giants, innovative startups, and significant foreign automakers. BYD, now the world's largest EV manufacturer by sales, is leading the market, which benefits from its vertically integrated supply chain, including in-house battery production that helps reduce costs and improve efficiency. Another key player is Tesla, which has established a strong presence in China through its Shanghai Gigafactory. This central production hub supplies the domestic market and exports vehicles to Europe and other regions. Beyond these industry leaders, a wave of Chinese startups—such as NIO, XPeng, and Li Auto—are driving innovation in premium EVs, autonomous driving technology, and battery-swapping solutions, catering to tech-savvy and high-end consumers (Dong & Liu, 2020).

Meanwhile, China's traditional automakers, including SAIC, Geely, and FAW, are rapidly expanding their EV portfolios, leveraging their existing manufacturing infrastructure and brand recognition to compete in the evolving market. The intense competition in China's EV sector has spurred rapid advancements in battery technology, vehicle range, and innovative mobility features, positioning the country as a global leader in the transition to electric transportation. Automakers focus on cost reduction, technological differentiation, and international expansion to maintain their market share in this fast-growing industry as competition intensifies. While competition has led to rapid innovation and price reductions, it has also resulted in market fragmentation and intense pressure on profit margins (Yuan, Liu, & Zuo, 2015). The cost of electric vehicle (EV) production in China has been steadily declining, driven by economies of scale, advancements in battery technology, and highly efficient supply chain management. One of the most significant cost reductions has come from the falling price of batteries, which typically account for 30-40% of an EV's total cost. Over the past decade, innovations in battery chemistry, particularly the widespread adoption of lithium iron phosphate (LFP) batteries, have helped lower production expenses while improving safety and longevity. However, several economic factors continue to influence EV pricing and profitability. One major challenge is material price volatility, as the cost of critical minerals like lithium, cobalt, and nickel has experienced fluctuations due to supply chain disruptions, geopolitical tensions, and surging global demand. These price swings directly impact battery costs, making it essential for manufacturers to secure stable and diversified sources of raw materials. Another factor shaping the cost structure is the gradual phase-out of government subsidies. While China's generous EV subsidies helped drive mass adoption, their reduction in recent years has put pressure on automakers to cut costs through efficiency improvements and innovation further. Without these incentives, manufacturers must find new ways to maintain competitive pricing while sustaining profitability. A key response to these challenges has been the increasing automation of manufacturing, with companies investing heavily in AI-driven robotics and intelligent production lines to reduce labour costs and enhance efficiency. These advancements improve production speed and precision, allowing greater flexibility in scaling operations to meet growing demand. As the Chinese EV market matures, continuous improvements in battery efficiency, supply chain resilience, and automation will be crucial in maintaining cost competitiveness and ensuring long-term growth (Gong, Wang, & Wang, 2013).

One of China's strategic advantages in accelerating the adoption of electric vehicles (EVs) is its extensive charging infrastructure, which is the largest in the world. By 2023, China had over 6 million public and private charging points, far surpassing any other country and ensuring EV owners can access convenient and reliable charging solutions. This rapid expansion has been driven by government-led initiatives, with state-owned enterprises and private companies investing heavily in deploying fast-charging stations across cities and highways. To further enhance convenience, China has also embraced battery-swapping technology, led by companies like NIO, which allows drivers to exchange depleted batteries for fully charged ones in minutes, eliminating long wait times associated with conventional charging. Integrating smart grid and vehicle-to-grid (V2G) systems is crucial in optimizing energy distribution. These technologies enable EVs to draw power from the grid and feed electricity back when demand is high, helping balance supply and reduce grid strain. However, despite these advancements, a significant urban-rural charging disparity remains, with rural areas still facing a shortage of charging stations. This infrastructure gap

challenges achieving widespread EV adoption outside significant cities, necessitating further investments in decentralized, off-grid solutions such as solar-powered charging stations and mobile charging units. As China continues to refine its EV ecosystem, addressing these regional disparities will be essential to ensuring nationwide accessibility and sustaining long-term growth in the sector.

The rapid adoption of electric vehicles (EVs) in China has profound environmental and economic implications, reshaping the country's energy landscape and industrial economy. One of the most significant impacts is the reduction in oil dependence, as the widespread shift to EVs decreases China's reliance on imported crude oil. Given that China is the world's largest oil importer, this transition enhances energy security, reduces vulnerability to global oil price fluctuations, and lowers the trade deficit associated with fossil fuel imports. On the environmental front, EVs contribute to lower emissions, particularly in urban areas where they help mitigate air pollution and improve public health. However, the overall carbon footprint of EVs depends mainly on the country's energy mix. While China is rapidly expanding its renewable energy capacity, a substantial portion of its electricity still comes from coal-fired power plants, limiting the full environmental benefits of electrification. Accelerating the transition to clean energy sources such as wind, solar, and hydro will be crucial to maximizing the climate benefits of EV adoption. The EV boom has also fueled job creation and economic growth, generating millions of jobs across multiple sectors, including vehicle manufacturing, battery production, charging infrastructure, and software development. China's EV and battery technology leadership has also positioned it as a global export powerhouse, strengthening its economic influence in the rapidly expanding clean energy sector. As the industry continues to evolve, China's ability to balance environmental sustainability with economic expansion will play a crucial role in shaping the future of global transportation (Ming, Song, Mingjuan, & Xiaoli, 2013).

Despite the rapid growth of China's electric vehicle (EV) industry, several challenges could affect its future trajectory. One of the most pressing issues is market saturation. In major cities, EV penetration has already surpassed 30%, and as the market matures, growth could slow unless new domestic and international markets emerge. Expanding EV adoption in less urbanized areas and abroad will be essential to maintaining momentum. Additionally, foreign competition intensifies, with European and U.S. automakers increasingly entering the Chinese market. These global players, with their advanced technologies and brand recognition, could disrupt the dominance of local manufacturers, making it necessary for Chinese companies to innovate and enhance their offerings continuously. Another challenge is battery recycling and sustainability. As EV adoption grows, managing battery waste and establishing a circular economy for critical materials like lithium, cobalt, and nickel will become crucial to ensure long-term resource availability and reduce environmental impacts. Without effective recycling systems, China risks facing material shortages and environmental issues. Moreover, global trade tensions and protectionist policies risk China's EV exports and supply chain security. Tariffs, export restrictions, and geopolitical conflicts could limit China's access to key markets and materials, potentially slowing the country's leadership in the EV sector.

Looking ahead, China remains well-positioned to lead the global EV transition due to its advanced manufacturing capabilities, significant infrastructure investments, and a strong policy environment. However, the industry's long-term success will depend on continued investment in research and development, further expansion of charging and battery infrastructure, and strategies to strengthen its international market presence. By addressing these challenges, China can solidify its role as a dominant player in the global shift toward sustainable transportation. China's EV industry exemplifies how strategic policy, industrial planning, and market dynamics can drive technological transformation. While challenges remain, China's EV production and innovation leadership is reshaping the global automotive landscape. As the industry evolves, China will play a pivotal role in defining the future of electric mobility worldwide.

3. Technical challenges

Electric vehicles (EVs) have become a cornerstone of sustainable transportation, offering an alternative to fossil fuel-powered vehicles. While EV technology has advanced significantly over the past decade, several technical challenges that impact efficiency, performance, and widespread adoption remain. Addressing these challenges is essential for the continued growth of the EV industry. This article explores EVs' key technical hurdles and ongoing efforts to overcome them (Schuman & Lin, 2012). One of the most significant challenges in developing electric vehicles (EVs) revolves around battery technology, particularly issues related to energy density, battery degradation, and raw material constraints. Energy density is a critical factor because, despite the advancements in lithium-ion battery technology, current batteries still have much lower energy density than gasoline, limiting the driving range of EVs. This restriction is a significant concern for consumers who worry about running out of charge during long trips or being unable to find charging stations in remote areas. To address this challenge, research is intensifying in next-generation battery technologies such as solid-state and lithium-air batteries, which promise higher energy storage capacities, faster charging times, and improved safety. However, these technologies are still in development and face significant engineering and production hurdles before they can be widely deployed.

Another challenge is battery degradation. Over time, EV batteries lose capacity, reducing the vehicle's driving range and overall performance. Several factors contribute to this degradation, including the number of charge cycles (the

number of times a battery is charged and discharged), temperature fluctuations, and charging speeds. Rapid charging can generate heat, which accelerates the breakdown of battery components. Manufacturers are investing in better cooling systems, advanced battery management systems, and new chemistries to prolong the lifespan of batteries and maintain consistent performance over time. Finally, raw material constraints represent a significant hurdle in scaling up EV production. Lithium, cobalt, and nickel are critical for producing high-performance batteries. Still, the minerals supply is volatile due to mining restrictions, geopolitical tensions, and environmental concerns. Ethical issues surrounding mining practices, particularly in countries with poor labour conditions or environmental standards, complicate the global supply chain. Efforts are underway to develop alternatives to these materials and improve battery recycling to create a more sustainable and circular economy for EV batteries, but solving these issues is vital to meeting the growing demand for electric vehicles. Together, these technological and supply chain challenges must be addressed to ensure the continued growth of the EV industry and make electric transportation a viable and sustainable alternative to traditional fossil-fuel-powered vehicles.

A widespread and efficient charging network is essential to successfully adopting electric vehicles (EVs). Still, several technical challenges remain that need to be addressed to improve convenience and accessibility for consumers. One of the most pressing issues is charging time. While advancements in fast-changing technology are progressing, current high-speed chargers still take significantly longer to charge an EV than refuelling a gasoline vehicle. Even with the latest fast chargers, a full charge can take anywhere from 20 minutes to an hour, depending on the battery size and charging station capabilities. This starkly contrasts with the few minutes it takes to fill a gasoline tank, and it can be a barrier for drivers who are used to the quick refuelling process. To improve charging times, research into more powerful charging solutions, higher energy density batteries, and even alternative technologies like wireless charging is ongoing, but it will take time to make these advancements widely available (Sheehan, 2023).

Another challenge is grid integration. As the number of EVs increases, so does the demand for electricity to charge them, placing additional strain on already stretched electrical grids. To accommodate this higher energy demand, grids will require significant upgrades and the implementation of innovative charging solutions. Smart charging technologies allow vehicles to communicate with the grid to optimize charging times, reducing peak demand and balancing power distribution. For example, EVs could be charged during off-peak hours to prevent grid overload. Additionally, vehicle-to-grid (V2G) systems could enable EVs to return excess energy to the grid, helping stabilize the power supply during high-demand periods (Song, et al., 2022).

Finally, standardization remains a significant hurdle. Different charging standards—such as the CCS (Combined Charging System), CHAdeMO, and Tesla's proprietary system—create compatibility issues between EV models and charging stations. Consumers may be frustrated if they cannot use a charger because it does not support their vehicle's charging port. This lack of uniformity complicates the user experience and hinders the widespread adoption of EVs, especially when cross-brand compatibility is not guaranteed. Industry stakeholders must work toward a more standardized approach to charging infrastructure to streamline the process and make it easier for consumers to access charging stations without worrying about compatibility issues. Addressing these technical challenges—charging time, grid integration, and standardization—will be key to creating an efficient and user-friendly charging network that supports the continued growth of the EV market and promotes mass adoption of electric vehicles (Xia, Wu, Wu, & Ma, 2023).

While electric vehicles (EVs) offer several advantages, such as instant torque and fewer moving parts, several technical challenges remain to be overcome in optimizing powertrain efficiency. These challenges impact overall vehicle performance and energy efficiency. One of the most pressing concerns is thermal management. EV powertrains generate substantial heat during operation, particularly during high performance or rapid acceleration. Effective cooling systems are crucial to prevent overheating, which could reduce efficiency and damage key components such as the battery, motor, and electronics. Managing this heat through advanced thermal management solutions is essential to maintaining optimal performance, extending the lifespan of powertrain components, and improving energy efficiency. Innovations such as liquid cooling systems, heat pumps, and better airflow designs are being explored to address this issue. Another limitation is regenerative braking. Regenerative braking allows EVs to recover some of the kinetic energy during braking and convert it back into usable energy, helping extend the driving range and improve efficiency. However, regenerative breaking has its limitations. It cannot recover all the kinetic energy, especially under hard braking or when the battery is fully charged. Additionally, regenerative braking is less effective at low speeds or during stop-and-go traffic. This results in energy loss and affects overall energy efficiency, requiring traditional friction brakes to intervene, which can reduce the energy recovery potential.

Weight and aerodynamics also impact the efficiency of EVs. Since EVs rely on large, heavy batteries to store energy, they tend to weigh more than their internal combustion engine (ICE) counterparts. This added weight can reduce the vehicle's efficiency, particularly regarding acceleration and braking. Moreover, weight affects driving dynamics, such as handling and cornering performance. EV manufacturers are working to address this by using lightweight materials, such as carbon fibre or aluminium, in the vehicle's frame and body and optimizing battery designs to minimize weight.

Additionally, the vehicle's aerodynamics play a crucial role in energy efficiency. EVs with better aerodynamics experience less air resistance, improving range and overall efficiency. Streamlined body shapes and design modifications, such as active grille shutters and lower ride heights, are key strategies to reduce drag and improve fuel economy. Addressing these technical issues—thermal management, regenerative braking limitations, and weight/aerodynamics—will be essential for optimizing the efficiency and performance of EV powertrains. As these challenges are overcome, EVs in terms of energy savings and sustainability benefits will become even more pronounced, supporting the widespread adoption of electric transportation. Cold temperatures pose significant challenges to electric vehicle (EV) performance and range, particularly in regions that experience harsh winters.

One of the primary issues is battery performance reduction. Cold weather causes the chemical reactions in EV batteries to slow, decreasing overall efficiency. This leads to a reduced driving range, as the battery cannot be discharged as efficiently as it would in warmer conditions. Additionally, charging speeds are affected in colder temperatures, as low temperatures make it harder for the battery to accept a charge quickly, resulting in longer charging times. To mitigate these effects, manufacturers are incorporating battery thermal management systems to help maintain optimal temperature ranges and minimize the impact of cold weather. However, these systems add complexity and cost to the vehicle. Another factor influencing EV performance in cold weather is cabin heating energy consumption. Unlike gasoline vehicles, which can utilize waste heat from the engine to warm the cabin, EVs rely entirely on energy from the battery for heating. Warming the cabin can draw significant energy, reducing the vehicle's range in cold temperatures. To address this challenge, EVs often incorporate heat pumps, which are more energy-efficient than traditional electric heaters, and advanced insulation to help maintain cabin warmth without overloading the battery. Some manufacturers also offer pre-conditioning features, allowing the vehicle to warm up while still plugged in so it doesn't drain the battery during heating (Xu, 2021).

Together, battery performance reduction and cabin heating energy consumption present notable challenges for EVs in cold climates, limiting their efficiency and range during winter. However, ongoing innovations in battery technology, thermal management systems, and energy-efficient heating solutions are helping to alleviate these issues, making EVs more viable in colder environments. Proper disposal and recycling of electric vehicle (EV) batteries present environmental and economic challenges that need to be addressed to ensure the sustainability of the EV industry (Zeng, Li, & Zhou, 2013). One of the key challenges is battery recycling complexity. The current recycling processes for EV batteries are inefficient, costly, and incapable of recovering all valuable materials. Many metals in EV batteries, such as lithium, cobalt, and nickel, are difficult to extract through conventional recycling methods. As a result, only a fraction of these materials are recovered, with the remainder either being lost or sent to landfills, contributing to environmental pollution. The complex structure of lithium-ion batteries and the need for specialized recycling facilities add further difficulty to scaling up recycling efforts. Improving recycling technologies and developing more cost-effective and efficient methods will be crucial for reducing environmental impact and recovering critical materials to support the growth of the EV market (Zhao, Zuo, Fan, & Zillante, 2011).

Another promising solution is the development of second-life applications for EV batteries. When an EV battery reaches the end of its useful life in a vehicle, its capacity may be reduced, but it can still retain significant energy storage potential. Repurposing these used batteries for energy storage applications—such as in stationary storage systems for renewable energy or as backup power for homes or businesses—can extend their usefulness. This approach could also help mitigate the demand for new raw materials, reducing environmental pressure. However, technological and economic feasibility studies are needed to assess the viability of second-life battery systems. Issues such as battery degradation, safety, and integration into energy storage systems must be addressed to ensure these second-life solutions are practical and cost-efficient.

In summary, the recycling and repurposing of EV batteries are vital to the transition to a sustainable EV future. While significant progress is being made in research and development, further advancements in recycling technologies and second-life applications are required to mitigate the environmental impact of used batteries and create a more circular economy for EV materials. Addressing these challenges will be key to ensuring the long-term success of electric vehicles while minimizing their ecological footprint (Zeng, Li, & Zhou, 2013). As electric vehicles (EVs) become increasingly connected and rely more on software, cybersecurity concerns are emerging as a critical challenge for the industry. One of the main risks is hacking. EVs with internet connectivity, including features like remote diagnostics, navigation systems, and autonomous driving capabilities, are susceptible to cyberattacks. If hackers gain unauthorized access, they could compromise vehicle control, causing safety risks, such as taking control of the vehicle's braking or steering systems. Additionally, hackers could exploit vehicle software vulnerabilities to turn off critical functions or cause disruptions. As the complexity of EVs increases, the need for advanced cybersecurity solutions to protect against such attacks becomes paramount. Another concern is software bugs and updates. Modern EVs rely on over-the-air (OTA) updates to improve functionality, fix bugs, or enhance features. While these updates offer convenience and allow manufacturers to address issues remotely, they also present security challenges. If the update process is not secured correctly, it could expose the vehicle to the risk of malware or unauthorized access. Even legitimate updates can introduce new software bugs affecting vehicle performance

or safety. Ensuring that OTA updates are secure and reliable is crucial to maintaining vehicle integrity and user trust.

Finally, there are growing data privacy concerns. EVs collect vast user data, including location information, driving patterns, and personal preferences. This data is often stored and transmitted to manufacturers or third-party services for vehicle performance analysis and optimization. However, this raises questions about how the data is being used, who has access to it, and how it is protected. Consumers are becoming more aware of the privacy risks, and stringent data protection regulations are required to ensure that user information is not misused or accessed without consent. Safeguarding personal data and ensuring transparency in handling it will be crucial to building consumer confidence in connected EV technologies. Addressing cybersecurity, software integrity, and data privacy concerns will be essential as EVs become more integrated with the digital world. Manufacturers must prioritize security measures, implement robust software testing and encryption, and be transparent about collecting and using user data. By doing so, they can protect both the safety of EVs and the privacy of their owners, ensuring the continued growth and acceptance of electric mobility. While electric vehicles represent the future of transportation, numerous technical challenges must be addressed to enhance their efficiency, reliability, and affordability. Advances in battery technology, charging infrastructure, and cybersecurity will play crucial roles in overcoming these obstacles. Continued research and innovation will help accelerate the transition to a fully electric automotive landscape, ensuring a sustainable and technologically robust future for EVs.

4. China’s stock price performance

Electric vehicle (EV) companies have become a primary focus for investors, with stock prices experiencing significant fluctuations over the past decade. The rise of Tesla, the emergence of Chinese EV giants, and the entry of legacy automakers into the EV space have driven market dynamics. This article explores the stock performance of key EV companies, the factors influencing price movements, and the future outlook for the sector.

Several electric vehicle (EV) companies have gained significant attention in the stock market due to their stock price volatility and impressive gains, with some emerging as major players in the global EV landscape. These companies represent a mix of established manufacturers and new entrants, each with unique challenges and opportunities. Tesla (TSLA) has been the most influential EV stock, capturing global investor attention for its growth trajectory and technological innovations. Tesla’s stock price surged from under $50 per share in 2019 to over $1,200 in 2021, driven by substantial delivery numbers, profitability milestones, and investor enthusiasm surrounding its leadership in autonomous driving, energy storage solutions, and battery technology. Despite experiencing significant corrections and fluctuations in its stock price, Tesla remains a dominant force in the EV market, with its prospects closely tied to ongoing production ramp-ups and innovation in energy solutions. BYD (BYDDF), the Chinese EV giant, has seen steady stock appreciation over the years. The company's success is mainly due to its dominance in the Chinese domestic market and its vertical integration, particularly in battery production. BYD produces a wide range of EVs, from passenger cars to commercial vehicles, and has become one of the largest producers of electric buses globally. As a result, its stock has benefited from the strong growth of EV adoption in China and increasing global interest in Chinese EV technology and manufacturing.

NIO (NIO), XPeng (XPEV), and Li Auto (LI) are notable Chinese startups that have seen rapid stock price fluctuations, often influenced by investor sentiment, quarterly delivery reports, and policy changes within China. These companies have focused on producing premium EVs and have captured the attention of investors due to their ambitions to challenge traditional automakers. NIO, for example, has gained attention for its autonomous driving capabilities and battery-swapping technology. At the same time, XPeng and Li Auto have also attracted significant investment in response to their growing sales and technological innovations. However, these companies are also susceptible to market sentiment and regulatory shifts, which can lead to sharp volatility in their stock prices. Legacy automakers such as General Motors (GM), Ford (F), and Volkswagen (VWAGY) have made significant commitments to the EV transition, leading to stock gains. These companies have announced ambitious plans to electrify their vehicle portfolios, with billions of dollars allocated to EV development and production. However, their stock prices have also been volatile due to execution risks, such as the challenges of transitioning from traditional internal combustion engine (ICE) vehicles to fully electric lineups, competition from newer EV manufacturers, and uncertainties surrounding supply chains and production timelines.

In summary, the EV sector has become a hotbed of investor activity, with a wide range of companies—from established automakers to emerging startups—experiencing stock price volatility due to production growth, market expansion, and investor sentiment. While Tesla and BYD remain leaders in the market, Chinese startups like NIO, XPeng, and Li Auto continue showing potential for rapid growth. At the same time, legacy automakers strive to execute their transition to electric mobility successfully. The performance of EV stocks is affected by multiple factors, including government policies and incentives, which play a pivotal role in shaping the electric vehicle (EV) market by influencing demand and company revenues. Governments worldwide have implemented a variety of subsidies, tax credits, and regulatory mandates to promote the adoption of zero-emission vehicles. These incentives make EVs more affordable for consumers, stimulate automakers to invest in EV production, and provide long-term support to accelerate

the transition to cleaner transportation.

For example, in the United States, federal tax credits have been a significant driver of EV adoption, allowing consumers to save thousands of dollars on the purchase price of eligible vehicles. Similarly, subsidies in Europe and China have encouraged both domestic and international manufacturers to ramp up EV production. Additionally, governments have implemented regulatory mandates requiring automakers to meet specific emissions targets, further incentivizing the shift toward electric mobility. These policies have provided a substantial financial cushion for EV manufacturers and played a key role in driving market growth.

However, policy shifts can also have significant impacts on the market. A notable example is the reduction of subsidies in China in 2022. As the government scaled back financial incentives for EV buyers and manufacturers, the market experienced a price correction in some EV stocks, with companies facing short-term volatility. The reduction in subsidies prompted consumers and manufacturers to reassess pricing and demand dynamics, causing some EV startups and even established players to adjust their strategies. While long-term policies may continue to favor EV growth, such fluctuations highlight the delicate balance between government incentives and market conditions.

5. EV stock price performance

EV stocks have often been subject to speculative trading, with retail investors and institutional players driving rapid price fluctuations. The highly dynamic nature of the EV sector, fueled by investor enthusiasm and growth potential, has made EV stocks an attractive yet volatile asset class. Speculative trading often leads to price surges and sharp corrections as investors react to news, earnings reports, and market sentiment rather than the companies' fundamentals. One of the key factors influencing this volatility is social media hype. Platforms like Reddit, particularly in the case of Tesla and NIO, have played a significant role in amplifying investor interest and driving stock prices to unsustainable levels. The so-called "Reddit-fueled rally" saw a surge in retail investors—often from forums like r/WallStreetBets—driving up valuations through mass coordination and enthusiasm. These movements can result in short-term volatility as social media communities rally behind certain stocks, pushing prices higher quickly before market corrections set in.

The influence of social media and the retail trading boom has also highlighted the growing power of individual investors in influencing stock prices. This trend is often amplified by institutional investors, who, aware of the speculative nature of the market, may either ride the wave of price momentum or attempt to stabilize stock values based on long-term expectations. While speculative trading and social media-driven hype can contribute to short-term gains, they also create volatility that can result in significant swings in the stock prices of EV companies. This has made the EV sector more unpredictable, with companies experiencing rapid valuations based on momentum rather than their actual financial performance or future outlook. For investors, this presents both opportunities and risks, as short-term price movements may not always reflect the underlying growth potential of the companies involved.

Quarterly earnings reports, vehicle delivery numbers, and profitability milestones are key indicators that significantly impact electric vehicle (EV) stock prices. These metrics serve as critical benchmarks for investors to assess a company's performance, growth potential, and ability to meet its targets, making them crucial drivers of stock price fluctuations. For Tesla, stock prices have often surged after the company exceeded delivery expectations or reached important profitability milestones. Tesla's consistently delivering strong quarterly results despite global supply chain disruptions has bolstered investor confidence. As the company continues to ramp up production, particularly with the introduction of new models and expansion into international markets, upbeat earnings reports and delivery numbers often serve as catalysts for price appreciation. When Tesla surpasses delivery forecasts or showcases robust financial growth, the market rewards the stock with significant price increases.

On the other hand, companies like Rivian (RIVN) and Lucid (LCID) have faced challenges that have negatively impacted their stock prices, mainly due to production bottlenecks. Rivian, for example, has struggled with scaling its manufacturing processes to meet demand, leading to delays in vehicle deliveries and concerns over its ability to achieve profitability in the near term. Similarly, Lucid has faced production hurdles and issues with meeting its ambitious delivery goals, which have resulted in lower-than-expected earnings reports and investor disappointment. As a result, both Rivian and Lucid have seen significant stock price volatility and price corrections as investors react to the challenges in meeting production targets and concerns about long-term viability. In summary, quarterly earnings, vehicle deliveries, and profitability are some of the most impactful factors driving the stock prices of EV companies. Companies that consistently outperform in these areas, like Tesla, tend to see their stock prices rise. At the same time, those who struggle with production issues, like Rivian and Lucid, may experience declines or volatility in stock valuations. As the EV industry matures, meeting production targets and achieving profitability will remain essential to sustaining investor confidence and long-term stock performance. Technological advancements and innovation are critical drivers of value in the electric vehicle (EV) sector, directly impacting stock valuations. Breakthroughs in battery technology, autonomous driving, and charging infrastructure can provide a significant competitive edge for companies, enhancing their growth prospects and attracting investor interest.

Battery technology plays a central role in the EV market, as improvements in energy density, charging speed, and cost

reduction are crucial for increasing vehicle range and making EVs more affordable. Companies that lead the way in developing next-generation batteries, such as solid-state or lithium iron phosphate (LFP) batteries, are well-positioned to benefit from increased demand. These advancements can positively affect stock valuations by signalling to investors that a company is likely to maintain a technological advantage, reduce costs, and meet the market's evolving needs.

Autonomous driving is another area where innovation can significantly influence the stock performance of EV companies. Companies like Tesla and Waymo (a subsidiary of Alphabet) have made significant strides in developing autonomous driving technology. The successful rollout of fully autonomous vehicles could revolutionize the automotive industry, leading to higher stock prices for companies that lead in this space. Moreover, the ability to offer driver assistance features, such as Tesla's Autopilot, not only enhances the appeal of the vehicles but also improves the long-term outlook for these companies. Charging infrastructure is equally critical for the widespread adoption of EVs. As companies expand their charging networks or develop innovative solutions like battery swapping or ultra-fast charging stations, one of the significant barriers to EV adoption—range anxiety- can be reduced. Companies that invest in and enhance charging infrastructure can significantly increase their customer base and, in turn, their stock valuations.

Companies that invest strongly in research and development (R&D) to drive innovation in these areas tend to attract long-term investors. This is because investors value firms committed to pushing the technological envelope and securing a competitive advantage in an evolving industry. R&D-focused companies are often perceived as having more significant growth potential, which can lead to higher stock prices over time. For instance, Tesla has consistently garnered investor interest due to its continuous innovation in battery technology, autonomous driving, and charging infrastructure.

In summary, technological breakthroughs in battery technology, autonomous driving, and charging infrastructure directly impact EV stock prices. Companies that demonstrate a commitment to innovation through substantial R&D investments are better positioned for long-term growth, attracting investors and leading to higher stock valuations. As the EV market evolves, these innovations will remain central to shaping the industry's future (Liu, Liu, Zhang, & Xie, 2022).

Interest rate hikes, inflation, and global supply chain disruptions have all played a significant role in EV stock corrections, creating additional market volatility. When interest rates rise, borrowing costs for consumers and companies increase, dampening consumer spending and reducing the demand for electric vehicles. Higher borrowing costs can also increase expenses for automakers looking to finance new projects or expand production capacity, negatively impacting investor sentiment and leading to stock price declines. Similarly, inflation has eroded purchasing power and raised operating costs across various sectors, including automotive manufacturing. As the cost of materials, labour, and logistics rises, profit margins for EV companies can be squeezed, especially for those still in the scaling phase or without robust cost control mechanisms. Inflation can also lead to concerns about future profitability as companies are forced to balance higher input costs with the need to keep prices competitive. Global supply chain disruptions—exacerbated by events like the COVID-19 pandemic, geopolitical tensions, and semiconductor shortages—have further strained production timelines and delivery capabilities. These disruptions have delayed vehicle production and delivery schedules, which has led to investor uncertainty. For instance, automakers have had to adjust their manufacturing plans due to shortages of essential components, resulting in lower-than-expected delivery numbers. Such setbacks can negatively affect stock prices as investors react to delays and the potential for missed financial targets. One of the most significant pressures on EV company margins is the rising cost of battery materials, particularly lithium and nickel. These materials are essential for producing the high-performance batteries that power electric vehicles, and their prices have surged due to increased demand driven by the global shift to electric mobility. As the cost of these critical inputs rises, battery prices also increase, leading to higher production costs for EV manufacturers. Companies may struggle to absorb these rising costs without passing them onto consumers, which could impact vehicle affordability and hurt demand. The volatility in the prices of raw materials can also affect investor confidence, as margin compression can be a sign of financial strain. For automakers with tight margins or those still ramping up production, these rising costs can result in lower-than-expected profits, contributing to stock price volatility. In particular, companies that rely heavily on external suppliers for battery production, such as Rivian or Lucid, may find themselves especially vulnerable to these price fluctuations (Shi, Feng, Zhang, Shuai, & Niu, 2023).

In summary, interest rate hikes, inflation, global supply chain disruptions, and rising material costs are key factors that have contributed to EV stock corrections. These external pressures can undermine consumer demand, squeeze profit margins, and create uncertainty for investors, leading to market volatility. As the EV industry expands, navigating these challenges will be crucial for maintaining profitability and stable stock valuations.

6. China’s stock price performance

Despite short-term volatility, the long-term growth prospects for EV stocks remain strong due to several key factors driving the industry’s expansion. EV adoption is projected to continue its upward trajectory as governments worldwide set ambitious goals for electrification. The transition to cleaner, more sustainable transportation is

supported by a mix of environmental regulations, incentives, and the increasing urgency to tackle climate change.

To analyze the financial performance of EV companies and assess the impact, the correlation of various Chinese EV companies is displayed based on financial KPI parameters. These parameters are the price-to-book ratio, total cash per share, return on equity, debt-to-equity, quick ratio, and others. The results are outlined in Figure 1, outlining a strong correlation between 300750.SZ and LI, as well as 300750.SZ and LI.

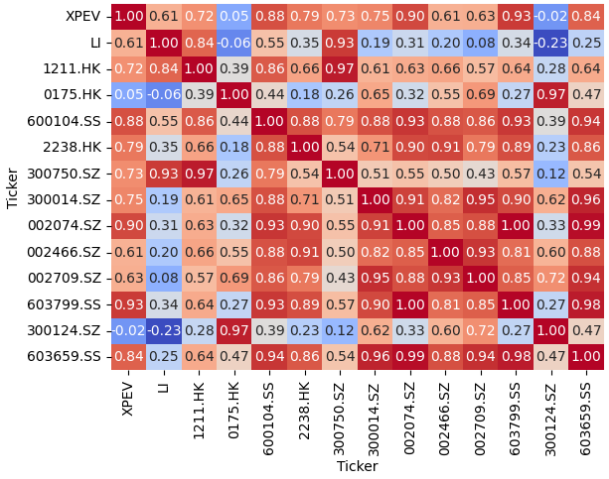

Figure 1: Correlations between the Chinese EV enterprises.

While these corporations show significant correlations, questions arise in terms of how these corporations may be grouped into two to distinguish between strong performers and those facing challenges. The comparison in terms of debt-to-equity and price-to-book ratios is exhibited in Figure 2. Further comparisons are made in Figure **3Figure 4**s 3 and 4, outlining that the main difference arises from those with a high price-to-book ratio with low debt-to-equity and those with a higher debt-to-equity ratio with a price-to-book ratio. The International Energy Agency (IEA) forecasts that EVs will account for more than 50% of global vehicle sales by 2040, driven by consumer demand and regulatory mandates. As countries implement stricter emission standards and incentivize EV purchases, the adoption rate will accelerate, creating a favourable market environment for EV companies. This broad-based growth will benefit established players like Tesla and BYD and emerging brands in the sector.

One of the most significant drivers for the long-term profitability of EV companies is the ongoing reduction in battery costs. Advancements in battery technology, including solid-state and lithium iron phosphate (LFP) batteries, are expected to continue improving energy efficiency, lowering production costs, and increasing vehicle range. As the cost of batteries decreases, the overall price of EVs can become more competitive with traditional gasoline-powered vehicles, leading to broader consumer adoption.

Figure 2: Comparison of debt to equity and price to book for the different companies.

Alongside technological innovations, increased production capacity and more streamlined supply chains will help address current bottlenecks in raw material sourcing and battery production. With a more reliable and cost-efficient supply chain, EV companies can scale up production, leading to better margins and profitability. Vertical integration in battery production, as seen with companies like BYD and Tesla, will further contribute to cost reductions and supply chain resilience.

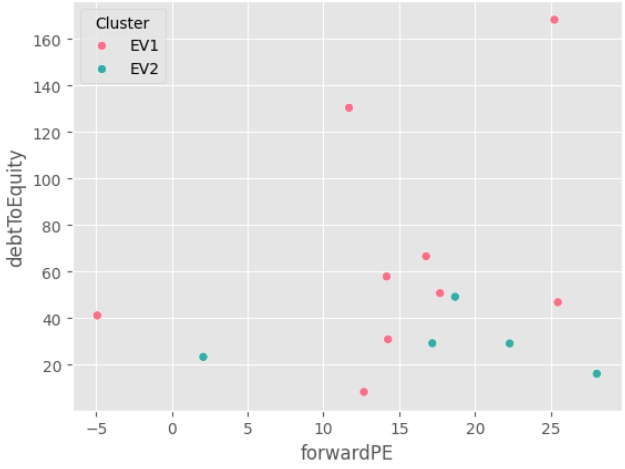

Figure 3: Comparison of the debt to equity and forward PE.

The electric vehicle (EV) market remains highly competitive, with a dynamic mix of established automakers, innovative startups, and tech companies striving to carve out their industry share. This intense competition has created opportunities and challenges, particularly for newer entrants that must contend with high production costs, supply chain complexities, and the need to establish brand credibility. However, market leaders such as Tesla and BYD dominate due to their strong brand recognition, extensive production capabilities, and ongoing technological advancements in battery efficiency, autonomous driving, and energy management. Their ability to scale production efficiently while maintaining strong consumer demand has given them a significant edge over emerging competitors. Meanwhile, weaker players that struggle to scale operations or achieve

profitability may face increasing pressure, potentially leading to industry consolidation through mergers, acquisitions, or partnerships with larger, more financially stable companies. Such consolidation could ultimately streamline the market, fostering a more sustainable growth trajectory as dominant players absorb weaker competitors, optimize resources, and expand their influence. Investors and industry analysts are keeping a close eye on these developments, as mergers and acquisitions within the EV sector can lead to significant fluctuations in stock valuations, impacting market sentiment and investment strategies. Additionally, government policies, environmental regulations, and advancements in battery technology will continue to shape the competitive landscape, influencing which companies thrive and which struggle to survive in the fast-evolving EV market. In conclusion, while the EV market faces short-term challenges and volatility, the long-term outlook for EV stocks remains positive. The global EV market's continued growth, battery technology and supply chain improvements, and ongoing competition and consolidation will provide a foundation for substantial industry expansion and profitability. Investors focusing on the sector's long-term fundamentals may find significant opportunities as the transition to electric mobility unfolds.

The stock price performance of EV companies has been marked by extreme volatility, driven by a mix of fundamental and speculative factors. While challenges remain, including economic headwinds and supply chain issues, the long-term outlook for the EV sector remains promising. Investors should consider both short-term risks and long-term growth potential when evaluating EV stocks.

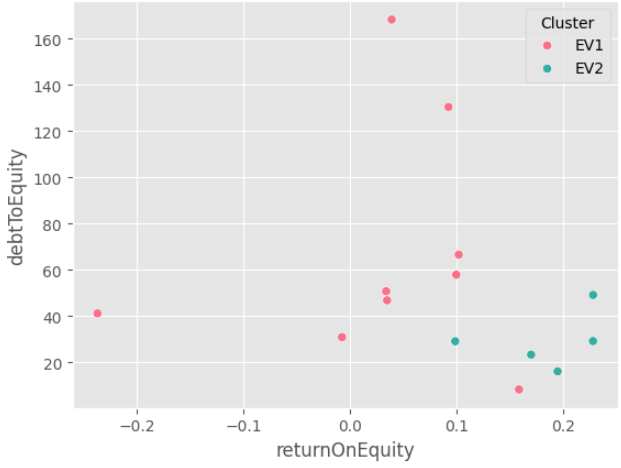

Figure 4: Comparison of debt to equity and return on equity.

7. Conclusion

China's electric vehicle (EV) industry has firmly established itself as a global frontrunner, underpinned by robust governmental policy support, rapid technological innovation, and evolving consumer preferences favoring environmentally sustainable transportation. This study offers a comprehensive examination of the financial performance and equity market trends of prominent Chinese EV manufacturers, including BYD, NIO, Li Auto, XPeng, and other emerging players in the sector. The analysis focuses on key financial metrics such as revenue growth trajectories, gross and net profit margins, research and development (R&D) expenditures, and debt-to-equity ratios. These indicators collectively provide a nuanced understanding of the sector's economic resilience and operational efficiency. The stock market performance of Chinese EV companies has exhibited significant volatility, shaped by a confluence of macroeconomic developments, regulatory shifts, and intensifying industry competition. Government policies, including subsidies, tax incentives, and the establishment of favorable regulatory frameworks, have played a pivotal role in influencing investor sentiment and facilitating capital inflows. However, exogenous challenges, such as global supply chain disruptions, shortages of critical raw materials like lithium and cobalt, and geopolitical tensions, particularly those arising from U.S.-China trade relations, have introduced heightened uncertainty, contributing to fluctuations in market valuations. Despite these headwinds, several Chinese EV firms have shown notable resilience, outperforming legacy automakers in terms of market capitalization and investor interest. Strategic international expansion—especially into Europe, Latin America, and Southeast Asia—has further bolstered financial performance and enhanced global brand recognition. Nevertheless, the domestic market faces potential saturation, heightened competitive pressures from both domestic incumbents and foreign entrants, and growing skepticism regarding the sustainability of current valuation levels.

Moreover, the rapid emergence of new energy vehicle (NEV) startups, coupled with escalating investments in next-generation technologies such as autonomous driving systems, solid-state batteries, and vehicle-to-grid (V2G) capabilities, signals a dynamic and increasingly complex competitive environment. The financial outlook for Chinese EV stocks is also tightly correlated with broader global market dynamics, including Federal Reserve monetary policy, inflation expectations, and the general appetite for high-growth, innovation-driven equities. In conclusion, while China's EV industry offers substantial investment potential, it is accompanied by considerable risks related to regulatory unpredictability, substantial capital expenditure requirements, and rapid technological evolution. The future performance of the sector will largely depend on sustained innovation, strategic cost management, successful international market penetration, and the ability to scale production efficiently in a highly competitive and ever-changing global automotive landscape.

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Araştırma Makalesi ● Research Article

Labor Market and Youth Employment: Statistical Analysis and International Comparison for Azerbaijan

İşgücü Piyasası ve Genç İstihdamı: Azerbaycan İçin İstatistik Analiz ve Uluslararası Karşılaştırma

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ANAHTAR KELİMELER

İşgücü Piyasası
Genç İstihdamı
Düzgün İş
İşsizlik
Eğitim
Azerbaycan
Uluslararası Karşılaştırma

ÖZ

Bu makalenin konusu günümüzün en önemli sorunlarından biri olan genç istihdamı sorunudur. Bu bağlamda çalışmada, ekonomik olarak aktif gençlerin işgücü piyasasındaki istihdam düzeyleri yaş gruplarına göre incelenmiştir. Bu amaçla, Azerbaycan Cumhuriyeti Devlet İstatistik Komitesi'nin istatistik bültenleri, Çalışma ve Sosyal Güvenlik Bakanlığı'na bağlı Devlet İstihdam Ajansı'nın verileri, Dünya Bankası, ILO ve diğer kaynakların raporları kullanılarak uluslararası karşılaştırmalar yapılmıştır. Yapılan karşılaştırmalar Azerbaycan'da genç işsizlik oranının küresel göstergelere yakın olduğunu göstermektedir. Pandemi döneminde zirveye ulaşmasına rağmen, bu gösterge sonraki yıllarda hem dünyada hem de Azerbaycan'da önemli ölçüde iyileşmiştir. İşgücü piyasasında genç istihdamının etkili bir şekilde organize edilebilmesi için, gençlerin doğru uzmanlık alanını seçmeleri, yeterli eğitim almaları ve eğitim düzeylerine, niteliklerine ve becerilerine uygun işlerde çalışmaları önemlidir. Mevcut koşullarda, mümkün olduğunca çok gencin mesleki ve uzmanlık eğitimlerine katılımını sağlamak, eğitimlerinin kalitesini artırmak ve girişimcilik faaliyetlerini desteklemek için çalışmalar sürdürülmelidir.

KEYWORDS

Labor Market
Youth Employment
Decent Job
Unemployment
Education
Azerbaijan
International Comparison

ABSTRACT

The article is devoted to the problems of youth employment, one of the most pressing issues of our time. Here, the employment levels of economically active youth in the labor market by age groups were studied. For this, statistical bulletins of the State Statistical Committee of the Republic of Azerbaijan, data from the State Employment Agency under the Ministry of Labor and Social Protection of the Population, as well as reports of the World Bank, ILO and other sources were used to conduct international comparisons. The comparisons show that the unemployment level of youth in Azerbaijan is close to global indicators. Despite reaching its peak during the pandemic, this indicator has significantly improved in subsequent years both in the world and in Azerbaijan. For the effective organization of youth employment in the labor market, it is important that they choose the right specialty, have adequate education and jobs that are adequate to their level of education, qualifications, and skills. In the current circumstances, work should be continued to involve as many young people as possible in vocational and specialized training, improve the quality of their education, and support entrepreneurial activity.

1. Introduction

The balance in the labor market and the improvement of employment opportunities are always in the focus of attention of both the government and the public. Many projects are being implemented in this direction in Azerbaijan, but in the current conditions there is a need for more targeted and large-scale measures. In our research, we study the labor market not only in the context of general indicators, but also from the perspective of ensuring effective employment, approaching it from a qualitative perspective. Every person has the right to a decent standard of living, and in this regard, one of the main issues is the formation of the necessary conditions for the realization of

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their labor potential and the adequate satisfaction of their material needs. For the quality of life of young people, it is important to create meaningful and sustainable employment opportunities, that is, to have decent jobs for them.

In general, the issue of employment, especially ensuring effective employment of young people, is considered one of the most important and urgent problems in the world. Thus, there are millions of unemployed people in the world, and most of them live below the poverty line. A particularly concerning thing is that there is a large number of young people among the unemployed all over the world. According to World Bank reports, there are 64.9 million unemployed youth in the world in 2023 and two-thirds of unemployed youth are women (ILO, 2023). Since it is young people who suffer the most from the problem of unemployment all over the world, special attention is paid to issues related to youth employment in the works of both local and foreign researchers.

Young people face great difficulties when entering the labor market for the first time. Not only young people without a profession and qualification, but even young people with higher education often cannot find a worthy place in the labor market, and in many cases they are forced to work in unpromising jobs that do not require qualifications. Studies show that unemployment among young people aged 15-24 in Azerbaijan is twice as high as among other age groups (ILO, 2016; SSCRA, 2024).

Since the issues mentioned are also relevant for the reality of Azerbaijan, assessing the situation of young people in the labor market is the main goal of this study. For this, statistical bulletins of the State Statistical Committee of the Republic of Azerbaijan, data from the State Employment Agency under the Ministry of Labor and Social Protection of the Population, survey materials, as well as reports of the World Bank, ILO and other sources were used to conduct international comparisons. The comparisons show that the employment level of youth in Azerbaijan is close to global indicators (13%). If one of the main reasons for unemployment is the lack of decent jobs, another reason is related to the inadequacy of education.

2. Literature Review

As we have noted, the employment problems of the population, especially of young people, remain one of the most urgent and important issues of our time. Economist J.B. Guliyev (2011: p.208) quite rightly notes that it is important for every person to work for himself and his family to live well, to have a suitable workplace for work, as well as to have a profession and specialty that meets the requirements of the workplace, otherwise many young people would have chosen crime as their profession. Despite positive changes, as noted in the "Country Programme of the Republic of Azerbaijan on Decent Work for 2016-2020", developed in cooperation between the government of Azerbaijan and the International Labor Organization (ILO), the national labor market is still characterized by structural deficiencies, including a mismatch between demand and supply, and a higher unemployment rate among young people aged 15-24 (twice as high as among those aged 25 and older) (ILO, 2016). According to Prof. G.A. Azizova (2005: p.99), "in order to achieve the reconciliation of labor supply and demand in the labor market, it is important to stimulate the process of creating new jobs, protect and modernize existing ones." The main goal here is to achieve effective employment of young people.

We completely agree with these ideas that in order to ensure effective employment of young people, first of all, there should be decent jobs. According to Prof. T.H. Huseynov (2015: p.114), "a decent job means that the salary (or income) received by the employee should ensure a normal, at least minimum, standard of living for him and his family". We also fully agree with the scientist's opinion that if earlier it was about preventing mass unemployment, now it is about creating decent jobs, mainly in the regions. Because due to the lack of jobs in our regions, a large part of the population migrates to cities. Thus, the number of urban population is steadily increasing, exceeding the number of rural population. According to statistics, in 2024, the share of urban population in Azerbaijan reached 54.4 percent, while the rural population is 45.6 percent. (SSCRA: Azerbaijan-facts and figures 2025). Our regions cannot keep up with economic development, which does not allow improving social welfare. G.Y. Şeren and J.R. Aliyeva (2024) very rightly note that employment plays a key role in achieving social welfare, and full and productive employment should provide decent working conditions. When talking about the employment problem, one of the important issues is the availability of a decent income for everyone. R.Ş. Muradov (2006: p.190) in his research, along with the importance of opening new jobs in improving employment, also emphasizes the importance of improving the mechanism of labor remuneration.

In order to improve the economic situation and living conditions of the population, providing every person with the ability to work with satisfactory work is one of the most important issues for our country, and increasing the employment level of the population is always in the spotlight. In this direction, various state programs are being implemented in accordance with internationally proven practices, especially since 2005, positive results have been achieved. During the implementation of the 1st Employment Strategy covering 2006-2015, the unemployment rate decreased from 7.3 percent to 5 percent, the poverty rate decreased from 29.3 percent to 4.9 percent, the income of the population increased by 5.2 times, the minimum wage by 3.5 times, and the average monthly nominal wage by 3.8 times (E-Kanun, 2018). The 2nd Employment Strategy covering 2019-2030, approved by Order No. 602 of the President of the Republic of Azerbaijan dated October 30, 2018, is also very important in terms of improving the employment situation of young people.

It should be noted that one of the most important active

employment measures is the implementation of self-employment programs. In connection with the implementation of the program, training of participants has been started since 2016. Efforts are being made to increase the number of those involved in self-employment every year, vocational training is first conducted for them, and citizens are provided with the necessary assets to set up their own business on business projects that are considered successful. The increase in the number of those involved in self-employment partially increases the employment level, but at the same time affects the number of people receiving unemployment benefits. According to J.R. Aliyeva (2022), "Through self-employment programs, the integration of young people into the labor market is facilitated and conditions are created for the formation of sustainable sources of income". As part of the implemented strategies and state programs, extensive attention is also paid to strengthening the social protection of the unemployed and job seekers.

3. A Brief Look at The Demographic Indicators of Youth ın Azerbaijan

First of all, it should be noted that, as in many countries, there is a decrease in the number of young people aged 14-29 in Azerbaijan. Table 1 illustrates that the number of young people aged 14-29 in Azerbaijan has decreased year by year since 2010 and in 2023 it will constitute only 22.7 percent of the country's population. In 2023, the share of young people in the country's population decreased by 8.7 percentage points compared to 2010, with a similar decrease of 9.4 percentage points in urban areas and 8.0 percentage points in rural areas. As for gender composition, in each of the years under review, the number of men in the 14-29 age group is higher than that of women, and this difference has gradually increased, that is, the number of women has decreased more than that of men, especially serious differences are observed in the 14-24 age group. In 2010, 49.8 percent of young people aged 14-29 were women, while in 2023 this figure will be 48.3 percent.The comparisons show that the employment level of youth in Azerbaijan is close to global indicators (13%). If one of the main reasons for unemployment is the lack of decent jobs, another reason is related to the inadequacy of education.

The decreasing trend also applies to children aged 10-14. According to the research of prof. Ş.M.Muradov (2021: p.364), the total fertility rate, which is considered the most important and general indicator of population reproduction, decreased from 2.9 to 1.8 in 1991-2019. Thus, both the birth rate and natural growth rate have shown a decrease from 1992 to 2002, a gradual increase from 2002 to 2012, and a decrease again in recent years. The mortality rate has been higher in recent years compared to the previous period.

Despite the fact that in 2020, which brought both victories and sad events to the history of our people, the birth rate was lower (30% lower) – 126,571 people, the death rate was 41 percent higher than in 2010, that is, 75,647 people.

Table 1. Dynamics of the Number of Young People Aged 14-29 in Azerbaijan (*thousand persons*) and Structure (*in%*)

	2010	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Number of young people aged 14-29, total	**2825,8**	**2574,7**	**2519,3**	**2445,3**	**2368,2**	**2328,5**	**2302,2**	**2295,1**
Share of young people in the total population, %	*31,4*	*26,3*	*25,5*	*24,5*	*23,7*	*23,2*	*22,9*	*22,7*
Men	1418,5	1325,4	1302,4	1270,2	1200,0	1186,7	1181,6	1186,4
Women	1407,3	1249,3	1216,9	1175,1	1168,2	1141,8	1120,6	1108,7
% in urban areas	*31,3*	*25,2*	*24,4*	*23,4*	*22,7*	*22,3*	*22,0*	*21,9*
% in rural areas	*31,6*	*27,4*	*26,7*	*25,8*	*25,0*	*24,4*	*24,0*	*23,6*

Source: Azerbaijan Youth 2024: pp. 16-27(SSCRA 2024).

One of the main reasons for the high death rate in 2020 is the martyrdom of young sons of the homeland in the Second Karabakh War (up to 3 thousand military martyrs, more than 100 civilians). All this ultimately leads to a decrease in the number of young generations in the composition of labor resources, as well as labor potential. Therefore, the issue of more efficient use of existing potential, that is, the young workforce, is becoming more prominent.

4. Assessing the Level of Youth Employment in the Labor Market

From our research on the labor market, it is known that there was an increase in the number of employed youth from 2012 to 2019, and a decreasing trend is observed in subsequent years (Gurbanova, 2022, 2024).

Table 2 shows that in 2023, compared to 2021, there was an increase in both the economically active population and the total number of employed population, but the number of youth in their composition decreased. While the share of youth in the employed population was 25.5 percent in 2018, this figure decreased by 1.4 percentage points in 2023 to 24.1 percent. If we look at unemployment statistics, we see that in 2018, 48.8 percent of the total unemployed were youth. In subsequent years, the share of young unemployed people gradually decreased, reaching 44.9 percent in 2022 and 43 percent in 2023.

Table 2. Number (thousand per.) and Structure (%) of Economically Active Youth (15-29 years old)

	2018	2020	2021	2022	2023
Total number of economically active population	**5133,1**	**5252,5**	**5141,6**	**5194,4**	**5249,7**
Number of economically active youth	1368,2	1378,0	1351,9	1324,7	1317,8
Share in the composition of the economically active *population, %*	*26,65*	*26,2*	*26,3*	*25,5*	*25,1*
Employed population, total	**4879,3**	**4876,6**	**4831,1**	**4901,1**	**4963,3**
Number of employed youth	1244,4	1223,9	1212,5	1193,0	1194,6
Share in the composition of the employed population, %	*25,5*	*25,1*	*25,1*	*24,3*	*24,1*
Unemployed population, total	**253,8**	**368,7**	**310,5**	**293,3**	**286,4**
Number of unemployed youth	123,8	154,1	139,4	131,7	123,2
Share in the composition of the unemployed population, %	*48,8*	*41,8*	*44,9*	*44,9*	*43,0*

Source: *State Statistical Committee of the Republic of Azerbaijan. Compiled by the author based on data from Labor Market Bulletins:* 2019, p. 118; 2021, p. 133; 2022, p.131; 2023, 2024 p. 131. (SSCRA, 2019-2024).

When examining the unemployment rate of economically active youth, we see that the highest unemployment rate in recent years was in 2020, when it was 11.2 percent in the 15-29 age group (15.4 percent in the 15-19 age group), and then gradually decreased and reached 9.3 percent in 2023 (Table 3). The situation is different by age group. Thus, while the unemployment rate of youth in the 25-29 age group decreased to 6 percent in 2023, this indicator is 13.1 percent for the 15-19 and 20-24 age groups, which is 2 times higher than for the 25-29 age group. It is known that most workplaces require experience when hiring young people. Most young people in the 25-29 age group already have some qualifications or work experience. Therefore, it is easier for them to get a job than young people in the 15-24 age group.

Table 3. Number of Economically Active Youth by Age Group (*thousand per.*) and Unemployment Rate

	2018	2020	2021	2022	2023
Economically active youth, total	**1368,2**	**1378,0**	**1351,9**	**1324,7**	**1317,8**
Including by age groups					
Number of young people aged 15-19	**106,2**	**107,6**	**105,3**	**105,1**	**105,8**
the share of unemployed people among them, %	*14,2*	*15,4*	*14,3*	*13,6*	*13,1*
Number of young people aged 20-24	**507,1**	**500,9**	**493,9**	**502,9**	**509,2**
the share of unemployed people among them, %	*12,4*	*15,0*	*14,6*	*13,5*	*13,1*
Number of young people aged 25-29	**754,9**	**769,5**	**752,7**	**716,7**	**702,8**
the share of unemployed people among them, %	*6,0*	*8,1*	*6,9*	*6,9*	*6,0*
Total unemployment rate of young people aged 15-29, %	***9,0***	***11,2***	***10,3***	***9,9***	*9,3*

Source: *State Statistical Committee of the Republic of Azerbaijan. Compiled by the author based on data from Labor Market Bulletins: 2019, p. 118; 2021, p. 133; 2022, p.131; 2023, 2024 p. 131. (SSCRA, 2019-2024).*

Note: *Since sample statistical surveys by age groups and education levels of the population are conducted separately for each year, the results of the population census conducted in 2019 were not taken into account in the indicators until 2022.*

The higher unemployment rate in the 15-19 age group can also be attributed to the fact that some of the young people with higher education cannot find suitable jobs and therefore have to work in jobs that do not require qualifications. On the other hand, a large number of full-time students in higher education also work, which means that a certain part of the vacancies on the labor market are occupied by them. In this case, some of the young people aged 15-19 who are looking for work but do not have vocational education are deprived of these positions, even though they could have held them, and are left out of both employment and education. It can be assumed that it is more advantageous for some employers to hire higher education students than young people without education, because when these students graduate from university and receive a diploma, employers will have both highly educated and experienced employees. In our opinion, this can explain the inability of economically active young people aged 15-19 to find work. Of course, young people in this age range have not completed higher education, most of them do not have vocational training, but they are forced to start working early. Therefore, it is important to involve these young people in vocational training so that they can enter the labor market more easily.

For the effective organization of youth employment, the issue of ensuring the compliance of quantitative and qualitative indicators of specialist training with the requirements of the labor market should always be in the

spotlight. Table 4. reflects the quantitative indicators of personnel training in higher, secondary specialized and vocational education institutions. When we look at the dynamics of general personnel training in our republic, we see that although there is no stable dynamics in the number of graduates of vocational and secondary specialized education institutions, the number of graduates of higher education institutions (except for 2018) is increasing year by year. In the total number of trained specialists, with the exception of 2017 and 2018, positive dynamics are observed in the period under review. Thus, the number of graduates of these educational institutions exceeded 82 thousand in 2023, 60 percent of whom have higher education.

Table 4. Number of graduates of vocational, secondary specialized and higher education institutions (*persons*)

	2010	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Total	**58641**	**65359**	**69179**	**68419**	**64973**	**65503**	**69152**	**73806**	**74997**	**82033**
Number of graduates of vocational education institutions	13011	15222	15135	14614	15496	15516	14304	14233	13865	14657
specific weight,%	*22,2*	*23,3*	*21,9*	*21,2*	*23,8*	*23,7*	*20,7*	*19,3*	*18,5*	*17,9*
Number of graduates of secondary specialized education institutions	14559	16432	17093	16299	12361	12425	14024	16164	15093	18955
specific weight,%	*24,8*	*25,1*	*24,7*	*23,8*	*1,.0*	*19,0*	*20,3*	*21,9*	*20,1*	*23,1*
Number of graduates of bachelor's level of higher education	31071	33705	36951	37506	37116	37562	40824	43409	46039	48421
specific weight,%	*53,0*	*51,6*	*53,4*	*54,8*	*57,1*	*57,3*	*59,0*	*58,8*	*61,4*	*59,2*

Source: *Education, science and culture in Azerbaijan. Statistical bulletins 2015, 2017, 2019, 2021, 2024,p. 41, 42, 123, 138,162* prepared by the author based on data (SSCRA, 2015-2024.

Thus, the number of graduates of higher education has been increasing steadily since 2018, according to these indicators, more than 200 thousand people with higher education should have entered the labor market in the last five years. However, according to the indicators in table 5., in 2023, the number of people with higher education among employed youth increased by only 2.2 thousand people compared to 2018. This suggests that the employment rate of young people with higher education is very low.

When looking at the educational structure of employed youth, it becomes clear that the share of those with vocational, secondary and higher education among them will increase by 3.5 percentage points in 2023 compared to 2018, reaching 38.8 percent. Thus, during that period, the share of those with higher education increased by 1.1 percentage points, that of those with secondary specialized education by 1.7 percentage points, and that of those with vocational education by 0.7 percentage points.

Table 5. Dynamics of Employed Youth by Educational Level (*thousand person*)

	2015	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Employed young people, total	**1177,5**	**1219,4**	**1237,1**	**1244,4**	**1250,5**	**1223,9**	**1212,5**	**1193,0**	**1194,6**
Their share in the employed population, %	***25,2***	***25,6***	***25,6***	***25,5***	***25,3***	***25,1***	***25,1***	***24,3***	***24,1***
Including									
with higher education	237,2	247,2	250,7	255,8	257,6	254,0	260,6	246,8	258,0
specific weight,%	*20,1*	*20,3*	*20,3*	*20,5*	*20,6*	*20,7*	*21,5*	*20,7*	*21,6*
with secondary specialized education	129,3	133,6	136,0	136,1	137,7	134,7	139,8	136,1	151,6
specific weight,%	*10,98*	*10,95*	*10,99*	*10,94*	*11,0*	*11,0*	*11,5*	*11,4*	*12,7*
with vocational education	*47,0*	*45,8*	*47,4*	*47,5*	*48,7*	*47,5*	*49,3*	*47,5*	*54,0*
specific weight,%	*4,0*	*3,75*	*3,8*	*3,8*	*3,9*	*3,9*	*4,1*	*4,0*	*4,5*
Number of employed young people with vocational, secondary specialized and higher education, total	**413,5**	**426,6**	**434,1**	**439,4**	**444,0**	**436,2**	**449,7**	**430,4**	**463,6**
specific weight,%	***35,1***	***34,98***	***35,1***	***35,3***	***35,5***	***35,6***	***37,1***	***36,1***	***38,8***

Source: *Labor market. Statistical bulletin 2017, 2019, 2021,2024. p. 140 prepared by the author based on data (SSCRA, 2015-2024).*

Studies show that the share of those with vocational and specialized education in the employed population was 33.2 percent in 2018, 33.5 percent in 2019, 33.6 percent in 2020-2021, 33.7 percent in 2022, and 34 percent in 2023. In other words, there was an increase of 0.8 percentage points in

2023 compared to 2018 (Gurbanova, 2024).

Based on the data in Table 4, the total number of specialists graduating from higher, vocational and specialized education institutions in 2018-2023 is 430.5 thousand people, including 253.4 thousand people who graduated from higher education, 89.0 thousand people who graduated from secondary specialized education, and 88.1 thousand people who graduated from vocational education. However, all these numbers did not have a significant impact on the indicators in Table 5 and the educational structure of the employed population in general due to the poor employment situation of young people.

Research shows that it is typical for most countries for young people, especially for the first time, to have difficulty entering the labor market. Young people with low levels of education are recruited to temporary jobs in the labor market, and sometimes they are forced out of the labor market by highly educated people who, unable to find suitable jobs, are forced to work in positions below their educational level and skills (Khokhlova and Khokhlov 2017). The large number of people working in fields and positions that do not correspond to their qualifications and professions really hinders the correct forecasting of occupations in the labor market and the efficient distribution of planned places by specialties. This does not allow to eliminate the mismatch between education and vacancy requirements in the labor market.

From surveys conducted and regular examination of job advertisements posted online by numerous employment sites, it can be concluded that in more than 90% of cases, employers are looking for experienced workers, mainly setting an age limit (many advertisements with low requirements relate to network businesses without a stable salary), but they are not particularly interested in where these young people will gain experience and their future (Gurbanova, 2022). Until effective cooperation between the vocational education system and employers is formed, there is a need to regulate this situation by law and implement incentive measures to encourage entrepreneurs to employ young personnel.

Employment can be improved by expanding the following programs implemented by the State Employment Agency, such as, employment strategy, regional development programs, self-employment program. Besides that the projects organized jointly with the Youth Fund, the “Create Your Business Marathon”, “Wage Subsidy for Employers” and “Professional Youth” projects, then the “Employment Support Project”, “Creation of Inclusive and Decent Jobs for Socially Vulnerable Groups of the Population”, “Development of Entrepreneurship and Self-Employment in Villages”, “Mobile Coffee Houses” and other such new social projects are essentially well-thought-out measures. Special attention is paid to young people in the programs, but all of these need to cover more young people. Better results can be achieved by increasing their frequency and scope.

5. Brief Overview of Surveys on Youth Employment

5.1. Results of the Survey on Employment of Vocational and Secondary Education Graduates

In order to assess the employment of graduates of secondary education and vocational education institutions, a sample statistical survey was conducted in 2021 to determine the number of economically active population and potential labor force not included in the labor force among young people who graduated from these educational institutions in 2016-2020. Of these graduates, 109.5 thousand are economically active, including 92.0 thousand (84%) of them employed, and 17.5 thousand, i.e. 16%, are unemployed. The number of graduates not included in the economically active population is 26.7 thousand, of which 15.5 thousand are considered potential labor force.

Thus, in 2016-2020, the economic activity level of graduates of vocational and secondary specialized education institutions was calculated to be 80.4 percent, and the employment level was 67.5 percent. Of the employed 47.7 percent were secondary specialized graduates, and 52.3 percent were vocational graduates (SSCRA, 2023). These analyses, that is, the distribution of graduates by employment and unemployment levels, give reason to say that it is easier to find a job with vocational education than with secondary specialized education. Also, there are more opportunities for entrepreneurial activity among people with vocational education than others. It is also realistic for them to benefit from the self-employment program (Gurbanova, 2025).

5.2. Results of the Survey of Higher Education Graduates

In order to study the impact of the admission score for the bachelor's level of higher education on career, a survey was conducted by the Career Center branch of the State Employment Agency (SEA) and the Labor Market Bulletin No. 2 was prepared (SEA, 2024c). According to the data of the State Employment Agency of the Republic of Azerbaijan, the number of people who started their education at the bachelor's level in 2003-2014 was 355,093 people. Of these, 1,670 people were involved in the survey, of which the data of 1,583 people were considered suitable for analysis. 58 percent of those who participated in the survey were bachelor's degree holders, 37 percent were master's degree holders, and 5 percent were doctoral degree holders. When classified according to the positions they held, they included specialist staff - 65.1 percent; administrative staff - 16.9 percent; support staff - 15.2 percent; senior management - 2.8 percent.

Only 65 percent of respondents chose their specialty on their own, while 41 percent of them said they would not choose another specialty even if they had scored higher, while 46 percent said the opposite, and 13 percent were unsure (State Employment Agency, 2024c). Our research, observations, and pedagogical experience suggest that most young people currently graduating from high school choose a group of specialties rather than a specific specialty.

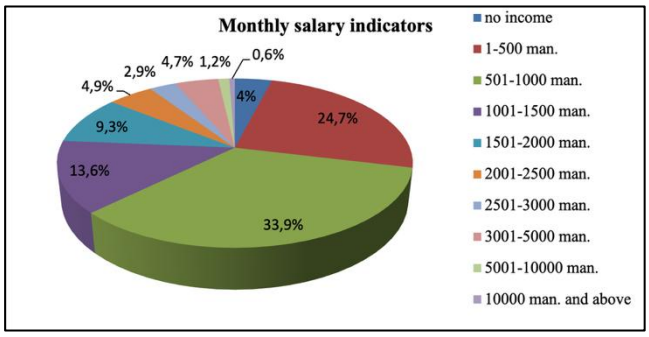
We noted that one of the problems causing mismatch in the labor market is the large number of people working in jobs that do not correspond to their specialization. The survey once again proves this, as only 51 percent of respondents answered that the job they are working in coincides with the specialization they studied, while 47 percent of them responded that their current job is in line with the career they planned during their undergraduate studies. 88.7 percent of respondents answered that the university and 91.09 percent answered that the specialization plays an important role in the success of a career.

The assessment of the impact of education level on wages showed that the average monthly income of those who completed a master's degree was 65 percent higher than that of those who completed a bachelor's degree and 13 percent higher than that of those who completed a doctorate. The average monthly income of those who completed a doctorate was 46 percent higher than that of those who completed a bachelor's degree and 11 percent lower than that of those who completed a master's degree. It was also determined that where they received their education had a certain impact on income, as the average monthly income of those who continued their master's education abroad was 45 percent higher than the average monthly income of those who continued their master's education in Azerbaijan.

As for the impact of the admission score on wages, it was found that the average salary of those who scored between 0-300 was 17 percent lower than that of those who scored 301-450, and 42 percent lower than that of those who scored 451-600. During the evaluation of the surveys, it was also found that the monthly income of those who participated in internship programs was 11 percent higher than that of others.

Monthly salary indicators are as follows: no income - 4%; 1-500 man. - 24.7%; 501-1000 man. - 33.9%; 1001-1500 man. - 13.6%; 1501-2000 man. - 9.3%; 2001-2500 man. - 4.9%; 2501-3000 manats - 2.9%; 3001-5000 manats - 4.7%; 5001-10000 manats - 1.2%; 10000 manats and above - 0.6%. 59.1 percent of respondents stated that their income did not correspond to market values, 37.3 percent said that it corresponded to them, and 3.6 percent even had income above market values.

What is noteworthy here is that more than 59 percent of respondents believe that their salary is lower than market values. This indicates that their income does not fully meet their material needs, in other words, their sense of satisfaction with their job is low.



Source: *Labor Market Bulletin No. 2 (SEA,2024c).*

Graph 1. Monthly Salary Hndicators of Higher Education Graduates

If we were to assess the effective employment level of graduates according to the survey results, we can use the following indicators:

- the number of people working in their profession and specialty;

- income levels (by education level or by specialty);

- job satisfaction index.

Based on the analysis of the surveys we reviewed and conducted, we can note that, first of all, the employment level of graduates is low: about 60 percent for higher education graduates, 67.5 percent for vocational and secondary vocational education graduates. Only 51 percent of employed higher education graduates work in jobs corresponding to their specialization. 59 percent of employed people think that their average monthly income is lower than market values. 24.1 percent of respondents reported complete satisfaction with their career, 33.5 percent reported satisfaction up to 80 percent, 31 percent rated it average, and 11.4 percent rated it low.

As we know, surveys cannot fully reflect reality and the data we collect also changes regularly. In this regard, since we do not have absolute statistical indicators, we can only make an approximate assessment. In order to have a high standard of living, people first of all need a high income, and if the average monthly income of those who are in line with the market value and above is only 41 percent, taking into account the other indicators above, we can estimate the effective employment rate of the employed as approximately 50 percent.

It should also be noted that, according to the results of a survey conducted with employers by the State Employment Agency (SEA, 2024b), although they prefer higher education personnel when hiring, they do not pay much attention to the suitability of the qualification for the vacancy, paying more attention to skills.

5.2.1. Employment Rating Indicators for Higher Education Graduates

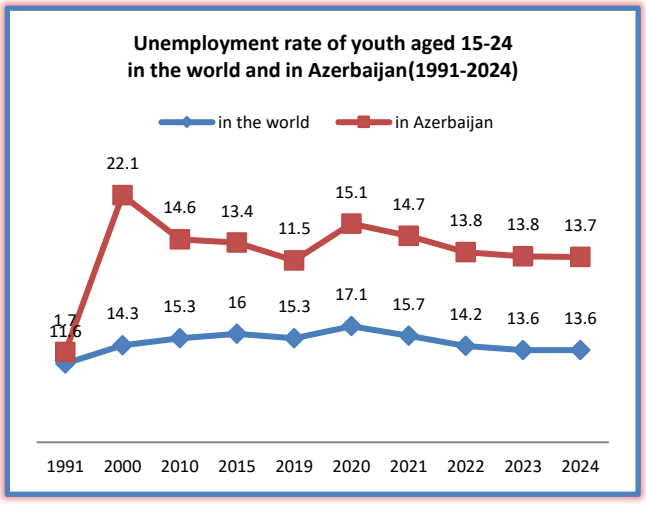
In recent years, the State Employment Agency has been preparing rating indicators for the employment level of higher education graduates. Here, the rating indicators of 102,749 graduates who graduated from only 30 universities in 2018-2022 were examined. It was found that 59,911 people (58.3%) of these graduates were employed (SEA, 2024a).

According to the SSCRA data, the areas with the lowest wages in the labor market are trade; provision of administrative and auxiliary services; tourist accommodation and public catering; recreation and entertainment. The vast majority of employed young people work in these areas. However, there are also young people working in the fields of finance and insurance; information and communication, where the average nominal wage is higher.

6. International Comparison

It is a global concern that millions of young people around the world are not in decent work, education, employment or training, and as a result are unable to provide a better life for themselves and their families. Despite the post-pandemic recovery in global labour markets, young people aged 15-24 are on average 3.5 times more likely to be unemployed than adults. In addition, the number of young people not in employment, education or training continues to grow; in 2023, this figure amounted to 269 million young people. Even for young people who are in employment, jobs are often characterized by poor quality, informality and low wages. The problem of youth employment is more acute in low- and middle-income countries than in high-income countries.The number of unemployed youth in 2023 will be 64.9 million, with an unemployment rate of 13 percent. This is the lowest figure in the last 15 years. Another issue of international concern is that 20 percent of young people are not in employment or education, and two-thirds of them are women (ILO, 2024). The report notes that there has been no progress in providing decent jobs for employed young people. Globally, more than half of young workers are in informal employment. Only in high- and upper-middle-income countries do the majority of young workers have regular and secure jobs. In low-income countries, almost three in four young workers, or 75 percent, are self-employed or work in temporary jobs.

According to World Bank data (WB, 2025a), in 1991, the unemployment rate of young people aged 15-24 in Azerbaijan was only 1.7% (the world average was 11.6%), and it rose steadily due to the political and economic situation in the country, reaching its peak (22.1%) in 2000. Starting in 2002, it gradually declined, with slight fluctuations in some years, reaching its lowest level in 2019 - 11.5%. After reaching its peak in recent years, reaching 15.1% in 2020 due to the pandemic period, it gradually decreased from 2021, falling to 13.8% in 2022, 2023, and 13.7% in 2024 (corresponding to the global indicator of - 13.6%), and has remained almost stable for the last 3 years (Graph 2.). In most years, this indicator in Azerbaijan has been lower than the global indicators.



Source: Prepared based on World Bank reports (WB, 2025a)

Graph 2. Unemployment rate of youth aged 15-24 (in %) in the world and in Azerbaijan (1991-2024)

In 2024 for some countries, this indicator was: 15.6% in Turkey, 22.8% in Iran, 9.3% in Russia, 29.9% in Georgia, 3.8% in Kazakhstan, 27.1% in Tajikistan, 9.6% in Turkmenistan, 3.3% in Moldova, 21.3% in Romania, 6.7% in Germany, etc (WB, 2025a). Among OECD countries, the highest unemployment rate for young people aged 15-24 was observed in Spain, at 26.5 percent, and the lowest in Japan, at 4 percent (OECD, 2024). As can be seen, the unemployment rate of youth aged 15-24 does not depend on whether the country is a developed or developing country, or a low-income or high-income country.

Although there was a dynamic in the overall employment level in the European Union (EU) countries until 2020, due to the global challenges caused by the coronavirus, the employment rate stopped six years of positive employment progress, reaching 72.4% in the third quarter of 2020. However, it is expected that by 2030, at least 78% of the population aged 20-64 will be involved in employment. Eurostat figures show that in 2021, one in five people in the EU were at risk of poverty or social exclusion (21.7% of the population or 95.4 million people), with child poverty at 24.4%. The EU youth unemployment rate (aged 15-25) peaked in 2013 at 24.4% as a result of the economic crisis, and has been gradually decreasing to 15% by the end of 2024 as a result of measures taken. The European Action Plan for Social Rights aims to reduce the share of people not in education or employment from 12.6% in 2019 to 9% by 2030 by improving employment prospects (EU, 2024a).

From 1990 to 2021, more than 220 active labor market programs targeting youth were implemented by the World Bank and the ILO in various countries around the world. As

a result of the implementation of these programs, youth employment and wages have increased significantly in low- and middle-income countries. According to research by World Bank experts (Susana Puerto et al., 2024), it was found that measures related to skills training and increasing entrepreneurship have a more effective impact on youth employment than investments in employment services and subsidized employment. It was found that while in high-income countries, skills training and wage subsidies have a significant impact, in low- and middle-income countries, supporting entrepreneurship and employment has a better impact. In low- and middle-income countries, the situation of young people in the labor market changes for the better after receiving a certificate in soft skills.

In general, the number of young people not in education, employment or training (NEET) in the world is high, and international funds allocate a large amount of financial resources to improve their living conditions, so that they can be involved in education and improve their skills. According to research by the World Bank (WB, 2025a), this indicator has decreased in most countries compared to previous years. For example, in 2023 it was 8.7% in Russia, 22.4% in Turkey, 24.9% in Georgia, and 13.3% in Moldova. For Azerbaijan, it was estimated to be 9.4% in 2009 and 9.6% in 2010, but indicators for subsequent years were not available.

Reducing youth unemployment and early school leaving is also a key objective for the European Union (EU). The European Commission calls on Member States to invest significantly in youth employment. Various projects and programmes are being implemented in Member States to support youth employment. Job creation, including in the emerging green and digital sectors, is a key priority in improving youth employment in the European Union countries. The Youth Guarantee, established in 2013 and reinforced in 2020, is the EU's reference policy framework for combating youth unemployment and inactivity. The priority objective is to equip young people with the skills they need to improve their employability and employability. (EU, 2024b).

The World Bank's 2019 report notes that even in the lowest-income countries, people are working in jobs that did not exist 30 years ago. Children who go to school in 2018 will grow up to work in jobs that do not yet exist (The World Bank, 2019: p. 70). Indeed, in recent years, new jobs have entered the labor market, and different skills are expected from workers. This requires maximum involvement of young people in education and, at the same time, continuous improvement of personnel training to adapt to the labor market.

The World Economic Forum's 2023 Future of Jobs Survey analyzed the labor market prospects of 673 million jobs using the ILO's global dataset of 820 million workers. According to the analysis, 69 million new jobs will be created and 83 million existing jobs will be eliminated between 2023 and 2027. This means a 14 million decrease in the number of jobs in the global labor market, or a 2% drop in employment (WEF, 2023).

Given the current growth and development pace of the Azerbaijani economy, we believe that these pessimistic forecasts will not be reflected in our country. In particular, the restoration of life in the liberated territories, the development of infrastructure there, and the increase in investments in the economy of our regions will have a positive impact on youth employment.

7. Conclusions

Improving youth employment is relevant not only in Azerbaijan, but also for almost all countries. The important issue here is to prepare young people as personnel in accordance with the requirements of the labor market. At a time when competition is increasing, young people should not be allowed to remain out of education. Conditions should be created for each of them to master any profession and specialty that brings them income and is in demand in the labor market. International experience also shows that improving youth employment is directly related to increasing their opportunities for education, in other words, the labor market and personnel training should operate in close unity with each other. Therefore, while on the one hand, measures should be taken to improve the functioning of the labor market in order to improve the employment of the population, on the other hand, effective organization of personnel training is very important to support the efficient functioning of the labor market.

The employment problem in Azerbaijan is no longer as acute as in previous periods, that is, it is possible to find a job, but in order to have efficient employment, it is necessary to find a decent job. In the current situation, this is possible primarily through the development of the regions and the use of their potential. The flow of population from the regions and villages to the center still continues, houses are empty, and lands suitable for agriculture remain unused. Therefore, investment through stimulating measures should be directed to the regions and villages so that a return flow occurs.

In this regard, if it is possible to transfer several higher education institutions to the regions, it could lead to great progress in this matter. If there are no conditions for earning income in the regions, we cannot force people to go and live there. However, if high investments are made in the regions and vocational and specialized education institutions are located there, this will mean an increase in jobs in those regions and a voluntary influx of people there.

Surveys and ratings have proven that not all higher education graduates work in jobs that match their qualifications and level of education. However, huge funds are spent on higher education, and both the state and citizens invest. If a person with higher education works in a job that is lower than their level of education and sometimes even does not require any qualifications, the investment in their education has not paid off. That investment could be used more efficiently. However, this does not mean that we are

against higher education and that investments should not be made in it. No. We really need educated higher education personnel, but they must also be in numbers and quality that meet the needs of the labor market. The important final result for the student himself is obtaining appropriate job security.

Therefore, in order for young people to take a worthy place in the labor market, it is important, first of all, to help them choose the right profession and develop their entrepreneurial skills. The realization of this goal should begin with general secondary education. If the demand in the labor market is less than the supply, in order to stimulate demand, we must prepare young people so that they become employers of the future, rather than job seekers. State support for self-employment can act as a motivating factor here. We noted above that in low- and middle-income countries, supporting entrepreneurship and employment has a better effect than professional development and subsidizing wages. It would be useful for Azerbaijan to apply each of these, depending on the field of economic activity and sector.

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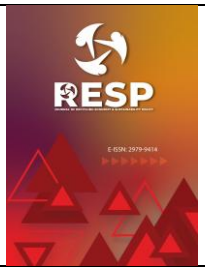

RESP

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Araştırma Makalesi ● Research Article

Analysis Of B2B Customers' Perceptions Regarding The Quality of Tissue Paper Produced From Recycled Pulp In The Algerian Paper Industry Sector

Cezayir Kağıt Endüstrisi Sektöründe Geri Dönüştürülmüş Selülozdan Üretilen Kağıt Mendil Kalitesine İlişkin B2B Müşterilerinin Algılarının Analizi

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ANAHTAR KELİMELER

Doku Kağıdı
Geri Dönüştürülmüş Pulp
Virgin Pulp
B2B Müşteri Algısı

ÖZ

Bu makale, Cezayir kağıt endüstrisi sektöründeki dört şirket (Sarl El-Wafa Faile, Sarl Africaine Paper Mills, Faderco Group ve EPE Tonic Industries) arasında, geri dönüştürülmüş hamurdan üretilen kağıt mendil rulolarının kalitesine ilişkin B2B müşterilerinin algılarını, işlenmemiş hamurdan üretilenlerle karşılaştırarak araştırmayı ve analiz etmeyi amaçlamaktadır. Çalışma, NVivo 15 yazılımını analiz aracı olarak kullanırken, tablo formatında düzenlenmiş yapılandırılmış görüşmelerin yanı sıra yapılandırılmış görüşme protokolü ile yönlendirilen yarı yapılandırılmış görüşmelerden oluşan nitel bir metodoloji kullanmaktadır. Bulgular, kağıt mendil rulolarını bitmiş ürünlere dönüştürmekle uğraşan şirketlerin genellikle geri dönüştürülmüş kağıt hamurundan üretilen rulolara olumsuz bir bakış açısına sahip olduğunu ortaya koymaktadır. Ayrıca, bu şirketler, bu tercihi, bakire kağıt hamuru ürünlerinin algılanan üstün kalitesine ve dönüşüm sürecinde karşılaşılan zorlukların azalmasına bağlayarak, bakire kağıt hamurundan üretilen rulolara tercih göstermektedir.

KEYWORDS

Tissue Paper
Recycled Pulp
Virgin Pulp
B2B Customer Perceptions

ABSTRACT

This article seeks to investigate and analyze the perceptions of B2B customers regarding the quality of tissue paper rolls manufactured from recycled pulp, compared to those produced from virgin pulp, across four companies within the Algerian paper industry sector (Sarl El-Wafa Faile, Sarl Africaine Paper Mills, Faderco Group, and EPE Tonic Industries). The study employs a qualitative methodology, utilizing structured interviews organized into a grid format, as well as semi-structured interviews guided by a structured interview protocol, while employing NVivo version 15 software as an analysis tool. The findings reveal that companies engaged in transforming tissue paper rolls into finished products generally hold a negative perception of rolls made from recycled pulp. Furthermore, these companies demonstrate a preference for rolls produced from virgin pulp, attributing this preference to the perceived superior quality of virgin pulp products and the reduction of challenges encountered during the transformation process.

1. Introduction

Tissue paper is one of the most extensively utilized products in various hygiene applications in daily life, and its market continues to evolve. In light of the rising demand for these products, industries are positioned to manufacture high-quality tissue papers that satisfy customer requirements.

Numerous studies indicate that the quality of tissue papers is influenced by various factors, particularly the quality of the pulp utilized in their production ((Ismail, M. Y., et al., 2020) & (Fišerová, M., et al., 2019)). Tissue paper can be manufactured using either recycled pulp or virgin pulp ((Vieira, J.C. et al., 2022) & (Fišerová, M., et al., 2019)). Indeed, recycled fibers serve as a significant alternative source to virgin fibers ((Reitbauer, J., et al., 2023), (Kuman et al 2022), (Zambrano et al 2021), (Haile, A., et al., 2021),

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(De Assis et al 2019) & (Wang, Y., et al., 2019)). However, several studies have reported that the utilization of recycled materials influences the technical characteristics of the product, stemming from the variability in the properties of the used materials ((Andrew-Munot. M & Ibrahim. R.N, 2013) & (Candido. L & al, 2011)). This uncertainty has meant that the reintroduction of recycled materials, at the upstream of the production cycle, does not always fulfill the same functionalities as primary raw materials (Arnsperger. C, Bourg. D, 2016). Consequently, the disparity in quality or properties between virgin materials and recycled materials may subsequently impact the quality of the finished products. This, in turn, could influence the quality perceptions among industrial customers (B2B customers), as the characteristics of the product are the primary factors that govern B2B transactions (Chumpitaz, R., & Swaen, V., 2004). Conversely, other studies have asserted that the incorporation of minimal proportions of recycled materials does not significantly affect the quality of the resulting products ((Keskisaari. A & Kadri. T, 2018), (Mehat. N.M & Kamaruddin. S, 2011), (Sadat-Shojai. M & Bakhshandeh. G.R, 2011) & (Balart, R., et al., 2006)).

These contradictory findings are also evident in studies focused on tissue paper. A subset of research confirms that the recycling process does not alter the morphology and quality of the fibers, therefore the quality of the tissue paper produced from these fibers is maintained ((Fišerová, M., et al., 2019) & (Hubbe, M. A., Venditti, R. A., & Rojas, O. J., 2007)). On the other hand, the second group of studies supports the notion that the quality of recycled fibers deteriorates with each recycling cycle, which adversely impacts the quality of tissue paper ((De Assis et al 2018), (Raunio, J. P., Löyttyniemi, T., & Ritala, R, 2018) & (Ali, I., 2012, p.212)). This degradation creates several challenges during the transformation of tissue paper rolls into finished products (Vieira, J. C., et al., 2022). This is why industrial companies favor the use of virgin materials to ensure the production of high-quality products ((Haghighatnejad. N & al 2016) & (Sadat-Shojai. M, & Bakhshandeh. G.R, 2011)).

The discrepancies in the findings of previous studies concerning the evaluation of the quality of products made from recycled materials, coupled with the limited research in this area, prompt us to investigate the perceptions of industrial customers (B2B customers) regarding the quality of tissue paper rolls produced from recycled pulp in comparison to those made from virgin pulp. This exploration will be conducted through directive and semi-directive interviews with production and quality managers of industrial companies specializing in the transformation of tissue paper rolls into finished products, such as napkin paper, facial tissue paper, paper towels, and toilet paper. The structured interviews are designed to gather precise and quantifiable perceptions of the quality of tissue paper rolls produced from both recycled and virgin pulp, utilizing a grid based on tissue paper characteristics. Meanwhile, the semi-structured interviews aim to elucidate and analyze the scores obtained from the structured interview grid.

2. Literature Review

Tissue paper is composed of cellulose fibers derived from either virgin fibers (virgin papers) or recycled fibers (recycled papers) ((Ogbonna, U., & Aguh, P., 2024), (Vieira, J. C., Fiadeiro, P. T., & Costa, A. P., 2023), (Vieira, J.C. et al., 2022), (Fišerová, M., et al., 2019) & (Bajpai, P., 2013)). Tissue paper rolls are converted into a variety of products utilized in numerous hygiene applications in everyday life. These applications include hygienic paper, facial tissues, paper napkins, and paper towels ((Kumar, R., et al.,2022), (Prinz, M., Zollner-Croll, H., & Wölfle, C. 2020) & (Masternak-Janus, A., & Rybaczewska-Błażejowska, M., 2015)), with napkins and facial tissues being produced as folded papers, while hygienic paper and paper towels are manufactured as rolled papers (Vieira, J. C., Fiadeiro, P. T., & Costa, A. P., 2023).

These papers must exhibit favorable characteristics such as softness, water absorption capacity, strength, thickness, grammage, and elongation ((Kumar, R., et al.,2022), (Vieira, J.C. et al., 2022), (Sinta, D., Azizah, F. N., & Nugraha, B., 2021), (Prinz, M., et al., 2021), (Prinz, M., Zollner-Croll, H., & Wölfle, C. 2020), (De Assis, T., et al., 2018), (Hollmark, H., & Ampulski, R. S., 2004) & (Foelkel, C., 1998)). These attributes represent the most sought-after properties for converting manufacturers ((Vieira, J.C. et al., 2022), (Morais, F. P., & Curto, J. M., 2022) & (Rastogi, V. K., et al., 2017)).

These characteristics are influenced by the properties of the fibers used in pulp preparation, as well as the chemicals incorporated during the production process and the technology employed ((Dias, A.C., et al.,2024), (Kumar, R., et al.,2022), (Vieira, J.C. et al., 2022), (Zambrano et al.2020), (Prinz, M., Zollner-Croll, H., & Wölfle, C. 2020), (De Oliveira Mendes, A., et al., 2020), (Morais, F. P., et al., 2019), (De Assis et al.2019), (Raunio, J. P., Löyttyniemi, T., & Ritala, R., 2018) & (Rastogi, V. K., et al., 2017)).

Indeed, numerous studies have established a strong correlation between the quality of the pulp and the quality of the resulting paper. Some research indicates that the incorporation of recycled fibers adversely affects the properties of tissue paper. For instance, recycled fibers exhibit lower flexibility in the wet state compared to virgin fibers ((De Assis, T., et al., 2019) & (De Assis, T., et al., 2018)). Consequently, tissue papers made from recycled fibers demonstrate reduced strength and softness, along with diminished inter-fiber bonding capacity ((De Assis, T., et al., 2019) & (De Assis, T., et al., 2018)). Furthermore, recycled pulp predominantly consists of short fibers due to multiple recycling cycles, and contains impurities that negatively impact the properties and quality of tissue paper (De Assis, T. et al., 2019), particularly in terms of water absorption, softness, and strength (Raunio, J.P., Löyttyniemi, T., & Ritala, R., 2018). As a result, economically-oriented tissue papers are typically produced

with a high percentage of recycled material, while high-quality papers are manufactured with a greater proportion of virgin fibers (Kumar, R. et al., 2022).

However, other studies challenge the findings of the previously mentioned research by asserting that the use of recycled pulp can enhance the properties of tissue paper, thereby improving its overall quality, particularly with respect to strength ((Debnath, M., et al.,2021), (Zambrano, F., et al., 2022)). Furthermore, the rigidity of recycled fibers contributes to the formation of a thicker fiber sheet, which may provide increased volume and water absorption capacity (Hubbe, M. A., Venditti, R. A., & Rojas, O. J., 2007). Additionally, other research indicates that the incorporation of recycled pulp can enhance the whiteness of tissue paper (Fišerová, M., et al., 2019).

The motivation for our article stems from the examination and analysis of industrial customers' perceptions regarding the quality of tissue paper rolls. Previous studies have predominantly concentrated on the differences in technical quality and characteristics between tissue papers produced from recycled pulp and those made from virgin pulp, while overlooking the converters' perceptions of these products' quality. Furthermore, the contradictory findings in earlier research concerning the quality of tissue paper also prompt this investigation.

3. Research Methodology

In conducting this exploratory study, a qualitative methodology was employed, utilizing both structured and semi-structured interviews. The interview serves as a data collection method in which one individual (the interviewer) poses questions to another individual (the interviewee) (Teddlie C., Tashakkori A., 2009, p.291).

The purpose of the structured interviews, designed in the form of a grid, is to accurately evaluate industrial customers' perceptions of the quality of tissue paper rolls produced from both recycled and virgin pulp. This assessment is based on technical quality criteria derived from the literature review and utilizes a scale ranging from 1 to 4 ([1] = "low", [2] = "medium", [3] = "high", and [4] = "very high"). Subsequently, to gain a deeper understanding of the reasons behind these evaluations and to analyze the scores obtained from the responses of the interviewed managers, semi-structured interviews were conducted, in accordance with Brancati's recommendations, which indicate that this interview format facilitates the collection of in-depth information (Brancati, D., 2018, p. 139).

In this context, we conducted interviews with quality and production managers from four companies in the paper industry: Sarl El-Wafa Faile, Sarl Africaine Paper Mills (APM), Faderco Group, and EPE Tonic Industries. We specifically selected quality and production managers for these interviews, as they are directly engaged in the production process and quality assessment of the products. Consequently, it is anticipated that they possess accurate and comprehensive insights regarding the quality of tissue paper. Each interview lasted, on average, between 30 and 45 minutes.

For the analysis of the structured interviews, we chose to calculate the scores assigned by each manager to each characteristic for both types of paper. Subsequently, these scores were represented in the form of a radar chart to facilitate analysis and interpretation. For the analysis of the semi-structured interviews, we utilized the content analysis method, which encompasses transcription, coding, and data processing (Andréani, J. C., & Conchon, F., 2005). Initially, we transcribed the interviews, noting that they were not recorded in accordance with the interviewees' request for confidentiality. We then proceeded with coding and processing the transcribed data using NVivo version 15 software. Finally, we presented and interpreted the results. To achieve this, we employed NVivo 15 software to calculate word frequency, which is illustrated in the word clouds included in this article, focusing on the 50 most frequently used words after excluding irrelevant terms. It is important to note that the limited number of words is attributable either to the removal of irrelevant terms or to the constrained responses of the interviewees.

4. Analysis and Discussion of the Results

4.1. Analysis and Discussion of the Results From the Structured Interviews

The structured interviews conducted with production and quality managers from the paper processing companies (Sarl El-Wafa Faile, Sarl Africaine Paper Mills (APM), Faderco Group, and EPE Tonic Industries) regarding their assessment of the quality of tissue paper rolls produced from recycled and virgin pulp yielded the following results (see Table 1 and Table 2): Table 1 and 2 are in the Annex.

To elucidate the results obtained, the scores have been represented in the form of a radar chart (see Figure 1.).

Source: Elaborated by the author.

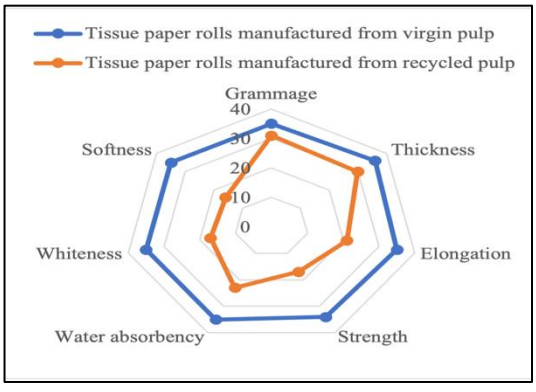


Figure 1. Presentation of the Scores Obtained From the Evaluation of the Quality of Tissue Paper Rolls Produced From Virgin Pulp and Recycled Pulp

Based on the scores obtained and presented in the radar chart above, it can be concluded that the overall characteristics (grammage, thickness, elongation, softness, strength, and water absorbency) of tissue paper rolls produced from virgin pulp are superior to those produced from recycled pulp. However, the characteristics of grammage and thickness are nearly identical for both types of paper. This finding is consistent with the study by Hubbe et al. (2007), Debnath et al. (2021) and Zambrano et al (2022), which indicated that the use of recycled pulp can achieve satisfactory thickness and volume. Similarly, the results regarding the strength and softness of the two types of paper align with the findings of De Assis et al. (2019) and De Assis et al. (2018). Conversely, the assessment of the whiteness of tissue paper made from virgin pulp reveals significantly higher values compared to that of tissue paper produced from recycled pulp, which contradicts the findings of Fišerová et al. (2019), who confirmed that the use of recycled pulp enhances the whiteness of tissue paper.

To analyze the nature of these managers' perceptions regarding the quality of tissue paper rolls produced from recycled pulp, we conducted semi-structured interviews with them. The results are presented in the following sub-section.

4.2. Analysis and Discussion of the Results From the Semi-structured Interviews

We concentrated on the evaluation of quality by consistently comparing it with the quality of tissue paper rolls produced from virgin pulp, specifically in terms of selection, quality assessment, and shaping challenges. In accordance with the recommendations of Andreani and Conchon, we organized the themes from the interviews into distinct categories (see Table 3.).

Table 3. Themes and Analysis Categories Pertaining to B2B Customers' Perception of the Quality of Tissue Paper Rolls Produced From Recycled Pulp

Themes pertaining to B2B customers' perception of the quality of tissue paper rolls produced from recycled pulp	**Analytical Categories**
1. Tissue paper rolls	• Priority in selecting tissue paper
2. Quality of tissue paper rolls	• Perception of the quality of tissue paper rolls • Quality defects in tissue paper
3. Transformation of tissue paper rolls made from recycled pulp	• Challenges in shaping tissue paper rolls into finished products

Source: Elaborated by the author.

Following the categorization of themes, we performed a thematic analysis using NVivo 15 software to calculate the word frequency for each respective category.

•**Theme 1 - Category 1:** Priority in the Selection of Tissue Paper

After posing the question, « If given the option between tissue paper rolls produced from virgin pulp and those manufactured from recycled pulp, which option would you select? », we generated the following word cloud based on the interviewees' responses (see Figure 2.):

Source: Output from NVivo version 15.

Figure 2. Word Cloud Visualizing the Priorities for Selecting Tissue Paper

Terms such as tissue, rolls, virgin, paper, among others, constitute the majority of the words utilized in the interviewees' responses, indicating a clear preference among all participants for tissue paper produced from virgin pulp as their primary choice. The following excerpts further corroborate these findings:

« … We unequivocally opt for tissue rolls made from virgin pulp » [Excerpt 1, production manager-EPE Tonic Industries].

« … It is noteworthy that tissue paper derived from virgin pulp typically exhibits superior characteristics compared to that made from recycled pulp… » [Excerpt 2, production manager- Sarl El-Wafa Faile].

« When presented with the option of selecting tissue paper rolls manufactured from virgin pulp versus those produced from recycled pulp, we unequivocally prefer tissue paper rolls made from virgin pulp…The quality of these rolls is significantly superior and cannot be matched by those made from recycled materials» [Excerpt 3, production manager-Faderco Group].

This supports the findings of previous studies indicating that industrial companies continue to favor products made from virgin materials, particularly as noted by Haghighatnejad et al. (2016) and Sadat-Shojai & Bakhshandeh (2011).

This finding can also corroborate the results of the studies conducted by Andrew-Munot and Ibrahim (2013) and Candido et al. (2011), which emphasized that the use of recycled materials adversely affects the technical characteristics of the resulting products.

•**Theme 2 - Category 1:** Quality of Tissue Paper Rolls

Question: « How do you perceive the quality of tissue paper rolls produced from recycled pulp compared to those produced from virgin pulp? »

The analysis of the interviews indicates that the interviewees emphasized specific terms, including "recycled, quality, tissue, impurities, inferior, tearing" (see Figure 3.). This suggests that the quality of tissue paper rolls produced from recycled pulp is perceived to be inferior compared to those made from virgin pulp.

Source: Output from NVivo version 15.

Figure 3. Word Cloud Visualizing the Perception of the Quality of Tissue Paper Rolls Made from Recycled Pulp

Indeed, all interviewees expressed a negative perception of the quality of tissue paper rolls produced from recycled pulp. They also referenced the quality of tissue paper rolls made from virgin pulp as a basis for comparison:

The quality manager of Sarl APM stated that « … The quality of tissue sheets produced from recycled pulp compared to those produced from virgin pulp is generally regarded as inferior » **[Excerpt 1]. The quality manager 1- EPE Tonic Industries** added that « In comparison to tissue rolls made from virgin pulp, those produced from recycled pulp are less effective, prone to tearing, and exhibit reduced absorption capacity… tissue rolls made from recycled pulp are regarded as being of inferior quality » **[Excerpt 2]. The managers of Sarl El-Wafa Faile and the Faderco Group** also confirmed that « The quality characteristics of tissue papers derived from recycled pulp are inferior to those produced from virgin pulp… » **[Excerpt 3, production manager-Groupe Faderco]**, and that « …the quality of tissue paper manufactured from recycled pulp is inferior » **[Excerpt 4, quality manager - Sarl El-Wafa Faile]**

These findings align with the conclusions of Arnsperger and Bourg's (2016) study, which asserts that the reintroduction of recycled materials into new product cycles does not consistently yield the same functionalities as those derived from primary materials. Consequently, this discrepancy is likely to impact the quality of products manufactured from these materials and influence the perceptions of industrial clients regarding their quality.

•**Theme 2 - Category 2:** Quality of Tissue Paper Rolls

Question: « What quality defects have you noticed in the tissue paper rolls produced from recycled pulp compared to those produced from virgin pulp? »

The word cloud associated with the inquiry in the category of quality defects of tissue paper rolls made from recycled pulp comprises a range of terms, including "quality, recycled, defects, paper, holes, strength, whiteness, stains, grains, thickness, inferior, irregularities, shrinkage, breaking" among others (see Figure 4.). This collection of terms indicates the presence of various quality defects in tissue paper rolls produced from recycled pulp, particularly concerning discrepancies in color, strength, density, and the occurrence of holes.

Source: Output from NVivo version 15.

Figure 4. Word Cloud Visualizing the Defects ın The Quality of Tissue Paper Made from Recycled Pulp

The recurring defects identified in the employees' responses include the following: « … the quality defects noted in tissue rolls made from recycled pulp compared to those made from virgin pulp include a decline in whiteness, the presence of stains and holes, and diminished strength of the paper » **[Excerpt 1, production manager-EPE Tonic Industries]**. Additionally, **the quality manager of Sarl El-Wafa** Faile noted that the quality defects frequently associated with tissue paper rolls produced from recycled pulp include: « … insufficient mechanical strength, the presence of significant impurities or residual inks, and inconsistencies in the quality of recycled materials. These issues can result in visible irregularities in the final product, such as spots or areas with varying density » **[Excerpt 2].** These issues can lead to visible irregularities in the final product, such as spots or areas with varying density. **The production manager of the Sarl APM** further cited defects including: « …the presence of impurities such as dust and wood, inadequate strength, poor roll formation, the occurrence of grains and holes, and sheet shrinkage » **[Excerpt 3]**.

In addition to the non-conformities of tissue papers identified in previous studies, such as reduced resistance, the officials also highlighted issues related to the presence of holes, stains, grains, and sheet shrinkage.

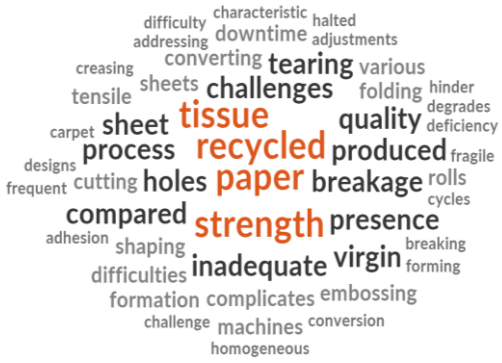
This is consistent with the findings of De Assis et al. (2018) and Raunio et al. (2018), which demonstrated that the

quality of tissue paper declines when produced using recycled fibers.

•**Theme 3 - Category 1:** The Transformation of Tissue Paper Rolls Made from Recycled Pulp

Question: « What are the primary challenges encountered during the process of converting tissue paper rolls made from recycled pulp into finished products, such as facial tissue, toilet paper, paper towels, and napkins, in comparison to those produced from virgin pulp?»

Based on the word cloud presented below (see Figure 5.), the challenges associated with shaping tissue paper rolls produced from recycled pulp into products such as paper towels, toilet paper, and facial tissues primarily stem from production interruptions caused by insufficient strength and sheet tearing.



Source: Output from NVivo version 15.

Figure 5. Word Cloud Visualizing the Shaping Obstacles of Tissue Paper Rolls Produced from Recycled Pulp ınto Finished Products

According to the **quality manager of Sarl APM**, several challenges arise during the production of finished products (such as facial tissue, toilet paper, paper towels, and napkins) from tissue paper made from recycled pulp. These challenges can be summarized as follows: « …the tearing of tissue sheets during various stages of the converting process, attributable to the inadequate strength of these sheets…the difficulty in addressing the issue of tissue sheet tearing during the production of different types of paper, which can hinder the ability to resume production effectively» **[Excerpt 1]**.

The managers of Sarl El-Wafa Faile and Faderco Group also noted similar concerns:

« … The presence of non-conformities, including holes, dust, and white spots, presents multiple challenges in the production process. These issues can result in paper breakage during machine processing (dry state resistance), as the holes increase the likelihood of breakage. Additionally, these non-conformities complicate the mastery of the production process, leading to inadequate embossing, disruptions in the separation lines, and suboptimal inking of designs on the paper ». **[Excerpt 2, production manager- Faderco Group]**

« The rigidity of the fiber suspension associated with recycled pulp compared to virgin pulp presents numerous challenges during the shaping process, particularly in cutting, folding, or winding operations. Additionally, tissue paper produced from recycled pulp contains shorter, less resilient, and more fragile fibers due to multiple recycling cycles… This issue complicates the formation of a solid and homogeneous paper structure, thereby increasing the likelihood of tearing, creasing, or breaking during shaping… Furthermore, the low mechanical strength of recycled pulp tissue paper can lead to breakage during unwinding, shaping, or rewinding. The dust generated from recycled materials may also obstruct cutting, folding, or packaging systems… ». **[Excerpt 3, quality manager- Sarl El-Wafa Faile]**

The results of these interviews indicate that all the companies have a negative perception of tissue paper rolls produced from recycled pulp. This type of paper exhibits several defects, resulting in numerous challenges during the transformation of the rolls into finished products. These issues may also adversely affect the quality of the final products, including hygienic paper, facial tissues, paper napkins, and paper towels.

These results align with the findings of Vieira et al. (2022), who identified several challenges associated with the use of recycled pulp in the production of tissue paper, particularly during the processing of the rolls into finished products.

5. Conclusions

This study aimed to investigate and analyze the perceptions of B2B customers responsible for transforming tissue paper rolls into finished products within the Algerian paper industry. Notably, no prior research has been conducted on this topic. Previous studies have primarily focused on assessing the quality of tissue paper rolls, whether produced from recycled or virgin pulp, while evaluating their characteristics from a technical standpoint.

The findings from the two types of interviews, directive and semi-directive, confirm that the quality of tissue paper rolls produced from recycled pulp is consistently inferior to that of those made from virgin pulp, despite a similarity in grammage and thickness characteristics between the two types of paper. This aligns with the conclusions of earlier studies, which indicated that the use of recycled pulp contributes to the degradation of the quality and characteristics of tissue paper.

Furthermore, tissue paper rolls produced from recycled pulp exhibit numerous quality defects or non-conformities, including reduced strength and whiteness, as well as the presence of stains and grains. These defects result in various challenges during shaping processes, such as production interruptions, which further explain the negative perceptions expressed by the interviewed company managers.

This study, while offering valuable insights into B2B customers' perceptions regarding the quality of tissue paper rolls produced from recycled pulp in the Algerian paper industry, it presents certain limitations that should be acknowledged. First, the study's qualitative design, based on structured and semi-structured interviews, prioritized depth of understanding over statistical representativeness. Consequently, the results mainly reflect subjective perceptions rather than quantifiable relationships between fiber origin and product quality. Moreover, the absence of complementary laboratory analyses, such as mechanical strength testing or whiteness index measurements, constitutes another limitation, as the study relied exclusively on perceived rather than objectively measured quality indicators. Finally, the geographical focus on Algerian B2B customers may restrict the external validity of the conclusions, given that perceptions of recycled materials can vary significantly across markets depending on technological, cultural, and environmental factors.

In light of these limitations, several avenues for future research can be proposed. Future studies could adopt a mixed-methods approach by integrating qualitative interviews with quantitative analyses or laboratory testing to obtain a more comprehensive assessment of tissue paper quality. Expanding the scope of research to include a larger number of firms, internationally firms particularly, would allow for comparative analyses of industrial perceptions and practices across different contexts. Additionally, investigating consumer (B2C) perceptions could provide complementary insights into how end-users value tissue paper products derived from recycled materials, particularly in relation to environmental awareness and brand image. Further studies could also focus on technological innovations in recycling and pulp treatment processes that enhance fiber quality and reduce the performance gap between recycled and virgin pulp.

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TABLES 1 AND 2

Table 1. Assessment of the Quality of Tissue Paper Made from Virgin Pulp

	Function	Quality criteria for tissue paper						
		Grammage	Thickness	Elongation	Strength	Water absorbency	Whiteness	Softness
Sarl El-Wafa Faile	Quality manager	4	4	4	4	4	4	4
	Production manager	3	4	4	3	4	3	4
Sarl APM	Quality manager	4	4	4	4	3	4	4
	Production manager	4	4	3	3	4	4	3
Faderco Group	Production manager	3	3	3	3	3	3	3
	Quality manager 1	3	3	3	3	3	3	3
	Quality manager 2	4	4	4	4	4	4	4
EPE Tonic industries	Production manager	3	3	3	3	3	3	3
	Quality manager 1	3	3	3	3	3	3	3
	Quality manager 2	4	4	4	4	4	4	4
Score		35	36	35	34	35	35	35

Source: Elaborated by the author.

Table 2. Assessment of the Quality of Tissue Paper Made from Recycled Pulp

	Function	Quality criteria for tissue paper						
		Grammage	Thickness	Elongation	Strength	Water absorbency	Whiteness	Softness
Sarl El-Wafa Faile	Quality manager	4	2	1	2	1	2	1
	Production manager	2	2	3	2	2	1	2
Sarl APM	Quality manager	3	4	1	1	3	1	1
	Production manager	4	4	2	2	3	2	2
Faderco Group	Production manager	3	3	2	2	2	2	2
	Quality manager 1	2	2	3	2	3	1	1
	Quality manager 2	4	4	2	1	3	3	2
EPE Tonic industries	Production manager	3	3	2	1	2	2	2
	Quality manager 1	3	3	2	2	1	2	1
	Quality manager 2	3	3	3	2	2	1	2
Score		31	30	21	17	23	17	16

Source: Elaborated by the author.

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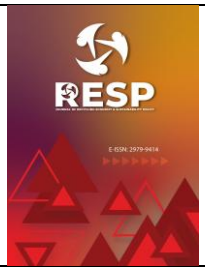

RESP

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Araştırma Makalesi ● Research Article

Environmental and Economic Benefits of Recycling Wastepaper: In Case of Ethiopia

Atık Kağıdın Geri Dönüşümünün Çevresel ve Ekonomik Faydaları: Etiyopya Örneği

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ANAHTAR KELİMELER

Katık Kağıt
Kağıt Pulp
Atık Kağıt Geri Dönüşümü
Katı Atık

ÖZ

Kâğıt üretimi, kökeni Antik Mısır'a uzanan ve teknolojik ilerlemelere rağmen önemini koruyan bir alandır; şehirleşme, nüfus artışı ve sanayileşme nedeniyle küresel talep kişi başı yaklaşık 60 kg'a ulaşmıştır. Odun temelli hammaddelere bağımlılık, ormansızlaşma, enerji kullanımı ve sera gazı emisyonlarını artırırken, geri dönüşüm döngüsel ekonomiyi desteklemekte ve çevresel baskıları azaltmaktadır; dünya genelinde her yıl yaklaşık 225 milyon ton atık kâğıt geri dönüştürülmektedir. Buna karşılık Etiyopya'da kişi başı tüketim 2 kg'ın altındadır ve yetersiz atık toplama ile geri dönüşüm sistemleri nedeniyle ülke büyük ölçüde ithal hamura bağımlıdır; yıllık 200.000 tonun üzerinde atık kâğıt üretilmesine rağmen sadece %5'i geri dönüştürülmekte ve dokuz geri dönüşüm tesisi atıl kalmaktadır. 2013–2024 dönemini (özellikle 2019–2024) kapsayan literatür incelemesi, atık kâğıt geri dönüşümünün artırılmasının emisyonları düşürebileceğini, enerji ve su tasarrufu sağlayabileceğini, Addis Ababa'daki çöp sahalarına olan baskıyı azaltabileceğini, istihdam yaratabileceğini ve döviz tasarrufu sağlayabileceğini göstermekte; ayrıca özellikle üretici sorumluluğunun genişletilmesi (EPR) alanındaki politika eksikliklerinin giderilmesi gerektiğini vurgulamakta ve Etiyopya'nın kâğıt sektörünün küresel sürdürülebilirlik uygulamalarıyla uyumlu hale gelmesi için bu adımların zorunlu olduğunu belirtmektedir.

KEYWORDS

Waste Paper
Paper Pulp
Waste Paper Recycling
Solid Waste

ABSTRACT

Papermaking, rooted in ancient Egypt, remains essential despite technological advances, with global demand rising to about 60 kg per capita due to urbanization, population growth, and industrialization. Reliance on wood-based raw materials drives deforestation, energy use, and greenhouse gas emissions, whereas recycling supports the circular economy and reduces environmental pressures; globally, around 225 million tons of wastepaper are recycled each year. Ethiopia, however, consumes less than 2 kg per capita and depends heavily on imported pulp because of weak waste collection and recycling systems; although generating over 200,000 tons of paper waste annually, the country recycles only about 5%, leaving its nine recycling plants underutilized. A literature review (2013–2024, with emphasis on 2019–2024) shows that increasing wastepaper recycling could lower emissions, save energy and water, reduce landfill pressures in Addis Ababa, create jobs, and save foreign exchange, while highlighting major policy gaps—particularly the absence of extended producer responsibility (EPR)—that must be addressed to align Ethiopia's paper sector with global sustainability practices.

1. Introduction

Papyrus, which was first used as a writing surface in ancient Egypt circa 3000 B.C., is still the basis for contemporary papermaking techniques (Rullifank et al., 2020). Modern paper is made by mixing pulp, mostly cellulose fibers, with different chemicals that affect its chemical and physical characteristics. The whiteness and quality of paper products are improved by additional chemical treatments like bleaching (Ozola et al., 2019).

Population growth, urbanization, and industrialization have

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all significantly increased the demand for paper worldwide, making it an essential part of social, economic, and environmental development. Throughout history, the development of civilizations and social structures has been impacted by the production and consumption of pulp and paper (Abd El-Sayed et al., 2020). Even with the introduction of digital technologies, the average person uses 60 kg of paper per year worldwide, with notable regional differences: 7 kg in Africa, 265 kg in the US, and 40 kg in densely populated Asia (Humagain et al., 2020).Paper is one of the most widely used materials in the world because it can be found in a variety of products, such as books, magazines, stationery, cardboard, commercial printing, and packaging (Awogbemi et al., 2022; Ma et al., 2021).

In both developed and developing nations, wood continues to be the most common raw material used to make pulp (Boadu et al., 2020). However, the need for cleaner production technologies has arisen due to environmental concerns and limited natural resources. In order to benefit ecosystems and industrial profitability, these strategies seek to maximize industrial output while minimizing environmental effects, lowering the cost of resource extraction, and increasing overall resource efficiency (Adane Haile et al., 2021). Around 406 million tons of paper and paperboard are produced annually worldwide, which includes 225 million tons of recycled paper, 176 million tons of wood pulp, and 12 million tons of other fiber pulp. The paper industry already uses more than 10% of the world's annual wood production (Małachowska et al., 2020). The demand for forest products is predicted to increase due to population growth and economic expansion, which will also increase competition for raw materials in the pulp and paper industry.

There are many opportunities to replace virgin wood fibers with waste and non-woody fibers, such as waste paper (Abd El-Sayed et al., 2020). Waste paper, which is defined as paper that is thrown away after use, makes up a sizable amount of recyclable material and roughly 10% of municipal solid waste (Tamiru & Abirham, 2022). Office paper, newspapers, cardboard, and paper sludge are among the sources; these materials can all be recycled to make new paper goods or used in different ways (de Oliveira et al., 2023).

By lowering reliance on virgin wood, minimizing environmental effects, conserving forest resources, saving energy, reducing pollution, lowering unemployment, and improving raw material efficiency, recycling waste paper is consistent with the principles of the circular economy (Agrawal et al., 2021; Ma et al., 2021). It encourages the shift to a more sustainable economic framework from the linear "extract-consume-dispose" model (Lorang et al., 2021). Deforestation, greenhouse gas emissions, and climate change have all been exacerbated by the overuse of wood in the paper industry (Worku et al., 2023).

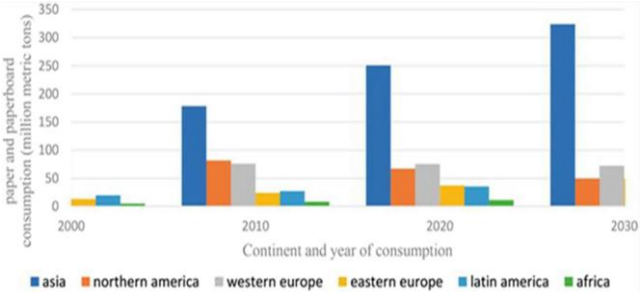
The situation is especially dire in Ethiopia. Despite consuming less than 2 kg of paper annually per person, every year Ethiopia imports raw materials valued at over $100 million USD for the paper industry to meet domestic demand(Global Business Network (GBN) 2020). Only about 5% of the more than 200,000 tons of paper produced annually by municipal solid waste is recycled locally.(Impact 2023)0. Due to ineffective waste collection systems, low public awareness, and a lack of policy support, the majority of Ethiopia's nine paper recycling industries are underutilized. This emphasizes how urgently structured collection systems, formalization of the unorganized sector, and expansion of recycling infrastructure are needed to promote the growth of sustainable industries.

This article examines the economic and environmental advantages of recycling waste paper, concentrating on Ethiopia and contrasting local customs with international patterns. With a focus on studies released between 2019 and 2024, a literature review covering publications from 2013 to 2024 was carried out using databases like Google Scholar and national reports. Relevance and data quality were taken into consideration when choosing reputable reports and peer-reviewed articles. In order to better understand cleaner production technologies and circular economy strategies, the review looks at production trends, consumption patterns, the environmental impact of paper production, and the financial potential of recycling.

2. Trends of World Pulp and Paper Manufacturing

Over the past few decades, the world's pulp and paper industry has experienced tremendous change due to population growth, technological advancements, and rising demand for sanitary, printing, and packaging goods. Plant materials are mechanically or chemically processed to create pulp, the fibrous structural element of paper (Małachowska et al., 2020). Hardwood and softwood together make up almost 90% of the raw materials used to produce pulp worldwide, but non-wood sources like agricultural waste are becoming more and more popular because they are easy to pulp, have good fiber qualities, and have a smaller environmental impact (Nagarajaganesh et al., 2022; Román et al., 2022).

Figure 1. Global Trend in Paper Consumption



Source: (Nagara jaganesh et al. 2022)

Ethiopia's population growth, urbanization, growing educational system, and growing use of packaging materials are all contributing to the country's rapidly increasing demand for pulp and paper products. Every year, the nation imports raw materials valued at about USD 100 million for the paper industry (GBN, 2020). Annual pulp imports between 2009 and 2016 varied between 82,000 and 154,000 tons (Megra et al., 2022), and the amount of paper and paper products coming into the nation has been rising by 12.6% annually (Tamiru & Abirham, 2022). Furthermore, Ethiopia imported 1,572 tons of scrap paper annually on average between 2015 and 2019 to augment domestic recycling inputs (Simret Girma 2022).Nine waste-paper recycling facilities with a combined annual production capacity of 114,710 tons are currently in the country; however, because of irregular and inadequate waste-paper supply, capacity utilization averages only 20%. In large urban centers, particularly Addis Ababa, informal networks known locally as "Korales" are the main source of waste-paper recovery, collecting a large portion of the recyclable material (GBN, 2020). Ethiopia's low recycling rate and reliance on imported raw materials have made better collection systems and domestic pulp substitutes more urgently needed.

Innovative initiatives to promote sustainable materials and lessen dependency on virgin pulp have recently surfaced. While businesses like Kirtas create environmentally friendly packaging from recycled paper, startups like Zafree have started producing pulp from banana leftovers and other agricultural waste(Hariram, Mekha, and Suganthan 2023). These changes show that Ethiopia's paper industry is increasingly moving toward resource-efficient production and circular economy strategies.

3. Trends Waste Paper Recycling Trends: Global and Ethiopian Context

Reducing reliance on virgin raw materials and minimizing the waste of potentially valuable materials are two important goals of recycling. In keeping with the well-known 4Rs—Reduce, Reuse, Recycle, and Recover—it entails the methodical gathering, sorting, and conversion of waste materials into new, reusable products. One of the most valuable recyclable resources is waste paper, which can be remanufactured into new, useful materials (Majeed et al., 2021). Newspapers, magazines, cardboard, office paper, and other paper goods produced on a daily basis by homes, businesses, and institutions fall under this category (Agrawal et al., 2021).

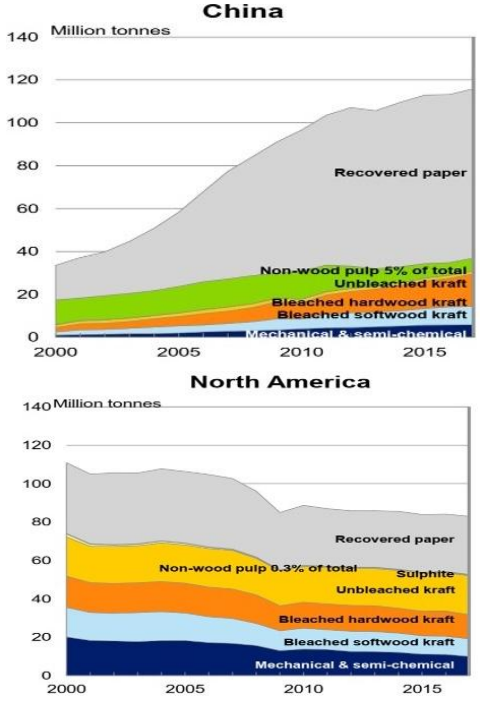
Paper accounted for roughly 17% of the world's solid waste generation, which reached 2.02 billion tons in 2016 and is expected to increase to 2.59 billion tons by 2030 and 3.4 billion tons by 2050 (Awogbemi et al., 2022). North America recycles 68% of its paper, Asia 53.9%, Latin America 47.2%, Africa 35.2%, Japan 80%, and Europe 72.3–73.3% (Yang et al., 2020; de Oliveira et al., 2023). In 2021, 1.15 million tons of paper and packaging were recycled in South Africa alone, representing a 66% recovery rate (Godfrey, 2021). While materials like glossy, waxed, or carbon paper are still difficult to recycle and have little commercial value, recycled paper is mostly used in office paper, tissue products, and packaging (Liu et al., 2020).

Ethiopia, on the other hand, performs noticeably worse in recycling even though waste generation is increasing. Every year, the nation generates 2.2 to 7 million tons of waste in urban areas and 0.6 to 1.8 million tons in rural areas (Teshome, 2020). Only around 5% of all waste is reused, frequently through unsafe and informal methods, despite the fact that per capita waste generation varies from 0.17 to 0.48 kg per day in urban areas and 0.11 to 0.35 kg per day in rural areas (Teshome, 2020). Ethiopia's waste paper recycling rate is only about 5%, far lower than Kenya's 15%, and over 200,000 tons of paper and cardboard are burned, dumped, or thrown out in the open annually (GBN, 2020).

However, recent Addis Ababa data shows signs of improvement. The city produced about 587,000 tons of solid waste in the fiscal year 2023–2024, of which 67,510 tons were recycled. Thanks to financial incentives like subsidies for collected recyclables, the recovery rate for paper and cardboard reached 11.5% (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH 2023)). However, manufacturers' access to high-quality recycled fiber is still hampered by fragmented collection systems and limited industrial recycling capacity (GBN, 2020).

Global trends show that recycling waste paper has both economic and environmental benefits, but Ethiopia's recycling industry is still in its infancy. This underscores the need for better infrastructure, better collection methods, and supportive policy frameworks to improve resource recovery.

Figure 2. IMFA Presentation 2019



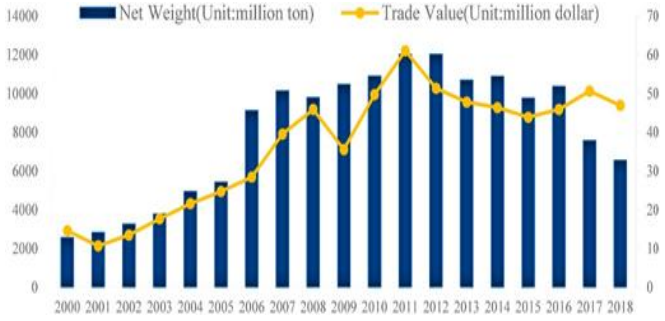
Source: (GBN) 2020)

4. Waste Paper Recycling Process

Paper recycling is one of the most well-established waste material recycling strategies, and its rates are steadily increasing as a result of economic and environmental initiatives (Defalque et al., 2021). Gathering, sorting, shredding, pulping with chemicals and hot water, bleaching to get rid of ink, and then creating new paper goods are the usual steps in the process (Kumar et al., 2020; Defalque et al., 2021). Research conducted in Ethiopia has demonstrated that recycled paper retains its high quality with little physical or chemical deterioration of fiber structures when processed appropriately (Tutus, 2021). Important physical and chemical characteristics of recycled fibers, such as bulk, moisture content, grammage, Kappa number, and water absorption, are mainly unaffected, allowing for efficient repurposing in the manufacturing of paper (Tutus, 2021). In an effort to lessen its dependency on imported virgin wood pulp, Ethiopia is also investigating the use of pulps derived from agricultural residues to supplement waste paper recycling.

5. Economic Benefits of Waste Paper Recycling

Through the creation of long-term employment opportunities, resource efficiency, and support for a circular economy, the collection and recycling of waste paper significantly benefits society (Ma et al., 2021). Recycling used paper improves the use of post-consumer materials, lessens reliance on virgin pulp, and conserves forest resources. Millions of tons of waste paper are produced annually worldwide; urbanization, increased literacy, and industrial development have all contributed to this trend. Paper recycling is now a crucial part of the global circular economy as a result. As waste paper's economic significance grows, the global trade in this product has grown dramatically since the beginning of the twenty-first century, from USD 2,136.5 million in 2001 to USD 12,204.3 million in 2018 (Xu et al., 2021). (Fig. 3).



Source: Xu et al. 2021

Figure 3. Annual Weight and Value of Global Waste Paper Trade from 2000 to 2018

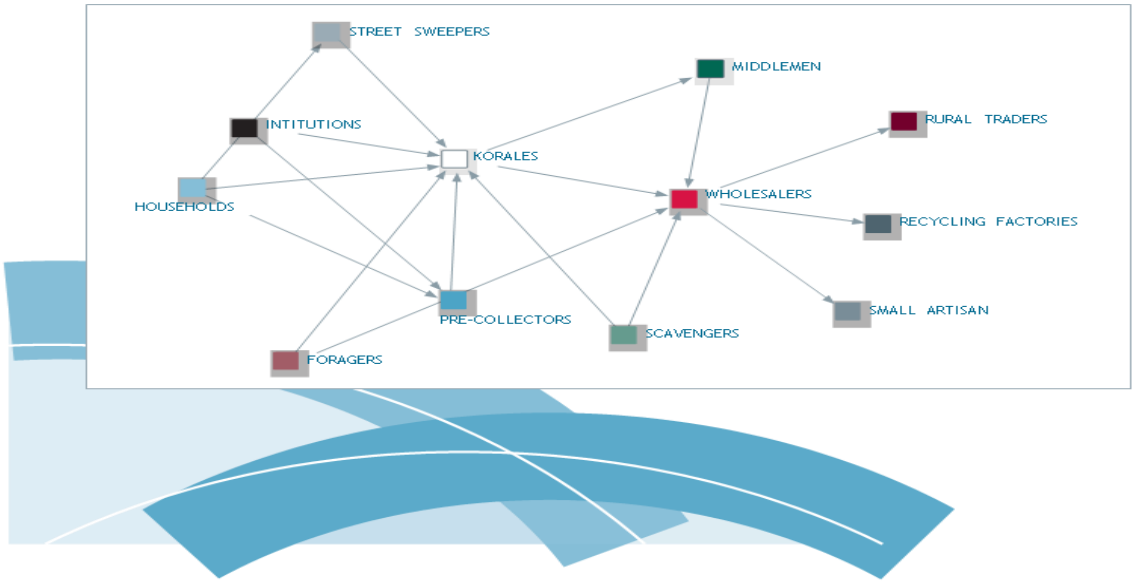
Cellulosic fibers, which must be blended with virgin fibers during the papermaking process because they lose strength and length with each cycle, are impacted by recycling paper. However, fibers are usually reusable three to eight times. Around 59.7% of paper worldwide was recycled in 2020; the highest percentages were found in Europe (73.3%), North America (68%), Asia (53.9%), Latin America (47.2%), and Africa (35.2%) (de Oliveira et al., 2023). Materials that can be remanufactured into new paper products are referred to as recyclable waste paper. Label stickers, papers with plastic coatings or waxes, and carbon paper are examples of non-recyclable waste that cannot be processed and, as a result, have little to no economic value (M. Liu et al., 2020).

Recycling used paper has financial benefits in addition to environmental ones. Due to its lower energy and chemical requirements, secondary pulp is usually less expensive to produce than wood pulp (Tutus, 2021). Additionally, it gives the paper industry a substitute raw material, making it less susceptible to changes in the market (Yılmaz et al., 2021). Additionally, recycling waste paper into building materials, biofuels, paper products, and other materials is economical, ensures appropriate waste management, fosters sanitation, and helps protect the climate (Awogbemi, Von Kallon, & Bello, 2022). Recycling has a wide range of social and economic benefits, including lowering resource use, energy consumption, waste production, and environmental pollution while prolonging the lifecycle of materials (Manandhar et al., 2022).

The recycling industry is still in its infancy in Ethiopia, a developing nation with a very low per capita paper consumption of less than 2 kg as opposed to the global average of 55 kg (GBN, 2020). To meet domestic pulp demand, the nation imported 1,572.4 tons of scrap paper annually on average between 2015 and 2019 (Simret Girma 2022). Due to the lack of a systematic collection system and the scarcity of high-quality waste paper, Ethiopia's nine formal waste paper recycling industries, which have a combined design capacity of 114,710 tons/year, only operate at about 20% of their full potential(Simret Girma 2022). The informal sector, which includes both individual collectors and community-based "Korales," is primarily responsible for managing the collection of recyclable waste (GBN, 2020).

In Ethiopia, recycling paper not only promotes environmental sustainability but also generates jobs in the fields of processing, sorting, and collection. Thousands of people make their living in the formal and informal sectors, and as recycling rates rise, there is even more room for job creation(Mcmillan and Zeufack 2022). Ethiopia can lessen its dependency on imported raw materials and preserve economic value domestically by using recycled paper, which will help create a more resilient and circular economy (GBN, 2020; Ma et al., 2021).

Figure 4. Waste Material Exchange Network Among Informal Actors in Addis Ababa



Source: (GBN) 2020)

6. Environmental Benefits of Waste Paper Recycling

Recycling waste has long been a major global environmental concern. Environmental sustainability has emerged as a major concern as countries work toward sustainable development, tackling issues like pollution, ecosystem degradation, climate change, and the depletion of natural resources (Haile Gelebo et al., 2021). Global paper consumption is still increasing despite the quick development of electronic media and digital communication. Significant environmental risks, such as deforestation, pollution emissions, and landfill overcrowding, are brought on by this rising demand. Paper recycling has therefore become a pressing worldwide issue (Liu et al., 2021).

In light of climate change, energy conservation and lowering greenhouse gas (GHG) emissions have drawn a lot of attention. The paper industry is one of the manufacturing sectors with the highest energy consumption and greenhouse gas emissions (Girma et al., 2021). When compared to other waste management techniques, recycling waste paper is thought to be a significant way to reduce carbon emissions (Shang et al., 2021).

Recycling paper has several advantages for the environment. Recycling saves landfill space for non-recyclable waste, lowers GHG emissions, conserves natural resources, and uses less energy (Shang et al., 2021). One ton of recycled paper can, on average, save 24–28 trees (12 m tall with a diameter of 15–20 cm), stop 36 tons of CO_2 and 267 kg of other pollutants from being released, save about 4,100 kWh of electricity, 1,750 liters of fuel oil, 38.8 tons of water, and save 3–4 m^3 of landfill space (Gupta et al., 2021). Paper and its waste can be recycled and biodegraded. Because 35% of the trees that are felled are used to make paper, the 400% increase in paper consumption over the past 40 years has contributed to deforestation.Recycling reduces the amount of heavy metals like Pb and Cd that are released during open burning or landfilling, as well as harmful gases like CO, SO_2, NOx, VOCs, ozone-depleting CO_2, and methane (Ozola et al., 2019; Agrawal et al., 2021).

When compared to the production of virgin pulp, the use of recycled fibers in Ethiopian papermaking can drastically cut carbon emissions and energy consumption by almost 50%)(MOHAMMED 2024). Recycling paper also lessens the need for landfills and deforestation, which addresses environmental risks related to burning or disposing of waste (Ozola et al., 2019; Agrawal et al., 2021). Additionally, incorporating agricultural waste—such as cotton, sugarcane, and banana stalks—into the paper recycling process improves sustainability and harmonizes Ethiopia's pulp and paper industry with the principles of the global circular economy (Sustainability MEA, 2023).All things considered, recycling paper is an important way to lessen the effects on the environment, conserve resources, and advance sustainable development in Ethiopia and around the world.

7. Conclusion

Ethiopia's paper consumption is still very low, at less than 2 kg per person annually, but the country imports more than USD 100 million worth of pulp and paper annually, while more than 200,000 tons of wastepaper are generated annually in municipal solid waste streams, of which only about 5% is recycled. This imbalance between high import dependency and low recycling performance emphasizes the urgent need for a national shift toward a circular paper economy. Recycling wastepaper offers significant environmental benefits and strong economic potential globally, but it is even more critical in the Ethiopian context,

as this review shows.

Ethiopia has significant unrealized potential in the environmental and economic aspects of recycling waste paper, according to the study's findings. Recycling waste paper can help the environment by lowering carbon emissions linked to the production of virgin pulp, saving a substantial amount of energy and water, and lessening the strain on forest resources. Research consistently demonstrates that one ton of recycled paper can prevent significant landfill usage and water pollution, save 4,100 kWh of energy, save about 36 tons of CO_2 equivalent emissions, and save about 24 to 28 mature trees. These advantages are immediately applicable in Ethiopia, where urban waste accumulation, land degradation, and deforestation are significant environmental issues. The review also emphasizes how replacing virgin wood pulp with recycled fibers, and possibly with pulp made from agricultural residue, can cut energy consumption and emissions by almost 50%, supporting Ethiopia's environmental sustainability and climate resilience objectives.

Economically speaking, the results highlight how recycling waste paper can lessen Ethiopia's dependency on imported raw materials, preserving foreign exchange and enhancing domestic production capabilities. Due to an irregular and inadequate supply of high-quality wastepaper, Ethiopia currently has nine wastepaper-based recycling industries with a combined yearly capacity of 114,710 tons, but these facilities only operate at around 20% of their full potential. Stable inputs for industry and long-term revenue opportunities can be created by fortifying the collection network, especially through the integration of the informal sector, which includes "Korales," who are essential to resource recovery. Experiences from other countries demonstrate that recycling sectors are labor-intensive and have the potential to create a significant number of formal and informal jobs throughout the value chain. Increased recycling rates in Ethiopia would lead to the creation of jobs in the transportation, processing, manufacturing, waste collection, and sorting industries, which would help to reduce poverty and promote inclusive urban development.

The study also finds that institutional and policy gaps, in addition to inadequate collection systems, are impeding Ethiopia's recycling industry. The sector's poor performance is caused by a number of factors, including a lack of Extended Producer Responsibility (EPR), insufficient incentives for recycling industries, shaky market connections, and low public awareness. The results indicate that formalizing the informal waste collection system, implementing EPR frameworks, and offering financial and technical assistance to recycling businesses could all greatly increase the wastepaper value chain's sustainability and efficiency. In the Ethiopian context, such reforms are both feasible and effective because, according to lessons learned from international best practices, coordinated policies can raise recycling rates from below 10% to above 50% in just ten years.

Furthermore, there is a significant chance to diversify the sources of raw materials thanks to creative methods that are being developed in Ethiopia, such as the production of pulp from cereal straws, banana stems, and other agricultural waste. This is in line with global trends toward resource-efficient production and bio-based materials. Ethiopia might create a hybrid pulp system that lessens its impact on the environment, lowers production costs, and strengthens ties between the rural and industrial sectors by combining recycled fibers with agricultural residues.

All things considered, the study's findings unequivocally show that increasing wastepaper recycling is a viable and strategic course for Ethiopia. In terms of the environment, it will lessen the pressure on urban landfills, greenhouse gas emissions, and deforestation. In terms of the economy, it will boost industrial competitiveness, save foreign exchange, and generate good jobs. Socially, it will promote livelihood opportunities in both the formal and informal sectors and enhance urban sanitation. Enhancing wastepaper recycling is therefore a comprehensive development strategy that is in line with Ethiopia's long-term economic and environmental priorities rather than just being an environmental intervention.

Coordinated efforts are required if Ethiopia is to reap these benefits. This entails developing clear policy frameworks, integrating informal collectors, enhancing recycling technologies, improving waste collection infrastructure, and increasing public awareness of waste sorting at the source. To further support evidence-based policy decisions, future research should concentrate on quantifying the potential for job creation, economic value recovery, and carbon savings using local data.

The results of this review conclude that recycling waste paper offers Ethiopia significant economic and environmental advantages. Ethiopia can turn wastepaper from an underutilized waste stream into a valuable economic resource by implementing a circular economy strategy and making investments in an efficient recycling system. This change has the potential to greatly improve sustainability, lessen reliance on imports, and make a significant contribution to the nation's green development agenda.

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RESP

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Araştırma Makalesi ● Research Article

A Potential Method For Adaption of Circular Economy Into the Textile and Apparel Industry? *

Döngüsel Ekonominin Tekstil ve Hazir Giyim Endüstrilerine Uyarlanmasi İçin Bir Potansiyel Yöntem?

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ANAHTAR KELİMELER

Döngüsel Ekonomi,
Tekstil,
Hazır Giyim,
Sürdürülebilir Üretim,
Çevresel Etkiler

ÖZ

Sera gazı emisyonlarındaki artış, iklim değişikliğinin yol açtığı kırılganlıklar ve doğal kaynakların hızla tükenmesi, şirketleri doğrusal ekonomiden döngüsel ekonomi modeline geçişe zorlamaktadır. Mevcut doğrusal model, tekstil ürünlerinin üretim, kullanım ve bertaraf aşamalarında sürdürülemez sonuçlar doğurmakta; 2023 yılında küresel elyaf üretiminin 124 milyon tona ulaşması ve her yıl 90–100 milyar giysi üretilmesi bu baskıyı artırmaktadır. Üretilen giysilerin yaklaşık 92 milyon tonunun çöplüklere gitmesi, tekstil atıklarının küresel depolama alanlarının en az %7'sini oluşturduğunu göstermektedir. Lif ve kumaş üretiminden başlayan ve fosil yakıtlara yoğun şekilde bağımlı olan bu süreçlerin, kaynak tüketimi ve çevresel etki açısından çok yüksek maliyetler yarattığı; sektörün küresel CO_2 emisyonlarının %3'ünden ve su kirliliğinin %20'sinden sorumlu olduğu bilinmektedir. Döngüsel tekstil modeli, ürün yaşam döngüsünün sonunda onarım, yeniden kullanım ve geri dönüşüm yoluyla malzemelerin ekonomik sistem içinde tutulmasını hedeflemekte ve sürdürülebilir büyüme, doğal kaynakların korunması ve ekonomik refah açısından stratejik bir zorunluluk olarak ortaya çıkmaktadır. Bu makale, tekstil ve hazır giyim işletmelerinin döngüsellik ve sürdürülebilirlik ilkelerini uygulayabileceği yöntemleri incelemekte; başarılı bir dönüşümün, işletme içi süreçlerin yanı sıra belediyeler, STK'lar ve tüketici tutumlarının desteğine bağlı olduğunu ortaya koymaktadır.

KEYWORDS

Circular Economy,
Textiles,
Apparel,
Sustainable Production,
Environmental Impact

ABSTRACT

Rising greenhouse gas emissions, climate-related vulnerabilities, and the depletion of natural resources are compelling companies to shift from a linear to a circular economic model. Within this context, the production, use, and disposal stages of textile products have become clearly unsustainable under the current linear structure. Global fiber production reached a record 124 million tons in 2023, and an estimated 90–100 billion new garments are produced annually. Alarmingly, about 92 million tons of these garments end up in landfills, where textile waste is estimated to account for at least 7% of total global landfill volume. The production chain—from fiber manufacturing to fabric processing—relies heavily on fossil fuels, resulting in significant resource consumption and environmental impact. The sector is known to contribute approximately 3% of global CO_2 emissions and 20% of global water pollution. The circular textile model aims to extend product life and maintain material flows within the economic system through repair, reuse, and recycling at the end of the product lifecycle. This approach is not a passing trend but a necessity for conserving natural resources, ensuring sustainable growth, promoting responsible consumption, and supporting overall economic well-being. This article reviews studies outlining methods through which textile and apparel firms can adopt circularity and sustainability principles. It argues that a secure transition requires coordinated actions at internal, external, and broader environmental levels, and that the speed and success of this transition depend not only on firms' circularity performance but also on the support of municipalities, NGOs, and consumer attitudes.

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1. Introduction

The circular economy is an economic model aimed at minimizing waste and making the most of resources. It emphasizes sustainability by promoting the reuse, recycling, and regeneration of materials, unlike the traditional linear economy, which follows a "take, make, dispose" approach. This traditional model appears to have reached its physical limitations (Ellen MacArthur Foundation, 2015). It is responsible for generating a total global waste of around 20 billion tonnes every year. This is an estimated figure calculated for the year 2017 (Maalouf & Mavropoulos, 2023) based on material flow analysis. It is supposed that the total waste arising requires the consideration of the entire life cycle of materials and products. These include mining and quarrying wastes (extraction); agricultural and forestry wastes; industry wastes (materials, parts, and product manufacturing); construction and demolition waste; commerce and institutions waste (distribution and services); consumption (households) and MSW (municipal solid waste). The consequences of those wastes on the Earth is huge, no matter it is hazardous or not. They lead to considerable damage on ecosystems and marine life, and pollution on water sources, and contribute to air pollution through greenhouse gases.

In recognition of the constitutional role of the environment together with its functions and interactions within the economic system, the circular economy (CE) has emerged as a promising alternative to the neoclassical economic model (Ghisellini et al., 2016). The concept of the circular economy has evolved over several decades, drawing from various fields and movements focused on sustainability and resource efficiency. The roots of the CE can be traced back to early environmental movements. The idea of "closed-loop" systems emerged. Kenneth Boulding was one of the pioneers promoting recycling and waste reduction for sustainable resource use. He described an alternative paradigm, a closed economy that might also be called a "spaceman" economy. Boulding refused to measure success based on levels of production and consumption and advocates for a measure based on the nature, quality, and total capital stock, including the state of human bodies and minds (Boulding, 1966).

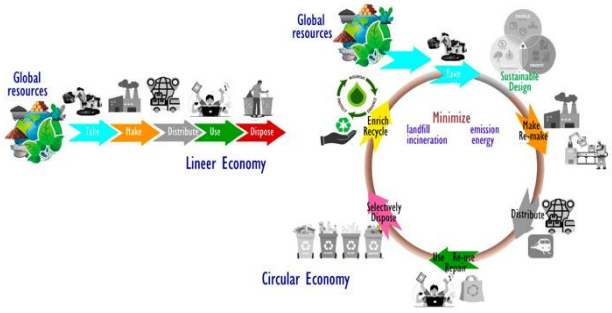

Figure 1. The Concept of Circular Economy and Comparison with the Linear Economy Model (adapted from various sources).

In the 1980s, the concept of Industrial Ecology was introduced, and the rise of eco-design principles encouraged manufacturers to consider the environment. The Earth was perceived as a single spaceship with no unlimited resources, and man had no alternative but to reconnect with the cyclical ecological system that could only provide materials to be reused continuously.

Pearce & Turner (1990) were reported as the first formal user of the term "circular economy" in an economic model for the first time by focusing on the principle that "everything is an input to everything else". The authors criticized the traditional linear economic system and introduced a new economic model, in the name of CE. This model was said to exploit the principles of the first and second laws of thermodynamics. It actually establishes a prominent link between the economy and the environment by incorporating three economic functions of the environment: resource supplier, waste assimilator, and source of utility. In the 2000s, the CE concept attracted great interest and increasing popularity. This approach was highly recognized by the European Union by emphasizing waste reduction and resource efficiency in its policies. The concept of the CE in comparison with the linear economy model is illustrated in Fig.1. As seen in the figure, the CE maintains a closed loop cycle on the base of a regenerative system that aims to maximise product and material utilizations and minimizes the entry and waste of resources, emissions, and expenditure of energy through slowing down, closing, and straightening material and energy circuits. Following the very first definition of Pearce & Turner, various definitions of the CE respecting several concepts have been presented by many researchers. A number of authors have specified resource-oriented definitions and interpretations, emphasising the need to create closed loops of material flows and decrease the consumption of virgin resources and their consequent harmful environmental impacts. They believe that the essential priority of the CE is the reduction of resource consumption, pollution, and waste in each step of the product's life cycle (Rizos, Tuokko, and Behrens, 2017).

A definition by the Ellen MacArthur Foundation (2013) has been one of the most frequently cited definitions that incorporates elements from various disciplines. The CE was defined as "*an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models*."

In the view of the cradle-to-cradle approach and systems thinking, this interpretation of the concept involves the distinction of two different types of materials: materials of biological origin that can return to the biosphere as feedstock (e.g., forest products) and technical materials, which cannot biodegrade and enter the biosphere (e.g., plastics and metals). Under this framework, the circular economy aims to keep both types of these materials at their highest utility

and value at all times through careful design, management, and technological innovation (Ellen MacArthur Foundation, 2013; 2015).

At the EU level, the European Commission (2015) has included a description of the concept in its Communication "Closing the loop – An EU Action Plan for the circular economy", which is part of the Circular Economy Package. Specifically, the circular economy is defined as an economy "where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste is minimised." A possible shift to a more circular economy would make "an essential contribution to the EU's efforts to develop a sustainable, low carbon, resource efficient and competitive economy". In this context, the EU Action Plan includes a series of measures aimed at addressing the full product cycle from production and consumption to waste management and the market for secondary raw materials.

The CE offers a reliable structure for radically improving the current economic model within the scope of developing a preventive and regenerative eco-industry, as well as boosting well-being based on recovered environmental integrity. Based on existing literature, key principles of CE may be summarised as follows:

1. Design for Longevity: Products should be designed to last longer, be easily repaired, and have modular components to facilitate upgrades.
2. Resource Efficiency: Usage of all resources should be conducted more efficiently by reducing consumption and minimizing waste in production processes.
3. Waste as a Resource: Materials that would typically be considered waste are viewed as potential resources for new products, fostering a closed-loop system.
4. Collaboration: Encourages cooperation among businesses, consumers, and governments to create sustainable systems and support each other in the transition.
5. Business Model Innovation: Shifts from ownership to service-based models such as leasing, or incorporating partnership and sharing , or reducing the need for new products

It must be emphasized that the CE cannot be obtained through attempts by individuals. Instead, the CE involves a systemic change in companies, industries, and economies through radical shifts in societal values, norms, and behaviours (Chizaryfard et al., 2020). Furthermore, the CE is intrinsically bound to environmental innovation in the way societies legislate, produce, and consume (Prieto-Sandoval et al., 2018; Suchek et al., 2021).

2. The Impacts of Textiles and Apparel Industry and Adaptation Models on the Circular Economy

The textiles and apparel industry is reported to represent 3.7 per cent of world merchandise exports in 2022 (WTO, 2024). The global apparel market size is expected to reach US$2.6 trillion in 2025, growing by a projected rate of 4%. The production of textiles and apparel is realized through geographically long and complex supply chains. Supply chains in the sector are labour-intensive, with economies specializing in the production and transformation of raw materials into fabrics, fibre, and finished products. This long and diverse chain consists of growers and processors of raw fibres, yarn spinners, weavers, knitters, dyers and finishers, garment makers, product manufacturers, and distributors. The range of textile products is quite varied, from interiors and automotive fit-outs to geo-textiles, Agri-textiles, and hygienic textiles, but the sector is primarily fashion-driven, as most global fibre production (60%) is used for clothing (Niinimäki et al., 2020). The current practices of the textile and apparel industries are widely criticized for environmental problems such as excessive waste generation, intensive use of hazardous chemicals, water, and energy, the release of air pollutants, greenhouse gas (GHG) emissions, and inadequate disposal of used textile products into the municipal solid waste (Ozek, 2023). The industry produces both operational and environmental waste during the life cycle of various products, including fiber, yarn, and fabric production, dyeing and finishing processes, and distribution and transportation operations (Niinimäki et al., 2020; Patti et al., 2021; Schmutz & Som, 2022). According to the Ellen MacArthur Foundation (2017), the GHG emissions from the textile and apparel industry exceed the combined emissions from maritime transport and international aviation. Further, it is expected that this industry will account for a quarter of the world's carbon emissions by 2050 if air pollution and GHG emissions continue along this path (Ellen MacArthur Foundation, 2017). The manufacturing processes of textile products such as garments, footwear, and technical and household textiles consume massive amounts of water and primary raw materials. According to an estimate, this industry consumes 93 billion cubic meters of water annually, discharges 20% of the global industrial wastewater, and 200,000 tons of untreated dyes; hence, it is recognized as the second largest water-polluting industry in the world (Khan et al., 2023; Saha et al., 2021; UNCTAD, 2019). The untreated wastewater discharge from textile companies has adversely affected groundwater purity, which causes a serious threat to human health and animal species (Saha et al., 2021). In addition, microplastics and chemicals are released into the wastewater from household washing of garments (Camilleri, 2020). Further, due to the low recycling rate, post-consumer textile waste is often incinerated, landfilled, or exported to developing economies (Camilleri, 2020).

Figure 2. Global Impacts of Textile and Apparel Industries Based on the Linear Economy Model

The ongoing practices of textile and apparel companies, acting in accordance with the concept of linear economy are liable to induce various impacts on the environment, social life, and economy. The primary impact factors are illustrated in Fig. 2. As shown in the figure, the conduction of textile and apparel production in respect of the current linear economy model results in serious harmful impacts in consideration of climate change, environmental safety, and human health. The long supply chains and high energy demand in manufacturing of textiles, apparel, and footwear industries produce 8–10% of the overall carbon emissions (European Parliament, 2021). Around 1.2 billion tonnes of CO2 equivalent (UNFCCC, 2018) generated by these sectors surpasses total emissions from international aviation and maritime shipping. The European Union is reported to produce 12.6 million tonnes of textile waste per year. Apparel and footwear alone are responsible for 5.2 million tonnes of waste, which is equivalent to 12 kg of waste for each person per year. Currently, only 22% of post-consumer textile waste is collected separately for reuse or recycling, while the remainder is usually incinerated or landfilled.

In general, companies in the textile and apparel industry have focused on the optimisation of a linear clothing economy, which enables an increase in speed, trendiness, and cheapness at the expense of quality and sustainability (Pedersen et al., 2019). This approach is likely to boost even higher clothing production (Ellen MacArthur Foundation, 2017), but also high pressure to reduce the use of natural resources such as water and land, as well as resultant harms on the waste growth, greenhouse gas emissions, and fresh water pollution (EEA, 2019).

Owing to the increasing sustainability issues, environmental regulations for the textiles and apparel industry are becoming more stringent and require manufacturers to implement circular design principles and practices to ensure their engagement in sustainable and closed-loop business models. By adopting such business models, manufacturers can reuse and recycle their resources, effectively handle the chemicals in an environmentally friendly manner, and drive consumers towards sustainable consumption practices (Camilleri, 2020). Among these models and business strategies, the circular economy (CE) is recognized as an emerging paradigm that has changed the definition of waste from materials, products, or substances that cannot be used anymore to a more valuable resource (Schmutz & Som, 2022).

In response to high pressure to move towards CE, the concept of circular economy is widely accepted and therefore attempts have been made to adapt into the manufacturing strategies in overwhelming crucial environmental issues through closed-loop production systems that foster reusing and recycling products, reducing raw material and natural resource consumption, minimizing waste, creating value, and achieving environmental stewardship (Awan et al., 2021; Ul-Durar et al., 2023). The presence of a strong relationship between the principles of CE and the sustainability concept was proved by a study (Colucci & Veccchi, 2020), endorsing the opinion that there is a beneficial interrelation between the two. The study exhibits the emergence of categories of CE-related practices as well as challenges for the CE adoptation. Some insights on the nature of these challenges hindering the CE implementation and also by what method they can be turned into sources of competitive leverage are demonstrated.

Figure 3. Individual Stages of a CE Model for Adaptation into Textiles and Apparel Industry (Furferi et al, 2022).

Possible directions for new ways and solutions to convert processed textiles into inputs or byproducts for re-manufacturing are referred to as a trump card for the future of the textile sector by an article about CE guidelines for the textile industry (Furferi et al, 2022). This study aims to provide a set of guidelines to lead textile industries in the transition from conventional production operations to a systematic approach in conjunction with the CE. The steps of operations proposed by the relevant method are applicable to products based on the use of regenerated materials or the combination of reused wool products certified as organic materials. This method was claimed to be capable of recovering a material "better than the virgin one" with important aesthetic characteristics and greater durability in terms of the product. The individual phases of the circular process developed by this particular approach are given in Fig. 3. In consideration of such a framework,

the following challenges are explained to be confronted with reference to a company in Italy.

- Definition and drafting of a Sustainability Report;
- Optimization of the (raw and recycled) materials was conferred.
- Eco-Design of textile products, so that they are as environmentally friendly as possible; Implementation of a supply chain traceability, integrating the Blockchain paradigm;
- Assessment of products and processes in terms of Life Cycle;
- Optimization of the textile products distribution;
- Improvement of the consumption practice by end-users and study of products' end of life; Reintroduce most products in the circular process.

There exist some studies in the literature proposing a roadmap or guidance for transmission. Such a transmission operation requires firm changes in the company logic they are creating, delivering, and capturing value, including changes in markets, business logic, and organisational culture (Lewandowski, 2019). One study proposed a roadmap to transform the current business model into a circular one (Frishammar & Parida, 2019). A theoretical framework of circular economy ecosystem emergence was presented in a study (De Vito, 2025), as a transitional phase or "real utopia". Potential drivers behind emergence were defined by uncovering the pivotal role ecosystem orchestrators play in governing the interdependencies between actors and activities across the different intersecting ecosystems. The study concluded that the power and efficiency of orchestration can play a very critical role in the transformation. However, in most studies, the nature and capabilities of the company relevant to the shift are not taken into consideration.

The companies are willing to develop capabilities for anticipating opportunities and quiting the perceived linear business culture, and also reorganizing all the resources of the company, accordingly. The point and grounds of the company within the global value chain affect the style companies can impelement the basics of circularity. A strong position that allows control over the circularity of the value chain can be achieved through ownership or by allying in business ecosystems. The three factors affecting the transition to the CE model are illustrated in Fig. 4. The stages of progress between the linear and circular economy model are redefined as linear incumbent, hesitant, circular incumbent, and born circular company. This study aimed to identify factors that affect the business model transformation process of incumbent textile companies and capabilities needed to overcome the inertia caused by these factors. It appears that dependency on the prevailing product portfolio, a product-oriented business model, and the position in the supply chain crucially affect the efficiency with which incumbent companies can become circular. Dependency on the prevailing product portfolio may serve the purpose of economic performance, but not necessarily ecological and sustainable performance.

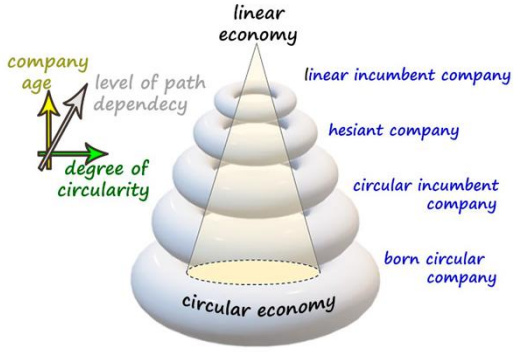

Figure 4. The Transmission Path of Textile and Apparel Companies from Linear to Circular Economy (adapted from Salmi and Kaipia, 2022)

Another study (Herrador & Imanisihi, 2025) investigated the dynamic field of the circular textiles and fashion industry of Japan, featuring its distinctive position and potential to catalyse business competition and collaboration with the European Union. It was based on desk research with a systematic literature search, and directed twenty interviews with partners from SMEs to large multinationals, government officials, clusters, and public and private sector stakeholders in Japan and the EU. The analysis of the circular textile and fashion industry of Japan pointed out the private company activities promoting circularity among local enterprises and consumer trends. The challenges in the transition operation were given as the lethargic circular textile and fashion commerce between demographic and economic trends, the collapse of traditional textile enterprises, and the domination of multinationals. The difficulty for manufacturing businesses is to become "self-sufficient" regarding product development and sales because they are concentrated in specific manufacturing fields, and in most cases, they rely on outsourced production rather than creating their own goods. The strengths and challenges of companies in the supply chain are tabulated with respect to company style in Table 1. -Table 1 is in the Annex.- Trading companies appear to conduct circularity better than others. A synergic cooperation was designed between EU and Japanese circular textiles and fashion businesses to promote circularity in both regions, address challenges, and seize opportunities. This article may provide helpful insights for policymakers and businesses, ranging from local startups to global enterprises, aiming to capitalize on Japan's CTF. Industry In the adaptation of CE, the existence of circular economy policies and planning approaches in cities is often remarked as a critical supporting factor and an emerging research field. A recent article (Christensen, 2021) examined how municipalities and constituent of city facilitate and support the adaptation of CE through multiple modes of governance, e.g., by means of their own assets. To keep the ownership of utility and waste companies for supporting the CE; the assignment of rule

enforcement or economic regulation, or through facilitating, coordinating, collaborating, and encouraging, is analysed in depth with reference to Denmark. It was stated that the Danish municipalities collaborated with local stakeholders to close the material loop for demolition materials and textile waste. The potential of increasing textile recycling in Denmark is analysed by a set of scenarios developed on a baseline projection and variations with increasing the amount of textiles recycled by mechanical and chemical processes. The first scenario was developed on the basis of an assumption that the current NGO-based system will be maintained, while a second scenario was designed to underline the potential of a new system whereby all textiles are collected under a municipal system and recycled in Denmark. A collection scheme was established to map and assess the quantity and quality of textile waste. The local municipality implemented a scheme for the use of clothing and shoes. Two different collection systems were used due to the lifestyle differences between the two socio-economic classes. It was seen that the collection rates for source-separated municipal solid waste are higher in one-family homes than in high-rise homes. The outline of the second scenario is given in Fig. 5, where the flow of materials is schematically shown with potential reuse and recycling steps. The ratios of reused and recycled materials are increased as much as 30-40%. It may seem that more than half of the 95.600 tonnes of textiles sold in Denmark are achieved to be reused or recycled within Denmark and other countries (ROW). The scepticism about the actual fate of the exported textiles and partly disposal details (landfilled, incinerated, or recycled) is pointed out as a drawback of this scenario. The revision on the second scenario assumes that it would be easier for municipalities to verify that the collected textiles are actually recycled and that the system will create a closed loop where textile fibres are continuously recycled and not landfilled after being reused once. The conclusion of this study has confirmed that municipalities can function as an important change agent to support and facilitate the transformation to CE.

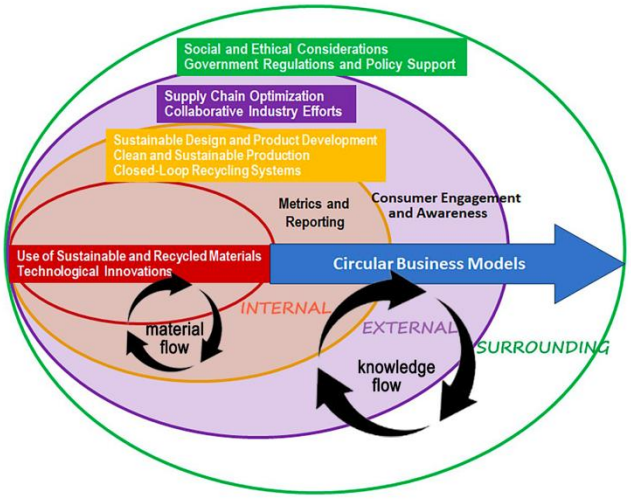

Figure 5. Baseline Textile Flow for a Scenario B: 2025 (modified for CE approach) in Denmark. (Christensen, 2021)

A study by Salmi and Kampia (2022) investigated the capabilities that enable clothing brands to transition from a linear economy to Circular Business Models. The study found that the company-level implementation of the circular economy is still poorly understood, leaving companies without clear guidelines on how to make the transition. The study focused on two key issues: how past trajectories influence the ability of clothing brands to adopt circular business models, and the specific capabilities needed to overcome transformation-related challenges. The research, conducted in seven fashion brand companies in Finland, revealed that a company's product orientation and its reliance on the current product portfolio significantly influence its ability to transform its business model.

3. The Proposed Method for Adaptation of Circular Economy Into Textiles and Apparel Industry

An assignement for implementing the selected CE model in the textiles and apparel industry should be conducted by a systematic approach that integrates sustainable practices throughout the full supply chain, from raw material sourcing to production, consumption, and end-of-life management. The prime main objectives are to minimize waste and to extend product life cycles by creating closed-loop systems where materials are continuously reused and recycled. These principles require systematic operations at both the inside and outside the company level. The internal tier involves the raw material supply, design, and production. The external tier extends until the customer purchases, uses, and disposes of it at the end of life. The surrounding tier consists of the actions of policy makers and the collaboration of local administration and municipalities. This model is illustrated in Fig.6.

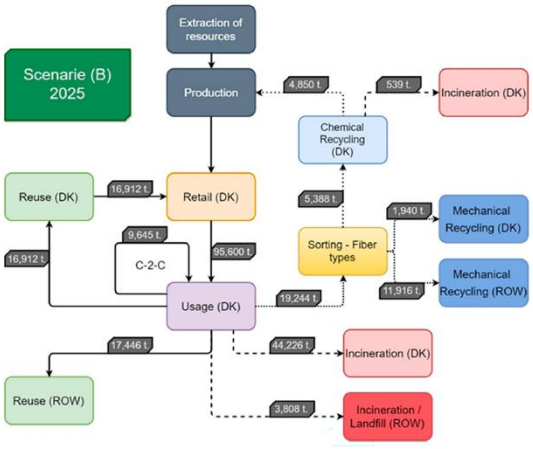

Figure 6. The Extent and Tasks of Three Tiers of CE Model for Textiles and Apparel Industry (borderlines of internal, external, and surrounding tiers)

Integration of these three tiers and the flow of material and knowledge between them are obviously critical in terms of circularity, collaboration, and transparency. The completion of each task in accordance with the conditions and

requirements of the company and also in comply with regulations is critical steps for the adaption of circular economy model. The essential tasks are reviewed below in relevance to tiers.

The Internal Tier (Level)

I. Use of Sustainable and Recycled Materials

- Organic and Renewable Materials: Using organic cotton, hemp, or bamboo can reduce environmental impacts, as these materials typically use less water and chemicals compared to conventional materials. Fiber supply from Better Cotton Initiative (BCI) or Responsible Wool campaigns and promoting ecological farming are also important. In the procurement of raw materials, internationally recognized standards, such as GOTS (Global Organic Textile Standard), OCS (Organic Content Standard), and GRS (Global Recycled Standard), may also be among the selection criteria.
- Recycled Fibers: Using fibres made from recycled materials, such as recycled polyester (from plastic bottles) or regenerated cellulose fibres (from textile waste), can reduce the need for virgin materials.
- Biodegradable Textiles: The Development and use of biodegradable fibres, which break down naturally at the end of their life, are crucial for reducing textile waste in landfills.

II. Technological Innovations

- Blockchain for Traceability: Implementing blockchain technology can ensure full transparency of materials, production processes, and product lifecycles. This can help brands track the origins of fibres, ensure ethical practices, and facilitate recycling.
- Digital Tools for Waste Reduction: Advanced technologies like 3D printing, AI-driven demand forecasting, and virtual fitting rooms can reduce waste in production and improve inventory management.

III. Sustainable Design and Product Development

- Design for Durability: Clothes should be designed to last longer, be repairable, and resist trends that encourage short-term use. This includes using durable materials, strong stitching, and modular designs.
- Design for Recycling: Products should be made from materials that can easily be disassembled and recycled. For example, avoiding mixed materials (like cotton and polyester blends) that are hard to recycle.
- Cradle-to-Cradle Design: This design philosophy focuses on creating products that can either be reused or safely returned to the environment, with materials cycling through biological or technical loops.

IV. Closed-Loop Recycling Systems

- Textile Collection and Sorting: Implement systems for collecting used clothing, either through brand take-back programs, third-party collectors, or municipal initiatives. Collected garments can then be sorted for reuse or recycling.
- Mechanical and Chemical Recycling: Establish recycling technologies to break down textiles into their raw components. Mechanical recycling is useful for cotton and wool, while chemical recycling can be applied to synthetics like polyester.
- Fiber-to-Fiber Recycling: Developing technologies that can turn post-consumer textiles back into high-quality fibres suitable for new garments is key for a closed-loop system, both biological and technical loops.

V. Clean and Sustainable Production

- Cleaner Production: Clean textile production conceptually leads to an integration of continuous applications of preventive environmental strategies to processes, products, and services, aiming to minimize possible risks to people and the environment, as well as to increase material efficiency. The utilization of clean production or Best Available Techniques (BAT) practices contributes to the preservation of raw materials and energy sources, reducing or eliminating toxic materials and minimizing the quantity and toxicity of the emissions and the residues during the production processes.
- Sustainable Production Technics: Plasma technology, ozone fading, enzymatic processing, and super whitewashing are the approaches to make textile wet processing more environmentally friendly. To conserve the world's resources while keeping up with surging consumer demands, necessitates the exercises of sustainable practices and processes.
- Implementation of the Green Production Concept: It is known that swings in fashion trends and the shortening of vogue cycles are major accelerators for the disruption of ecological balance. A profusion of pioneering initiatives and advancements to achieve certain sustainable remedies within the production and consumption paradigms of the contemporary clothing sector is critical. Moreover, sustainable techniques within the apparel sector encompass not just environmentally friendly supply chain control, but also the facilitation of a cost-effective and socially agreeable production setup.

VI. Circular Business Models

- Search for CE Business Models: A circular business model is a powerful tool that articulates how an organization can create, deliver, and capture value for its stakeholders while minimizing ecological and social costs. By adhering to the circular economy's principles

of Designing out waste and pollution, Keeping products and materials in use, and Regenerating natural systems, these models have the potential to significantly reduce waste and inspire a more sustainable future.

- Green Deal Concept: A business model complying with the conditions of European Green Deal which was officially launched in 2019 is essential. A new phase of ambitious environmental action and sustainable development within the EU has evolved into a comprehensive policy framework with various initiatives and legislative proposals (Lüttin, 2025) aimed at achieving its sustainable green production and consumption objectives.
- Resale and Second-Hand Markets: Brands can set up platforms to sell pre-owned clothes or partner with second-hand marketplaces to extend the life of garments.
- Rental and Leasing Models: Instead of ownership, consumers can rent clothing for specific occasions (e.g., formal wear, maternity wear), helping to reduce overconsumption and waste.
- Repair and Refurbishment Services: Providing repair services or offering incentives for customers to repair damaged garments can extend product lifecycles. Brands can also refurbish and resell slightly used or damaged items.
- Cleaner Production: Clean textile production conceptually leads to an integration of continuous applications of preventive environmental strategies to processes, products, and services, aiming to minimize possible risks to people and the environment, as well as to increase material efficiency. The utilization of clean production or Best Available Techniques (BAT) practices contributes to the preservation of raw materials and energy sources, enabling the reduction or elimination of toxic materials and minimizing the quantity and the toxicity of the emissions and the residues during the production processes.
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VII. Circular Business Models

- Search for CE Business Models: In general, a circular business model is expected to articulate the logic of how an organization creates, delivers, and captures value to its broader range of stakeholders while minimizing ecological and social costs. An appropriate model adhering to the circular economy's three fundamental principles, namely Design out waste and pollution; Keep products and materials in use; and Regenerate natural systems, should be selected and implemented.
- Green Deal Concept: A business model complying with the conditions of European Green Deal which was officially launched in 2019 is essential. A new phase of ambitious environmental action and sustainable development within the EU has evolved into a comprehensive policy framework with various initiatives and legislative proposals (Lüttin, 2025) aimed at achieving its sustainable green production and consumption objectives.
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The External Tier (Level)

VIII. Metrics and Reporting

- Circularity Metrics: Brands need to track and report on key circularity indicators, such as the percentage of recycled materials used, the amount of waste diverted from landfills, and the lifecycle extension of garments.
- Life Cycle Assessment (LCA): Conducting LCAs for products can help companies identify the environmental impacts of their operations and make improvements in areas like water usage, carbon footprint, and waste generation.

IX. Supply Chain Optimization

- Efficient Use of Resources: Optimize the supply chain to reduce resource use, including water, energy, and

chemicals. Technologies like digital printing and waterless dyeing can minimize environmental impact.

- On-Demand Production: Shifting towards on-demand or small-batch production reduces overproduction and unsold inventory, which often leads to waste.
- Local Production and Shorter Supply Chains: Localizing production can reduce transportation emissions and support more agile and responsive manufacturing systems.

X. Consumer Engagement and Awareness

- Promote Conscious Consumption: Brands can educate consumers on the environmental impact of fast fashion and encourage them to buy less but better-quality, durable products.
- Transparency and Labelling: Providing clear information on the origin of materials, recyclability, and care instructions can help consumers make informed decisions and prolong the life of their clothes.
- Incentivizing Sustainable Choices: Offering discounts or loyalty rewards for returning used garments, renting instead of buying, or choosing sustainably-made products can motivate consumer participation in circular systems.

XI. Collaborative Industry Efforts

- Shared Infrastructure: Collaborating with other brands, suppliers, and even competitors to share recycling facilities, repair centres, and logistics can reduce costs and improve the scalability of circular solutions.
- Industry Standards and Certifications: Adopt and develop industry-wide standards for sustainable and circular practices, such as certifications for recycled materials, fair labour practices, and eco-friendly production methods.

The Surrounding Tier (Level)

XII. GGF Government and Policy Support

- Extended Producer Responsibility (EPR): Governments can mandate that brands take responsibility for their products throughout the entire lifecycle, including take-back schemes and recycling.
- Incentives for Sustainable Practices: Financial incentives, such as tax reductions for companies using recycled materials or penalties for excessive waste, can encourage more circular practices.
- Regulations on Waste and Pollution: Introducing strict regulations to limit textile waste, reduce emissions, and ensure proper disposal of hazardous chemicals can drive the transition towards circular practices.

XIII. Social and Ethical Considerations

- Fair Labor and Ethical Production: Circular models must also ensure fair wages, safe working conditions, and respect for workers' rights throughout the supply chain.
- Inclusivity in Circular Systems: Engaging with local communities, small businesses, and marginalized groups can create inclusive circular solutions that benefit everyone, not just large corporations.

4. Outcomes Of the Adaptation of the Circular Economy

The transition to a circular economy in the textile and apparel industry offers several potential outcomes, which can positively impact the environment, economy, and society. The important outcomes of such progression may be divided into two groups: corporational benefits and collective benefits. Potential benefits and earnings at the company, economic, and social levels are critical to maintaining the circular economy model.

Corporational Benefits

Resource Efficiency: Conservation of Raw Materials and Closed-Loop Systems

Circular practices focus on recycling fibres and reusing materials, reducing the need for virgin resources like cotton, polyester, and water. Fibers can be recycled into new products, creating a closed-loop supply chain where waste is minimized, and materials are continuously reused.

Reduction in Waste and Pollution: Extended Product Life Cycle and Minimized Pollution

Circular economy promotes designing for durability, repair, and reuse, significantly reducing the volume of textile waste that ends up in landfills. By recycling materials and reducing the need for virgin fibres, emissions from textile production (such as water pollution and CO2 emissions) can be minimized. This leads to a cleaner, more sustainable supply chain. Lower waste generation reduces environmental pollution, including microplastics in oceans and chemicals released from synthetic fibres.

Improved Supply Chain Transparency: Traceability and Accountability

The circular economy requires transparent supply chains to track the flow of materials, increasing consumer awareness of product sourcing and production processes. This can also build trust between brands and consumers.

Cost Savings for Businesses: Reduced Production Costs and Lower Waste Disposal Costs

By using recycled or reclaimed materials, businesses can lower material costs in the long term, leading to more efficient production cycles. On the other hand, companies can also save on waste management expenses by designing products that are easier to disassemble, reuse, or recycle.

Improved Brand Reputation: Sustainability Leadership and Customer Engagement

Brands that embrace circular practices are seen as leaders in sustainability, which can attract environmentally-conscious consumers and enhance brand loyalty. It is also believed that the circular model encouragea customers to participate in take-back programs, resale platforms, and repair services, fostering stronger connections between brands and their audience.

Economic Growth and New Business Models: Resale and Rental Markets, Innovation in Materials, and Job Creation

The rise of second-hand clothing, rental services, and clothing swaps can become more mainstream, creating new business opportunities and revenue streams. The development of sustainable textiles (e.g., biodegradable fabrics, textiles from recycled waste) may lead to new material innovations, sparking economic growth and attracting investment. Additionally, new job opportunities could emerge in areas like textile recycling, repair services, and circular business design.

Consumer Behaviour Shift: Ethical Consumerism and Increased Demand for Durable Products

The adoption of circular models encourages consumers to move towards more conscious consumption habits, valuing quality and sustainability over fast fashion trends. With more awareness of environmental impacts, consumers may prefer longer-lasting products, which can reduce the overall volume of clothing consumed.

Environmental and Social Benefits: Decreased Carbon Footprint and Social Impact

Circular production models can significantly reduce the carbon footprint of the textile industry, as recycling fibres requires less energy than producing new materials. By promoting fair labour practices and ensuring that clothes are designed for reuse or recycling, circular models can improve working conditions and support ethical manufacturing practices.

Regulatory and Policy Impacts: Government Incentives and Policy Changes

Governments may introduce incentives or regulations that promote circular business models, such as tax breaks for recycling or penalties for waste. This could further accelerate the adoption of circular practices across the industry. Various means of government supports and incentives for supporting circular practices may also be introduced through legislation, like extended producer responsibility (EPR) policies, tax incentives, and subsidies for sustainable businesses.

Global Collaboration and Standardization: Harmonized Standards and Standardization and Transparency

The shift to a circular economy may encourage the creation of global standards for textile recycling, reuse, and eco-labelling, enabling brands to collaborate across borders on sustainability goals. Global regulations and standards for recycling, eco-labelling, and sustainability practices can improve transparency, benefiting both consumers and businesses.

Global Sustainability Goals : Contribution to SDGs

The circular economy can help the textile and apparel industry align with global sustainability goals, such as responsible consumption and production (SDG 12), climate action (SDG 13), and decent work (SDG 8).

5. Conclusion

This study is hoped to make some theoretical contributions to the understanding of CE practices in the textile and apparel industry and their relevance to sustainability. The basics of CE and possible benefits and challenges of adapting a CE business model are discussed, and a framework for CE model adaptation into the textile and apparel industry is proposed. There appears to be a significant positive correlation between sustainability practices and the adoption of CE strategies in the textile and apparel industry. Therefore, the application of circular economy in the textile and apparel industry is expected to lead to more sustainable production processes, reduced environmental impact, and a shift towards ethical and responsible consumerism by means of new business models. A circular economy in the textile and apparel industry is very likely to generate transformative outcomes. However, this transformation requires systemic changes, collective efforts, and collaborations of producers, retailers, particularly brand holders, consumers, and policymakers. Changing the focus of business to CE is vulnerable to facing various obstacles such as managerial reluctance and limited customer and governmental support, as well as barriers to obtaining the appropriate technologies (Saha et al., 2021). Meanwhile, the demand and market for new circular products have still been developed (Lüdeke-Freund et al., 2019; Lewandowski, 2016) since the last decade.

It is clear that such a transition from traditional production schemes to a systematic circular economy is not an easy and individual operation. Every step of the transition will require a strong commitment from the company towards its stakeholders and the implementation of several procedures, often accompanied by a certification from third parties. It also requires a mutual partnership between stakeholders to contribute to common problems throughout the flow of material and knowledge. In regard to the proposed methodology, the conduction of required tasks at the internal level may be handled relatively easily compared with other tiers. The pace and success of internal operations should depend on the degree of circularity of the company. It is expected to be rather easier in the cases of young and circularity-focused companies. On the other hand, the external and surrounding tiers are more challenging and cumbersome. Coordinating and unifying all partner companies and eliminating their traditional characteristics

and old habits. In this sense, product-orientation, the existing product portfolio, and the position in the supply chain are very likely to build up significant inertia and resistance to transforming the business model.

The awareness and attitudes of consumers, as well as the collaboration and participation of NGOs and municipalities in the reusing and collecting textile materials and products, are also among the critical success factors of this transition. It is also known that several regulations and initiatives globally aim to promote the circular economy in the textile industry at local, national, and international levels. The United Nations Environment Programme (UNEP) is initiating resolutions to provide strategic leadership and promote cooperation across sectors to expedite a fair transition towards a sustainable and circular textile value chain. The policymakers and local authorities are also expected to facilitate this transition period by preparing persuasive, mandatory, and fair regulations. Hopefully, these findings and beneficial insights will enable practitioners and policymakers to accelerate circular economy transformation.

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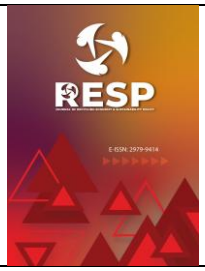
Appendix.

Table 1. Companies in each supply chain, in their strengths and challenges (Herrador & Imanishi, 2025).

Supply Chain	Enterprise type	Strengths	Challenges
Upstream (synthetic textile manufacturing and spinning industry)	Mainly large companies (e.g., Toray, Teijin, Toyobo).	Technological development capabilities (e.g., development and expansion of carbon fibre and new materials and applications, development of materials derived from non-fossil raw materials)	Diversified and textile businesses' revenue streams are non-clothing
Middle stream (dyeing and processing industry, textile industry)	Focus on small and medium-sized enterprises, textile production areas throughout Japan	Processing technology coordination (with material manufacturers and other process companies), cooperation with different fields (e.g., with the automotive and electronics industries), and technology transfer (human resources development)	Expansion and independence in non-clothing (own product development and sales)
Downstream (sewing, manufacturing, apparel)	SMEs	Ability to disseminate fashion information (brand power)	Increasing global competitiveness, responding to human rights issues, and ecology.
Other (trading companies, SPAs)	Mainly large companies (e.g., Itochu, Uniqlo)	Ability to disseminate fashion information (brand power, internat. expansion), grade of responsiveness to environmental protection and consumer safety (recycling, false labeling, measures against hazardous substances).	Increasing global competitiveness, responding to human rights issues, and ecology.



RESP

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Araştırma Makalesi ● Research Article

Evaluation of Water and Energy Efficiency Using Leed and Gsb Certificates for the Bursagaz Building *

Su ve Enerji Verimliliğinin Leed ve Gsb Sertifikalarını Kullanarak Bursagaz Binası Üzerinden Değerlendirilmesi

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ANAHTAR KELİMELER

Sürdürülebililirlik
BURSAGAZ Binası
Enerji Verimliliği
Su Yönetimi
LEED ve GSB

ÖZ

Doğal kaynakların hızla tükenmesi, plansız kentleşme, arazi kullanımındaki değişimler (kentsel alanlarda yeşil alanların azalarak geçirimsiz sert zeminlerin sürekli artması) ile plansız ve çarpık yapılaşma, çevresel sorunların incelenerek çözümlenmesini zorunlu kılmaktadır. Günümüzde farklı disiplinlerde yürütülen sürdürülebilirlik çalışmaları çoğunlukla bina sektörü üzerinden yürütülmektedir. Bu kapsamda, yeşil bina sertifikasyon sistemleri ve kılavuzları, yapılarda sürdürülebilirlik uygulamalarını yönlendiren önemli araçlar olmakla birlikte, içerik ve değerlendirme kriterleri bakımından farklılıklar göstermektedir. Bu çalışmada, yeşil bina kılavuzlarından LEED (Leadership in Energy and Environmental Design) ve GSB (Guideline for Sustainable Building) sistemleri, su ve enerji verimliliği kriterleri açısından BURSAGAZ ana binası örneği üzerinden güçlü ve zayıf yönleriyle karşılaştırılmıştır. Elde edilen bulgular, söz konusu sistemlerin iklim değişikliğinin dinamiklerine uyum sağlayacak biçimde sürekli olarak güncellenmesi gerektiğini ortaya koymaktadır.

KEYWORDS

Sustainability
BURSAGAZ Building
Energy Efficiency
Water Management
LEED and GSB

ABSTRACT

The rapid depletion of natural resources, unplanned urbanization, changes in land use (the continuous increase in impervious hard surfaces and the decrease in green spaces in urban areas), and unplanned and distorted construction necessitate the examination and resolution of environmental issues. Today, sustainability efforts across various disciplines are mostly carried out through the building sector. In this context, green building certification systems and guidelines are important tools that guide sustainability practices in buildings, but they differ in terms of content and evaluation criteria. In this study, the LEED (Leadership in Energy and Environmental Design) and GSB (Guideline for Sustainable Building) systems, which are green building guidelines, were compared in terms of their strengths and weaknesses using the BURSAGAZ main building as an example, focusing on water and energy efficiency criteria. The findings reveal that these systems need to be continuously updated to adapt to the dynamics of climate change.

1. Giriş

İklim değişikliğinin binalar ve kentsel altyapı üzerindeki etkileri, dünya genelinde insan yaşamını doğrudan veya dolaylı biçimde etkileyen karmaşık bir olgudur. Bilinçsiz enerji kullanımı, hızlı nüfus artışı, plansız kentleşme ve bitki örtüsünün tahribi gibi etmenler; ani sel, taşkın, kuraklık ve sıcaklık artışına bağlı ölümler gibi afetlere yol açmaktadır (BBC News, 2011; Çolakoğlu, 2019; The Nordic Insurance

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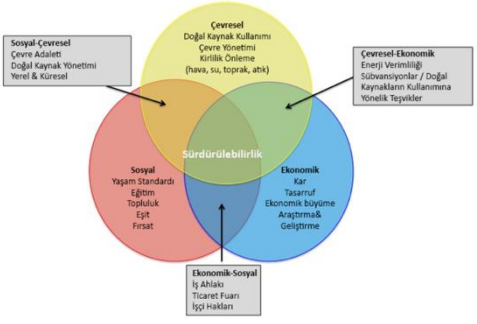
Associations, 2013). Yağış rejimlerindeki düzensizlikler ve kısa süreli yoğun yağışlar nedeniyle altyapının zarar görerek su kaynaklarının kirlenmesi binalarda temiz su erişimi zorlaştırarak enerji tüketimini artırmaktadır (Ogundeji & Jordaan, 2017).

Artan kentleşme oranı, yerleşim alanlarının doğal sınırlarını aşarak küresel karbon döngüsünde düzensiz büyümeye neden olmaktadır (Hutyra vd., 2014). İklim değişikliği, binaların enerji talebini doğrudan etkilemekte; sıcaklık artışları soğutma ihtiyacını artırarak enerji tüketimini yükseltmektedir. Araştırmalar, bu durumun enerji verimliliği odaklı tasarım stratejilerinin yeniden değerlendirilmesini zorunlu kıldığını göstermektedir (Bai ve Song, 2021; José vd., 2017). Ayrıca, su temini ve altyapı sistemlerinin inşası, işletimi ve yenilenmesi de doğal kaynaklar üzerindeki baskıyı artırdığından (Silva vd., 2015; USDE, 2006; Arpke ve Hutzler, 2006); hidroelektrik enerjinin önemli olduğu yerlerde (Ortiz-Beviá vd., 2012) iklim değişikliğinin su ve enerji sistemleri arasındaki karşılıklı bağımlılığı giderek daha belirgin hale gelmektedir. Su ve enerji kaynaklarının yönetimi, özellikle binalar ve kentsel altyapı için önemli olurken bu kaynakların korunması aşamasında çevrenin tahrip edilmemesi de gerekmektedir. Bu nedenle, bina üretiminde geleneksel su ve enerji yönetimi sistemleri yerini gelişmiş sürdürülebilir sistemler almaya başlamıştır.

Çevresel sorunların giderek karmaşık bir hâl almasıyla birlikte, geleneksel yöntemlerle inşa edilen binaların sera gazı emisyonlarının yaklaşık %30'undan sorumlu olduğu, küresel elektrik tüketiminin %60'ını ve içme suyunun %15'ini kullandığı çeşitli araştırmalarda ortaya konmuştur (Castro-Lacouture vd., 2009; Dwaikat ve Ali, 2016). Sürdürülebilir bina üretimi, yapıların tasarım, inşaat, kullanım, bakım ve yıkım süreçlerinde çevresel, ekonomik ve sosyal etkilerin (Şekil 1.) en aza indirilmesini ve kaynakların etkin kullanımını esas alan bütüncül bir yaklaşımdır (Ohueri & Enegbuma, 2018).



Şekil 1. Sürdürülebilirliğin Üç Temel Bileşen ile İlişkilendirilmesi (Saulters, 2012)

Bu yaklaşımı teşvik etmek amacıyla, uluslararası protokoller, ulusal ve bölgesel yönetmelikler, standartlar ve yeşil bina sertifikasyon sistemleri uygulanmaktadır Allen vd., 2015). Çevresel etkileri azaltmak ve bina yaşam döngüsünün (LCA) etkinliğini artırmak amacıyla geliştirilen bu sertifikasyon sistemleri, ulusal ve uluslararası düzeyde benzer değerlendirme ilkelerine dayansa da bazı farklılıklar göstermektedir. Çeşitli sertifika sistemlerinin özellikleri Tablo 1.'de özetlenmiştir (Tablo 1. EKTE yer almaktadır).

Çeşitli uluslararası yeşil bina sertifikalarında enerji verimliliği genellikle daha yüksek ağırlık taşırken, su verimliliği de farklılıklar göstermektedir.

Almanya merkezli GSB (Guideline for Sustainable Building), Federal Ulaştırma, İnşaat ve Konut Bakanlığı tarafından 2001 yılında, sürdürülebilir mimarlık ve inşaat uygulamalarını teşvik etmeye yönelik bir çerçeve ve referans sistemi niteliğinde yayımlanmıştır. Rehber, bina yaşam döngüsünün (LCA-Life Cycle Assesment) tüm aşamalarında (tasarım, yapım, kullanım, bakım ve yenileme) çevresel, ekonomik ve sosyal sürdürülebilirlik kriterlerinin bütüncül bir biçimde yapıya entegre edilmesini amaçlamaktadır. Bu kılavuz, Almanya'nın ulusal düzeyde uyguladığı DGNB sertifikasyonunun temelini oluşturmuştur (BMVBW, 2001). Planlama süreci, bina inşasını değil, mevcut yapı stokunun etkin biçimde yeniden kullanılmasını da içerdiğinden dolayı tasarım kararları; arazinin ekolojik uygunluğu, yapının uzun ömürlülüğü, esnekliği ve yeniden kullanılabilirliği gibi ölçütler temelinde alınmaktadır. Malzeme seçiminde geri dönüştürülebilir, düşük emisyonlu ve çevreye zararsız ürünlerin tercih edilmesi önerilmekte; yıkım aşamasında ise malzeme ayrıştırma ve yeniden kullanım esas alınmaktadır. Bu kapsamda, arazi ve binaların tasarımı, inşası, bakımı, işletimi ve kullanımı süreçleri DIN (Deutsches Institut für Normung) standartları ve ilgili değerlendirme kriterleri doğrultusunda analiz edilmekte ve değerlendirilmektedir. Kılavuzun güncellemeleri de bu doğrultuda yapılmaktadır. Kılavuzun içeriğinde herhangi bir puanlama bulunmamakla birlikte, Türkiye'de bu kılavuza göre oluşturulan bina sayısına ulaşılamamıştır.

Sürdürülebilir inşaat uygulamalarını teşvik etmek ve yapıların çevresel etkilerini en aza indirmek amacıyla geliştirilen bir diğer sertifika ise LEED dir. uluslararası geçerliliği ve yüksek güvenilirlik düzeyi ile öne çıkan ABD merkezli LEED (Leadership in Energy and Environmental Design), 1998 yılında ABD Yeşil bina konseyi (USGBC) tarafından geliştirilmiştir (Madson, vd., 2022). Sürdürülebilirlik ve dirençlilik kavramlarındaki değişimlere ve teknolojik gelişmelere paralel olarak güncellenmektedir (Muehleisen 2010; Wu vd., 2016; Sarkar, 2023). LEED sertifikası, dünya genelinde en yaygın kullanılan yeşil bina değerlendirme sistemlerinden biridir. Asya-Pasifik bölgesinde sürdürülebilir bina uygulamalarının yaygınlaştırılmasında önemli bir rol oynarken, Vietnam'da özellikle bina kalitesini yükseltmek ve kaynak tüketimini azaltmak amacıyla kullanılmaktadır (Pham vd., 2020). LEED sertifikasında ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) standartları kullanılmaktadır.

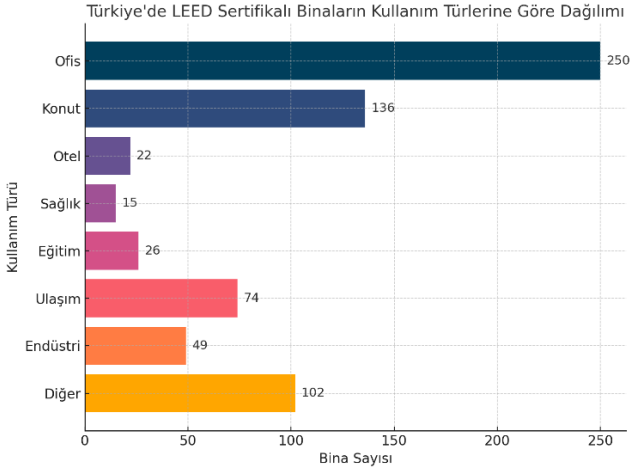
Tablo 2'deki (Tablo 2. EKTE yer almaktadır) birçok yeşil bina sistemlerinden görüldüğü üzere bir binada yapılan birçok operasyon su ve enerji kullanımıyla doğrudan ilişkilidir. Bu durum, söz konusu başlıkların yalnızca bina

içi süreçlerle sınırlı kalmayıp, bina dışı arazi kullanımlarında da su ve enerjiyle etkileşim içinde olduğunu ortaya koymaktadır.

LEED sertifikalı binaların enerji talebinde geleneksel binalara kıyasla ortalama %15 ila %36 oranında daha az enerji tükettiği çeşitli çalışmalarda yer almaktadır (Knapik, 2023). Ancak bu tasarruf düzeyleri, genellikle Gold ve Platinum sertifika seviyelerinde istatistiksel olarak anlamlı bir fark yaratmakta; Certified ve Silver seviyelerinde ise enerji verimliliğindeki kazanımların sınırlı veya önemsiz düzeyde kaldığı görülmektedir (Scofield vd., 2021; Seyis, 2022; Newsham, vd., 2009; Amiri, vd., 2019). Su verimliliği ise özellikle Gold ve Platinum seviyelerinde belirgin şekilde artmaktadır. Bu seviyelerde su tüketiminde %27-70 arasında azalma sağlanabilmektedir (Soliman vd., 2024). Örneğin, bir LEED Gold konut binasında su tüketimi % 66 oranında azaltılmıştır (Seyis, 2022; Kiasıf, 2020).

Dünyada olduğu gibi, Türkiye'de de son yıllarda yeşil bina uygulamalarında belirgin bir artış gözlenmektedir. Ancak, bu artışa rağmen mevcut düzeyin henüz yeterli olgunluğa ulaşmadığı değerlendirilmektedir. 2025 yılı Kasım ayı itibariyle USGBC sitesinden alınan verilere göre 674 adet LEED sertifikalı binadan 88 tanesi Platinum (% 13.06), 460 tanesi Gold (% 68.25), 83 adet Silver (% 12.31), 43 adet Certified (% 6.38) sertifikalı olduğu ve bu binaların büyük çoğunluğunun ofis binası (%37) olarak kullanıldığı (Şekil 2.) görülmektedir (USGBC, 2025a).

Şekil 2. Türkiye'de LEED Sertifikası Alan Binaların Kullanım Tiplerine Göre Dağılımı (USGBC, 2025a).



Sürdürülebilirlikle ilgili ulusal çalışmalar bakıldığında, Çevre Dostu Yeşil Binalar Derneği tarafından 2015 yılında Binalarda Ekolojik ve Sürdürülebilir Tasarım-Konut (B.E.S.T) sertifikası geliştirildiği görülmektedir (Büyükünsal ve Alıcı, 2023). Bununla birlikte; 12.6.2022 tarihli ve 31864 sayılı Resmi Gazete'de "Binalar ile Yerleşmeler İçin Yeşil Sertifika Yönetmeliği" (ÇŞİB, 2022) yayımlanarak uygulamaya geçirilmiştir.

Mevcut literatürde, LEED sertifikasyon sisteminin bina enerji verimliliği (Scofield vd., 2021; Seyis, 2022; Newsham, vd., 2009; Amiri, vd., 2019) ve su tasarrufu (Soliman vd., 2024; Seyis, 2022; Kiasıf, 2020) gibi konulardaki etkisini araştıran çalışmalar bulunduğu görülmektedir. Bununla birlikte, GSB sisteminin yerel bağlamda uygulanabilirliğine ilişkin akademik çalışmaların oldukça sınırlı olduğu görülmektedir. Ayrıca, binalarda LEED ve GSB sistemlerinin karşılaştırmalı olarak ele alındığı akademik kaynakların da yetersiz olduğu tespit edilmiştir. Bu çalışma, BURSAGAZ projesini bir vaka analizi olarak inceleyerek, her iki sertifikasyon sisteminin binalarda su ve enerji verimliliği üzerindeki etkilerini ortaya koymaktadır.

Bu çalışma, sürdürülebilir bina üretimi kavramına odaklanarak yeşil bina sertifika sistemleri ve kılavuzların bu süreçteki rollerini incelemektedir. Literatürde yer alan enerji ve su değerlendirmeleri, çevresel etkilerin azaltılması ve sürdürülebilir bina standartlarının teşvik edilmesi açısından önem taşımaktadır. Artan enerji talebi ve küresel su krizi dikkate alındığında, bu konu günümüzde daha da kritik hale gelmiştir. Çalışma, sürdürülebilir bina üretiminde su ve enerji verimliliğinin artırılmasında sertifika sistemlerinin katkılarını değerlendirmeyi amaçlamaktadır. Bu kapsamda, Bursa'nın ilk LEED-Platinum sertifikalı yeşil binası olan BURSAGAZ Merkez Binası örneklem olarak seçilmiş; projenin LEED sertifikasına sahip olması, çalışmada ulusal ve uluslararası sürdürülebilirlik kriterlerinin bütüncül biçimde ele alınmasına olanak sağlamıştır.

Çalışmanın kapsamı, Türkiye'de sürdürülebilir bina üretiminde su ve enerji verimliliği uygulamalarının yaygınlaştırılmasının önemine dikkat çekmektedir. Bu bağlamda, yapı sertifika sistemlerinin bina üretim süreçlerine entegrasyonunun yerel ve ulusal düzeyde yasal ve kurumsal düzenlemelerle desteklenmesi gerekliliği önerilmektedir.

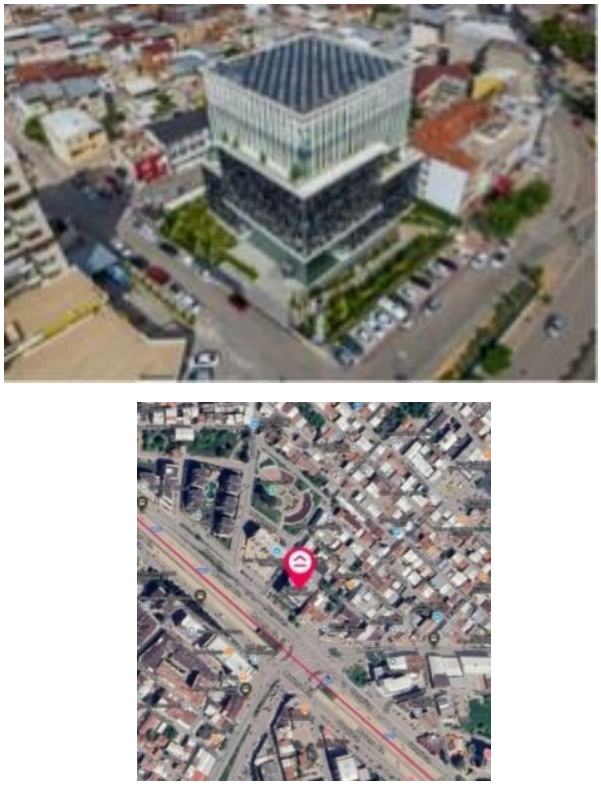
2. Materyal ve Yöntem

Sürdürülebilir bina değerlendirme sistemlerinin genel çerçeveleri benzer olsa da, aralarında belirli farklılıklar bulunmaktadır. LEED ve GSB gibi sistemler, binaların yaşam döngüsü boyunca sürdürülebilirliğin sağlanmasına yönelik önemli kılavuzlar sunmaktadır. Bu sistemlerde, binalar su yönetimi, enerji verimliliği, kaynak kullanımı, malzeme seçimi ve atık yönetimi gibi kriterler temelinde değerlendirilmektedir. Çalışmada, incelenen projenin su ve enerji verimliliği performansı LEED ve GSB kriterleri doğrultusunda karşılaştırmalı olarak analiz edilmiştir. Bu analiz aracılığıyla her iki sistemin sunduğu avantajlar, yenilikçi yaklaşımlar ve sürdürülebilir bina üretim sürecine katkıları ortaya konulmuştur. Sonrasında, Bursa'nın ilk yeşil binası olan ve LEED BD+C: NC (Yeni İnşaat) v3.0-Platinum sertifikasına sahip BURSAGAZ Merkez Binası ele alınarak, binanın elde ettiği puanlar, uyguladığı stratejiler ve bu uygulamaların GSB rehberindeki karşılıkları incelenmiştir. Son bölümde ise bu tür projelerin yaygınlaştırılması ve sürdürülebilir bina uygulamalarının artırılmasına yönelik öneriler sunulmuştur.

2.1. Alan Araştırması: BURSAGAZ Binası Hakkında

Genel Bilgiler

Bursa ilinde doğalgaz dağıtım hizmeti veren BURSAGAZ'ın merkez binası, Osmangazi ilçesi Bağlarbaşı Mahallesi sınırları içerisinde, 929 Ada 1 Parsel'de (Şekil 3.) konumlanmaktadır. Tapu kayıtlarına göre toplam alan 2.409,27 m²'dir (TKGM, 2024). Yapının inşaat alanı ise 7.373 m² olarak belirtilmiştir (Altensis, 2024a). Proje, mevcut yapının yıkılarak yerine üç bodrum ve yedi normal kattan oluşan yeni binanın inşasıyla gerçekleştirilmiş ve 2013–2016 yılları arasında tamamlanmıştır. (Arkitera, 2024).



Şekil 3. Tesisin Konumu ve Üstten Görünümü (Endeksa, 2024; Google earth, 2024)

Proje, konumu itibarıyla eski ve yoğun konut alanlarının yürüme mesafesinde, Mudanya Yolu'na paralel uzanan 1. Hürriyet caddesi üzerinde (Şekil 3) yer almaktadır. Yapı, en yakın otobüs durağına 131 m, metro istasyonuna 469 m, hastaneye 327 m, eczaneye 48 m, yeme-içme alanına 189 m ve parka 276 m mesafede yer almaktadır (Endeksa, 2024).

2.2. BURSAGAZ Projesinin Sürdürülebilirlik Ölçütleri Açısından (Su ve Enerji Verimliliği) Analizi

Proje, tasarım ve kullanım süreçlerinde sürdürülebilirlik kriterleri temel alınarak geliştirilmiştir. Konumu sayesinde toplu taşımaya erişim kolaylaşmış; otoparkların büyük bölümü yer altına alınarak kısa süreli kullanımlar için sınırlı açık otopark alanı planlanmıştır (Termodinamik, 2017). Ayrıca çalışanlar için servis sağlanarak ön bahçede elektrikli araç şarj üniteleri ve bisiklet park alanları oluşturulmuştur.

Yüksek kotta yer alması nedeniyle sel riski taşımayan yapı, altyapı üzerinde ek yük oluşturmamaktadır. Peyzajda yerel bitki türleri ve çalı türlerinin kullanılması sulama gereksinimini azaltmıştır. Çatı yüzeylerinden, klima yoğuşma hatlarından, arıtma (içme suyu) sisteminden ve peyzaj drenajından elde edilen sular bodrumdaki depoda toplanarak filtrelenip yeniden kullanılmaktadır (Bursagaz, 2025). 2020–2021 döneminde, yağmur suyu ve drenaj suyu hasadı binanın toplam su ihtiyacının yaklaşık %38'ini karşılamıştır (Bursa Görüş, 2021). Düşük debili armatürler ve alternatif su kaynaklarının kullanımı (yağmur suyu, gri su) sayesinde altyapıya giden su miktarı azaltılmıştır. Binanın su verimliliğinin ortak bir su yönetimi sayesinde 2023 yılında %72'lere, 2024 döneminde ise %74'e ulaştığı belirtilmektedir (Bursagaz, 2025).

Tasarımda, geleneksel çift cidarlı cephe yerine doluluk–boşluk oranları optimize edilmiş prizmatik kütlelerden oluşan ve gün ışığı ile manzaradan en yüksek düzeyde yararlanmayı hedefleyen bir cam cephe sistemi benimsenmiştir (Tago Mimarlık, 2024). Isı ve ses yalıtımı için cephede üç katmanlı cam kullanımı mevcuttur. Binanın enerji verimliliği; solar enerji (çatıda fotovoltaik paneller ile elektrik ve sıcak su temini ve cepheye yerleştirilmiş fotovoltaik paneller yardımıyla elektrik üretimi), trijen sistemi (soğutma için), kaskad sisteminden sağlanmaktadır.

Çatı yüzeyinde fotovoltaik paneller (Şekil 4), güney cephesinde ise modüler ve transparan BIPV (binaya entegre fotovoltaik) paneller uygulanmış; diğer cepheler ise gölgeleme işlevi sağlayan boyalı cam elemanlarla tasarlanmıştır (Altensis, 2024a; Arkitera, 2024; Altensis, 2024b). Her prizmatik kütlede yer alan açık teraslara entegre edilen güneş panelleri, eşzamanlı olarak enerji üretimi sağlamakta ve pasif gölgeleme bileşeni olarak işlev görmektedir (Arkitera, 2024).

Cephe ve çatıda bulunan fotovoltaik panellerin toplam gücü 4,845 kWp olup, yıllık enerji üretimi 0,744 MWh/yıl, CO_2 emisyonu azaltımı ise 0,498 ton/yıl olarak hesaplanmıştır (Endura Enerji, 2024). Bu sayede, yalnızca fotovoltaik modüllerden yaklaşık %15,35 oranında enerji tasarrufu sağlanmaktadır. Cephede kullanılan BIPV modüllerinin arka yüzeyinin boşluklu bir detayla çözümlenmesi, aşırı ısınmanın önüne geçerek panel verimliliğinin düşmesini engellemekte ve sistemin uzun vadeli performansını artırmaktadır. Üretilen yenilenebilir elektrik enerjisi bir UPS sisteminde toplanarak binanın enerji gereksiniminin bir bölümü bu şekilde karşılanmaktadır (Altensis, 2024b).

Bina içinde hareket ve gün ışığı sensörleri kullanılarak pasif aydınlatmadan yararlanılmıştır. Binanın ayrı cephelerine bakan mekanlarda yatay bölgelemelerle fotometrik planlama yapılarak, aydınlatmada enerji verimliliği sağlanmıştır.

Şekil 4. Binanın Çatısında Güneş Paneli Uygulaması (Tago Mimarlık, 2024; Endura Enerji, 2024)

Şekil 5. Cephede kullanılan BIPV ve açıklıklar (Tago Mimarlık, 2024)

Bununla birlikte, çatıda güneşe göre konumunu ayarlayan iki kollektör ve fiber optik kablolar aracılığıyla (Şekil 6a. ve Şekil 6b.) gün ışığı almayan bodrum katlarında günışığıyla aydınlatma sağlanmıştır (Altensis, 2024b).

a)

b)

Şekil 6. (a) Binanın Ön Bahçesinde Yer Alan Gelişmiş Gün Işığı Sistemleri (Bursagaz, 2025), (b) Biber Optik Kablolar ile Gün Işığının Taşınımı (Archello, 2024)

Binada sağlanan enerjinin bir bölümü de (151,211 kWp) doğalgaz ile çalışarak hem elektrik hem ısı üretebilen modüler kojenerasyon sistemi aracılığıyla karşılanmış; ayrıca bu sistemden elde edilen atık ısı, absorbsiyonlu chiller (ABS) kullanılarak soğutma süreçlerinde değerlendirilmiştir (Bursa Görüş, 2021). Yenilenebilir enerji uygulamalarından biri olan rüzgâr türbini ise 600 W elektrik üretim kapasitesi ile enerji verimliliğini desteklemektedir (Altensis, 2024a; Altensis, 2024b). Binada kullanılan yenilenebilir enerji sistemlerinin toplamı ile 2022'de %22,71, 2023'de %32,93 ve 2024'de %28,41 enerji verimliliği sağlandığı belirtilmektedir (Bursagaz, 2025).

Binada iç hava kalitesini yükseltmek amacıyla, her mekandaki taze hava miktarı ASHRAE'nin öngördüğü minimum sınır değerlerinin en az %30 üzerinde olacak şekilde tasarlanmıştır. Ayrıca, taze hava debisi belirlenen eşik değerlerin altına düştüğünde uyarı veren ve otomatik olarak devreye giren bir bina otomasyon sistemi uygulanarak, kesintisiz ve sağlıklı bir iç mekân hava kalitesinin sürdürülmesi hedeflenmiştir (Termodinamik, 2024).

Bir diğer sürdürülebilir uygulama kapsamında, binanın yapım sürecinde metal, karton, plastik, cam, palet ve kalıp gibi geri dönüştürülebilir atıkların düzenli takibi için özel depolama alanları oluşturulmuştur. Kullanım aşamasında ise ofis ve ortak mekânlara yerleştirilen geri dönüşüm kutuları ile toplama noktaları aracılığıyla atık yönetimi sistematik şekilde desteklenmiş ve süreçlerin etkinliği artırılmıştır.

- *BURSAGAZ Projesinin LEED BD+C: NC v3.0 Kapsamında Su Verimliliği ve Enerji Performansının*

Değerlendirilmesi:

LEED yeşil bina sertifika sistemi, değerlendirme kapsamına göre farklı kategorilere ayrılmaktadır. LEED BD+C (yeni bina tasarımı ve inşaatı), LEED O+M (mevcut bina işletme ve bakımı), LEED ID+C (iç mekân tasarımı ve inşaatı), LEED ND (mahalle geliştirme, kentsel dönüşüm ve yeni saha uygulamaları) ve LEED Homes (az ve orta katlı konutların sürdürülebilirlik performansı) artırılmasına yönelik değerlendirmeleri içermektedir (USGBC, 2025a; ERKE, 2024).

LEED sistemi, sürdürülebilirlik alanındaki gelişmelere paralel olarak düzenli biçimde güncellenmiştir. İlk sürüm olan LEED v1.0 (1998), temel sürdürülebilirlik kriterlerini içermekteydi. Bunu izleyen v2.0 (2000) ile sertifika kapsamı genişletilmiş ve daha fazla bina tipi değerlendirme sürecine dahil edilmiştir. v2.1 (2002) sürümünde kredi gereksinimleri netleştirilmiş, puanlama sistemi güncellenmiştir (Wu vd., 2016). v2.2 (2005) ile LEED uluslararası düzeyde yaygınlık kazanmıştır. V3.0 (2009) sürümünde kredi ağırlıkları yeniden düzenlenerek, puanlama sistemi gözden geçirilmiş ve bölgesel öncelikler sisteme eklenmiştir. v4.0 (2013) ise daha sıkı enerji ve malzeme standartları ile yeni kredi kategorilerini içermektedir. En güncel iyileştirmelerden biri olan v4.1 (2019), özellikle Enerji ve Atmosfer kategorisinde sera gazı azaltımı ve yeni enerji sınıflandırmalarına yönelik güncellemeler getirmiştir (Madson, 2022; Marzouk, 2024; Sarkar, 2023). Güncel sürüm ise LEED v5.0 (2025), gömülü karbon azaltımı, kullanıcı sağlığı, ekolojik koruma, bölgesel uyum ve malzemelerin yeniden kullanımı gibi zorunluluklar getirilmiştir (USGBC, 2025b).

BURSAGAZ Merkez Binası LEED BD+C: NC (yeni inşaat) v3.0-Platinum sertifikasına sahip binanın LEED puan tablosu incelendiğinde, su ve enerji verimliliği açısından gerekli kriterleri karşıladığı görülmektedir (Tablo 3) (Tablo 3. EKTE yer almaktadır). Ancak, arazinin sürdürülebilirliği; su verimliliği ve enerji kullanımı üzerinde dolaylı etkilere sahip olduğundan, bu konu da ayrıca ele alınmıştır.

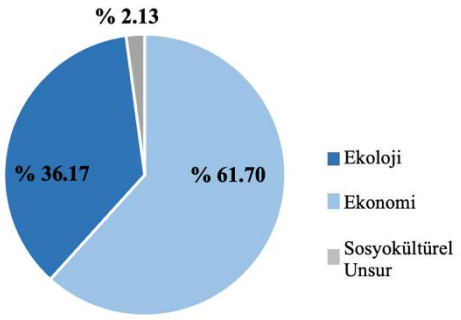
LEED v3.0'de iç mekândaki su verimliliği hesaplanırken, kullanıcı gruplarının türü dolayısıyla belirlenen kullanım sıklıkları, süreleri, kullandıkları armatürlerin debileri dikkate alınmıştır. Bu versiyona göre, tuvaletlerde 6.05 lt/sifon, pisuarlar için 3.08lt/sifon, ortak lavabolar fotoselli için 4.7 lt/dakika ve kullanım süresi 12 saniye olarak alınmıştır. LEED v3.0'de, sağlanan su verimlilik oranlarına göre alınabilecek puanlarda %30, %35, %40 su verimliliği sağlanırken sırasıyla 2, 3 ve 4 puan alınabilmektedir (USGBC, 2016). Örnek bina için v3.0' e göre yapılan hesaplamada, %40 su verimliliği ile birlikte ilgili krediden 4 puan alındığı görülmektedir.

Proje, su ve enerji verimlilikleri açısından LEED sertifika sistemine göre sırasıyla 'Su Verimliliği' ve 'Bölgesel Öncelik' kategorilerinden % 100, 'Sürdürülebilir Alanlar' kategorisinden % 96,15, 'İnovasyon' kategorisinden % 83,33 ve son olarak 'Enerji ve Atmosfer' kategorisinden % 80 puan almıştır. Bu kriterler değerlendirildiğinde proje, alması gereken su ve enerjiye ilişkin kredilerden %88.88 oranında başarı sağlamaktadır.

- *GSB Kapsamında Su ve Enerji Verimliliği Performansının Değerlendirilmesi:*

GSB Kılavuzu'nda yer alan ekler temel alınarak, ekolojik, ekonomik ve sosyo-kültürel unsurlar başlıklarını kapsayan toplam 47 alt kriterden oluşan bütüncül bir değerlendirme sistemi geliştirilmiştir. Ön ekolojik, ekonomik ve sosyo-kültürel değerlendirmeler ayrı ayrı yapılarak genel not belirlenmektedir.

Şekil 7.'de, GSB'nin Ek-1 kontrol listesinde yer alan kriterlerin sayısına bağlı olarak belirlenen ağırlıklı oranlar gösterilmektedir. Bu kılavuzda ele alınan kapsam, yeni binaların planlanması ve inşası ile mevcut yapıların kullanımı, işletilmesi, yenilenmesi ve dönüştürülmesi süreçlerini yansıtmaktadır.



Şekil 7. GSB Ağırlıklı Kategorileri

Kılavuzda yer alan değerlendirme tablosu:

1-Ekolojik değerlendirme: binanın planlama aşamasındaki sürdürülebirlik kriterleri (+ veya daha iyi)

2-Ekonomik değerlendirme: binanın planlama, kullanım, bakım ve süreçleri maliyetleri

3-Sosyo-kültürel değerlendirme: dış etki, iç etki, engelsiz yapı esasları doğrultusunda yapılmaktadır.

GSB Kılavuzu'nda kılavuzunda su verimliliği, tüketimin azaltılması ve yağmur suyunun etkin yönetimi vurgulanmakta; su temini ve drenaj tesisatlarının ortak servis şaftlarında toplanması ile her birim için sıcak–soğuk su sayaçlarının kullanılması önerilmektedir. Yağmur suyu yönetiminde ise merkezi olmayan kullanım, yerinde sızdırma (infiltrasyon) ve depolama sistemleri desteklenmekte; bu yaklaşım akış hacmini azaltarak yeraltı suyu beslenmesine katkı sağlamakta ve kirli su ile yağmur suyunun ayrı sistemlerde yönetilmesini gerekli kılmaktadır. Enerji verimliliği açısından ise, kompakt bina formu, ısı köprülerinin önlenmesi, geniş cam yüzeylerin sınırlandırılması, etkili ısı yalıtımı ve hava geçirmezlik gibi pasif tasarım ilkeleri öne çıkmaktadır. Verimli mekanik sistemlerin kullanılması elektrik talebini azaltmakta; güneş, rüzgâr, jeotermal enerji, toprak ısısı/soğuğu, biyokütle ve hidroelektrik gibi yenilenebilir enerji kaynaklarının

bütünleşmesi teşvik edilmektedir. Ayrıca, bina kullanım sürecinde tüketim izleme sistemlerinin kurulması, su ve enerji performansının düzenli olarak değerlendirilmesine olanak tanımaktadır.

Tablo 4.'de (Tablo 4. EKTE yer almaktadır) BURSAGAZ projesinde su ve enerji verimliliğine yönelik uygulanan sürdürülebilir bina tasarım stratejilerinin, GSB kılavuzundaki sürdürülebilirlik politikaları olarak karşılıklarının neler olduğunu göstermektedir. Kılavuzda puanlama sistemi yer almadığından söz konusu proje için hedefi sağlayan durumlar '+', sağlamayan durumlar '-', şeklinde belirtilmektedir.

BURSAGAZ projesinin su ve enerji verimliliği, GSB kılavuzu kapsamında 24 değerlendirme ölçütünden, 19 tanesini sağlayarak, %79,17 oranında başarı sağlamaktadır. Her bir kategoride sağladığı ölçütlere oranlandığında ise, proje %91,7 oranında 'Enerjinin Rasyonel Kullanımı' kategorisinde en yüksek orana sahip olduğu değerlendirilmektedir.

3. Bulgular ve Tartışma

Çalışmanın bu bölümünde BURSAGAZ merkez binası projesinin su ve enerji verimliliği performansının LEED ve GSB açısından karşılaştırmalı analizi ve yeni bina üretimine etkileri değerlendirilecektir.

3.1. BURSAGAZ Binasının Su Verimliliği ve Enerji Performansının Değerlendirilmesi

Bursagaz projesi, her iki sistemde de kriter sağlama oranına göre başarı göstermektedir. Projenin su ve enerji verimliliği; LEED üzerinden değerlendirildiğinde, %88,88 oranında başarı sağlarken, GSB üzerinden değerlendirildiğinde bu oran %79,17'dir. Proje, LEED yeşil bina sertifika sistemine göre daha başarılı bulunmaktadır.

BURSAGAZ projesi, 2017 yılında tamamlanmış olmasına karşın, Bursa'da sayısı halen sınırlı olan sürdürülebilir bina örneklerinden biri olarak öne çıkmaktadır. Proje, LEED ve GSB sistemlerinin kriterlerine göre değerlendirildiğinde çeşitli güçlü ve zayıf yönler sergilemektedir.

LEED açısından değerlendirildiğinde, binanın su verimliliği için yağmursuyu ve gri su gibi alternatif su kaynakları ile kayıp kaçak ve tüketim izleme gibi akıllı bina teknolojileri ile sisteme entegre edilerek sürekli kayıp ve kaçakların izlenmesi bu kategoride kayda değer bir başarı göstermesini sağlamıştır. Atık sular binanın bodrum katında yer alan bir depoda biriktirilmektedir. Yine bodrum katında yer alan bir izleme odası ile her türlü kaçak tespiti ve enerji tüketimi gibi veriler sürekli izlenerek kayıt altına alınmaktadır. Alternatif su kaynakları yönetiminin bir parçası olan su deposu herhangi bir bakteriyel sorun yaşanmaması için aylık olarak otomatik klorlanmakta olup; 6 aylık periyotta da lisanslı kuruluş tarafından ters ozmoz yöntemiyle dezenfekte edilmektedir (Bursagaz, 2025). Bu da kullanım süreçlerinde sistemin bileşenlerinin sürekli denetim ve bakım olması gerektiğinin bir örneğini teşkil etmektedir.

Enerji verimliliğinde ise yenilenebilir enerjiler ile inovatif teknolojilerin(parans gün ışığı taşıma) etkin kullanımı ve buların sisteme dahil edilerek tüketim verilerinin sürekli izlenmesi enerji verimliliği ve atmosfer kategorisinde başarı gösterilmesini sağlamıştır. Ancak, şebekeye olan ihtiyacın yerinde yenilenebilir enerjilerden karşılanması belirli bir düzeyde kalmasından dolayı bu kategorideki ilgili krediden 4 puan alınmasına neden olduğu değerlendirilmektedir.

GSB kılavuzu açısından değerlendirildiğinde, mevcu binanın yerinde değerlendirilmeden yeni bina yapılışı, kentsel çevreyle ve terk edilmiş alanlarda ya da kentsel boşluklarda kullanımın olmaması ve binanın cephelerinin saydam olması nedeniyle enerji sarfiyatının DIN standartlarına göre sağlanamaması gibi nedenler projenin bu kategorilerde hedefi sağlayamamasına neden olarak değerlendirilmektedir. Ancak, projede yenilenebilir enerjiler ile gün ışığın pasif kullanımı vb. sisteme entegre edilmesi enerji verimliliğini artıran unsurlar arasındadır. Ayrıca, projenin konumunun toplu taşıma ve diğer birimlere yakın oluşu karbon emisyonunu düşüren etkenler arasındadır. Tasarım, yapım ve kullanım süreçlerinde su ve enerji verimliliğinin sürekli izlenerek iyileştirme çabaları projenin genel sürdürülebilirlik performansını desteklemektedir.

BURSAGAZ projesi, her iki sürdürülebilirlik sisteminin kriterlerini belirli ölçüde karşılasa da, bu sistemlerin dayandığı standartlar ile geliştirilmiş oldukları coğrafi ve iklimsel bağlam, proje koşullarıyla tam uyum gösterememektedir. Ayrıca, su ve enerji verimliliği arasında doğrudan bir ilişki bulunmamakla birlikte, su verimliliğine yönelik uygulamalar sırasında kullanılan enerji ve yerel iklim koşulları toplam enerji tüketiminin artmasına neden olabilmektedir. Ofis kullanımlı bu yapıda yenilenebilir enerji kaynaklarını destekleyici ek politikaların geliştirilmesi ise şebekeye olan bağımlılığı önemli ölçüde azaltarak sürdürülebilirlik hedeflerine daha güçlü bir katkı sağlayacaktır.

3.2. LEED ve GSB nin Karşılaştırmalı Analizi

LEED, çevresel kriterler ve enerji verimliliğine odaklanırken, GSB çevresel, sosyal ve ekonomik boyutları daha dengeli bir çerçevede ele almaktadır. GSB'nin yaşam döngüsünün tüm süreçlerine yönelik ekonomik göstergeleri değerlendirmeye dâhil etmesi, sistemi daha bütüncül bir sürdürülebilirlik yaklaşımına yaklaştırmaktadır.

LEED NCv3 yalnızca yeni binalara yönelik olup, LEED'in farklı yapı türlerine göre (yeni bina, mevcut bina vb.) ayrı sertifika süreçleri barındırması, yeni binaların kullanım aşamalarında yeniden başvuru gerektirmesi nedeniyle ekonomik sürdürülebilirlik açısından ek maliyet oluşturarak kullanım sürecinde denetimini de sınırlı kılmaktadır. En yaygın kullanılan yeşil bina sertifika sistemi olan LEED, sistemin ölçütleri her zaman gerçek enerji ve su performansındaki değişimlerini tam olarak yansıtmayabilir. Bu nedenle, kullanım aşamalarına yönelik kriterlerin artırılması gerekmektedir (Payne ve Layton, 2025).

ABD kökenli LEED'in puan alabilmek için aşamalı olarak ilerlediği kullanıcıları daha az su ve enerji tüketmeye yönlendirme amaçlı olduğu, uygulama aşamasında ASRAE, IESNA, ASTM ve CIBSE standartlarını kullanmaktadır. LEED sertifika sisteminin su ve enerji verimliliği alt başlıklarının iyi detaylandırılmış oluşu bu konularda verimliliğin istatistiksel olarak ölçülebilmesini kolaylaştırmıştır. Kömürlü ve arkadaşları tarafından yapılan bir çalışmada (2014), sistemin Amerikan standartlarına dayalı oluşu ülkemizde kullanılan standartlar ve ilgili mevzuat ile iklim malzeme ve uygulama alışkanlıklarına tam uyum sağlayamadığını göstermektedir.

Buna karşılık, Almanya kökenli GSB kılavuzu DIN standartlarına dayalı olup, pasif tasarım yaklaşımlarını teşvik etmesi ve tasarım–üretim–kullanım–yıkım süreçlerinin tümüne yönelik uygulamalar sunmasıyla sürdürülebilir bina üretimine farklı bir perspektif kazandırmaktadır. GSB'nin çeşitli DIN, RBBau ve VDI standartlarıyla desteklenen bir yapı sunduğu görülmektedir. Bu kapsamlı teknik çerçeve, birçok konuda ayrıntılı teknik verilere erişim sağlaması bakımından önemli bir avantajlı olsa da, bazı uygulama alanlarında sistemi daha zorlayıcı hâle getirebilmektedir. GSB'de belirli bir puanlama sistemi veya sertifikasyon mekanizmasının bulunmaması, uygulayıcılar açısından teşvik unsurunu sınırlamaktadır. Ayrıca, sistemin uluslararası düzeyde tanınırlığının nispeten düşük olması, yaygın uygulanabilirliğini olumsuz etkileyen bir diğer faktördür.

LEED sertifikasyon sistemi, düzenli olarak yayımlanan yeni versiyonlarla güncellenmekte; bu güncellemeler hem kriterlerde hem de puanlandırma yapısında değişiklikler içermektedir. Puan sistemindeki bu revizyonların temel amacı, proje sahiplerini daha yüksek puan elde edebilmek için su ve enerji tüketimini azaltmaya ve buna bağlı CO_2 emisyonlarını düşürmeye teşvik etmektir. Buna karşın, GSB sisteminde benzer kapsamda periyodik güncellemelere rastlanmamaktadır.

LEED, farklı iklim koşullarına sahip ülkeler için bölgesel öncelik tanımlamaları sunması ve uluslararası ölçekte geniş bir yaygınlığa sahip olması nedeniyle güvenilirlik açısından GSB'ye kıyasla daha üstündür. Bu bağlamda LEED daha net, yaygın ve kullanıcı dostu bir sistem olarak öne çıkarken, GSB sürdürülebilirliği çevresel, ekonomik ve sosyal boyutlarıyla daha dengeli ve bütüncül bir çerçevede ele almaktadır. Dolayısıyla, sertifika sisteminin seçimi proje hedefleri ile bölgesel gerekliliklere göre değerlendirilmelidir.

GSB benzeri kılavuzların sunduğu kapsamlı ve çeşitlendirilmiş değerlendirme kriterleri, binaların yapım, kullanım ve yıkım süreçlerinin daha ayrıntılı, niteliksel ve niceliksel verilere dayalı biçimde incelenmesine olanak tanımaktadır. Bu açıdan, LEED kriterlerine dayalı bir değerlendirme süreci, GSB'nin standardizasyon düzeyi ve teknik kapsamıyla desteklenerek zenginleştirilebilir. GSB'nin alt başlık ve değerlendirme ölçütlerinin, LEED kriterlerinin geliştirilmesinde ve daha bütüncül bir analiz yapılmasında tamamlayıcı bir referans niteliği taşıyabileceği; bu nedenle çeşitli yeşil bina sertifikasyon sistemlerinin birbirlerinin olumlu kriterlerini referans alarak geliştirilebilmesi mümkün olduğu değerlendirilmektedir.

3.3. LEED ve GSB'nin Su ve Enerji Yönetimi Açısından Bina Üretimine Etkileri

Her iki sistem de, bina yapım süreçlerinde kaliteyi ve çevresel performansı artırmaktadır. LEED belgelendirme sürecinde, proje yönetiminde standartlaşma ve operasyonel verimlilik sağlamaktadır (Amiri, vd., 2019). Çeşitli araştırmalar, LEED sertifikalı binalarda enerji tasarrufu düzeylerinin özellikle Gold ve Platinum seviyelerinde istatistiksel olarak anlamlı farklılık yarattığını; buna karşılık daha düşük sertifika seviyelerinde benzer bir etkinin gözlenmediğini ortaya koymaktadır (Seyis, 2022; Newsham vd., 2009; Amiri vd., 2019). Binaların gerçek performanslarının uzun dönemli olarak izlenmesi, tüketim verilerinin düzenli biçimde takip edilmesi ve raporlanarak paylaşılması (Scofield vd., 2021) ise hem mevcut sürdürülebilirlik performansının doğrulanmasına hem de yeni bina üretim süreçlerinin daha etkin biçimde yönlendirilmesine kılavuzluk edecektir. Bununla birlikte, bina yapım süreçlerindeki uygulama kalitesi ve tasarım ve uygulama süreçlerinde yer alan aktörlerin konu ile ilgili farkındalığı da bu konuya katkıda bulunmaktadır.

Su verimliliği ise LEED sertifikasında özellikle Gold ve Platinum seviyelerinde belirgin şekilde artmaktadır. Bu seviyelerde su tüketiminde %27-70 arasında azalma sağlanabilmektedir (Soliman vd., 2024). Bununla birlikte, sertifika süreçlerinin zor ve yüksek maliyetli oluşu küçük ölçekli projelerde uygulanabilirliğini sınırlamaktadır.

GSB, bina yaşam döngüsüne (LCA) odaklanması ve pasif enerji stratejilerini teşvik eden kapsamlı kriterler içermesi nedeniyle enerji verimliliğini bütüncül bir yaklaşımla ele almaktadır. Sistem, su tüketimi ve atık su yönetimine ilişkin özel değerlendirme ölçütleri sunmakta olup, su verimliliği "arazi ve doğal kaynak kullanımı" başlığı altında ele alınmaktadır. Su verimliliğine ilişkin performansın kullanılan teknolojilere ve yerel koşullara bağlı olarak değişebilmesi, GSB'nin bağlama duyarlı yapısını ortaya koymaktadır. Bu çerçevede sistem, enerji ve su verimliliğini yalnızca teknik bir performans göstergesi olarak değil, aynı zamanda ekonomik ve sosyal sürdürülebilirlik boyutlarıyla birlikte değerlendiren bir perspektif sunmaktadır.

Yeşil bina sertifikalarının ve kılavuzlarının bina üretiminde etkili olabilmesi ve uygulamada yaygınlaştırılabilmesi için; tasarım ve uygulama süreçlerinde yer alan paydaşların aktif katılımı (Yusuf vd., 2024), uygulayıcıların teknik bilgi ve deneyimlerinin artırılması (Dobrucalı vd., 2024), sürdürülebilir bina projelerine yönelik finansal teşvik mekanizmalarının artırılması (Siddiqui vd., 2024), ulusal ve yerel mevzuatta sürdürülebilirlik ile ilgili hükümlerin daha ayrıntılı biçimde tanımlanması (Moshood vd., 2024), sertifika ya da kılavuzların performans göstergelerinin üretim sürecinin tüm aşamalarında izlenip raporlanması, bu

doğrultuda geri bildirim mekanizmalarının işletilerek sürekli iyileştirmenin sağlanması gerekmektedir (Caselles ve Guevara, 2024).

4. Sonuç ve Değerlendirmeler

Sürdürülebilir bina üretimine yönelik sertifika sistemleri ve kılavuzlar, çevresel etkilerin azaltılmasında önemli bir rol üstlenmektedir. Ancak bu sistemlerde su ve enerji verimliliği ilişkisinin giderek daha fazla önem kazanmasına karşın, coğrafi, ekonomik, iklimsel ve kültürel farklılıklar, bu sistemlerin bina üretim süreçlerinde uygulanmasında daha bütüncül ve uyumlaştırılmış yaklaşımlara ihtiyaç duyulduğunu göstermektedir (Bacenetti, 2020). Farklı sistemlerin karşılaştırmalı olarak incelenmesi ise özellikle su stresinin yaşandığı veya yaşanma potansiyeli yüksek olan bölgelerde, su verimliliğinin yanı sıra enerji verimliliğine yapılan vurgunun bölgesel farklılıkları ortaya koyması bakımından önem taşımaktadır (Khahro vd., 2021). Bununla birlikte, her sistemin kendine özgü gelişmiş özellikleri bina üretimine katkıda bulunmaktadır. Bu bağlamda yürütülen çalışma, sürdürülebilir bina üretiminde su ve enerji verimliliğinin artırılmasına yönelik olarak sertifika sistemlerinin katkılarını değerlendirmekte ve binalarda gerçekleştirilen birçok operasyonun su ve enerji kullanımından doğrudan etkilendiğini ortaya koymaktadır. Bu durum, söz konusu iki başlığın hem bina içi süreçlerde hem de bina dışı arazi kullanımlarında sürekli ve karşılıklı bir etkileşim içinde olduğunu göstermektedir. BURSAGAZ projesinin LEED ve GSB sertifikasyon sistemleri kapsamında su ve enerji verimliliğinin karşılaştırmalı analizi sürdürülebilirlik kriterlerine göre verimlilik düzeylerinin farklılığını ortaya koymuştur.

LEED yeşil bina sertifikasında temel amaç, belirli kredileri karşılayarak sertifikayı elde etmek ve sertifika seviyesini yükseltmektir. Su ve enerji verimliliğine ilişkin başlıklar incelendiğinde, özellikle Gold ve Platinum seviyelerinde istatistiksel olarak anlamlı farklılıklar ortaya çıkmasına karşın, daha alt seviyelerde bu farkın belirgin olmadığı görülmektedir. Yüksek sertifika seviyelerine ulaşmak için su tüketiminin azaltılmasının yanı sıra alternatif su kaynaklarının kullanımı ve yenilenebilir enerji sistemlerinin otomasyonla entegrasyonu gibi uygulamaların hayata geçirilmesi gerekmektedir. Ancak söz konusu uygulamaların yüksek maliyetleri, sertifikasyon sürecindeki her basamağın ücretli olması ve sistemde kullanılan Amerikan ASHRAE standartlarının ulusal mevzuatla tam uyum göstermemesi, adaptasyon sürecini zorlaştırarak yerel ölçekte yaygınlaşmayı sınırlamaktadır.

Bununla birlikte, GSB Kılavuzu da Alman DIN standartlarını temel alarak kapsamlı sürdürülebilirlik kriterleri sunmaktadır. Ancak, her iki sistemin ve bileşeni olan standartların yabancı dilde hazırlanmış olması, uygulayıcılar açısından dil temelli zorluklar oluşturabilmektedir. GSB, yönlendirdiği projelerde pasif tasarım stratejilerinin uygulanmasını ve yerel malzeme kullanımını teşvik ederek yapım maliyetlerinin azaltılmasını amaçlamaktadır. Ayrıca, çevresel, ekonomik ve sosyal sürdürülebilirlik kriterlerini bina yaşam döngüsü boyunca eşit düzeyde ele alması, sürdürülebilir bina üretimine önemli bir katkı sağlamaktadır. Ancak puanlama ve sertifikasyon mekanizmasının bulunmaması, ödüllendirme süreçlerinin de olmaması, kılavuzun uygulamadaki teşvik edici etkisini sınırlamaktadır.

Çalışmada, literatür aşamasında yeşil sertifika sistemleri ve çeşitli kılavuzların bina üretiminde su ve enerji verimliliğine kılavuzluk ettiği görülmüştür. Ancak, yüksek dereceli sertifika alan sayılarının yeterli düzeyde olmadığı görülmektedir. Bina üretiminde yeşil sertifika sistemlerinin sayısının artması için çeşitli stratejilerin uygulanması gerekmektedir. Türkiye bağlamında sürdürülebilir bina üretiminin yaygınlaştırılması için yasal mevzuatlara konu ile ilgili detayların konulması ve TSE standartları ile uyumlu Yes-Tr gibi ulusal sertifika sistemlerinin ulusal politikalarla desteklenerek kamu ve özel kurumlara tanıtılarak çeşitli destek ve mevzuatlarla yaygınlaştırılması gerekmektedir. Bu doğrultuda;

- Bina üretiminde maliyetlerin Türkiye gibi gelişmekte olan ülkelerde önemli bir yeri olması nedeniyle yeşil sertifikalı ya da sürdürülebilirlik standartlarını yerine getiren projeler için (yenilenebilir enerji, alternatif su kaynaklarının kullanımı, vb.) vergi indirimleri, sübvansiyonlar ve kredi kolaylıkları sağlanmasının (Kömürlü vd., 2024) yanı sıra ilk yatırım maliyetlerini olabildiğince düşüren pasif sistemlerin kullanımı teşvik edilmelidir.

- Binalarda uygulanan bu sistemlerin çalıştığına yönelik denetimlerin yıllık periyotlarla çeşitli kamu kurumları ya da lisanslandırılmış kurumlar tarafından yapılması (Keskin vd., 2020) sisteme dair olumsuzlukların belirlenerek güncellenmesine olanak sağlayacaktır.

- Sürdürülebilirlik kriterlerine ilişkin rehberlerin, Türkiye'nin farklı coğrafi bölgelerine uygun biçimde TSE standartları ve yasal mevzuatla uyumlu hâle getirilerek yapı ruhsatı süreçleriyle entegre edilmesi, konunun yerel ölçekte uygulanabilirliğini ve yaygınlaşma potansiyelini önemli ölçüde artıracaktır.

- Konu ile ilgili tasarım ve yapım süreçlerinden sorumlu tüm disiplinlerin (proje müellifleri, fenni mesul-yapı denetim görevlileri, yükleniciler, uygulayıcılar, kamuda denetim göreviyle sorumlu yetkililer, mal sahibi, vb) sürdürülebilirlik ile ilgili farkındalıklarının artırılarak eğitilmelidir (Kömürlü vd., 2024). Sürdürülebilirliğin uzun vadeli faydaları ve örnek projeler kamuoyuna belirli periyotlarla anlatılarak farkındalık oluşturulmalıdır (Akçay, 2023).

- Bina üretiminde sürdürülebilir yerel malzeme üretimi ve kullanımı ile ilgili çeşitli ar-ge çalışmaları yapılmalıdır. Ayrıca, bu çalışmalar yapay zeka gibi teknolojilerin geliştirilerek uygulanması desteklenmelidir (Farmanesh vd., 2025).

Sonuç olarak, Türkiye'de sürdürülebilir bina üretimi için en etkili yol, devlet politikaları, finansal teşvikler, yerel ve

çevre dostu malzeme kullanımı, yenilenebilir enerji entegrasyonu, eğitim ve toplumsal farkındalığın birlikte geliştirilmesidir. Bu stratejiler, inşaat sektöründe sürdürülebilir uygulamaların benimsenmesini teşvik edecek ve çevresel etkilerin azaltılmasına katkıda bulunacaktır.

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EKLER.

Tablo 1. Çeşitli Yeşil Bina Sertifika Sistemleri ve Kriterler

Değ. Sist.	Tarih	Ülke	Kriterler	İlgili Olduğu Alanlar	Sertifika Seviyeleri
BREEAM	1990	İngiltere	Yönetim, Ulaşım, Sağlık ve Konfor, Atık Malz., Arazi Kullanımı ve Ekoloji, Kirlilik, Su, Yenilik, Enerji	Yönetim, Sağlık ve refah/sosyal ve ekonomik refah, Tehlikeler, Enerji ve CO_2 emisyonu/Kaynak ve enerji, Ulaşım, Su, Malzeme, Atık, Arazi kullanımı ve ekoloji, Çevre kirliliği, Yüzey suyu akıntısı, Yenilikçililik	Outstanding, Excellent, Very Good, Good, Pass, Unclassified
LEED	1998	ABD	Yenilik ve Tasarım, İç Mekan Hava Kalitesi, Malzeme ve Kaynaklar, Sürdürülebilir Arsalar, Su Etkinliği, Enerji ve Atmosfer	Bütünleşik süreç, Konum ve ulaşım, Sürdürülebilir arazi, Doğal sistemleri ve ekoloji, Su verimliliği, Enerji verimli bina kabuğu, Enerji ve atmosfer, Malzemeler ve kaynaklar, İç ortam kalitesi, Yaşam kalitesi, Tasarımda ino., Bölgesel öncelik	Platinum, Gold, Silver, Certified
Greenmark	2005	Singapur	Yenilik ve Tasarım, Sürdürülebilir Arsalar, Su Etkinliği, Enerji ve Atmosfer, Malzeme ve Kaynaklar, Atık Malz., Ulaşım	Enerji Verimliliği, Çevre Koruma, Çevresel Kalite, Su Verimliliği ve Diğer Yeşil Özellikler	Platinum, Gold Plus, Gold, Certified
GreenStar	2003	Avusturalya	Enerji Malzeme, İç Mekan Çevre Kalitesi, Ulaşım, Yönetim, Su Arazi Kullanımı ve Ekoloji Kirlilik, Yenilik		Dünyanın En İyisi, Avustralya'nın En İyisi, Çok İyi, İyi, Ortalama, Düşük
CASBEE	2001	Japonya	İç Mekan Çevresi, Servis Kalitesi, Arsada Dış Mekan Çevresi, Enerji, Kaynaklar ve Malz., Arsa Dışındaki Çevre		S, A, B+, B-, C
GSB	1998	Almanya	İç Mekan Hava Kalitesi, Enerji ve Kaynak Tüketimi, Çevresel Yükler, Sosyal ve Ekonomik Esaslar, Kültürel ve Algısal Esaslar, Arsa Seçimi, Proje Planlama ve Geliştirme	Binanın ve Arsa Tasarımına İlişkin Sürdürülebilir Planlama, Kullanıcı Sağlığı ve Konfor, Enerji ve Bina Tesisat İlişkisi, Sosyo-Kültürel Değerlendirme ve Bina Uzun Dönem Kullanımı	Puanlama ve sertifika seviyesi yoktur.
Yes-TR	2021	Türkiye	BBT-Bütünleşik Bina Tasarım, Yapım ve Yönetimi, YMD-Yapı Malzemesi ve Yaşam Döngüsü, İOK-İç Ortam Kalitesi, EKV-Enerji Kullanımı ve Verimliliği, SAY-Su ve Atık Yönetimi, İNO-İnovasyon Bina	Bütünleşik Bina Tasarımı, İç Ortam Kalitesi, Yapı Malzemesi ve Yaşam Döngüsü, Enerji Verimliliği, Su ve Atık Yönetimi ve İnovasyon	Ulusal Üstünlük, Çok İyi, İyi, Geçer

Kaynak: ÇŞİB, 2024; Mohammed vd., 2024'dan yararlanarak yazar tarafından oluşturulmuştur.

Tablo 2. Farklı Yeşil Bina Sertifika Sistemlerinin Enerji ve Su Verimliliklerinin Karşılaştırılması

Sistemler	Enerji Verimliliği Kriterleri ve Toplam Puana Katkısı	Su Verimliliği Kriterleri ve Toplam Puana Katkısı
BREEAM	*Enerji ve emisyonların azaltılması *Enerji izleme teknikleri *Dış aydınlatma optimizasyonu *Düşük karbonlu tasarım önlemleri *Soğuk hava depoları için enerji verimliliği *Enerji verimli taşımacılık *Enerji verimli ekipman kullanımı	*Su tüketimi *Su izleme *Su kaçağı tespiti *Su tasarruflu ekipman
	% 22-25	% 7
LEED	*Enerji Devreye Alma ve Doğrulama *Minimum Düzeyde Enerji Performansı *Bina Enerji Ölçümü Seviyesi *Bina Enerji Ölçümü Seviyesi *Enerjiyi Optimize Etme *Gelişmiş Enerji Ölçümü *Enerji Talep Azaltımı *Optimize Edilmiş Soğutucu Akışkan Yönetimi *Yeşil Enerji ve Karbon Ofsetleri	*Dış Mekan Su Tüketiminin Azaltılması *İç Mekan Su Tüketiminin Azaltılması *Bina Su Ölçüm Seviyesi *Dış Mekan Su Kullanımının Azaltılması *İç Mekan Su Tüketiminin Azaltılması *Soğutma Kulesi Su Tüketimi *Su Ölçüm Kurulumu
	% 30	% 9
CASBEE	*Bina Termal Yükü *Doğal Enerji Kaynaklarından Yararlanma *Verimli Hizmet Sistemi Oluşturma *Verimli Çalışma Stratejisi	*Su Kaynakları
	% 20	% 5
GreenStar	*Sera Gazı Emisyonları *Pik Elektrik Talebinin Azaltılması	*İçilebilir Su Azaltma Teknikleri *Yağmursuyu Yeniden Kullanımı ve Yönetimi *Verimli peyzaj sulaması *Su sayacı ekipmanları *Isıtma Suyu Azaltma
	% 20-25	% 11
GreenMark	*Bina Kabuğu *Klima *Yapay Aydınlatma *Otoparklar Havalandırma *Ortak Alanlar Havalandırma *Asansörler ve Yürüyen Merdivenler *Verimlilik *Enerji Verimli Uygulamalar *Yenilenebilir Enerji uygulaması	*Su Verimli Armatürlerin montajı *Su Tüketimi ve Kaçak Tespiti *Peyzaj için Sulama Sistemi *Soğutma Kulesi Su Tüketimi
	% 55	% 10

Kaynak: Mohammed vd., 2024'dan yararlanılarak yazar tarafından oluşturulmuştur.

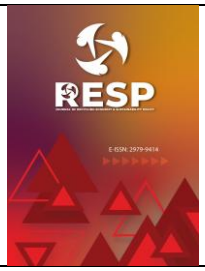
Tablo 3. Projenin Su ve Enerji Verimliliği Açısından LEED Puan Tablosu (USGBC, 2024)

LEED v3.0- Platinium Yeşil Bina Sertifikalı		**72/81**	
Kategori		**Hedef**	**Puanlama**
Sürdürülebilir Alanlar	**SSp1** İnşaat faaliyet kirliliğinin önlenmesi	+	Gerekli
	SSc1 Site seçimi	+	1/1
	SSc2 Gelişim yoğunluğu ve topluluk bağlantısı	+	5/5
	SSc3 Brownfield yeniden geliştirme	-	0/1
	SSc4.1 Alternatif ulaşım - toplu taşıma erişimi	+	6/6
	SSc4.2 Alternatif ulaşım-bisiklet muhafazası ve soyunma odaları	+	1/1
	SSc4.3 Alternatif ulaşım - düşük emisyonlu ve yakıt tasarruflu araçlar	+	3/3
	SSc4.4 Alternatif ulaşım - park kapasitesi	+	2/2
	SSc5.1 Site geliştirme - yaşam alanını koruma veya onarma	+	1/1
	SSc5.2 Site geliştirme - açık alanı en üst düzeye çıkarın	+	1/1
	SSc6.1 Yağmursuyu tasarımı - miktar kontrolü	+	1/1
	SSc6.2 Yağmur suyu tasarımı - kalite kontrolü	+	1/1
	SSc7.1 Isı adası etkisi - çatısız	+	1/1
	SSc7.2 Isı adası etkisi - çatı	+	1/1
	SSc8 Işık kirliliğinin azaltılması	+	1/1
	14/15		**25/26**
Su Verimliliği	**WEp1** Su kullanımının azaltılması	+	Gerekli
	WEc1 Su tasarruflu peyzaj	+	4/4
	WEc2 Yenilikçi atık su teknolojileri	+	2/2
	WEc3 Su kullanımının azaltılması	+	4/4
			10/10
Enerji ve Atmosfer	**EAp1** Bina enerji sistemlerinin temel devreye alınması	+	Gerekli
	EAp2 Minimum enerji performansı	+	Gerekli
	EAp3 Temel soğutucu akışkan yönetimi	+	Gerekli
	EAC1 Enerji performansını optimize edin	-	15/19
	EAC2 Yerinde yenilenebilir enerji	-	4/7
	EAC3 Gelişmiş devreye alma	+	2/2
	EAC4 Gelişmiş soğutucu yönetimi	+	2/2
	EAC5 Ölçüm ve doğrulama	+	3/3
	EAC6 Yeşil güç	+	2/2
			28/35
Yenilik (İnovasyon)	**IDC1** Tasarımda yenilik	+	+4
	IDC2 LEED Akredite Profesyonel	+	+1
	Bölgesel öncelikli krediler		**5/6**
Bölgesel öncelikli krediler	**EAC1** Enerji performansını optimize edin	+	+1
	Denklem c7.2Termal konfor - doğrulama	+	+1
	SSc6.1 Yağmursuyu tasarımı - miktar kontrolü	+	+1
	SSc7.2 Isı adası etkisi - çatı	+	+1
			4/4

Kaynak: USGBC, 2024

Tablo 4. Projenin GSB Açısından Su ve Enerji Verimliliğinin Değerlendirilmesi

GSB Kılavuzu		**19/24**
Değerlendirme Kriterleri		**Hedef**
Bina gereksinim analizi	Bina gereksinimi (Yeni bina zorunluluğunun irdelenmesi)	-
	Mevcut binaların kullanımının sürdürülmesi (Mevcut yapı yıkılıp yeni bina yapılmıştır)	-
		0/2
İnşaat arazilerinin ve doğal kaynakların kullanımı ve su verimliliği	Terk edilmiş arazileri/binalar arasındaki yeniden kullanımı	-
	Yüzey sızdırmazlığı	+
	Alan talebinin sınırlandırması	+
	Yeraltı suyunun kullanımı/korunması	+
	Yağmur suyunun kullanımı ve depolama	+
	Kentsel çevreye ve peyzaja entegrasyon	-
	Bozulmamış ekolojik yapıların korunması, gelişmemiş arazilerin biyoçeşitliliğinin desteklenmesi	+
	Su tüketiminin azaltılması	+
	Temizlik ve bakım maliyetlerinin kullanım aşamasında izlenmesi	+
		7/9
Enerjinin rasyonel kullanımı	Enerji dostu inşaat yönetimi (kompakt inşaat yönetimi, iç mekanda yer alan odaların homojen dağılımı, gürültülü caddelere bakan odaların yalıtımı, sıhhi tesisatlar için boru ağı)	+
	Yüksek düzeyde ısı yalıtımı sağlanması	+
	Binanın doğal havalandırılması	+
	Güneş enerjisinin pasif kullanımı	+
	Kaynak tüketimi için bina otomasyonu uygulanması	+
	Yapıda doğal havalandırma tasarlanması	+
	Cephelerde saydam yüzeylerin optimum kullanımı	-
	Emisyonlara karşı koruma (sera gazları/gürültü)	+
	Yaz sıcağına karşı doğal yalıtım yapılarak mekanik soğutmanın önlenmesi (hava sirkülasyonu)	+
	Yenilenebilir enerji kaynaklarının aktif kullanımı	+
	Entegre enerji tedariki	+
	Yerel toplu taşıma sistemine yakınlık	+
		11/12
Sosyokültürel unsurlar	İç dış etkiler ve erişilebilir yapı tasarımı	+
		1/1



RESP

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Araştırma Makalesi ● Research Article

Is The Natural Resource Drive Thailand National Income *

Doğal Kaynaklar Tayland'ın Milli Gelirini Artırıyor mu?

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ANAHTAR KELİMELER

Milli Gelir
Kentsel Nufüs Artışı
Tasarruf
Doğal Kaynaklar
Cinsiyet Kapsayacılığı
Thailand
Eşzamanlı Denklemler Modeli

ÖZ

Bu çalışma, 1972–2020 döneminde kentleşme, tasarruflar, doğal kaynak kullanımı ve kadın girişimciliğinin Tayland'ın milli gelirini eşanlı olarak nasıl etkilediğini incelemektedir. Eşanlı denklem modeli ve iki aşamalı en küçük kareler (2SLS) yöntemi kullanılarak yapılan analiz, değişkenler arasındaki önemli ilişkileri ortaya koymaktadır. Bulgular, kadın girişimciliğinin milli gelir üzerinde anlamlı ve olumlu bir etki yarattığını, dolayısıyla toplumsal cinsiyet eşitliğinin ekonomik büyümedeki kritik rolünü göstermektedir. Kentleşme ise karmaşık bir etkiye sahiptir: Basit modellerde hızlı kentleşme milli geliri düşürürken, içsel bir değişken olarak ele alındığında milli gelire olumlu katkı sunmaktadır. Tasarrufların milli gelir üzerinde hafif negatif etkisi, tasarrufların verimli yatırıma dönüştürülmesindeki aksaklıklara işaret etmektedir. Doğal kaynaklar milli geliri doğrudan artırmamakla birlikte kentleşmeyi teşvik etmektedir; ancak bu kanal 2SLS sonuçlarında anlamlı bir etki yaratmamaktadır. Genel olarak çalışma, uzun vadeli ekonomik büyüme için toplumsal cinsiyet eşitliğini güçlendiren, sürdürülebilir kentleşmeyi destekleyen, tasarruf kullanımını iyileştiren ve doğal kaynakların sorumlu yönetimini önceleyen politikaların gerekliliğini vurgulamaktadır.

KEYWORDS

National Income,
Urban Population Growth
Savings
Natural Resources
Gender Inclusiveness
Thailand
Simultaneous Equations Model

ABSTRACT

This study examines how urbanization, savings, natural resource use, and women's business activity jointly influence Thailand's national income from 1972 to 2020. Using a simultaneous equations framework and the two-stage least squares (2SLS) method, the analysis reveals that women's business activity significantly enhances national income, emphasizing the economic importance of gender equality. Urbanization shows a mixed effect: while rapid urban population growth appears to reduce national income in simple models, it contributes positively when treated as an endogenous factor, reflecting the complexity of urban dynamics. Savings have a slightly negative impact on national income, suggesting inefficiencies in converting savings into productive investment. Natural resources do not directly increase national income but do stimulate urban population growth, although this channel does not produce a significant effect under the 2SLS estimation. Overall, the study highlights the need for policies that support gender equality, efficient urban development, improved use of savings, and responsible natural resource management to foster long-term economic growth.

1. Introduction

National income, typically measured by indicators like Gross Domestic Product (GDP) or Gross National Income (GNI), serves as a crucial metric for assessing a country's economic performance and overall well-being. These measures are the key metric for shaping monetary policy

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(Ghosh & Ranjan, 2023), representing the total value of goods and services produced within a country's borders over a specific period. In particular, GNI measures the total income earned by a country's residents, including income from abroad. These indicators offer valuable insights into the size and health of an economy and are often used to gauge economic growth rates and compare economies globally (Shams et al., 2024).

Understanding the determinants of national income offers several benefits for policymakers and economists, as it allows them to develop informed strategies. For example, in Kosovo, remittances have been identified as the leading contributor to economic growth (Govori & Fejzullahu, 2020). Such insights enable policymakers to encourage investments in sectors like manufacturing to create jobs and reduce import dependence.

Nonetheless, the relationship between economic factors and national income can be complex and sometimes contradictory. While FDI and economic growth generally have a positive bilateral association in ASEAN countries (Sijabat, 2023), research on the US suggests that industrial specialization, ather than industrial diversity, may contribute more to the growth of economy (Zhong et al., 2023). These findings highlight the need for context-specific of the relationships.

Researchers have extensively explored the determinants of economic growth, employing various methodologies to analyze these factors. Studies like those by Khan et al. (2021) use advanced econometric techniques, such as second-generation panel unit root tests and generalized least squares (GLS) regressions, to examine the impact of energy trilemma on economic growth. Similarly, Osei et al. (2019) employs the system generalized method of moments to investigate trade openness and its relationship with economic growth in African countries. Other studies focus on specific growth factors. for example, Dokas et al. (2022) analyzes the dynamics of energy consumption across developed and developing countries using error correction models and causality tests their relation with growth. However, contradictions exist in the findings. While Haseeb et al. (2020) demonstrate a positive impact of natural resources on economic growth in Asian economies, Gu et al. (2023) validate the resource curse hypothesis for the US, showing how natural resources can hinder long-term growth. This divergence underscores the importance of context in analyzing economic growth determinants. Given the complexities of economic growth, this study aims to explore additional factors influencing national income, particularly in Thailand by focusing on key variables such as urban population growth, natural resource rents, adjusted savings, and women's economic participation, as measured by the Women Business and the Law Index (WOB). By utilizing a simultaneous equations model, the study seeks to provide a comprehensive understanding of how these interconnected factors influence Thailand's net national income (NNI) over the period from 1972 to 2020. This research contributes to the literature by exploring the simultaneous relationships between economic and social variables that influence national income. The subsequent sections will provide a literature review that emphasizes the empirical foundations of the research, followed by the methodology section, which will define the data sources, variables, and multiple regression model used for analysis. The results section will present the findings, which will be followed by a discussion of the policy implications.

2. Literature Review

This section will provide some background of some factors that influence economic growth. Savings play a crucial role in influencing economic growth, as demonstrated by several studies. Financial development, which includes the mobilization of savings, can stimulate economic growth, particularly in high-income countries by providing the necessary capital for economic activities (Ikhsan & Satrianto, 2023). Savings act as a mechanism for meeting financial resource needs and contribute to overall economic expansion. In open economies, investments can be financed not only through domestic savings but also through foreign capital flows, allowing countries to achieve investment levels beyond their domestic saving capacity (Atique & Ahmad, 2022). However, the effects of savings on economic growth are not always straightforward and can vary depending on various factors. In some cases, savings have been found to have a positive impact on economic growth. For instance, in the Developing-8 countries, national savings help mitigate environmental degradation over the long term, indirectly supporting sustainable economic growth (Majekodunmi et al., 2023).

Additional research supports the positive association between savings and economic growth. A study using the Spatial Durbin Model (SDM) across 158 countries from 1990 to 2019 found that higher savings rates contribute to increased economic growth (Jayadevan et al., 2024). Similarly, a PVAR system GMM model applied to a panel of 184 countries from 1981 to 2020 showed that savings, in conjunction with other factors such as oil prices, CO2 emissions, oil rents, and energy consumption, jointly Granger-cause economic growth (Ajayi, 2024). This causal relationship was found to be particularly strong in high-income and upper- middle-income countries. However, other studies reveal the complexity of this relationship. In Pakistan, for example, gross domestic savings were found to negatively affect economic growth according to certain regression techniques (Rehman et al., 2023). These contrasting findings illustrate that while savings generally provide capital for investments and promote financial development, their effects can be influenced by factors such as environmental concerns, financial market conditions, and the economic structures specific to each country. Policymakers must account for these nuances when designing strategies to enhance savings and economic growth (Majekodunmi et al., 2023; Rehman et al., 2023). Moreover, Ajayi (2024) found that in low-income and

lower-middle-income countries, the combined effect of savings and other variables on economic growth was not statistically significant. This finding suggests that the relationship between savings and economic growth may be more complex in developing economies, where additional factors could moderate this relationship.

Population growth can stimulate economic growth by increasing demand and production, but its impact depends on several factors such as age structure, health, and country-specific circumstances. The relationship between population growth and economic growth is complex and multifaceted, with varying effects depending on different countries and contexts. Several studies have identified a positive relationship between population growth and economic development. For example, in China, at the national level, a 1% increase in the population growth rate was associated with a 1.7% increase in the economic growth rate (Fang & Leong, 2014). In Kenya, research found a positive correlation between population growth and economic growth, with population increases contributing to higher economic growth (Thuku, 2013). Similarly, a study of Organization of Islamic Cooperation (OIC) countries from 1980 to 2016 revealed a positive and statistically significant long-term impact of population growth on economic growth, with a bidirectional relationship in the short run (Mahmoudinia et al., 2020). In Singapore, a unidirectional Granger causality relationship was observed between population growth and economic growth during the period from 1970 to 2020, further emphasizing the positive link between these variables (Suluk, 2021).

Natural resources can significantly impact economic growth, with both positive and negative effects depending on various factors. In G7 economies, for example, natural resource rents negatively affect economic growth in countries with low GDP but positively influence those with high GDP (Meng et al., 2022). Contradictory, In China, an increase in natural resource exploitation negatively impacts economic development in the long run (Li et al., 2023). The impact of natural resources on economic growth depends on various factors such as institutional quality, trade openness, and technological advancement. While some countries benefit from their natural resource endowments, others struggle with the "resource curse," where resource dependence leads to poor economic performance. To maximize the positive effects of natural resources on economic growth, countries should focus on efficient resource utilization, economic diversification, and the adoption of clean and green energy technologies (Khan et al., 2023; Zhou et al., 2023). Furthermore, strong institutions and effective policies are essential for harnessing the potential of natural resources for sustainable economic development (Kerner et al., 2023).

While natural resources can affect economic growth, the impact is far from straightforward. The key lies in how these resources are managed and integrated with other factors of production. Policymakers must prioritize diversifying revenue sources, fostering financial expansion, and investing in renewable energy systems to create more equitable and sustainable growth (Xue et al., 2024).

Women's entrepreneurship and business ownership can significantly impact economic growth, as evidenced by numerous studies. Women-owned businesses contribute to job creation, innovation, and overall economic development (Gulvira et al., 2024; Rizvi et al., 2023). The economic role of women is crucial for fostering growth and achieving a more equitable distribution of wealth, particularly in developing countries (Gulvira et al., 2024). Research shows that women's economic rights have a positive effect on growth, with a 75% spillover effect that benefits neighboring countries (Naveed et al., 2023). Women's economic role is not only vital for overall economic development but also for achieving a more equitable distribution of wealth (Gulvira et al., 2024). Digital technologies hold great potential for empowering women entrepreneurs and helping them overcome socio-cultural and economic barriers (Salamzadeh et al., 2024). Moreover, the inclusion and integration of migrant women entrepreneurs within entrepreneurial ecosystems can positively affect diversity and sustainability in countries (Aman et al., 2024). However, to fully realize the potential of women's entrepreneurship, it is crucial to create more favorable conditions, implement thoughtful policies, and take decisive actions aimed at empowering women entrepreneurs (Gulvira et al., 2024). Despite these positive impacts, women still face significant challenges in starting and expanding their businesses, including limited access to markets, technology, networks, and financing (Veckalne & Tambovceva, 2023). Promoting women's entrepreneurship and addressing gender disparities in business can lead to substantial economic benefits. Empowering women through education, employment, and business ownership is essential for accelerating economic and financial progress (Mubeen et al., 2022). To fully harness this potential, policymakers should focus on creating favorable conditions for women entrepreneurs by implementing thoughtful policies and taking decisive measures aimed at empowering women in the business world (Gulvira et al., 2024; Veckalne & Tambovceva, 2023).

3. Methodology

Simultaneous equations models are systems of structurally related equations where multiple dependent variables are determined jointly, often used in econometrics, biostatistics, and experimental design (Henningsen & Hamann, 2007). These models capture complex relationships between variables that influence each other simultaneously. Two-stage least squares (2SLS) is a widely used estimation technique for simultaneous equations models. It is particularly useful when errors across equations are not correlated and the equations are over- identified or exactly identified (Mishra, 2008). The 2SLS method involves two stages: first, it estimates the endogenous variables using instrumental variables, and second, it uses these estimates in

$$NNI = a_1 + a_2UPG + a_3SAV + a_4WOB$$ the structural equation (Amemiya, 1982; Lee et al., 2015). In this research, the simultaneous equations model is written as follows:

$$UPG = a_5 + a_6TNR + a_7SAV + a_8WOB$$

where NNI is adjusted net national income per capita, SAV denotes adjusted savings: carbon dioxide damage as a percentage of GNI. UPG presents urban population growth, TNR is total natural resources rents, and WOB exhibits women business and the law index score.

The model formulation presented in the simultaneous equation's framework captures the complex interrelationships between key economic and social variables, reflecting the idea that these variables do not operate in isolation but influence each other simultaneously. The first equation models Net National Income (NNI) as a function of Urban Population Growth (UPG), Adjusted Savings (SAV), and the Women, Business, and the Law Index (WOB). This suggests that national income is driven by urbanization, the level of savings (adjusted for environmental damage), and the level of gender inclusiveness in legal and business environments. The second equation models UPG as a function of Total Natural Resource Rents (TNR), SAV, and WOB. Here, urban population growth is influenced by the country's ability to generate income from its natural resources, savings, and the legal empowerment of women.

This research uses Data from Thailand between 1972 and 2020 downloaded from the World Bank database for model estimation.

3. Results

This section presents the key findings from the correlation analysis and regression models by OLS and 2SLS methods. Table 1 shows descriptive statistics.

Table 1. Descriptive Statistics

Variable	Mean	Std. dev.	Min	Max
NNI	2,169.014	1,705.540	191.579	6,082.000
SAV	1.677	0.718	0.649	2.860
UPG	3.028	1.251	1.480	5.441
TNR	1.747	0.788	0.546	3.717
WOB	60.434	10.178	51.875	78.125

Table 2. Correlation Analysis

Variable	NNI	SAV	UPG	TNR	WOB
NNI	1.000				
SAV	0.626	1.000			
UPG	-0.511	-0.247	1.000		
TNR	0.355	0.250	0.423	1.000	
WOB	0.904	0.728	-0.241	0.565	1.000

Table 2 presents the correlation analysis of the variables in the study, revealing important relationships between them. Net National Income (NNI) is positively correlated with Adjusted Savings (SAV) (0.626), Total Natural Resource Rents (TNR) (0.355), and the Women, Business, and the Law Index (WOB) (0.904), suggesting that these variables are associated with higher national income. However, Urban Population Growth (UPG) shows a negative correlation with NNI (-0.511), indicating that higher urban population growth may be linked to lower national income.

Table 3 demonstrates that the coefficient for SAV is negative (-264.834) but not statistically significant at the 10% level (P-value = 0.107), indicating a weak relationship between savings and NNI. Conversely, UPG has a strong negative impact on NNI, with a significant coefficient of -448.539 and a P-value of 0.000, suggesting that higher urban population growth is associated with lower net national income. TNR, however, shows a positive coefficient (33.609) but is not statistically significant (P-value = 0.844), implying that natural resource rents have an insignificant effect on NNI in this model. On the other hand, WOB has a highly significant positive impact, with a coefficient of 150.247 and a P-value of 0.000, indicating that improvements in women's legal and business rights contribute substantially to increasing national income. The overall model is robust, with an R-squared value of 0.914, indicating that 91.4% of the variance in NNI is explained by the model, and an F-statistic of 117.10, confirming the overall statistical significance of the model.

Table 3. Full Regression Model Estimation

NNI	Coefficient	Std. err.	t	P>|t|	95% conf. interval lower	95% conf. interval upper
SAV	-264.834	160.985	- 1.650	0.107	-589.279	59.611
UPG	-448.539	87.449	- 5.130	0.000	-624.782	-272.297
TNR	33.609	169.423	0.200	0.844	-307.841	375.060
WOB	150.247	15.928	9.430	0.000	118.146	182.347
_cons	-5,167.302	771.853	- 6.690	0.000	-6,722.870	-3,611.735
Number of obs	49.000	R-squared	0.914			
F (4,44)	117.100	Adj R-squared	0.906			
Prob > F	0.000	Root MSE	522.010			

Table 4. UPG Regression Model Estimation

UPG	Coefficient	Std. err.	t	P>|t|	95% conf. interval lower	95% conf. interval upper
SAV	0.2466012	0.2719525	0.91	0.369	-0.3011392	0.7943416
WOB	-0.10172	0.0225227	-4.52	0.000	-0.147083	-0.0563571
TNR	1.357429	0.2060681	6.59	0.000	0.9423865	1.772471
_cons	6.391101	0.9074702	7.04	0.000	4.563362	8.21884
Number of obs	49.000	R-squared	0.526			
F (4, 44)	16.640	Adj R-squared	0.494			
Prob > F	0.000	Root MSE	0.890			

Table 5. NNI Regression Model Estimation

NNI	Coefficient	Std. err.	t	P>|t|	95% conf. interval lower	95% conf. interval upper
UPG	-423.780	88.140	-4.810	-	-601.302	-246.258
SAV	-270.940	153.138	-1.770	0.084	-579.376	37.497
TNR	152.765	10.778	14.170	-	131.058	174.473
_cons	-5,325.542	633.835	-8.400	-	-6,602.152	-4,048.932
Number of obs	49	R-squared	0.914			
F (4, 44)	150.440	Adj R-squared	0.908			
Prob > F	0.000	Root MSE	516.650			

Table 6. Simultaneous Model Estimation by 2SLS

NNI	Coefficient	Std. err.	t	P>|t|	95% conf. interval lower	95% conf. interval upper
UPG_hat1	1.030	0.146	0.030	-	0.736	1.323
SAV	4.745	153.079	0.030	0.975	-303.572	313.063
TNR	-4.748	25.584	-0.190	0.854	-56.276	46.781
_cons	214.441	1,162.204	0.180	0.854	-2,126.358	2,555.241
Number of obs	49.000	R-squared	0.914			
F (4, 44)	159.520	Adj R-squared	0.908			
Prob > F	0.000	Root MSE	516.410			

Tables 4, 5, and 6 present different regression models of analysis. Table 4 examines the determinants of UPG, with SAV, TNR, and WOB as explanatory variables. The results show that WOB has a significant negative effect on UPG, suggesting that improvements in women's legal and business rights reduce urban population growth. TNR has a significant positive effect, indicating that higher natural resource rents are associated with increased urban growth, while SAV has no significant impact. Regarding, Table 5 focuses on the relationship between NNI and its predictors (UPG, SAV, and WOB). Here, UPG has a strong negative effect on NNI, indicating that higher urban population growth is linked to lower national income.

WOB continues to show a positive and significant effect on NNI, highlighting the importance of women's rights in boosting national income, while SAV shows a marginally significant negative relationship with NNI. According to Table 6 applies a simultaneous equations model using Two-Stage Least Squares (2SLS), where UPG is treated as endogenous (instrumented as UPG_hat1). In contrast to the negative relationship in Table 5, UPG_hat1 shows a significant positive effect on NNI, indicating that when endogeneity is addressed, urban population growth contributes positively to national income. However, in this model, SAV and WOB are not significant, suggesting that the relationship between these variables and NNI changes when UPG is accounted for as an endogenous factor.

When compare between results in Table 6 and Table 3. It was found that, in Table 3, where ordinary least squares (OLS) regression is used, UPG has a negative impact on NNI, consistent with the findings in Table 5. However, in Table 6, the 2SLS model shows a positive relationship between UPG and NNI, demonstrating that addressing the endogeneity of UPG significantly alters its effect.

4. Discussion

One of the central findings from the results is the strong positive impact of WOB on NNI. Across all models, WOB consistently emerges as a significant driver of national income growth, highlighting the importance of gender inclusiveness in fostering economic development. This result aligns well with the broader literature, which suggests that women's economic participation and legal empowerment significantly contribute to economic growth. For instance, the literature review references studies demonstrating how women-owned businesses and greater gender equality in business rights lead to job creation and overall economic development (Gulvira et al., 2024; Rizvi et al., 2023). Therefore, the findings support existing previous findings that emphasize the critical role of women's legal and economic empowerment in boosting national income. Conversely, the negative effect of UPG on NNI, as shown in the OLS models (Table 5), indicates that higher urban population growth is associated with lower national income. This relationship is complex and contrasts with some of the expectations in the previous empirical findings. For instance, the previous studies discuss how population dynamics, particularly favorable age structures, can positively affect economic growth in certain contexts (Jayadevan et al., 2024). However, this study suggests that rapid urban population growth may strain resources and infrastructure, negatively impacting income. This finding could be context-specific, reflecting challenges associated with urbanization in the sample region, Thailand, where rapid urbanization may not be accompanied by adequate infrastructure development or resource allocation. however, the 2SLS model in Table 6 presents a contrasting view. When UPG is treated as endogenous, it shows a positive effect on NNI, indicating that urban population growth contributes positively to national income when its simultaneous relationship with other variables is accounted for. This result challenges the negative association found in the OLS models and suggests that UPG might have a more complex, potentially beneficial role in economic growth when proper controls are in place.

The role of SAV in this study presents another intriguing dimension. The OLS results indicate that SAV has a marginally significant negative impact on NNI, which runs counter to much of the literature that generally positions savings as a positive contributor to economic growth. For example, financial development through savings mobilization is often seen as a critical factor for capital formation and investment in high-income countries (Ikhsan & Satrianto, 2023).

The negative impact of savings in this context may reflect issues related to inefficient allocation of savings or environmental factors, as mentioned by some previous studies. In some cases, savings have been found to negatively affect growth, particularly when other structural issues, such as environmental degradation or poor financial management, come into play (Majekodunmi et al., 2023; Rehman et al., 2023). This could explain why SAV has a mixed effect in this model, particularly in the specific context of Thailand, where savings may not be translating into productive investments.

Lastly, TNR exhibits an insignificant effect on NNI across the models, which departs from the expected positive relationship often found in previous studies, especially in resource-rich countries. The literature review discusses how natural resource rents can either positively or negatively affect growth depending on the country's institutional quality and economic structure (Meng et al., 2022). In Thailand's case, the neutral or insignificant effect of TNR could be a result of weak institutional mechanisms or the "resource curse," where reliance on natural resources does not necessarily lead to sustainable economic development.

5. Policy Implementation

The analysis reveals several policy implications for enhancing economic growth in Thailand and similar contexts. First, the significant positive relationship between the Women, Business, and the Law Index (WOB) and Net National Income (NNI) highlights the importance of promoting gender equality in economic and legal frameworks. Policymakers should prioritize legal reforms that enhance women's participation in the economy, such as improving access to financial resources, expanding women's legal rights in business ownership, and eliminating barriers to female entrepreneurship. The analysis also highlights the complex role of Urban Population Growth (UPG). This suggests that policymakers should focus on improving urban planning and infrastructure development, ensuring that cities are equipped to handle population growth sustainably. Investments in transportation, housing, and public services will enable urban areas to act as engines of economic growth rather than sources of strain.

Furthermore, the mixed results for Adjusted Savings (SAV) imply that while savings are generally important for economic growth, their impact may be moderated by how efficiently they are used. Policies should focus on enhancing the productivity of savings by encouraging investments in sectors that generate long-term economic benefits, such as education, technology, and sustainable industries.

6. Future Research

Future research could explore the conditions under which urbanization promotes economic growth. This includes investigating the role of infrastructure development, public services, and regional economic policies in moderating the effects of rapid urbanization. Another area for further investigation is the impact of Adjusted Savings (SAV) on economic growth. The mixed results in this study suggest that savings may not always translate into productive investments. Future research could examine the mechanisms through which savings contribute to or detract from growth, particularly in developing countries. Finally, research could further examine the significant role of Women, Business, and the Law Index (WOB) in driving growth, particularly in diverse cultural and economic contexts.

7. Conclusion

This research explored the relationships between several economic variables in Thailand, specifically focusing on Net National Income (NNI), Urban Population Growth (UPG), Adjusted Savings (SAV), Total Natural Resources Rents (TNR), and the Women, Business, and the Law Index (WOB) during the period from 1972 to 2020. To capture the interdependencies among these variables, the study employed a simultaneous equations model, utilizing data sourced from the World Bank. Both ordinary least squares (OLS) regression and Two-Stage Least Squares (2SLS) were implemented to address potential endogeneity issues within the model. The findings yielded several key insights. First, the analysis highlighted a positive and significant effect of the WOB on NNI, underscoring the critical importance of women's economic and legal empowerment in fostering economic growth. Second, the relationship between UPG and NNI was found to be complex. While the OLS models indicated that rapid urban population growth negatively affects national income, the 2SLS model suggested that, once endogeneity is accounted for, UPG can actually contribute positively to economic growth. Lastly, the results regarding SAV were mixed, indicating that while savings are an important factor in economic growth, their impact may vary depending on how efficiently they are utilized. Consequently, the research suggests that policymakers should prioritize legal reforms aimed at empowering women in business, as this has a strong and positive influence on economic growth. Furthermore, managing urbanization effectively requires a focus on infrastructure development and sustainable urban planning to harness the benefits of urban growth. Finally, enhancing the productivity of savings through targeted investments in education, technology, and sustainable industries will help maximize the economic benefits derived from savings.

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RESP

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Challenges and Opportunities in Lebanon's Post-War Recovery: A Comparative Analysis with Iraq

Lübnan'ın Savaş Sonrası İyileşmesinde Zorluklar ve Fırsatlar: Irak ile Karşılaştırmalı Bir Analiz

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ANAHTAR KELİMELER

Savaş Sonrası İyileşme
Sürdürülebilir Ekonomik Kalkınma
Altyapının Yeniden İnşası
Çevresel Sürdürülebilirlik
Yönetişim ve Şeffaflık
Yoksulluğun Azaltılması

KEYWORDS

Post-war Recovery
Sustainable Economic Development
Infrastructure Reconstruction
Environmental Sustainability
Governance and Transparency
Poverty Alleviation

ÖZ

Bu makalenin temel amacı, savaştan etkilenen iki gelişmekte olan Lübnan ve Irak arasında karşılaştırmalı bir analiz yapmaktır. Makale, her ülkenin ekonomik durumunu sunar ve her birinin ekonomik sürdürülebilirliğini sağlamak için karşılaştığı benzersiz zorlukları inceler. 2003 yılındaki Irak deneyiminden yararlanan makale, iyileşme programlarının uygulanmasında karşılaşılan temel başarıları ve engelleri vurguluyor ve ülke Irak'ın yolunu izlemeye istekliyse Lübnan için olası sonuçları öngörmeyi amaçlamaktadır. Sonuçlarımız, Lübnan'ın durumunun yönetim sorunları, siyasi müdahale ve yolsuzluk karşısında daha karmaşık olduğunu vurguluyor. Bu nedenle, ekonomik sürdürülebilirliği sağlamak için kendi iç politikalarını uygularken uluslararası kurumlarla iş birliğini teşvik ediyoruz.

ABSTRACT

The main objective of this article is to conduct a comparative analysis between Lebanon and Iraq, two emerging countries that have been affected by war. The paper presents the economic situation of each country and examines the unique challenges each one of them faces to achieve its economic sustainability. Drawing from the experience of Iraq in 2003, the article highlights the key successes and obstacles faced in implementing the recovery programs and aims to project the possible outcomes for Lebanon, if the country is willing to follow Iraq's path. Our results emphasize that Lebanon's situation remains more complicated in the presence of governance problems, political intervention, and corruption. Therefore, we encourage its collaboration with international institutions while implementing its own internal policies to achieve economic sustainability.

1. Introduction

In the aftermath of a war period, a country faces difficulties in restoring its economic sustainability due to the deterioration of its infrastructure, environment, and deforestation. Lebanon and Iraq, two countries that have been affected by war in 2024 and 2019, respectively, share similar national characteristics, making them a good example for comparison. For a country that has pegged its national currency to a foreign one, the challenge that remains is the time to recover due to high inflation, the increase in poverty rate as well as to the currency fluctuations. This kind of regime makes the country depend on external factors such as foreign investments, tourism, and real estate in Lebanon and oil exports in Iraq. (Barbier, 2013).

After pegging the Lebanese lira to the US dollar in 1990, Lebanon has faced many years of fiscal mismanagement, corruption, and high levels of debt. In 2019, Lebanon was affected by a twin banking and currency crisis, followed by a 2020 sovereign default. In September 2024, Lebanon was significantly affected by the war with Israel, which caused remarkable damage, particularly in affecting its infrastructure, increasing the unemployment rate, and displacing populations, as well as accelerating economic and

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environmental decline. Moreover, its currency lost over 90% of its value, and its banking sector faced over 72 billion dollars in losses. The war compounded these vulnerabilities, inflicting further damage on infrastructure.(World Bank, 2021)

In the aftermath of financial crises and post-war periods, the nation is encouraged to collaborate with international institutions to implement recovery programs in order to stimulate the economy, as the main purpose of a sustainable economy is to support ongoing economic development, reduce pollution and deforestation, and restore social equity (Barbier, 2013).

In this paper, we will study Iraq's post-conflict recovery in 2003 and try to assess its applicability to Lebanon's current crisis. Despite all the efforts made in Iraq to rebuild its infrastructure, promote economic growth, and achieve economic sustainability, Lebanon's unique situation makes it a good example to predict its path should it want to implement he same policies adopted in Iraq. Due to the recent war, corruption, infrastructure deterioration, deforestation in the South, the huge number of displaced citizens, and the devaluation of its national currency, Lebanon is currently facing a serious situation in trying to achieve its economic sustainability. Consequently, the Lebanese government is encouraged to implement a recovery plan based on Iraq's experience in 2003.(World Bank, 2021).

The core of the study is bridging two emerging countries affected by war, trying to project the possible outcome into the Lebanese situation while studying Iraq's situation. Therefore, this article will first provide a comparative analysis of the macroeconomic trajectories of both nations. Second, it will review the core literature on sustainable economic and environmental strategies in post-conflict settings. Third, it will present a detailed case study of Iraq's post-2003 recovery programs to evaluate their successes and failures. Finally, the paper will conclude by analyzing the specific institutional and governance challenges unique to Lebanon that obstruct a similar path to achieving long-term sustainability.

2. Macroeconomic Presentation of Lebanon and Iraq pre and Post War Situation.

Lebanon and Iraq share a similar macroeconomic situation covering the major sector of the country and were both affected by severe war, making it hard to achieve economic sustainability. In the aftermath of the Lebanese war in 1990, the country pegged its national currency to the US dollar in order to attract international investments and foreign deposits. As a result, the economic system was heavily reliant on the external inflows, tourism, and real estate, rather than on the national production. (Blom Invest Bank, 2019). Pegging the national currency to the US dollar was followed by a lot of debt in foreign currency, forcing the country to accumulate a public deficit estimated at 172% of GDP (CEIC Data, 2025).

In 2019, and following the COVID-19 pandemic, Lebanon was affected by a twin crisis: a banking crisis followed by a currency crisis. This situation caused a total collapse of the system, and the government declared the default of payment of its debt in 2020. (Georgetown Jia, 2023). Moreover, depositors lost confidence in the banking system and were not allowed to withdraw their deposits. As a result, the Lebanese lira devaluated drastically and has lost over 98% of its value, the banking sector losses were estimated to be around 72 billion dollars, and the country faced hyperinflation (Trading Economics, 2025).

This situation was exacerbated by the 2024 conflict, diminishing all the trust in the banking system and eliminating all the chances to implement any macro policies or collaborate with the International Monetary Fund. As a result, it's hard for Lebanon to achieve economic sustainability within the current factors and the corruption in the public sectors. (World Bank, 2025).

Concerning Iraq's macroeconomic situation, the nation also pegged its national currency to the US dollar in order to attract foreign investments. During the period 1996 – 2003, Iraq was a command economy where it was strongly dependent on oil exports. It's largely dependent on the UN Oil-for-Food Program, which has limited oil exports in exchange for humanitarian imports. As a result, GDP per capita decreased by around $700 in 2002, and the unemployment and poverty rates increased drastically. Furthermore, the country has faced a high level of inflation followed by a lot of corruption in the public sector. (Economic Research Forum, 2020).

On the other hand, and in the aftermath of the fall of Saddam Hussein's regime, Iraq was transformed into a hyper-rentier state, almost entirely dependent on oil, which accounts for over 90% of government revenue. The Coalition Provisional Authority (CPA) encouraged the liberalization of the market, privatization, and the opening of trade and banking sectors. Despite these efforts, the absence of security and governance discouraged investments and slowed reconstruction. As a result, economic sustainability couldn't be achieved in the presence of its oil dependent, massive population and corruption. (Trading Economics, 2025).

3. Literature Insights on Sustainable Economic and Environmental Strategies Following Conflict

War can severely impact the country's different aspects, including its infrastructure and social sector. In the aftermath of conflicts, the nation usually borrow from other countries to implement a recovery program in order to achieve economic sustainability. Therefore, the government often faces fiscal deficits and substantial debt.

According to Collier et al. (2003), the main objective of recovery programs is to stimulate economic growth without taking into account the necessity of reducing poverty and inequalities. Ignoring these aspects will limit its success and may worsen the situation.

Similarly, in his study conducted in 2012, Bouvier highlights the necessity of good coordination between recovery programs and social aspects. The author argues that special attention should be given to the displaced citizens to ensure equality and justice. Without taking these aspects into consideration, recovery programs could fail to achieve economic sustainability.

To ensure that recovery programs are correctly implemented and are achieving their goals, it's important that the country collaborates with international institutions such as the World Bank, the International Monetary Fund (IMF), the United Nations Development Programme (UNDP). These plans aim to restore environmental sustainability, enhance social welfare, and aid displaced citizens in securing future stability and long-term growth. In addition, they should be able to reduce pollution and deforestation issues. Although the collaboration remains a must for the country, it should adopt its own national policies that align with the main objective of the program. (Barbier, 2013; Unruh & Williams, 2013).

On the other hand, post-war periods are usually followed by an increase in the level of deforestation and pollution as well as a decrease in landscaped and agricultural areas. This situation results from the extensive use of chemicals in bombs and missiles. Consequently, nations that mainly depend on agriculture and natural resources face greater challenges in achieving a rapid and smooth recovery. Therefore, the nation should focus on green technologies, renewable energy sources, and agriculture in order to achieve a sustainable economy. (Suarez et al., (2018) ; Nguyen et al., (2023).

Cairns (2003) examines the determinants of sustainable international trade in the post-Soviet region following the Russia–Ukraine conflict. The findings show that war negatively impact the infrastructure and decreases the economic growth as well as pollutes the environment. Moreover, it can decrease the GDP per capita for several years even after the conflict ends. The study concludes that rebuilding Ukraine's transport infrastructure is crucial for restoring regional trade sustainability and ensuring stable international food supply chains.

Moreover, Collier et al. (2008) studied the challenges during post-conflict periods. The author confirms the need to combine an economic recovery and social equalities to prevent renewed conflict. Additionally, the study emphasizes the need to implement adequate national policies and to collaborate with international institutions in order to stimulate economic growth. Finally, the study shows that adopting the right policies can reduce the risk of renewed conflict from 40% to 31%. However, the main key to success and to achieving economic sustainability is to collaborate with external support and gradual economic recovery, recommending that post-conflict aid be allocated inversely to a country's income level to address greater risks in poorer nations.

In addition, Serneels et al. (2015) investigate Rwanda's civil war impact on long-term economic growth in the early 1990s. The findings emphasize that consumers' level of spending remains low even six years after the conflict and the unemployment rate was relatively high. Moreover, the study reveals that violence tends to persist in the country for years after the conflict has officially ended.

Furthermore, Manpaa et al. (2024) explore how post-conflict societies can achieve sustainable development, focusing on Northeast Nigeria after the Boko Haram insurgency. Although the country made efforts to recover from massive destruction, loss of lives, and large-scale displacement, progress toward a sustainable economy was hindered by limited financial resources, corruption, weak institutions, and poor coordination among national actors.

Moreover, Jundi (2024) studied the impact of war on economic growth and sustainability in South Sudan. Based on data collected from the World Bank, IMF, UN, and government sources, the study shows that as long as the war is prolonged, so many of the country's aspects will be hurt. The study reveals that the war left the country's infrastructure in ruins and caused economic losses exceeding six billion dollars. South Sudan was hit particularly hard, as the nation was heavily reliant on agriculture and oil exports. It emphasizes the urgent need to rebuild infrastructure, assist displaced people, and strengthen the agricultural sector to secure lasting economic recovery.

Similarly, Hassoun (2025) highlights that the war in Gaza was one of the most severe in the world, with the excessive use of bombs and missiles, coupled with shortages of food and basic necessities. These conditions contributed to rising poverty and increased inequality across the region. Therefore, an urgent need is recommended for sustainable reconstruction, effective resource management, and strong international cooperation to restore resilience and promote long-term sustainability in Gaza.

Mohammed et al. (2025) analyze the impact of Iraq's war on the economic and social sectors by comparing it to Saudi Arabia and Algeria. Results show that Iraq experienced short-term GDP growth during the recovery period but suffered long-term declines in GDP per capita estimated at around −30.6% relative to Saudi Arabia and a high level of inflation. Additionally, the findings emphasize that Iraq's oil exports increased by 45% compared with Algeria post invasion. On the other hand, human development indicators show low profits in education and healthcare sectors, and CO_2 emissions per capita fell by 79.3% relative to Saudi Arabia, reflecting industrial decline rather than environmental improvement. Finally, the authors confirm that a country that faces weak governance and economic instability can limit its recovery.

4. Post-War Recovery Programs in Iraq: Insights and Lessons

Following the war in Iraq (2003), the country implemented a recovery plan as part of restoring economic sustainability. The recovery strategies are illustrated in the subsequent tables (Table 1 and Table 2 are in the Annex).

Following the adoption of the programs, their impact on Iraq was considered positive in numerous areas. Table 2 outlines the different aspects affected and the obstacles that hindered the full achievement of the programs.

Following the reconstruction plan implemented in Iraq that focuses on restoring infrastructure, eliminating corruption, ensuring transparency in public sectors, encouraging education, agriculture and industrial sectors, as well as supporting displaced populations, the country was able to restore sustainability and economic growth. In collaboration with international aid, Iraq took advantage from the recovery plan and was able to achieve a sustainable post-war growth. (Barbier, 2013).

5. Lessons from Iraq's Post-Conflict Recovery: Anticipated Institutional and Governance Challenges for Lebanon

Although Iraq's experience offers valuable lessons to Lebanon in achieving economic sustainability, applying the same policies to the Lebanese context is unlikely to achieve similar results due to the country's unique political system and governance structure and characteristics.

Similar to Iraq, the first step is to collaborate with international institutions. This situation offers both substantial opportunities and challenges. It can attract foreign investments but would face the resistance of the main actors. The program should focus on adopting strong governance and transparency, factors of success in Iraq. Therefore, the Lebanese government can combat corruption and restore transparency within public institutions. Moreover, a special attention should be given to natural resources and the country's necessities following the rapid deterioration of water supply, electricity, healthcare, and education.

On the other hand, we can learn from Iraq that the CPA reforms failed because they lacked local ownership. Consequently, as the trust in the public sector is null in Lebanon, it's hard for international institutions to achieve economic sustainability. Similarly, the USAID Program had limited sustainability in Iraq due to weak coordination and lack of maintenance. While Lebanon usually adopts policies and laws that protect the politician and the governmental sector, it remains challenging to collaborate with international institutions that limit their control over the primary sectors.

Concerning the fiscal and monetary sector and as the country declares payment default in 2020, the current public debt remains high, limiting the ability for additional borrowing and to finance social and developmental programs. In addition, the Lebanese lira has lost more than 90% of its original value, leading to hyperinflation and a decline in purchasing power. As a result, economic sustainability couldn't be achieved without restoring the consumers' purchase power, the main booster of economic growth.

Furthermore, the continuous emigration of skilled professionals as doctors, teachers, and engineers has reduced Lebanon's human capital, making it harder to rebuild productive capacity and slowing its recovery. On the other hand, the presence of 18 different religions in the country, can create resistance to implementing and accept these new policies. This factor may also contribute to renewed internal conflicts.

A particular attention should be given to the South, which covers a lot of displaced citizens. The government should ensure there's enough food supply, health care, and education. On the other hand, the country should also focus on restoring the destroyed and deforested areas by planting more trees to ensure smooth environmental recovery.

Finally, the direct intervention of Lebanon in other countries' wars may discourage the international institutions from collaborating and adopting their programs, which will delay their long-term sustainability.

6. Conclusion

This paper presents a comparison between Lebanon's and Iraq's post-conflict recovery. Its originality lies in taking lessons from Iraq's recovery in order to predict Lebanon's possible outcome if the country adopted the same policies. Both countries share similar economic situation in pegging their national currency to the US dollar, accumulating high public debt, and recognizing high levels of inflation, unemployment, and poverty rates. However, each one possesses its own characteristics, making their recovery different.

We can learn from Iraq's experience that governance transparency and the collaboration with international institutions are key factors to achieve economic sustainability. To reach that goal, the country should adopt policies related to primary sectors, agriculture, and economic and social sectors, eliminate corruption, and encourage governance transparency. While focusing on rebuilding its infrastructure, promoting environmental governance, controlling pollution, and subsidizing health and educational sectors, Iraq was able to restore investors' confidence and to achieve economic sustainability. However, weak governance and corruption limited the success of the program. While Iraq's experience offers valuable insights, Lebanon's distinct political fragmentation, lack of natural resource wealth, and regional entanglements present limitations to the direct applicability of Iraq's recovery model.

The country should also encourage investments in damaged areas and restore the trust in the country's main sectors. Furthermore, the implementation of legal frameworks and

regulations within the public sector is imperative to restore transparency and to combat corruption. On the other hand, Lebanon's direct involvement in the regional war can't restore investors' confidence, a major key of success of recovery programs.

In conclusion, and in order to achieve sustainable growth, Lebanon should implement policies that combine fundamental political and institutional transformation that control corruption, restore governance transparency, and restore investors' confidence. The lessons from Iraq are stark: technical recovery plans and international aid, while necessary, are insufficient to overcome a state that isn't willing to solve its imbalances and promote economic sustainability.

Several limitations must be acknowledged to this article. Iraq's oil dependence and centralized governance differ from Lebanon's political system and limited fiscal capacity, which may restrict the applicability of certain policy recommendations. While Lebanon's war is recent and the country hasn't applied any policy or program yet, as well as it is not willing to collaborate with international institutions, it's hard to make a clear projection for its future economic sustainability. Future research should examine the evolution of key macroeconomic indicators, particularly unemployment, poverty rates, and environmental degradation, in order to assess the effectiveness of potential recovery frameworks through empirical analysis and fieldwork.

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Annexes.

Table 1. Recovery program for Iraq

Program Title	Category	Lead Institution(s)	Core Components	Purpose / Impact
USAID Infrastructure Reconstruction Program	Basic Services	USAID, Iraqi Ministries	Water & sanitation, electricity, schools, health, agriculture	Restore essential services and boost local economic resilience
Five-Year Environmental Governance Roadmap	Institutional & Policy Reform	Ministry of Environment, UNDP	Legal reforms, pollution standards, decentralized management, local engagement	Establish environmental institutions and participatory governance
UNEP Pollution Hotspot Remediation	Environmental Remediation	UNEP, Iraqi Government	Identification and cleanup of 60+ industrial/war-related hotspots	Reduce health risks, improve environmental quality
National Solid Waste Management Plan (2007)	Urban Environmental Reform	Ministry of Environment	Policy planning, technical capacity, public education	Improve urban health and waste services
Marshlands Restoration & KBA Projects	Ecosystem Rehabilitation	Nature Iraq, UN Partners	Re-flooding, biodiversity mapping, eco-tourism, community monitoring	Restore the Mesopotamian wetlands and protect biodiversity
Mosul Public Health Recovery Program	Health System Recovery	U.S.-Iraqi Univ. Consortium	Training, rebuilding facilities, inclusive public health access	Rehabilitate war-affected health infrastructure
Legal & Economic Reforms (CPA Period)	Institutional Reform	Coalition Provisional Authority	Privatization, property law, environmental governance setup	Encourage investments in infrastructure
Green Mosul Initiative (2021–2023)	Civic Green Urbanism	Mosul Eye, UN-Habitat	Tree planting, community education, partnerships with universities and municipalities	Promote urban greening and post-conflict reconciliation
Regional Water & Environmental Cooperation	Transboundary Governance	Iraq, Iran, Turkey, UNEP	Water diplomacy, dust storm mitigation, joint environmental frameworks	Address regional environmental risks collaboratively

Source: Center for Strategic and International Studies (2017); United States Institute of Peace (2005); European Institute of the Mediterranean (2017); Matsunaga (2019) and Italian Institute for International Political Studies (2020).

Table 2. Impact of the recovery program in Iraq

Program Title	Impact and Obstacles on Iraq	Impact
USAID Infrastructure Reconstruction Program	Rapid rehabilitation of essential infrastructure; improved short-term access to services; limited sustainability due to weak coordination with Iraqi institutions and lack of maintenance capacity.	Positive with limitations
Five-Year Environmental Governance Roadmap	Strengthened legal and institutional frameworks for pollution control and environmental planning; improved stakeholder inclusion and decentralization; however, enforcement remained uneven due to administrative fragmentation.	Positive
UNEP Pollution Hotspot Remediation	Identification and partial cleanup of over 60 contaminated sites; reduced public health risks in targeted areas; technical success but limited follow-up capacity for long-term monitoring and maintenance.	Positive
National Solid Waste Management Plan (2007)	Provided a national framework for waste policy; increased public awareness and technical training at municipal levels; practical implementation varied widely across regions depending on local capacity.	Positive but uneven
Marshlands Restoration & KBA Projects	By 2008, over 60% of the original Mesopotamian Marshlands had been restored, helping to revive biodiversity and support local livelihoods. However, this progress remains vulnerable due to irregular water flows and the absence of regional water agreements.	Positive
Mosul Public Health Recovery Program	Improved access to health services in post-conflict Mosul; upgraded facilities and trained medical personnel; promoted inclusive health access, though ongoing insecurity posed challenges.	Positive
Legal & Economic Reforms (CPA Period)	Introduced market-oriented reforms and new property/environmental laws; created basic environmental governance structures; lacked local ownership, leading to limited enforcement and long-term legitimacy.	Mixed to negative
Green Mosul Initiative (2021–2023)	Reforested degraded urban spaces and promoted civic environmentalism; engaged youth, universities, and municipalities; contributed to reconciliation and post-war urban recovery.	Positive
Regional Water & Environmental Cooperation	Initiated diplomatic dialogues with Iran and Turkey on shared water resources; fostered regional awareness of dust storms and environmental risks; concrete policy outcomes still limited.	Positive but limited

Source: Center for Strategic and International Studies (2017); United States Institute of Peace (2005); European Institute of the Mediterranean (2017); Matsunaga (2019) and Italian Institute for International Political Studies (2020).

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Derleme Makale ● Review Article

Prospects of A Conservative Environmental Philosophy *

Muhafazakâr Bir Çevre Felsefesinin Geleceği Üzerine

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ANAHTAR KELİMELER

Muhafazakar çevre felsefesi
Neoliberalizm
Doğa

ÖZ

Bu çalışmada, çevresel sorunların çözümünde sorumluluğu bireylere, onların örgütlerine ve özel girişimlere yükleyen muhafazakâr bir çevre felsefesinin gerekçelendirilebilirliğini inceleyeceğiz. Muhafazakâr yaklaşım, tehditlere yerel uyumu ve yerel çözümlerin değerlendirilmesini öngörür; radikal adımlardan kaçınır ve özellikle sorunların bir parçası hâline gelmişse, düzenlemelerin kaldırılmasına veya gevşetilmesine yol açar. Bu felsefenin temelinde, yerel toplulukların en yakın doğal çevrelerine olan bağlılığı yatar. Topluluklar, bu çevreyi temiz tutmak ve sürdürülebilir kalkınma imkânları sağlamak isterler; böylece bu alanı gelecek nesillere aktarabileceklerdir. Bu bağlılık, topluluğun yararına olduğu kanıtlanmış köklü kültürel ve ahlaki geleneklerle iç içedir. Muhafazakâr ekoloji yaklaşımı, hava kirliliği izinlerinin satışı yoluyla meta-para ilişkilerinin gelişigüzel yayılmasından ayrılır; zira bu uygulama vergi mükelleflerine gereksiz bir yük getirir, karanlık yapılara kazanç sağlar ve ulusal sanayinin gelişim imkânlarını sınırlar. Özetle, muhafazakâr çevre felsefesi küçük ve mütevazı adımlar atmayı öngörür; ancak bu adımlar, yaşadığı somut çevreyi kutsal sayan, geleneksel üretim ve toprak işleme yöntemlerini benimseyen, yaşadığı yeri temiz ve gelecek nesillere uygun biçimde korumak isteyen insanlar için tamamen anlamlıdır. Çevresel muhafazakârlık, her topluluğun, ulusal toplumun ve özgür bireylerin ve örgütlerinin kendi evini koruma amacıyla bağımsız karar alma hakkını ve egemenliğini savunur.

KEYWORDS

Conservative environmental philosophy
Neoliberalism
Nature

ABSTRACT

In our paper, we will analyze the prospects for justifying a conservative environmental philosophy that assigns the responsibility for solving environmental problems to citizens, their organizations and private initiatives. The conservative approach implies a local adjustment to threats and consideration of local solutions, avoids radical steps and leads to the repeal or loosening regulations, especially if they are part of the problem. At the base of this philosophy stands the attachment of local communities to their closest natural environment, which they want to keep clean and to provide opportunities for its sustainable development in order to pass it on to the next generations. This attachment is tied to well-established cultural and moral traditions whose adherence has proven beneficial for the respective community. The conservative approach in ecology is distinguished from the indiscriminate invasion of commodity-money relations through the sale of air pollution allowances, because it unnecessarily burdens taxpayers, brings profits to shady structures and leads to the limitation of opportunities for the development of national industry. We can summarize that the conservative environmental philosophy implies small and modest steps, but they are entirely in the interest of people who love a sacred concrete environment, the place where they live, traditional methods of production and cultivation of the land, and want to keep them their home clean and suitable for future generations. Environmental conservatism defends the sovereignty and the right to make independent decisions to protect one's home for each community, for the national society, and for free citizens and their organizations.

* This study was presented at the International Congress Of Recycling Economy & Sustainability Policy-II held on 17-18 October 2024 in Tekirdağ, Türkiye.

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1. Introduction

In our paper, we will analyze the prospects for justifying a conservative environmental philosophy that assigns the responsibility for solving environmental problems to citizens, their organizations and private initiatives. The conservative approach implies a local adjustment to threats and consideration of local solutions, avoids radical steps and leads to the repeal or loosening regulations, especially if they are part of the problem. At the base of this philosophy stands the attachment of local communities to their closest natural environment, which they want to keep clean and to provide opportunities for its sustainable development in order to pass it on to the next generations. This attachment is tied to well-established cultural and moral traditions whose adherence has proven beneficial for the respective community. The conservative approach in ecology is distinguished from the indiscriminate invasion of commodity-money relations through the sale of air pollution allowances, because it unnecessarily burdens taxpayers, brings profits to shady structures and leads to the limitation of opportunities for the development of national industry.

2. Findings and Discussion

The approach we defend opposes liberal projects to entrust the care of ecopolitics entirely to the state in its "night watch" function, which is supposed to protect people from harming each other (as an environmental Leviathan) and, as a result, leads to voluntarist decisions born of provoked panic for the future of the planet. There are enough examples of the campaign closure of coal plants without a clear prospect of replacing them with another source. Ridiculous policies to restrict livestock and poultry also make this list. The neoliberal establishment sees it as justified for rich and powerful countries to impose restrictions on everyone else's industrialization by making them pay much more for their carbon emissions. Poor countries are being shaken off several times in favor of the rich and powerful who have already used the lack of restrictions for their own industrialization, leading to negative effects on the natural environment. This is also the nature of some of the policies included in the "Green Deal", aimed at a circular economy and zero greenhouse gases by 2050. But the fact is that there is no global consensus around radical environmental measures and the process started with the Kyoto Protocol in the 90s now is declined. Even if Europe fulfills the environmental plans, it will not lead to a significant change in the state of the ecology on a global scale. Many big countries oppose these restrictions.

Today, we are witnessing a distortion of the foundations of normal life by propaganda, which relies on dubious data and tries to impose severe restrictions on economic and human development. The mechanism is known to us since the time of the global pandemic. We must say that corporate business has been preparing for a long time for the great transformation of the economy from relying on natural, but limited and expensive, resources such as oil and gas to ecological production, from which countless riches are expected. In the 1960s, a group of politicians, scientists, economists created the Club of Rome, which in a 1972 report called "The Limits to Growth" (Meadows 1972), based on computer simulation, developed the ideological thesis that human productive activity threatens nature and depletes limited natural resources. They find the exponential growth of the population with a limited resource. The forecast is that by 2013 the resources of a number of precious metals and oil will be exhausted. In fact, it is a modernized version of Malthusianism, but based on some objective facts and aimed at seeking direct economic benefits by pushing policies in the interest of rich countries. The concept is presented in humanitarian pathos in the books of Aurelio Peccei (1976), but there it already begins to resemble a religious doctrine.

In 2007, the journalist Mark Lynas took the next step towards inciting panic with his book "Six degrees: our future on a hotter planet", in which he predicted that very soon our ecosystem will go into a state of chaotic disequilibrium (Lynas, 2007). "Lynas's book is truly frightening - writes the English philosopher Roger Scruton in The Green Philosophy - the reader closes the last page trembling and drenched in a cold sweat" (Scruton, 2019, 43). In it, as a journalist, he talks about his interviews with climate experts who tell him about global warming and describes his panicked experiences from what was told. The purpose of this kind of psychotherapy is to create a sensation and a wide response among readers and zombify them for radical environmental policies. We find similar content in Al Gore's book "An Inconvenient Truth" (2008) and the lover of all kinds of crises, Bill Gates (2021). In the debate, the UN joins the side of the proponents of the thesis of global "warming" by forming the Intergovernmental Panel on Climate Change (IPCC), which disseminates the most alarming conclusions in its documents. The UN project on "sustainable development" and the "global goals of the century" was an ideological complement to this propaganda.

In a pattern already known to us from the period of the global pandemic, the voice of real science is silenced. Academic climatologists Patrick Michaels and Robert Balling Jr. in "Satanized Gases" (Michaels and Balling 2000) predict only moderate cyclical warming in the early 21st century, similar to the last third of the 20th century, but with beneficial effects on production of food and resource management. We are already living in such a period and we see that the predictions are justified. After such warming comes usually a period of cooling. The title of NASA climatologist Roy Spencer's book, “How Global Warming Hysteria Leads to Bad Science, Pandering Politicians and Misguided Policies That Hurt the Poor”, is persuasive (Spencer 2008). Opinions critical of "global warming" are collected at https://www.climatedepot.com/. The scientists supporting negative opinions have worldwide academic authority and number more than 1,500. An important argument in favor of "global warming" was the so-called

"ozone hole", but today it seems to be closing (Lecheva 2023). Left-wing environmentalists are missing their main point. However, we must say that we do not deny the deepening of environmental problems, only the globalization of panic reactions and attempts to impose policies based on bad science.

Global approaches to the problems of ecology do not lead to its solution. The countries that latched onto the Green Deal and defended the resulting draconian regulations may be a large minority, and self-imposed deprivations may prove ineffective. We see a good basis for conservative measures in the 1987 report of the World Commission on Environment and Development, chaired by Gro Harlem Brundtland, "Our Common Future", which, in response to the debate on the "limits to growth", highlighted the need for development, where attention is paid to environmental issues. There is also a perspective in the decentralization of energy provision, but with the active participation of local communities to build small water and wind plants, photovoltaic systems and to reject brutal external investors in the sector. In our country, many politicians built photovoltaic parks with the help of the EU and the state, and ordinary consumers pay the bill.

Conservative environmental philosophy excludes utopian global projects such as the „Green Deal" or attempts to influence the weather and limit sunlight. It is based on the love and attachment of people from local communities to the surrounding nature of the place where they live. It is not an ideology, but a way of thinking in defense of the interests of citizens and their rights. It finds its justification in the promotion of traditional civic values - freedom, balance of interests, guaranteeing democracy through the work of representative institutions. It does not aim to reject the concern for nature conservation as a policy priority, but to make it more effective and in the interest of citizens and countries - not only the rich who profit from quotas of carbon trading, but also the poor trying to make their economic progress. Conservatism in ecology is a struggle for effective local solutions in the interests of people. All this excludes the Brussels model of imposing more and more regulations and restrictions on economic activity in the interests of selected oligarchic circles.

Conservative environmental philosophy wants us to listen to the voice of scientists, not to the propaganda of paid political pundits who defend corporate interests. It demands care and responsibility for the preservation of our immediate natural environment, in which man is born, lives, raises a family, works, and seeks happiness. This way of thinking excludes the ominous predictions that human activity can destroy our planet and it does not accept the imposition of environmental policies through decrees by bureaucrats who do not represent the citizens. Environmental justice cannot be achieved in the manner of communism through mandatory global measures. People can turn to recycling industries in areas where this is possible and effective.

An example of such a practice could be the desire of Eastern European countries, including Bulgaria, to defend nuclear energy against voluntarism in the EU as an environmentally clean and the only adequate substitute for coal-fired energy production. To this we can add hydropower plants and the use of wind energy. But the financial burden for the transformation in energy consumption should not be borne only by citizens as taxpayers. Replacing "green" energies such as carbon or solar do not save humanity, but open a new path for development that hides many dangers.

The conservative environmental philosophy can rightly be criticized for replacing a global approach with a commitment by citizens to protect their own immediate environment, and for not being effective in confronting large-scale crises such as nuclear accidents or space disasters. It is also true that the imposition of regulations can sometimes prevent abuses. We can also add that experts often share different opinions and we can always find those in support of one thesis or its opposite. However, politically and economically motivated opinions dominate the propaganda of environmental activism.

The conservative approach requires turning to tradition and preserving the status quo. Let us recall that in the "golden" years of conservatism in the New Age, it was an ideology of the aristocracy that sought to resist revolutionary changes and the destruction of statehood. Conservatism is a fairly developed political doctrine that appears in European culture in various forms. It starts from an anthropological pessimism, presupposing the imperfection of man, the original sin, egoism and tendency to aggression, ruled by emotions and not by reason. A person pursues his interest, but derives it from what is embedded in community traditions, moral and religious values.

The moral or social order that will enable imperfect man to overcome what is wrong and be a disciplined member of a particular community is considered to be a problem of primary importance. Conservatives often refer in this context to the moral and social function of religion, which gives the individual a life orientation and worldview, as well as virtues to consider living among other people. The communal dimension of human life is seen as more important than the individual. Communities are understood according to the organismic metaphor – participation in them is the result of free contracts, as well as some values, rooted in tradition. They become harmonious wholes in which each individual can realize his life goals, which the given community sanctions as acceptable. These communities exhibit inequalities and hierarchies that are as natural as they are. Conservatism emphasizes man's obligations to his family, his community - and we can add - to his immediate natural environment. Things are bad when the freedom of the individual is unfettered by the tradition and rights of the community. Conservatives do not recognize absolute, timeless and universal rights.

Among the leading conservative minds we can point to Edmund Burke (1727-1797). According to him, society should be united by the mutual interest of people.

Communities are fundamental to human flourishing, and the best life begins in the "small places"—family, church, and local community—that orient people to virtues such as temperance and fortitude.

The first principle of any conservative policy, not only in the environmental sphere, is the refraining of the state from performing tasks that can be better performed by the citizens, by their initiatives and in defense of their interests in the protection of the territory they inhabit. This does not mean leaving things unchecked, but only controlling a rational division of labor between global and local environmental organizations, the state and civil communities. Conservatism advocates discipline and responsibility for consequences, especially in actions that may harm the environment. Undoubtedly, there are big problems that only the state and even associations of states can deal with, such as overcoming major production accidents, their prevention, limiting dangerous production. Today, the thesis of the "limits to growth" and the predictions of the Club of Rome have been disproved, but through financial measures to limit hydrocarbon emissions, the burden of environmental taxes is transferred to the people of poor countries, and this is unacceptable and immoral. These countries cannot be forced to close their production and buy "air" at exchange prices. Industrial greenhouse gas emissions rights often favor vested interests of environmental groups and industries, and this limits the prospects for research and development that could lead to emissions-free production.

It is particularly important to note that development is not sustainable if it relies on environmentally impure energy. But there is still no visible trend toward global clean energy that has even a small chance of being accepted by reconciling the various competing interests. Wind energy is a partial solution that can provide only a small fraction of the energy needed, but it also shifts the cost burden unfairly to consumers. It is not clear whether the production of batteries will not pollute nature much more than the extraction of natural resources. There is also no solution for the storage of obsolete photovoltaics and batteries. Carbon power plants can be too bulky compared to traditional sources. Manipulation for clean energies will not solve these issues. The use of energies must take into account the social cost, which is also part of the content of sustainable development.

So far, it looks that there is no alternative to nuclear energy in terms of environmental cleanliness and efficiency. With advanced electronic technology today, it is becoming more and more secure. However, there are too few serious players left in this sphere - the countries and companies that can build working nuclear power plants. Thus, we have another issue with possible consequences for the poor countries and those without capacity for building nuclear installations.

We would also add that policies are needed that encourage small producers in agriculture and the food industry. The countless regulations on special packaging, scary warnings of dangers, the elimination of traditional methods of food production and their replacement with chemically processed substances must be eliminated. More producer markets are needed where they can freely sell their products prepared using traditional methods. Localization is the most reliable path to sustainable agriculture and natural food production. It is also a strong demotivating factor for outsourcing costs to external factors. Only in this way will the small producers be able to defend themselves against the big players and the dictates of the supermarkets, they will be able to sell natural products and profit from their work. A little protectionism and protection of native products will also contribute to the protection of nature and people's health.

With the negligible profit tax in our country, the big food chains export the huge part of their income, they bombard the consumer with low-quality mass products, worse than the ecological ones in Western countries. It is necessary to put these relations in order, for supermarket chains to make a greater contribution to the financial system, and to introduce advantages for the shops of small producers.

Air pollution control is also a problem. The car manufacturers' desire for excess profits is having an effect, leading to massive production, even though hybrids and electric cars are already being made in large volumes, mainly in rich countries. The increase in the prices of heating with electricity and gas, the result of the selfishness of traders and the sanctions, led to an increase in the consumption of wood and coal in winter. Sanctions only increased their profits. We are also against damaging shale gas production technologies.The state can introduce rules to limit the profits of these traders and help consumers.

3. Conclusion

We can summarize that the conservative environmental philosophy implies small and modest steps, but they are entirely in the interest of people who love a sacred concrete environment, the place where they live, traditional methods of production and cultivation of the land, and want to keep them their home clean and suitable for future generations. It is primarily an antidote to neoliberal policies that rely on the escalation of panic messages, restrictive policies, and burdening the state with extraneous functions. It supports the production of healthy foods, efficient and socially acceptable methods of energy production and use. Environmental conservatism defends the sovereignty of states and humans and the right to make independent decisions to protect one's home for each community, for the national society, and for free citizens and their organizations.

The principles of conservative environmental philosophy can become the basis for the inclusion of the most powerful countries, which are now skeptical of the neoliberal consensus on the restrictions of the "Green Deal" and the trading of carbon emission allowances. Concern for sustainable development cannot be an obstacle to the economic prosperity of countries, especially with a growing

population. Ways of cooperation should be sought along these lines of developed strengths and poor countries that want to rapidly develop their economic base.

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Araştırma Makalesi ● Research Article

Türkiye'de Yenilenebilir Enerji Alanındaki İlerlemenin Kapsamlı Bir Analizi *

A Comprehensive Analysis of Progress In Renewable Energy in Turkey

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A N A H T A R K E L İ M E L E R

İklim değişikliği
Sürdürülebilir ekonomi
Yenilenebilir enerji

Ö Z

Bu çalışmanın amacı, Türkiye'de yenilenebilir enerji kullanımının gelişim sürecini ve bu sürece yön veren dinamikleri analiz etmektir. Bu doğrultuda, öncelikle küresel ölçekte hızlı nüfus artışı ve sanayileşmenin yol açtığı iklim değişikliği ile çevresel tahribatın önlenmesine yönelik uluslararası girişimler ele alınacaktır. Ardından, Türkiye'nin taraf olduğu uluslararası eylem planları ve bu planlar çerçevesindeki yükümlülükleri değerlendirilecektir. Sürdürülebilir ekonomik büyümenin sağlanması ve iklim değişikliğiyle etkin mücadele açısından, Türkiye'nin yenilenebilir enerjiye geçişi stratejik bir gereklilik haline gelmiştir. Bu bağlamda, diğer ülkelerde olduğu gibi Türkiye'de de yenilenebilir enerjiye geçiş süreci öncelikli bir politika alanı olarak ele alınmalıdır. Çalışmada, 2000'li yılların başından itibaren Türkiye'nin yenilenebilir enerji alanında kat ettiği mesafe değerlendirilecek; bu süreçte karşılaşılan başlıca yapısal sorunlar -altyapı eksiklikleri, düzenleyici çerçevenin yetersizliği, yüksek depolama ve dağıtım maliyetleri ile toplumsal farkındalık eksikliği- analiz edilecektir. Son olarak, yenilenebilir enerji potansiyelinin etkin şekilde kullanılabilmesi için geliştirilen kamusal destek mekanizmalarına yer verilecektir.

K E Y W O R D S

Climate change
Sustainable economy
Renewable energy

A B S T R A C T

The aim of this study is to analyze the development process of renewable energy use in Turkey and the dynamics that drive this process. In this regard, international initiatives aimed at preventing climate change and environmental damage caused by rapid population growth and industrialization on a global scale will be discussed first. Subsequently, the international action plans that Turkey is a party to and its obligations under these plans will be evaluated. In terms of ensuring sustainable economic growth and effectively combating climate change, Turkey's transition to renewable energy has become a strategic necessity. In this context, as in other countries, the transition to renewable energy should be addressed as a priority policy area in Turkey. The study will evaluate the progress made by Turkey in the field of renewable energy since the early 2000s and analyze the main structural problems encountered during this process, such as infrastructure deficiencies, inadequate regulatory frameworks, high storage and distribution costs, and lack of social awareness. Finally, the public support mechanisms developed to effectively utilize renewable energy potential will be discussed.

1. Giriş

Uluslararası Enerji Ajansı (IEA), 2000'lerin başında yayınlamış olduğu raporda önümüzdeki otuz yıl içerisinde dünya enerji talebinin enerji kaynakları ile karşılanmayacak ölçüde artacağını ve enerji güvenliğinin yanı sıra enerji üretiminden ve kullanımından kaynaklanan çevresel hasarlar konusunda ciddi endişelerin söz konusu olacağını vurgulamıştır (IEA, 2002). Çevre ve insanın korunmasına yönelik ilk uluslararası konferans 1972 yılında İsveç'in

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Stockholm kentinde düzenlenmiştir. Bu konferansın yirminci yıl dönümünde 3-14 Haziran 1992 tarihlerinde Brezilya'nın Rio de Janerio kentinde yenilenebilir enerji kaynakları kullanımını da içerisine alan 27 evrensel ilkenin benimsendiği Birleşmiş Milletler Çevre ve Kalkınma Konferansı (UNCED) gerçekleştirilmiştir. 179 ülkeden siyasi liderin, diplomatın, bilim insanının, sivil toplum örgütünün ve medya temsilcisinin katılım gösterdiği bu Dünya Zirvesi farklı sosyal, ekonomik ve çevresel faktörlerin yüksek ölçüde birbirine bağlı ve bağımlı yapısını ortaya koymuştur. Bu noktada sürdürülebilir kalkınma kavramının yerel, ulusal, bölgesel ve uluslararası değil dünyadaki tüm insanları kapsayıcı olduğuna vurgu yapılmıştır. Bu Dünya Zirvesinin en önemli çıktılarından biri sürdürülebilir kalkınmaya yönelik yeni strateji çağrısı olmuştur (United Nations, 1992a). "Gündem21" olarak devreye alınan eylem planı enerji ve kaynak kullanımında verimliliğin teşvik edilmesine vurgu yapmıştır. Bu kapsamda mal ve hizmet üretiminde birim başına enerji ve malzeme kullanımının azaltılması, çevresel baskının hafifletilmesi, çevreye duyarlı kaynak kullanımının yaygınlaştırılması amaçlanmıştır. Bu hedef doğrultusunda çevreye duyarlı teknolojilerin araştırma ve geliştirme faaliyetlerinin teşvik edilmesi, enerji ile ilgili kirliliği azaltmaya yardımcı yenilenebilir enerji kullanımının önceliklendirilmesi şeklinde bir dizi uygulamaya yer verilmiştir (United Nations, 1992b). 1997 yılında Gündem21'de kaydedilen ilerlemenin beş yıllık incelemesi yapılmıştır. Yine yüzü aşkın ülkenin katılımı ile sosyo-ekonomik kalkınmanın çevre üzerinde yaratmış olduğu sorunlar tespit edilmeye çalışılmıştır. 1997 yılının aralık ayında Kyoto Protokolü kabul edilmiş; oldukça karmaşık bir onay sürecinin ardından 2005 yılının şubat ayında yürürlüğe girmiştir. Protokol, sanayileşmiş ve geçiş sürecindeki ekonomilerin sera gazı emisyonlarını sınırlamaya ve azaltmaya mecbur bırakan birtakım politikalar ve önlemler devreye almıştır. Protokol emisyon hedeflerinin izlenmesi noktasında şeffaflığı sağlamak ve tarafların sorumluluk paylaşımını izlemek üzere inceleme ve doğrulama sistemi kurulmuştur (United Nations Climate Change, 2024). 2000 yılının 6-8 Eylül'ünde New York'ta Milenyum Zirvesi toplanmıştır. Devam eden süreçte Johannesburg'da 2002 Dünya Sürdürülebilir Kalkınma Zirvesi toplanmış; ekonomik kalkınmaya giden yolda çevreye duyarlı uygulamalar devreye alınmıştır. Su, enerji, sağlık, tarım, biyolojik çeşitlilik gibi konuları kapsayan bir dizi başlık gündeme alınmıştır. Enerji konusunda, enerji tedariğini çeşitlendirme ve yenilenebilir enerji kaynaklarına yönelim ihtiyacı vurgulanmıştır. Kyoto Protokolünü onaylayan devletler açısından sera gazı emisyonunun azaltılmasına yönelik hükümlere de yer vermiştir (United Nations, 2002).

21. yüzyılın ilk on yılında (2005, 2008 ve 2010 yılları) Binyıl Kalkınma Hedefleri görüşülmüş, 2012 yılında Rio+20 toplanmıştır. 2015 yılında ise Gündem 2030 ve on yedi adet sürdürülebilir kalkınma hedefi ortaya koyulmuştur. Sürdürülebilir kalkınma hedeflerinden yedincisi (SDG 7) doğrudan erişilebilir ve temiz enerjiyi konu almıştır. 2030 yılına kadar uygun fiyatlı, güvenilir ve modern enerji hizmetlerine evrensel düzeyde erişim hedeflenmiştir. Bu doğrultuda yine 2030 yılına kadar yenilenebilir enerji arzının küresel enerji arzı içerisindeki payının artırılması, enerji verimliliğinin iki katına çıkarılması, temiz enerji teknolojisinde altyapı yatırımlarının teşviki konusunda eylem planları sunulmuştur (UN Türkiye, 2025). Dolayısıyla gezegene insan eli ile verilen zararın azaltılmasına yönelik çabalar 20. yüzyılın son çeyreğinde hız kazanmıştır. Özellikle fosil yakıt kullanımının iklim değişikliği ve küresel ısınma üzerindeki etkileri yenilenebilir enerji konusunu bugün oldukça önemli hale getirmiştir.

Enerji üretiminde yenilenebilir enerji kaynaklarının kullanılması bugün sıklıkla dile getirilen bir konu olsa da tarihi neredeyse bir milyon yıl öncesine dayanmaktadır. Tarihin erken dönemlerinde insanlar kurutulmuş bitkileri ve odunları yakarak, ısınma ve aydınlanma ihtiyacını karşılamıştır. Biyoenerji denilen kaynakların kökeni bu döneme dayanmıştır. M.Ö 3200'lü yıllarda Eski Mısırlılar Nil Nehrini yelkenliler ile geçmek üzere rüzgârın gücünden; M.Ö 200'lerde Çin ve Orta Doğu ülkeleri de su pompalamak üzere yel değirmenlerinden faydalanmıştır. Romalıların su ve ev ısıtmak üzere güneş ve jeotermal enerjiden, Yunanlıların buğday öğütmek üzere su gücünden istifade ettiği de bilinmektedir. Su gücü orta çağda en önemli enerji kaynaklarından biri olmuştur. 19. yüzyıl ise yenilenebilir enerji kaynaklarının elektriğe dönüşebilmesi için bilimsel çabaların başladığı döneme tekabül etmiştir. Ancak Sanayi Devrimi gerek ucuz gerekse de kolay bulunabilir olması nedeniyle kömür başta olmak üzere fosil yakıtların kullanımını yaygınlaştırmıştır. Fosil yakıtlar dünyanın enerji tedariğine hâkim olmuştur (EIB, 2024).

Kömür, petrol ve gaz gibi fosil yakıtlar küresel sera gazı emisyonlarının %75'inden fazlasını, tüm karbondioksit emisyonlarının ise yaklaşık %90'ını üretmektedir. Güneşin ısısını hapseden sera gazları küresel ısınmaya ve iklim değişikliğine neden olmakta; doğanın olağan dengesini bozmakta, dünyadaki tüm yaşam formları için risk oluşturmaktadır. Sera gazı emisyonlarına bağlı artan küresel yüzey ısıları hastalıkların artmasına, orman yangınlarına, şiddetli fırtınalara, kuraklığa, yükselen okyanuslara, eriyen buzullara, biyoçeşitlilik kaybına, ürün veriminin düşmesine neden olmaktadır (United Nations, 2025). Fosil yakıt kullanımının atmosferde neden olduğu bu ölümcül sonuçlar, doğa temelli çözümlere ihtiyaç yaratmıştır. Yenilenebilir enerji de bu noktada fosil yakıtlara alternatif olarak yeniden gündeme gelmiştir.

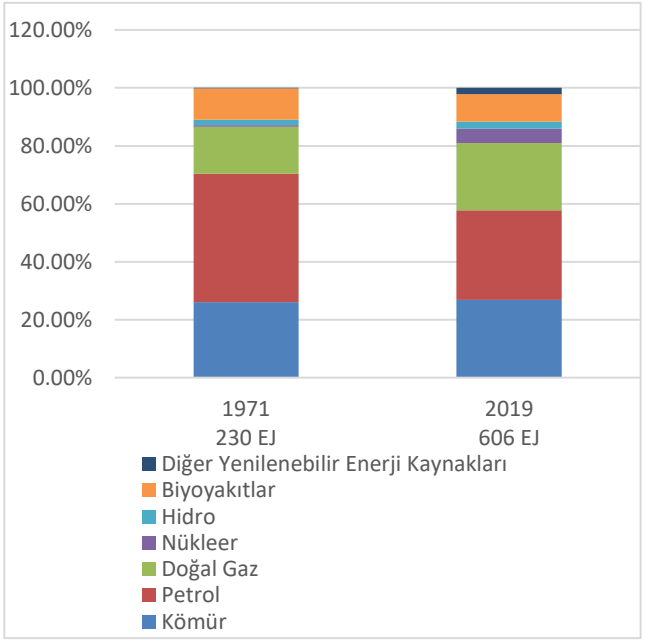
Yenilenebilir enerji güneş, gelgitler ve rüzgâr gibi doğada sınırsız olarak bulunan kaynaklardan elde edilmekte; elektrik üretimi, yaşam alanlarının ve suyun ısıtması/soğutması, ulaşım gibi birçok alanda kullanılabilmektedir. Yenilenebilir enerji çevre korumasına destek olmasının yanı sıra enerjide dışa bağımlılığı azaltmakta, yeni istihdam alanları yaratmaktadır. Su, güneş, rüzgâr, biyokütle, gel-git, dalga gibi yenilenebilir enerji

kaynakları doğanın kendi sistematiği içerisinde gün aşırı kendini yenileyebilmektedir. Dolayısıyla kömür, doğal gaz, petrol gibi fosil yakıtlara alternatif ve çevre dostu kaynaklar olarak kabul edilmektedir (Office of Energy Efficiency & Renewable Energy, 2024; Sayed vd., 2023).

Enerji tedariğinde güvenliği sağlamak ve çevresel olarak sürdürülebilir uygulamalar hayata geçirmek ekonomik kalkınmanın da gerekli koşulu olarak kabul edilmiştir. Önümüzdeki on yıllarda ortaya çıkacak enerji ihtiyacının temiz ve güvenilir bir şekilde karşılanması için yenilebilir enerji kaynaklarına yönelim de bu doğrultuda önemli bir strateji sunmaktadır. Küresel ısınma, çevre kirliliği, enerjide dışa bağımlılık ve beraberinde getirdiği bir dizi olumsuzluk AB başta olmak üzere dünya üzerinde yenilenebilir enerjiyi uluslararası bir mesele haline getirmiştir. 2030 yılına kadar istikrarlı bir şekilde artması beklenen enerji talebi büyük oranda fosil yakıtlardan karşılanacak ve bu enerji talebinin yaklaşık üçte ikisi gelişmekte olan ekonomilerden kaynaklanacaktır. Mevcut enerji politikaları temelinde enerji kullanımının karbondioksit emisyonlarını artırmaya devam edeceği düşünülmektedir (Özkaya, 2022; IEA, 2002; IEA, 2024).

IEA'nın 2022 yılında yayınlamış olduğu rapor küresel ölçekte dünya enerji kullanımındaki değişimi ortaya koymuştur. Şekil 1'de sunulduğu üzere 1971 ila 2019 yılları arasında dünyadaki toplam enerji arzının 2,6 kat arttığı ve yapısal olarak büyük bir değişim yaşadığı görülmüştür. Petrol arzı 1971 ile 2010 yılları arasında %44'ten %31 seviyesine düşmüş; doğal gaz ise %16'dan %23'e yükselmiştir. Kömür dünya elektrik üretiminin baskın olan yakıtı iken yenilenebilir enerji arzında artış söz konusu olmuştur (IEA, 2022a).

Şekil 1. Yakıt Bazında Toplam Birincil Enerji Arzı, 1971-2019



Kaynak: IEA, 2022a

Özetle ekonomik, sosyal, kültürel gelişim süreci dünya enerji arzının yakın bir gelecekte sınırına ulaşılacağını; ekonomik büyümenin çevresel tahribat pahasına gerçekleşeceğini ve gerekli önlemler alınmadığı takdirde ulusal ve küresel bazda sürdürülebilir kalkınmanın çok uzağına düşüleceğini göstermektedir. Bu doğrultuda yenilenebilir enerji kaynaklarına başvurmak ve yaygınlaştırmak gezegenimiz için önemli bir alternatif sunmaktadır. Maliyet etkinliği sağlaması, kıtlık problemi olmaması ve doğaya duyarlı olması nedeniyle ulusal ve uluslararası ölçekte önemli bir konu haline gelmiştir. Bu kapsamda özellikle on dokuzuncu yüzyılın ikinci yarısından itibaren yenilenebilir enerji konusu gündemi meşgul eder hale gelmiştir.

Çevre, enerji, sürdürülebilir kalkınma konuları her ne kadar küresel hadiseler olsa da çözüme yönelik uygulamaların ülke bazında kabul edilmesi ve hayata geçirilmesi gerekmektedir. Türkiye de bu doğrultuda "Dünya Sürdürülebilir Kalkınma Zirvesini" benimseyen ülkelerden biri olmuştur. AB üyesi ülkelerin enerji tüketimi içerisinde yenilenebilir enerji kaynaklarını artırma yönündeki çabaları, Türkiye'nin AB'ye üyelik sürecinin erken dönemlerine tekabül etmiştir. Bu politik aşama Türkiye'nin uyum sürecinde enerji politikalarını şekillendirmiştir. Üyelik hedefleri ve ulusal çıkarın korunması amacıyla bu dönemde yenilebilir enerji kaynaklarının kullanımı teşvik edilmiştir. Bu bağlamda 24 Temmuz 2003 tarihinde, "Avrupa Birliği Müktesebatı'nın Üstlenilmesine İlişkin Türkiye Ulusal Programı" yürürlüğe girmiştir (Özkaya, 2022). Bu düzenlemenin öncelikli hedefleri arasında yenilenebilir enerji kaynaklarından sağlanan enerji üretiminin artırılması yer almıştır. Türkiye ekonomisi açısından enerjide ithalat bağımlılığının azaltılması ve arz güvenliğinin sağlanması için yenilenebilir enerji kaynaklarının kullanımının desteklenmesi ulusal enerji politikalarının önemli bir bileşeni olmuştur. Bu bağlamda çevrenin koruması ve yenilenebilir enerjinin nihai tüketim payının artırılması amaçlanmıştır (T.C. Resmî Gazete, 2003).

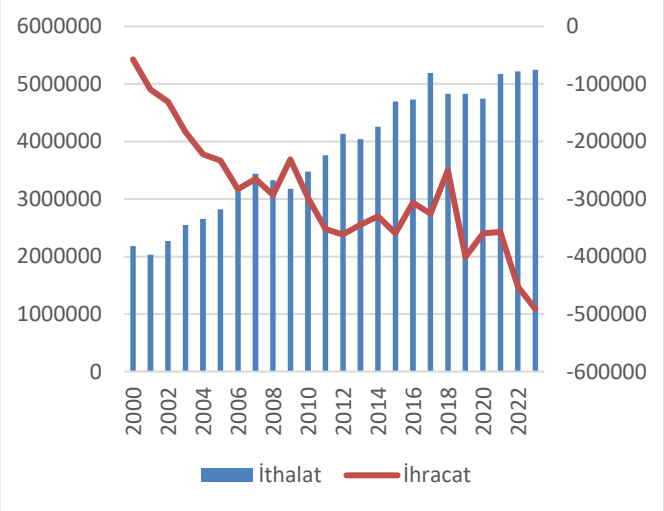
Yenilenebilir enerji kullanımı yeşil dönüşümün yanı sıra ekonomik büyümenin de önemli bir tamamlayıcısı olmaktadır. Gözkün ve Orhangazi (2025), Türkiye'de rüzgâr ve güneş enerjisi yatırımlarının olası etkileri üzerinden 2053 yılına kadar toplam emisyon, ekonomik büyüme, istihdam ve dış ticaret açığı tahminlerini ortaya koymuştur. Enerji sektörünü dönüştüren 10 yıllık temiz enerji yatırımlarının 2020 yılına kıyasen emisyon seviyelerini %28-77 oranında azaltabileceği, ekonomik büyümeye %0,6-1,8 oranında ek katkı sunacağını, %1,3-3,4 seviyelerinde istihdam yaratabileceğini, net ticaret dengesini ise 6,9-14,6 milyar dolar iyileştirebileceğini öngörmüştür. Dolayısıyla yeşil dönüşüm süreci çevresel hedeflere ulaşmanın yanı sıra ekonomik göstergeler açısından da iyileştirici etkiler yaratmaktadır.

Budak (2025), 1990-2022 dönemi için Türkiye ekonomisinde yenilenebilir enerji tüketiminin ekonomik büyüme üzerindeki etkisi incelenmiş ve benzer sonuçlara

ulaşılmıştır. Çalışma ilgili dönemde ekonomik büyüme ve yenilenebilir enerji tüketimi arasındaki uzun ve kısa dönemli ilişkiyi analiz etmiştir. Bulgular uzun dönemde yenilenebilir enerji tüketiminin, toplam enerji tüketimi içerisindeki payının %1'lik artışına büyüme değişkeninin %5,7'lik bir artışla tepki gösterdiğini ortaya koymuştur. Değişkenler arasındaki nedensellik ilişkisi çift yönlü olarak tespit edilmiştir. Dolayısıyla Türkiye ekonomisi açısından enerji arz güvenliğinin ve sürdürülebilir kalkınmanın; yenilenebilir enerji yatırımlarındaki artış, yerli üretim kapasitesindeki iyileştirme ve Ar-Ge çalışmalarıyla sağlanacağı vurgulanmıştır.

Türkiye ekonomisinin 2000 ila 2023 yılları arasındaki toplam enerji ithalatı ve toplam enerji ihracatı rakamları Şekil 2'de sunulmuştur. Türkiye'de enerji ithalatı ilgili yıllar içerisinde istikrarlı bir artış göstermiştir. 2019 ve takip eden yılda pandeminin etkisi ile ekonomideki genel durgunluk halinin bir yansıması olarak düşüş eğilimi göze çarpmıştır. İhracat rakamları ise tersi bir eğilim göstermiştir. Yurtiçinde artan enerji talebi enerji kaynaklarının ülke içerisinde tüketimine tahsis edilirken aynı zamanda da enerji verimliliği ve iklim değişikliği hedefleri nedeni ile uluslararası talepteki düşüş de bu durumu açıklar nitelikte olmuştur.

Şekil 2. Türkiye'de Enerji Ticareti (İthalat-İhracat)



Kaynak: IEA, 2025

Türkiye'de enerji tüketiminin artan hacmi ve enerjinin büyük oranda dış kaynaklardan sağlanıyor olması, enerjide yüksek bir ithalat bağımlılığı yaratmaktadır. IEA'nın raporunda özellikle petrol ve gaz da sırasıyla %93 ve %99 oranlarında yüksek ithalat bağımlılığının altı çizilmiştir. Bu bağlamda ilgili enerji kaynaklarında ithalat bağımlılığını azaltmaya yönelik stratejiler ve yenilenebilir enerji kaynaklarının kullanımı önceliklendirilmiştir. Özellikle de enerji çeşitliliğindeki önemli artışa rağmen yeşil enerji dönüşümünde ve enerji ithalatında istenilen performansa henüz ulaşılamamış olması ulusal politikaları yönlendirmiştir (IEA, 2021b). Sekizinci Kalkınma Planı da dâhil olmak üzere ulusal stratejik amaç haline gelen yenilebilir enerji kullanıma yönelik teşviklere ek olarak idari yapı içerisinde de birtakım düzenlemelere gidilmiştir. Kurum ve kuruluş nezninde yenilenebilir enerji kaynaklarına dayalı üretim tesislerinin kurulumuna ve işleyişine yönelik bir takım kolaylaştırıcı uygulamalara başvurulmuştur (T.C. Resmî Gazete, 2003).

Bu çalışmada Türkiye açısından yenilenebilir enerjiye geçiş süreci, enerji kullanımının sektörel ve bölgesel dağılımı, yine Türkiye ekonomisi açısından yenilenebilir enerji kullanımına ilişkin teşvikler ve engeller, mevcut potansiyel ele alınacaktır. Bu konu özellikle 2053'e kadar karbon nötr uygulamasını içeren iklim değişikliği ile mücadelede önemli bir rol oynamaktadır.

2. Türkiye'de Yenilenebilir Enerji Kaynakları

Türkiye'de enerji kullanımı nüfus artış hızına, artan refah düzeyine, hizmet sektörünün güçlenmesine ve sanayileşme hamlelerine bağlı olarak diğer gelişmiş ülkeler nispetinde hızlı bir yükseliş trendi yaşamıştır. Bu durum Türkiye ekonomisi açısından enerji verimliliğini önemli hale getirmiştir (T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2018). Türkiye ekonomisinin fosil yakıtlara olan yüksek bağımlılığı ve enerji ithalatı göz önüne alındığında kısa dönemde bütünüyle yenilenebilir enerji kaynaklarına geçiş, çok gerçekçi görünmemektedir. Bu nedenle de özellikle fosil yakıt kullanımının neden olduğu çevre hasarının azaltılmasında enerji verimliliğini artıracak teknolojilerin hayata geçirilmesi son derece önemli olmaktadır (Naimoglu ve Akal, 2023). Artan enerji verimliliği enerji arzında güvenliğin sağlanması, enerjide dışa bağımlılığın beraberinde getirdiği risklerin azaltılması ve/veya bertaraf edilmesi, enerji maliyetlerinin sürdürülebilir kılınması, iklim değişikliği ile mücadele ve çevre korumasına yönelik stratejik hedeflerin sağlanması noktasında ek faydalar yaratmaktadır.

Türkiye açısından 2007 yılında yürürlüğe giren Enerji Verimliliği Kanunu önemli bir dönüşüm sürecini harekete geçirmiştir. Kanunun amacı enerjinin etkin kullanımını sağlamak, israfı önlemek, enerji maliyetlerini hafifletmek ve çevrenin korunması için enerji kullanımında verimliliği artırmak olarak belirlenmiştir. Bu amaca hizmet edecek eğitim ve bilinçlendirme faaliyetlerinin yanı sıra enerji verimliliğini artırıcı uygulamalar devreye alınmıştır. İzleyen süreçte Enerji ve Tabii Kaynaklar Bakanlığının Enerji Verimliliği Strateji Belgeleri yayınlanmıştır. Belgeler Türkiye'nin mevcut durum analizinin yanı sıra güncel ihtiyaçlarının da altını çizmiştir (T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2018; T.C. Resmî Gazete, 2007).

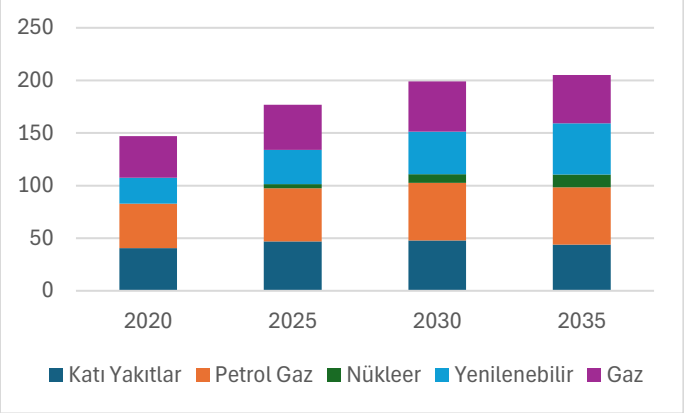
Enerji Verimliliği Strateji Belgesi (2012-2023), Türkiye'nin ilgili yıllardaki durum analizini ortaya koymuştur. Türkiye'nin birincil enerji yoğunluğu (Birincil enerji yoğunluğu bir birim gayri safi yurtiçi hasılan yaratabilmek için tüketilen enerji miktarını ifade etmektedir) 2008 yılında 1998 yılı nispetinde %0,24 oranında (dolar cinsinden, baz yılı 2000) azalmıştır. 2007 yılında yürürlüğe giren Enerji Verimliliği Kanunun yarattığı dönüşüm enerji

yoğunluğundaki azalmayı desteklese de elektrik enerjisi kullanımının artma eğiliminde olduğunu ifade etmek mümkündür. Bu gelişim eğilimi özellikle elektrik enerjisine yönelik talebin azaltılması gereğini ortaya koymuştur. 1998-2008 dönemi için enerji tüketimindeki artış %3,81 olarak hesaplanmıştır. Sektörel olarak ise sanayide %3,56, konutta %3,49, ulaştırmada %4,07, hizmette %7,44 oranında artış yaşanmıştır. Özellikle bireysel araç kullanımı ve hizmet sektörünün bu dönemde yakaladığı yükseliş ivmesi enerji tüketimini bu iki sektör açısından dikkat çekici hale getirmiştir. Yine doğalgaza dayalı tesislerin kapasitesi artarken, yenilenebilir enerji kaynaklarının payı düşüş göstermiştir. Yenilenebilir enerji kaynağı olarak jeotermal, rüzgâr ve biyokütle santrallerinin sayısı artış göstermiş olmasına rağmen enerji üretme kapasitesi oldukça sınırlı kalmıştır. Bu belge ile 2023 yılında Türkiye'de GSYİH başına tüketilen enerji miktarının 2011 yılı değerine göre en az %20 seviyesinde azaltılması hedeflenmiştir. Bu hedef doğrultusunda sanayi ve hizmet sektöründe enerji yoğunluğunun ve enerji kayıplarının azaltılması, yenilenebilir enerji kaynakları kullanan sürdürülebilir çevre dostu binaların yaygınlaştırılması, enerji verimli ürünlerin piyasaya sürülmesi, ileri teknoloji kullanımının yaygınlaştırılması ve bu amaçla uygun finansman oluşturulması şeklinde bir dizi stratejik amaç ortaya koyulmuştur (T.C. Resmî Gazete, 2012).

Bakanlık benzer şekilde 2017-2023 yıllarını içerisine alan ikinci bir eylem planını devreye sokmuştur. Bu eylem planı ise bina ve hizmetler, enerji, ulaştırma, sanayi ve teknoloji, tarım ve yatay konular olmak üzere toplamda altı adet kategoride birincil enerji tüketiminin 2023 yılına kadar %14 seviyesinde azaltılmasını hedeflemiştir (T.C. Resmî Gazete, 2017). Dolayısıyla 2000'li yılların erken dönemleri Türkiye ekonomisi açısından enerji verimliliğin sağlanması yönünde hedefler ve bu hedeflere ulaşmak üzere belirlenen stratejilerle beslenen bir dönem olmuştur. Şekil 3. Türkiye'de kaynağına göre birincil enerji tüketimini ortaya koymaktadır. 2020 yılında birincil enerji tüketimi 147,2 Mtep (milyon ton petrol eşdeğeri) olarak gerçekleşmiş ve 2035 yılına kadar bu değerin 205,3 Mtep seviyesine ulaşacağı ve birincil enerji tüketiminde yenilenebilir enerji kullanımının da %16,7'den %23,7 seviyesine ulaşacağı vurgulanmıştır.

Avrupa Birliği, iklim değişikliği ile mücadelede yeşil ve dijital dönüşümün yol haritasını 11 Aralık 2019 Avrupa Yeşil Mutabakatı ile açıklamış ve uluslararası ticari faaliyetleri de içerisine alan birtakım regülasyonlar ortaya koymuştur. AB üyesi ülkelerin Türkiye ekonomisi açısından önemli birer ticaret ortağı olduğu düşünülürse, ticari ilişkilerin devamlılığı açısından Yeşil Mutabakatın gereklerinin sağlanması oldukça önemlidir. Bu amaçla T.C. Ticaret Bakanlığı 2021 yılında "Yeşil Mutabakat Eylem Planını" devreye almıştır. Bu eylem planı ile Türkiye ekonomisi Mutabakatın gereklerine hizmet edecek dönüşüm sürecini kabul ettiğini beyan etmiştir. Türkiye ekonomisi açısından kapsayıcı ve sürdürülebilir bir büyüme hedefi benimsenmiştir. Küresel tedarik zincirinin geliştirilmesi ve uluslararası yatırımların artırılması da amaçlar arasında sıralanmıştır.

Şekil 3. Kaynaklara Göre Birincil Enerji Tüketimi



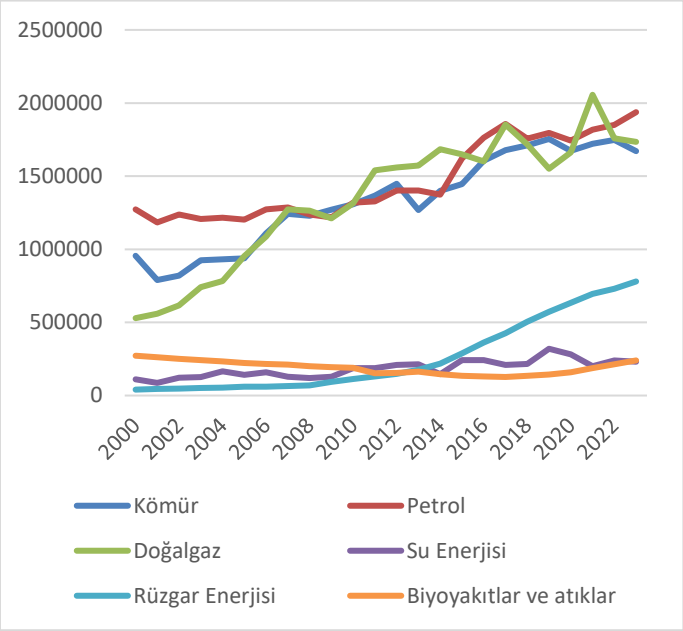
Kaynak: T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2022a

Bu süreç ekonominin sanayi, tarım, enerji, ulaştırma vd. alanlarında bütüncül bir yaklaşımı gerektirmektedir. Dolayısıyla da eylem planı hazırlık süreci kamunun ilgili tüm kurumlarının koordinasyonu ile mümkün kılınmıştır. Cumhurbaşkanlığı Strateji ve Bütçe Başkanlığı, Çevre ve Şehircilik Bakanlığı, Dışişleri Bakanlığı, Enerji ve Tabii Kaynaklar Bakanlığı, Hazine ve Maliye Bakanlığı, Sanayi ve Teknoloji Bakanlığı, Tarım ve Orman Bakanlığı, Ulaştırma ve Altyapı Bakanlığı kapsayıcı ve ekonominin her alanına nüfuz edecek stratejileri ortaya koymak üzere birlikte hareket etmiştir. Yeşil üretimi sağlayacak teknolojilerin geliştirilmesi ve yaygınlaştırılması amaçlanmıştır. Bu amaca hizmet edecek araştırma ve geliştirme çalışmalarının, yeşil finansmanın, sürdürülebilir ve akıllı taşımacılık altyapısının güçlendirilmesini içeren bir dizi eylem ortaya koyulmuştur (T.C. Ticaret Bakanlığı, 2021). Dolayısıyla ülkemizde AB Yeşil Mutabakatı çerçevesinde enerji güvenliğinin ve enerji verimliliğini sağlamaya yönelik hamlelerin esasında 2007 yılına uzandığını ifade etmek mümkündür. Ancak yine de Türkiye'nin yeşil dönüşüm taahhüdünün en net şekilde Enerji ve Tabii Kaynaklar Bakanlığının 2022 yılında yayınlamış olduğu raporda sunulduğu kabul edilmiştir (PwC, 2023). Bakanlık raporunda elektrik sisteminin mevcut durumu ve gelişme potansiyeli göz önüne alınarak rüzgâr ve güneş gibi yenilenebilir enerji kaynaklarının toplam elektrik üretimi içerisindeki payının artırılması hedefi açıkça ifade edilmiştir (T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2022a).

Türkiye'de yenilenebilir enerji arzı büyük oranda hidrolik kaynaklar, rüzgâr, güneş, jeotermal ve biyokütleden (odun, bitki ve hayvan atıkları) oluşmaktadır. 2021 yılının sonunda birincil enerji arzı 159,4 Mtep iken yerli üretim 46,7 Mtep değerine ulaşmış; yerli üretimin %62'si ise yenilenebilir enerji kaynaklarından sağlanmıştır. 1990 yılı ile kıyaslandığında 2021 yılında yenilenebilir kaynaklardan sağlanan enerji miktarı %274 oranında artış göstermiştir (T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, 2024). Şekil 4'te de görüldüğü üzere 2000 ila 2023 yılları

arasında rüzgâr enerjisi başta olmak üzere Türkiye'de yenilenebilir enerji konusunda önemli ilerlemeler kaydetmiş olsa da enerji dönüşümü teknik bir değişimin ötesinde ekonomik, siyasi, toplumsal boyutları olan bütünsel bir süreçtir. Ve Türkiye'de bu dönüşüme karşı yapısal engellerle karşı karşıya kalmıştır. Politik belirsizlikler, toplumsal direnç ve finansal erişim sorunları bunların başında gelmektedir (Akiner, 2025).

Şekil 4. Türkiye'de 2000-2023 Yılları ArasındaYerli Enerji Üretiminin Evrimi



Kaynak: IEA, 2025

Çalışmanın bu bölümünde, Türkiye'de enerji güvenliğinin sağlanması ve enerji sektöründe yeşil dönüşümün gerçekleştirilmesi hedefi doğrultusunda ortaya konulan stratejik politikalara yer verilmiştir. Devam eden bölümde Türkiye'nin yenilenebilir enerji kaynakları bakımından mevcut durumu analiz edilecektir. Bu bağlamda, başlıca yenilenebilir enerji kaynakları olan hidroelektrik, rüzgâr, güneş, jeotermal ve biyokütle enerjisine yönelik kurulu güç kapasitesi, üretim potansiyeli ve coğrafi dağılım haritalarına yer verilecektir.

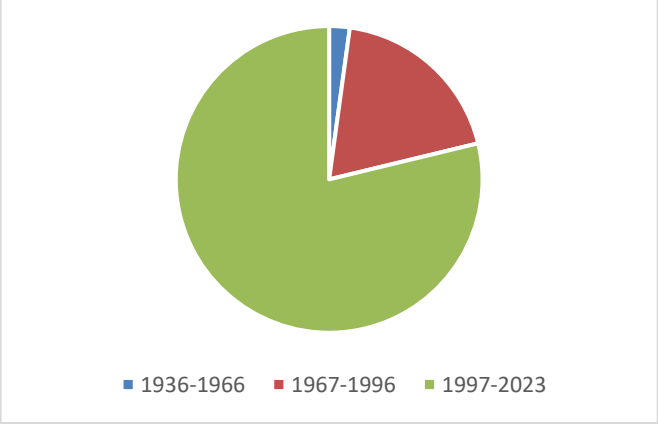
2.1. Hidroelektrik Enerji

Hidroelektrik enerji, akarsu ve nehir gibi hareketli su kaynaklarından elde edilmektedir. Enerji üretim sürecinde su, yüksek bir seviyeden daha düşük bir seviyeye çeşitli kanallar ve/veya borular aracılığı ile yönlendirilmektedir. Seviye farkından dolayı belirli bir hareket kazanan su, akış güzergahı üzerinde yer alan ve türbin adı verilen yapılarda belirli bir dönüş hareketi yaratmaktadır. Bu sayede suyun akışından kaynaklanan kinetik enerji, türbinlerde mekanik enerjiye dönüşmektedir. Ardından da jeneratörler aracılığı ile elektrik enerjisi üretilmektedir. Hidroelektrik enerjisi, dünya genelinde tüm yenilenebilir teknolojilerin toplamından daha fazla elektrik üretmektedir. IEA tahminleri hidroelektriğin mevcut üstünlüğünü 2030 yılına kadar korumaya devam edeceğini ortaya koymaktadır (IEA, 2024). Dünya elektriğinin yaklaşık %20'sini üreten hidroelektrik küresel ölçekte önemli bir enerji kaynağı olarak kullanılmaktadır. Çevreye duyarlı, verimliliği yüksek, görece maliyet etkin ve uzun ömürlü yerli bir kaynak olan hidroelektrik santraller enerji kaynağı olarak tercih edilmektedir. Hidrojen tamamen yeşil enerji üretmekte ve üretilen elektrik çevre kirliliği yaratmamaktadır. Hidroelektrik enerjisinin kullanımına yönelik büyük ölçekli uygulamalar biyoçeşitliliğin kaybolması, toprak erozyonu, akarsuların serbest akışına ket vurma ve canlı nüfusu yerinden etme gibi bir takım olumsuz sonuçlar ortaya çıkarsa da sera gazı emisyonu üretmemektedir. Ek olarak santrallerin işletilmesinde doğaya herhangi bir zehirli atık bırakılmamaktadır (Önal ve Yarbay, 2010; Ürker ve Çobanoğlu, 2022; Karayel vd., 2023).

Dünyada olduğu gibi Türkiye'de de yerli ve yenilenebilir enerji kaynaklarının başında hidroelektrik enerji gelmektedir. Alternatif enerji kaynakları arasında geniş kullanım ağına ve yüksek enerji rezervine sahip önemli bir enerji kaynağıdır. Modern yenilenebilir enerji kaynakları arasında hidroelektrik üretimi %2,3 payla ilk sırada yer almakta; bunu rüzgâr ve biyoyakıt enerjisi takip etmektedir (T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2022b, DSİ, 2023a; IEA, 2022b).

Türkiye'de hidroelektrik enerjisi üretme potansiyeli ülkenin doğu kesimlerinde; tüketimi ise İstanbul, İzmir, Bursa başta olmak üzere batı bölgelerinde yoğunlaşmıştır. Hidrolik enerji elektrik üretiminin yanı sıra Güneydoğu Anadolu Projesi (GAP) gibi tarımsal sulama amaçlı da kullanılabilmektedir. Ek olarak turizm, ulaşım ve spor amaçlı faaliyetlere imkân sunarken, ekonomik değer ve istihdam yaratma potansiyeli son derece yüksektir (Sarhan vd., 2023). Devlet Su İşleri (DSİ)'nin 2023 yılı resmi su kaynakları istatistiklerine göre Türkiye'de 1936-2023 yılları arasında, hidroelektrik enerjisi üretmek üzere yapımı tamamlanan baraj sayısı 1018 olarak kaydedilmiştir. Şekil 5.'te yapımı tamamlanmış baraj sayısını yıllara göre görmek mümkündür (DSİ, 2023b).

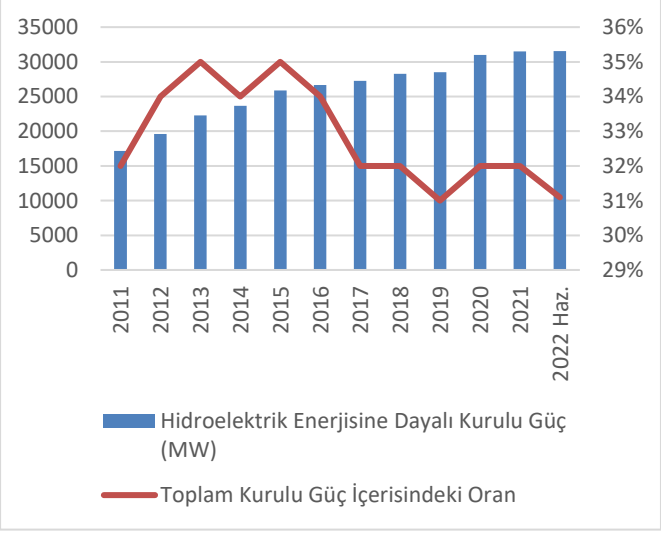
Şekil 5. Yapımı Tamamlanmış Baraj Sayısı



Kaynak: DSİ, 2023b

Artan tesis sayısıyla paralel olarak Türkiye'de 2011-2022 yılları arasında hidroelektrik enerjisine dayalı kurulu güç (Kurulu güç, bir enerji santrali veya üretim tesisinin genellikle megawatt (mw) cinsinden olmak üzere maksimum üretim kapasitesini ifade etmektedir. Başka bir ifade ile bir tesisin en yüksek verime ulaştığı anda üretebileceği maksimum enerji düzeyidir) (megawatt-mw) sürekli bir artış eğilimi göstermiştir. Hidroelektrik enerjisine dayalı kurulu güç ve hidroelektrik enerjisinin toplam kurulu güç içerisindeki payı Şekil 6'da sunulmuştur. Ancak burada dikkat çeken bir gelişme hidroelektrik enerjisine dayalı kurulu güç sürekli bir artış gösterirken, toplam kurulu güç içerisindeki payı benzer şekilde mutlak bir yükselme eğilimi içerisinde olmamıştır. Bu durum özellikle güneş ve rüzgâr enerjisine dayalı güç üretimindeki hızlı ve agresif büyüme ile ilişkilendirilebilmektedir (T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2022b, DSİ, 202; IEA, 2022b) 2024 yılında da benzer bir yükseliş eğilimi gözlenmiş; Türkiye'de üretilen enerjinin %20'den fazlası hidroelektrik santrallerden sağlanmıştır. Ülkenin hidroelektrik potansiyeli devlet ve özel sektör iş birliği ile artmaya devam etmekte; bu bağlamda enerji bağımlılığın azaltılması hedeflenmektedir (DSİ, 2025).

Şekil 6. Hidroelektrik Enerjisine Dayalı Kurulu Güç (MW) – Toplam Kurulu Güç İçerisindeki Oran



Kaynak: T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2022b

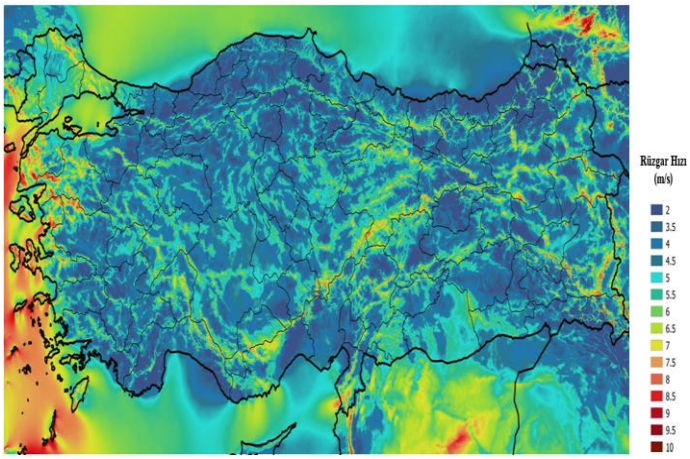
Ancak kurulu güç kapasitesinin tamamıyla üretilen enerji miktarına denk olmadığını da eklemek gerekmektedir. Santrallerde ortaya çıkan teknik arızaların, bakım için faaliyetlerdeki duraklamaların, mevsimsel etkiler ile yaşanan kuraklığın ve diğer dizi etkenin üretim kapasitesini olumsuz yönde etkilediğini ifade etmek mümkündür. Yapılan çalışmalar hidroelektrik santrallerinde yıllık ortalama olarak kurulu gücün yaklaşık %70'lik bir kısmının çalışmadığını ortaya koymuştur. Özellikle kuraklığa bağlı olarak düşen yağış miktarı santrallerin çalışma düzenini etkilemiştir (Sarhan vd., 2023). Ek olarak hidroelektrik enerji santrallerinin belirli bir planlama dahilinde inşa edilmesi son derece önemli bir konu olmaktadır. Kontrolsüz bir şekilde inşa edilen tesisler su kaynaklarına zarar verdiği gibi su kalitesine de zarar vermektedir (Bilhan, 2024).

2.2. Rüzgâr Enerjisi

Rüzgâr enerjisi yeryüzünün coğrafi farklılıklarından ve ısının homojen olmayan yayılımından kaynaklanmaktadır. Güneşin yeryüzüne göndermiş olduğu enerjinin %1 ila 2 gibi oldukça küçük bir bölümü rüzgâr enerjisine dönüşmektedir. Hız ve yön parametrelerine bağlı olarak oluşan kinetik enerji, rüzgâr türbinleri aracılığı ile elektrik enerjisine dönüştürmektedir. Rüzgâr enerjisinin elektrik enerjisine dönüşümüne imkân sağlayan tesislerin ilk yatırım maliyetlerinin yüksek oluşu ve enerji üretiminin doğa durumuna bağlı olarak değişkenlik göstermesi bir handikap olarak görülmektedir. Mevcut dezavantajlarına rağmen aynı zamanda da yenilenebilir ve temiz bir enerji kaynağıdır. Rüzgâr enerjisi ek olarak tükenme riski ve maliyet artışı söz konusu olmayan, bakım ve işletme harcamaları düşük, teknolojisi görece basit ve üretime geçiş süreci son derece hızlı bir enerji kaynağıdır (T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2022c). Rüzgâr enerjisi aynı zamanda yenilenebilir enerji kaynakları arasında en büyük üretim kapasitesine ve kullanım alanına sahip enerji kaynağıdır. Türkiye rüzgâr enerjisi açısından son derece elverişli coğrafyada iken bu potansiyelin ortaya çıkarılmasına yönelik çabalarda geç kalınmıştır. Ticari ölçekte elektrik üretimi yapan rüzgâr türbinleri ilk olarak 1984 yılında Çeşme'de kurulmuştur. Rüzgâr çiftlikleri ise Avrupa'da 1990'ların başında kurulmaya başlamışken Türkiye'de 1998 yılına kadar uzanmıştır (Başkaya, 2017). Kurulu gücün bölgesel dağılımına bakıldığında Marmara Bölgesi en yüksek rüzgâr enerjisi kapasitesini sahip iken Ege Bölgesi ikinci sırada yer almaktadır. İzmir, Balıkesir, Çanakkale, İstanbul ve Manisa ise sırası ile en yüksek kurulu güce sahip şehirler olarak sıralanmaktadır (Türkiye Rüzgâr Enerjisi Birliği, 2025).

Şekil 7. üzerinden Türkiye genelinde yıllık ortalama rüzgâr hızı dağılımını görmek mümkündür. Ege kıyıları ve Marmara'nın kuzeybatı kesimlerinin yanı sıra Hatay'ın kıyı kesimleri ve Mersin dolayları da yüksek rüzgâr hızlarının görüldüğü iller arasındadır. Yine sahip olduğu yükseltilerin de etkisi ile Doğu Karadeniz özellikle de Artvin yüksek oranda rüzgâr enerjisi potansiyeline sahiptir. Doğu ve Güneydoğu Anadolu'nun iç bölgeleri ile İç Anadolu'nun merkezi ise düşük rüzgâr hızına sahip alanlardır. Bu bölgelerin denizden uzak olması ve çoğunlukla dağlık araziler ile çevrelenmiş yüksek platolar oluşu rüzgâr akışını zayıflatmakta ve enerji potansiyeli düşük olmaktadır. Bu nedenle de ülkemizdeki rüzgâr enerjisi yatırımları çoğunlukla batı kıyılarında yoğunlaşmaktadır.

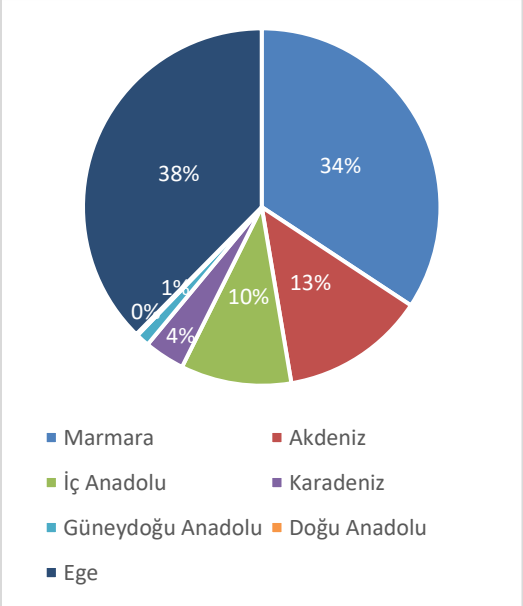
Şekil 7. Yıllık Ortalama Rüzgâr Hızı Dağılımı



Kaynak: T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2025a

Rüzgâr enerji santrallerinin 2019 yılı itibari ile bölgesel dağılımı Şekil 8.'de sunulmuştur. Yıllık ortalama rüzgâr hızına paralel olarak tesis yoğunlukları da Marmara ve Ege Bölgelerinde toplanmıştır.

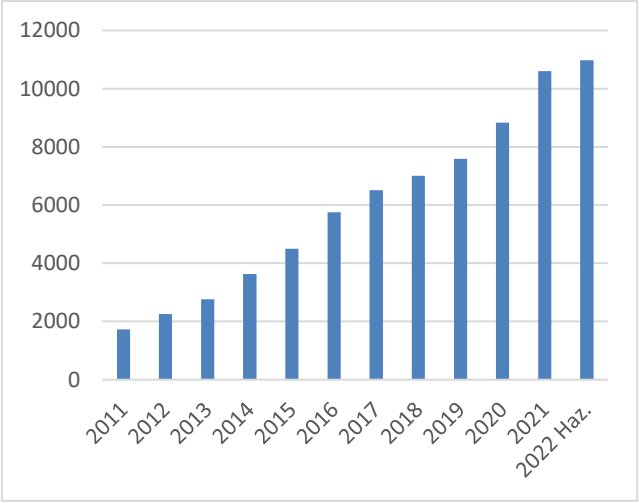
Şekil 8. Rüzgâr Enerji Santrallerinin Bölgesel Dağılımı-2019



Kaynak: Türkiye Rüzgâr Enerjisi Birliği, 2019

Türkiye rüzgâr enerjisi kurulu güç anlamında da önemli bir ilerleme kaydetmiştir. Şekil 9. ilgili göstergedeki değişimi 2011 ila 2022 Haziran dönemi için ortaya koymuştur. 10 yıllık periyotta rüzgâr enerjisine dayalı kurulu güç yaklaşık altı katlık bir artış göstermiştir. 2022 yılı haziran sonunda rüzgâr enerjisine dayalı kurulu güç 10.976 MW ölçeğindedir ve 2011 yılından itibaren istikrarlı bir artış göstermiştir. Bu değer Türkiye açısından toplam kurulu gücün %10,81'ine tekabül etmektedir. Türkiye'nin rüzgâr enerjisi üretme potansiyeli değerlendirildiğinde özellikle kıyı şeritleri, yüksek bayırlar, dağların tepeleri ve açık alanlar oldukça önemli rüzgâr kaynakları olmaktadır. 7 m/s'den büyük rüzgâr hızı göz önüne alındığında Türkiye'nin enerji potansiyelinin 48.000 MW olduğu tespit edilmiştir. Bu üretim potansiyeli Türkiye'ye dünya pazarında ciddi avantajlar sunabilecek ölçektedir. Bu noktada rüzgâr sanayisinin gelişimine katkıda bulunmak yeni yatırım fırsatları da doğuracaktır (Türkiye Rüzgâr Enerjisi Birliği, 2024). Türkiye 2024 yılının sonunda rüzgâr enerjisine dayalı kurulu güç anlamında Almanya, Birleşik Krallık, İspanya, Fransa ve İsveç'in ardından altıncı ülke olarak yerini almıştır (Türkiye Rüzgâr Enerjisi Birliği, 2025).

Şekil 9. Rüzgâr Enerjisine Dayalı Kurulu Güç (MW)



Kaynak: T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2022c

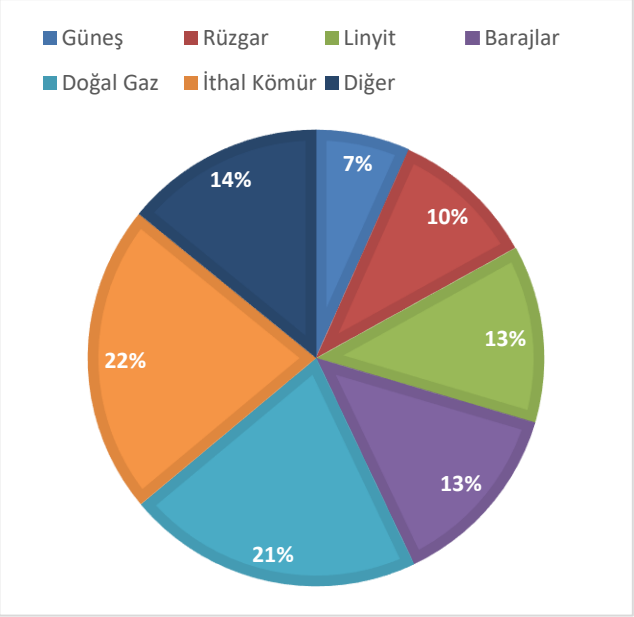
2.3. Güneş Enerjisi

Güneş, yeryüzünün en temel ve en güçlü enerji kaynağıdır. Güneşin enerjisi ısı ve ışık kaynağı olarak kullanılmakta; çeşitli teknolojiler aracılığı ile elektrik enerjisine dönüştürülebilmektedir. Yapılan çalışmalar güneşin enerji üretme potansiyelinin; fosil yakıtlar, nükleer enerji ve hidroelektrik enerjisinin mevcut toplam kapasitesinin yaklaşık 15 katına tekabül ettiğini ortaya koymaktadır. Güneşin potansiyelinden faydalanmak üzere 1970'li yıllardan itibaren çeşitli teknolojiler geliştirilmiştir. Güneş enerjisi teknolojileri; ısıl güneş teknolojileri ile fotovoltaik güneş teknolojileri olarak kategorize edilmektedir. Isıl güneş sistemleri; düşük sıcaklıklı uygulamalar ile yüksek sıcaklığa ihtiyaç duyan ısıl işlemleri ifade etmektedir. Bu sistemler sıcak su temini ve ısıl enerjinin elektrik enerjisine dönüştürülmesini sağlamaktadır. Fotovoltaik teknolojiler ise güneş ışığının doğrudan elektrik enerjisine dönüştüğü sistemlerdir. Günümüzde güneş enerjisi; konut ve iş yerlerinde ısıtma-soğutma sistemleri, sıcak su temini, tarımsal faaliyetler, sera iklimlendirmesi, deniz suyundan tatlı su elde edilmesi, güneş pilleri, ulaşım, iletişim ve sinyalizasyon gibi çok çeşitli alanlarda kullanılmaktadır. Türkiye içerisinde bulunduğu iklim kuşağı nedeniyle güneş enerjisinden yararlanma potansiyeli yüksek bir ülkedir (Varınca ve Gönüllü, 2006; T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2022d). Güneş enerjisi doğa dostu olması ve bol miktarda bulunması nedeniyle alternatif bir enerji kaynağı

olsa da insan faaliyetlerinde kullanıma uygun hale getirilme sürecinde zorluklar ortaya çıkmaktadır. Ek olarak geleneksel enerji kaynaklarına kıyasen güneş enerjisi doğa durumuna bağlı olarak istikrarsız bir eğilim göstermekte ve kesintiye uğrayabilmektedir. Bu noktada enerji tedariğinde güvenliği sağlamak üzere tek bir enerji kaynağına bağımlı kalınmamasının altını çizmek gerekmektedir (Sahmerdan vd., 2025; Varınca ve Gönüllü, 2006).

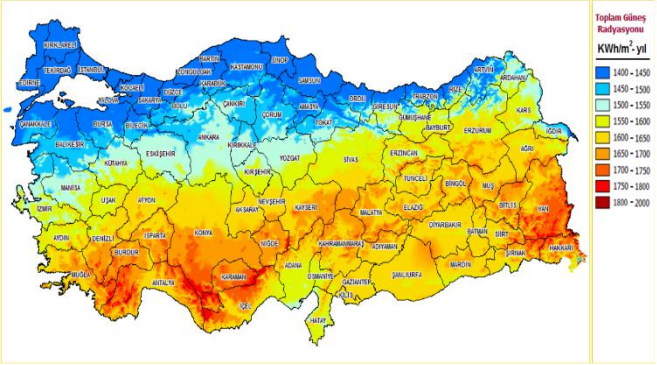
Şekil 10'de Türkiye elektrik enerjisi üretiminde kullanılan kaynakların dağılımı yer almaktadır. Elektrik üretimi 2023 yılı için büyük oranda ithal kömür ve doğalgazdan sağlanmakta iken güneş enerjisinden elektrik üretimi %7 gibi düşük bir seviyede kalmıştır. Türkiye fosil yakıt ve doğalgaz açısından büyük oranda ithalata bağımlı olmasına rağmen güneş enerjisinin elektrik üretme potansiyelini yeterince değerlendirilemediğini ifade etmek mümkündür. Bu noktada güneş enerjisi yatırımlarının teşvik edilmesi son derece önemli olmaktadır.

Şekil 10. 2023 Yılı Türkiye Elektrik Enerjisi Üretiminin Kaynaklara Göre Dağılımı



Kaynak: TEİAŞ, 2023

Şekil 11. Güneş Enerjisi Potansiyel Atlası (GEPA)

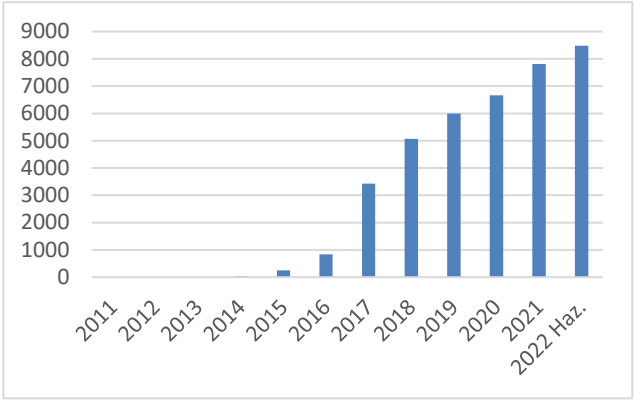


Kaynak: Enerji İşleri Genel Müdürlüğü, 2025a

Şekil 11. Türkiye'deki güneş enerjisi potansiyelini, güneş radyasyonu haritası ile ortaya koymuştur. Güneydoğu Anadolu ve Akdeniz Bölgesi en yüksek güneş enerjisi potansiyeline sahiptir. Güneşlenme süresi ve bulutlu gün oranı bakımından zayıf olan Karadeniz'in özellikle kıyı kesimleri ve Marmara Bölgesinin kuzey bölgeleri güneş enerji potansiyeli açısından görece verimsizdir.

Türkiye'de yıllık ortalama güneşlenme süresi 2.741 saat olup, toplam ışınım değeri ise 1.527,46 kHW/m^2 olarak hesaplanmıştır. Türkiye'de mevcut potansiyeli ortaya çıkarak çalışmalar hız kazanmış, Bakanlık nezninde girişimler hayata geçirilmiştir. 2022 yılının haziran sonu itibariyle güneş enerjisine dayalı elektrik kurulu gücü 8,479 MW, toplam kurulu güç içerisindeki payı ise %8,35 olarak sunulmuştur. Bakanlığın güneş enerjisine dayalı kurulu güç verileri Şekil 12 üzerinde sunulmuş; ilgili değerin 2011-2022 zaman diliminde istikrarlı artışı gözlenmiştir (T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2022d).

Şekil 12. Güneş Enerjisine Dayalı Kurulu Güç (MW)



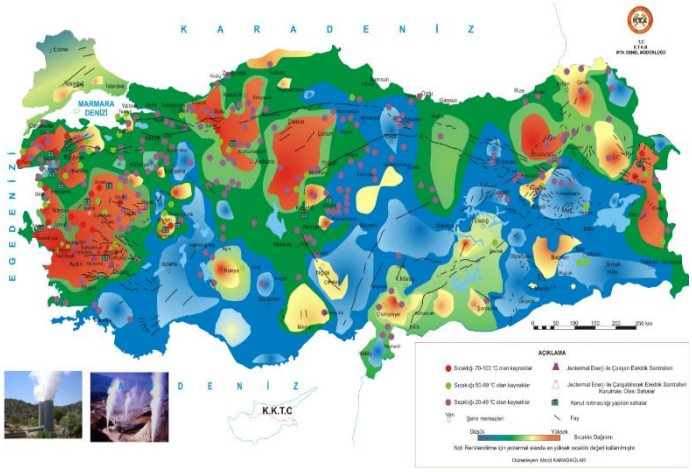
Kaynak: T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2022d

2.4. Jeotermal Enerji

Jeotermal enerji yerkabuğunun derinliklerinde birikmiş enerjinin tamamıdır. Tektonizmanın yarattığı kırık ve zayıf alanlardan sığ derinliklere ve/veya yeryüzüne kadar ulaşan magma faaliyetleri jeotermal ısının kaynağıdır. Jeotermal enerji, elektrik enerjisi başta olmak üzere konutların ve seraların ısıtması, termal turizm ve tedavi gibi bir dizi alanda kullanılmaktadır (Arslan vd., 2001). Jeotermal enerji yenilenebilir bir enerji kaynağı olmasının yanı sıra çevre dostudur. Ülkemiz jeopolitik ve coğrafi konum olarak jeotermal açıdan oldukça zengindir. Özellikle aktif bir tektonik kuşak üzerinde yer alması ülkenin hemen her yerine yayılmış jeotermal kaynaklarının varlığına imkân sunmuştur. Jeotermal enerji potansiyenin %78 gibi büyük bir kısmı Batı Anadolu, %9'u İç Anadolu, %7'si Marmara, %5'i Doğu Anadolu ve %1'i diğer bölgelerden kaynaklanmaktadır (MTA, 2024). Şekil 13 Türkiye'nin jeotermal kaynaklar ve uygulama haritasını göstermektedir. İzmir, Aydın, Denizli, Çanakkale, Balıkesir, Kütahya ve Afyonkarahisar sıcaklık dağılımı açısından en yüksek potansiyele sahip illerdir. Harita aynı zamanda fay hatlarının jeotermal enerjinin yeryüzüne çıkışındaki önemli alanlar

olduğunu göstermektedir.

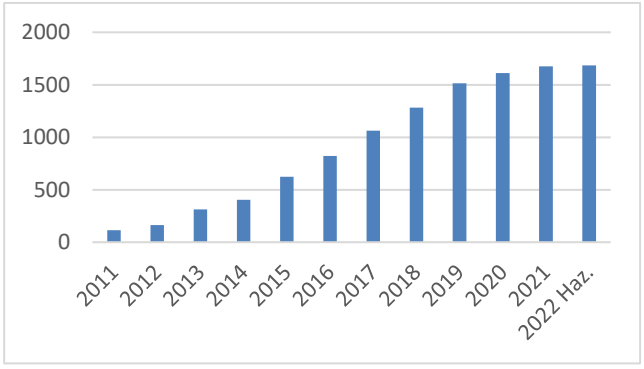
Şekil 13. Jeotermal Kaynaklar ve Uygulama Haritası



Kaynak: MTA, 2025

Ek olarak Türkiye jeotermal potansiyeli açısından Avrupa'da ilk sırada ve kurulu güç bakımından ise Dünya'da dördüncü sırada yer almaktadır. 2022 Haziran sonu itibariyle bölgesel ısıtmanın yanı sıra elektrik üretiminde de yaygın olarak kullanılan jeotermal enerjiye dayalı kurulu güç 1.686 MW olarak ölçülmüş; toplam kurulu güç içerisinde bu oran %1,66'ya tekabül etmiştir. Şekil 14'te 2011-22 dönemi için jeotermal enerjiye dayalı kurulu gücün değişimini görmek mümkündür (T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2022e).

Şekil 14. Jeotermal Enerjiye Dayalı Kurulu Güç (MW)

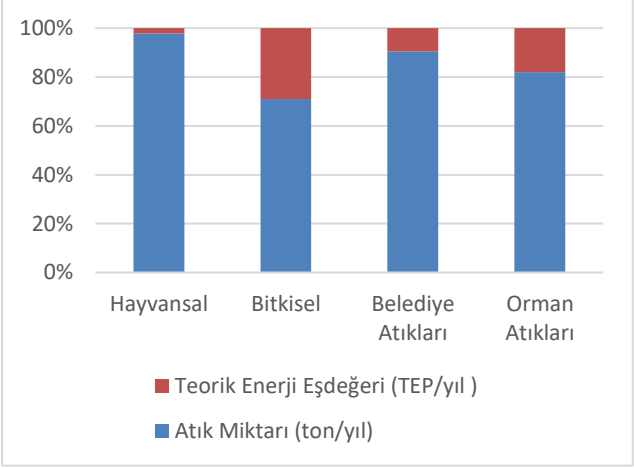


Kaynak: T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2022e

2.5. Biyokütle Enerjisi

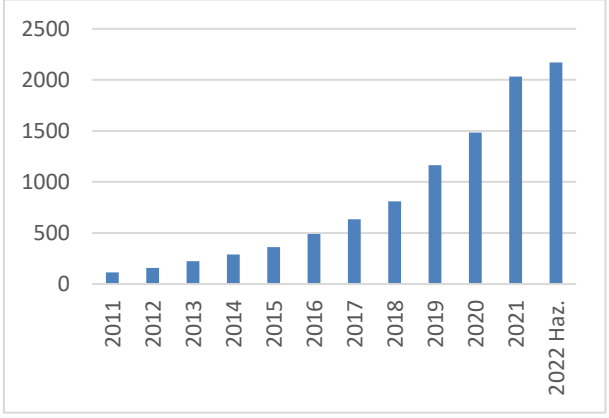
Biyokütle yaşayan veya yakın bir zaman içerisinde yaşamış olan canlılardan elde edilen fosilleşmemiş biyolojik malzemelerin bütününü ifade etmektedir. Bu kapsamda biyoenerjinin ana bileşeni bitkisel ve hayvansal kökenli organik maddelerdir. Biyokütle yakıt olarak kullanılabileceği gibi katı, gaz ve sıvı formlarda da kullanılabilmektedir. Klasik kullanımı odun, bitkisel ve hayvansal atıkların doğrudan yakılması ile ortaya çıkan enerjidir. Modern kullanım ise hayvansal, tarımsal, evsel-kentsel-endüstriyel organik içerikli atıkları ile diğer sucul ve karasal atıkların dönüştürülerek ısı ve elektrik enerjisine dönüştürülmesidir (İlleez, 2020). Şekil 15 üzerinden hayvansal ve bitkisel atık miktarı, enerji eşdeğeri ve ekonomik enerji eşdeğerine ulaşmak mümkündür. Şekilden anlaşılacağı üzere Türkiye'de bitkisel atıklardan enerji üretme potansiyeli diğer atıklara göre oldukça yüksektir. Orman atıklarının enerjiye dönüşme potansiyeli %22, belediye atıklarının %10, hayvansal atıkların ise %2 seviyelerindedir. Bitkisel atıklar için bu oran yaklaşık %41 seviyelerindedir. Bu durum büyük oranda Türkiye'nin zengin bir tarım ülkesi olması açıklanabilmektedir. Özellikle de şekerpancarı, mısır, buğday, ayçiçeği gibi bitkisel ürünlerin atık yoğunluğu düşünüldüğünde biyoenerji açısından zengin olması şaşırtıcı değildir. Hayvansal atıklar açısından sınırlı potansiyel ise hayvan yetiştiriciliğinin tarımsal üretim kadar yaygın olmayışı ve hayvansal atıkların görece yüksek taşıma ve depolama maliyetleri ile açıklanabilmektedir. Orman atıkları açısından ise özellikle ormanların ekosistem dengesi ve sağlığı açısından koruma alanları olması ve belirli sınırlamalara tabi olmasından kaynaklanmaktadır. Belediye atıkları açısından mevcut durum ise ayrıştırma ve geridönüşüm süreçlerindeki operasyonel zorluklardan kaynaklanmaktadır.

Şekil 15. Türkiye Biyokütle Enerjisi Potansiyeli Atlası



Kaynak: Enerji İşleri Genel Müdürlüğü, 2025b

Şekil 16. Biyokütle ve Atık Enerjisine Dayalı Kurulu Güç (MW)



Kaynak: T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2022f

2022 yılının haziran sonunda biyokütle ve atık ısı enerjisine dayalı kurulu güç 2172 MW olarak hesaplanmış; bu değer toplam kurulu gücün %2,14'üne karşılık gelmiştir. (T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2022f).

Özet olarak Türkiye artan enerji talebini karşılamak, enerjide dışa bağımlılığı azaltmak, enerji kullanımının yarattığı çevresel hasarı önlemek ve sürdürülebilir bir ekonomik büyüme sağlamak üzere yenilenebilir enerji kaynaklarına öncelik vermiştir. Bu amaçla ulusal ve bölgesel düzeyde çeşitli stratejiler belirlemiş; özellikle 2000'li yıllar itibariyle enerji politikalarında önemli dönüşümler gerçekleştirilmiştir. Toplam enerji arzı içerisinde hidroelektrik, rüzgâr, güneş, jeotermal ve biyokütle enerjisinin ağırlığını artırmak hedeflenmiştir. Avrupa Yeşil Mutabakatına Uyum ve Paris İklim Anlaşması hedeflerini sağlamak üzere mevzuat değişiklikleri ve kamusal teşvikler devreye alınmıştır. Yenilenebilir enerjiye dönüşümünde Türkiye, dünya sıralamasında önemli bir ilerleme kaydetmiştir. Özellikle hidroelektrik enerji üretme kapasitesinde ciddi artışlar söz konusu olmuş; hidroelektrik santrallerinin sayısı büyük ölçüde artırılmıştır. Rüzgâr enerjisi üretim kapasitesi de kayda değer bir artış göstermiştir. Güneş enerjisinde de yine çok sayıda küçük ölçekli lisanslı ve lisanssız proje devreye alınmıştır (PwC, 2021). Jeotermal ve biyokütle enerjisi ise bahsi geçen kaynaklara nispeten sınırlı düzeyde kalmıştır. Ancak Türkiye'nin sahip olduğu coğrafi konum ve jeolojik yapı, yenilenebilir enerji kaynakları açısından önemli bir potansiyel sunmakla birlikte, bu potansiyelin yeterli düzeyde değerlendirilemediğini ifade etmek mümkündür. Özellikle de enerji dönüşümünde karşılaşılan yüksek maliyetler ve finansal kaynağa erişimde yaşanan engeller bu durumu açıklamaktadır. Bu kapsamda dönüşüm sürecini finansal, bürokratik ve toplumsal açıdan kolaylaştıracak kamusal ve özel teşvikler son derece önemlidir. Enerji arz güvenliğini sağlamak adına kaynak çeşitliliğine dayalı bir yaklaşımın benimsenmesi gerekmektedir. Özellikle güneş ve rüzgâr gibi doğa durumuna bağlı enerji kaynaklarında yaşanması olası kesintiler kaynak erişiminde güçlükler yaratabilecektir. Dolayısıyla tek bir kaynağa bağımlı kalmamak enerji tedariği sürecinde olası aksamaların önüne geçecektir. Son olarak dönüşüm sürecinde enerji altyapısının sağlıklı ve uzun ömürlü çalışmasını mümkün kılan bütüncül bir planlama yapılması da altı çizilmesi gereken bir konu olmaktadır.

3. Türkiye'de Yenilenebilir Enerji Teşvikleri ve Karşılaşılan Zorluklar

3.1 Yenilebilir Enerjiye Geçişte Karşılaşılan Zorluklar

Yenilenebilir enerji potansiyelinin değerlendirilmesi ve mevcut kapasitenin geliştirilmesi her zaman mümkün olmamaktadır. Sürdürülebilir bir dünya için yenilenebilir enerjinin önünde birtakım engeller bulunmaktadır. Bu engellerin başında yüksek kurulum maliyetleri gelmektedir. Doğal kaynakları yenilenebilir enerjiye dönüştürecek ve nihai tüketicinin kullanımına sunacak teknoloji bugün hala oldukça maliyetlidir. Yenilenebilir enerji maliyetlerindeki düşüşe rağmen maliyetlerin ciddi bir engel olduğunu ifade etmek mümkündür (Akdoğan, 2016; Kayışoğlu ve Diken, 2019). Aynı zamanda yenilenebilir enerji üretiminin yapılacağı tesislerin başlangıç sermaye maliyetleri, işlem maliyetleri, yönetim maliyetleri de ciddi dezavantajlar yaratmaktadır. Yenilenebilir enerji sektöründe piyasa başarısızlıkları söz konusu olmakta bu durum kamu müdahalesini gerekli hale getirmektedir. Yerli üretimin yaygınlaşmasını sağlayacak kamusal müdahaleler ve teşvik sistemleri beraberinde yatırımcılar için bir dizi bürokratik süreci de yaratmaktadır. Lisans almak ve bir tesis kurmak için gerekli belge ve bilgi temini oldukça katı bir düzenlemeye tabi tutulmuştur. Yenilebilir enerji kullanımının ulusal ve küresel olarak kullanımının sağlayacağı avantajlar konusunda bilgi ve farkındalık eksikliğinden söz etmek de mümkündür. Aynı zamanda yenilenebilir enerjiye dayalı ekonomi Türkiye açısından henüz gelişim aşamasında olduğundan bu alanda nitelikli eleman bulma konusu da önemli bir handikap olmaktadır (Akdoğan, 2016; Kayışoğlu ve Diken, 2019).

Ek olarak şirketlerin karbonsuzlaşma hedeflerine ulaşmak ve gelecekte ortaya çıkması olası fiyat oynaklıklarına karşı korunmak üzere hükümet politikalarının dışında doğrudan rüzgâr ve güneş enerjisine artan yatırımları da bir noktada olumsuz durum yaratabilmektedir. Artan yatırım projelerine devam eden süreçte düşen elektrik talebi ve elektrik fiyatları eşlik etmektedir. Bu noktada projelerde yeniden değerleme riski ve buna bağlı zayıf finansman ortamı doğmaktadır (IEA, 2021a). Yenilenebilir enerji yatırımlarının yaygınlaştırılması noktasında kredi sağlayıcı kuruluşlar diğer tüm kredilerde olduğu gibi anapara ve faizin geri ödenmesine odaklanmaktadır. Başka bir ifade ile yenilenebilir enerji potansiyelini ortaya çıkaracak projeler herhangi bir özel yatırım ve/veya finans modeli olmadan serbest piyasa koşulları altında finanse edilmektedir. Bu iş modeli de ilgili alanlarda yatırımların tamamlanması noktasında riskler oluşturmakta; enerji yatırımlarını teşvik edecek politik/kurumlar üstü düzenlemeleri önemli hale getirmektedir (Akdağ ve Gözen, 2020).

Akıner (2025), Türkiye'de enerji dönüşümünün önündeki yapısal engelleri ortaya koyacak bir çalışma yürütmüştür. Çalışmanın bulguları yenilenebilir enerji teknolojilerine geçişte ihtiyaç duyulan finansal kaynakların ve teşviklerin önemli bir engel olduğu yönündedir. Düzenleyici çerçeveler, parasal kısıtlamalar, teknolojik engeller ve sosyokültürel faktörler de yine geçiş sürecinde karşılaşılan zorluklar arasında sıralanmıştır. Türkiye açısından güneş ve rüzgâr enerjisinde ortaya çıkan kesintiler de yenilenebilir enerjiye geçişteki engellerden biri olmaktadır. Özellikle yenilenebilir enerji arzındaki dalgalanma enerji dağıtımı ve depolaması açısından da önemli handikaplar oluşturmaktadır. Kamuoyu algısı ve katılımı geçiş sürecini etkileyen önemli unsurlardır. Türkiye açısından yeni teknolojilere direnç ve yenilenebilir enerjiye karşı süpheli yaklaşım oldukça yaygın bir durum olmuştur. Aynı zamanda Türkiye'de enerji dönüşümünün kömür madenlerinin

kapatılması örneğinde olduğu gibi işsizliğe yol açması, toplumsal eşitsizlikler yaratmakta ve kamu direncine yol açmaktadır.

Türköz (2023), 1970-2020 dönemi için Türkiye'deki doğrudan yabancı yatımların yenilenebilir enerji ve fosil enerji tüketimi üzerindeki etkisini analiz etmiştir. Ampirik sonuçlar, Türkiye'de doğrudan yabancı yatırım girişlerinin uzun dönemde fosil yakıt tüketimi üzerinde pozitif ve anlamlı bir etkisi olduğu sonucunu göstermiştir. Dolayısıyla doğrudan yabancı yatırımların temiz enerji tüketimini desteklemek bir yana fosil yakıt kulanımını artırdığını ve sürdürülebilir çevresel hedeflerden uzaklaştırdığını ifade etmektedir.

Ural ve Karaca (2016)'nın çalışmasında ele aldığı hidrojen ekonomisine geçiş sürecinde karşılaşılan güçlükler, Akıner (2025)'in ortaya koymuş olduğu bulgular ile büyük oranda benzerlik taşımaktadır. Hidrojen ekonomisine geçiş, enerjide kaynak güvenliğinin yanı sıra çevre koruması sağlayacak olsa da piyasanın direnç göstermesi ve finansal kaynağa erişememe bu dönüşümü sekteye uğratmaktadır. Ek olarak mevcut durumda fosil yakıtlara yüksek bağımlılık da dönüşüm sürecini engelleyen unsurlardan biridir. Bu noktada geçişi mümkün kılan altyapı yatımlarının oluşturulması, maliyetlerin düşürülmesi, hükümet ve sanayiden gelen finansman desteği önemli olacaktır.

Kılınç ve Şahbaz (2021), seçili ülkelerde 2003-2019 dönemi için enerjiye yönelik Ar-Ge harcamalarının ve inovasyonun yenilenebilir enerji üretimi üzerindeki etkisini analiz etmiştir. Panel ARDL yönteminden elde edilen bulgular uzun dönemde Ar-Ge ve demonstrasyon harcamaları ile inovasyon göstergesi olan patent başvurusu sayısında meydana gelecek %1'liik artışın, yenilebilir enerji üretimini sırası ile %0,23 ve %0,42 oranında artıracağını ortaya koymuştur. Çalışma bulgularını tersten okumak gerekirse, yenilenebilir enerji dönüşümünü sağlayacak Ar-Ge ve inovasyon yatırımlarının göz ardı edilmesi dönüşüm süreci önündeki engeller arasında sıralanmaktadır.

3.2. Yenilenebilir Enerji Teşvikleri

Türkiye'de yenilenebilir enerji kullanımını teşvik etmeye yönelik uygulamaların tohumları 2000'li yılların başında atılsa da 2010 yılı itibariyle hız kazandığını söylemek mümkündür. Sabit fiyat garantisi, lisanssız üretim, KDV muafiyeti ve gümrük vergisi muafiyeti gibi mali teşvikler, yeşil sertifika, paya dayalı kitle fonlaması vd. şeklinde sıralamak mümkündür (Yılmaz ve Hotunluoğlu, 2015; Akdağ ve Gözen, 2020). Bu teşvikler doğrudan devlet yardımları yerine daha ziyade uygulamada kolaylıklar şeklinde sunulmaktadır. Bu bağlamda elektrik enerjisi satın alım teminatları, şebekeye satılan elektrik enerjisi için satış tarifesi, yenilenebilir enerji santrallerine yönelik belirlenen satış tarifeleri, şebekeye bağlanan enerjide önceliğin yenilenebilir enerjiye sağlanması, lisans işlemlerinde indirim ve 500 kW altında ücret muafiyetleri şeklinde sıralanmaktadır (WWF, 2011).

Yenilenebilir Enerji ve Yeni Teknolojiler Dairesi Başkanlığı toplam elektrik enerjisi üretiminde yenilenebilir enerjinin payını artırmaya yönelik teşvik ve mekanizmalarını kategorize etmiştir. Bunlardan ilki "Yenilenebilir Enerji Destekleme Mekanizması (YEKDEM), 2005 yılında çıkarılan 5346 sayılı YEK Kanunu ile devreye alınmıştır. YEKDEM, tarife garantisi ile yenilenebilir enerji kaynaklarından üretilen elektrik enerjisi için piyasa fiyatının üzerinde sabit bir fiyat garantisi verilmektedir. Bu destek 10 ila 15 yıllık zaman zarfında piyasadaki arz ve talep dengesine, kur riskine, ekonomik ve politik belirsizliklere bağlı fiyat oynaklıklarına karşı koruma sağlamaktadır. YEKDEM yenilenebilir enerji kaynaklarına dayalı yatırımlarda artış, 2011 yılından günümüze CO_2 emisyonunda önemli bir düşüş, doğalgaz ve kömür ithalatında sırasıyla 50 milyar $ ve 43 milyar $ seviyesinde azalma ve 300 bine kadar kişiye istihdam olanağı yaratmıştır (T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2024). Tablo 1. hidrolik, rüzgâr, biyokütle, jeotermal, güneş, depolamalı rüzgâr/güneş, pompaj depolamalı hidroelektrik ve dalga/akıntı türlerindeki yenilebilir enerji tesislerinin 1/7/2021 öncesi ve sonrasında YEK Belgesi kapsamında destekleme fiyatları ve destekleme sürelerini ortaya koymuştur. YEKDEM Türkiye'nin enerji güvenliğini sağlama, karbon emisyonlarını azaltma ve iklim değişikliği ile mücadele kapsamında hedeflerine ulaşma noktasında önemli bir destek mekanizması sunmuştur. Yenilenebilir enerji tesislerinde üretilen elektriğe $ cinsinden garantili alım imkânı ciddi bir finansman desteği sağlamıştır. YEKDEM, Türkiye'nin kurulu güç kapasitesi içerisindeki yenilenebilir enerji kaynakları payının artmasında önemli bir güce sahiptir (Güler ve Yumurtacı, 2021).

İkinci bir destek mekanizması Yerli Aksam Teşvikidir. Bu mekanizma sayesinde 2024 yılına kadar 126 adet sistem tedarikçisi, 500 adet alt tedarikçi kurulmuş; yaklaşık 50 bin kişilik istihdam sağlanmıştır. Yenilenebilir enerji aksamlarında teknoloji transferi gerçekleştirilmiştir. Bir diğer destek mekanizması ise Yenilenebilir Enerji Kaynak Alanları (YEKA) Modelidir. YEKA Yönetmeliği, 9 Ekim 2016 tarihli ve 29852 sayılı Resmî Gazete'de yayınlanmıştır. Bu model yenilenebilir enerji kaynaklarının değerlendirilmesinde yeni bir dönemi başlatmıştır. Temel amaç kamu ve hazineye ait taşınmazlar ile özel mülkiyete konu taşınmazlarda yenilenebilir enerji kaynaklarının daha etkin ve verimli kullanımını sağlamak olmuştur. Yenilenebilir enerji teknolojilerinin yerlileştirilmesi ve bu sayede doğrudan ve dolaylı istihdam alanlarının yaratılması, yan sanayinin geliştirilmesi, araştırma ve geliştirme faaliyetlerinin yaygınlaştırılması şeklinde bir dizi strateji benimsenmiştir. Büyük ölçekli yenilenebilir enerji kaynak alanları oluşturmak; bu alanlarda üretilen enerjinin görece ekonomik şartlarda satın alınmasını sağlamakla birlikte lojistik fayda da yaratmaktadır. Proje sahası olarak belirlenecek YEKA'lar Bakanlıkça idari ve teknik çalışmalar neticesinde belirlenmekte; uygun yatırımcıya tahsis edilmektedir (T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2024). Özetle; Türkiye yenilenebilir enerji

potansiyeli son derece yüksek bir ülkedir. Ancak bu potansiyelin ekonomik bir değere dönüştürülmesi ekonomik, sosyal, idari birtakım engellerle karşı karşıya kalmaktadır. Bu aşamada kamu desteği ve toplumsal bilincin artırılması son derece önemli olmaktadır. Bu bilinçle devreye alınan YEKDEM, YEKA ve Yerli Aksam Teşvikleri yenilenebilir enerjiye geçiş sürecini destekleyici mekanizmalar olarak sıralanmaktadır.

Tablo 1. YEKDEM ve Yerli Katkı Fiyatları

TESİS TİPİ		1/7/2021 TARİHİNE KADAR İŞLETMEYE GİREN YEK BELGELİ TESİSLER				1/7/2021 TARİHİNDEN SONRA İŞLETMEYE GİREN YEK BELGELİ TESİSLER					
		Yekdem fiyatı ($/kwh)	Yekdem uygulama süresi (yıl)	Yerli katkı fiyatı ($-kwh)	Yerli katkı fiyatı uygulama süresi (yıl)	Yekdem fiyatı (01-31.10.2023) (tl/kwh)	Yekdem uygulama süresi (yıl)	Yekdem taban ($/kwh)	Yekdem tavan ($/kwh)	Yerli katkı fiyatı (01-31.10.2023) (tl/kwh)	Yerli katkı fiyatı uygulama süresi (yıl)
HİDROLİK	Rezervuarlı	7,3	10	2,3	5	215,37	10	6,75	8,25	43,08	5
	Nehir Tipi					201,91	10	6,30	7,70	43,08	5
RÜZGÂR	Karasal	7,3	10	3,7	5	158,54	10	4,95	6,05	43,08	5
	Deniz üstü					215,37	10	6,75	8,25	57,50	5
BİYOKÜTLE	Çöp Gazı/ÖTL	13,3	10	5,6	5	158,54	10	4,95	6,05	43,08	5
	Biyometanizasyon					258,74	10	8,10	9,90	43,08	5
	Termal Bertaraf					201,78	10	5,75	8,00	32,28	5
JEOTERMAL		10,5	10	2,7	5	302,14	15	9,45	11,55	43,08	5
GÜNEŞ	Fotovoltaik	13,3	10	6,7	5	158,54	10	4,95	6,05	43,08	5
	CSP			9,2							
DEPOLAMALI RÜZGÂR / GÜNEŞ		-	-	-	-	186,96	10	5,85	7,15	57,50	10
POMPAJ DEPOLAMALI HİDROELEKTRİK		-	-	-	-	302,14	15	9,45	11,55	57,50	10
DALGA / AKINTI		7,3	10	2,3	5	201,91	10	6,30	7,70	57,50	10

Kaynak: T.C. Enerji ve Tabii Kaynaklar Bakanlığı, 2024

4. Sonuç

Türkiye'de yenilenebilir enerji alanında önemli ilerlemeler kaydedilmiştir. Yenilenebilir enerji kaynaklarına yönelik atılan adımlar çevresel hedeflerin yanı sıra enerjide dışa bağımlılığı azaltmak için de son derece önemli olmaktadır. Özellikle fosil yakıt ithalatına yüksek oranda bağımlılık gösteren Türkiye ekonomisi açısından, yerli kaynak kullanımı cari açıklar üzerindeki baskıyı hafifletici bir unsur olacaktır. Yenilenebilir enerjiye geçişin makro iktisadi ve çevresel katkılarına rağmen dönüşüme yönelik somut adımlar Avrupa Birliği Yeşil Mutabakatına uyum süreciyle birlikte daha sağlam atılmıştır. Türkiye'de hidroelektrik, güneş, rüzgâr, jeotermal ve biyokütle enerjisine dayalı yenilenebilir enerji yatırımları büyük ölçüde artış göstermiş olsa da mevcut potansiyelin yeterince kullanılmadığının altını çizmek gerekir. Özellikle Türkiye'nin sahip olduğu coğrafi konum, iklim özellikleri ve jeolojik yapı zengin bir kaynak çeşitliliği sunmaktadır. Yıllık güneşlenme süresi bakımından Güneydoğu Anadolu, Akdeniz ve İç Anadolu Bölgesi güneş enerjisi; Ege ve Marmara Bölgeleri ise rüzgâr enerjisi açısından elverişli bir ortam sunmaktadır. Hidroelektrik elektrik tesisleri de keza ülkenin her yerine yayılmış, bugün sayısı 1000'i aşmıştır. Yine tektonik hareketlerin ve fay hatlarının yoğunluğuna bağlı olarak jeotermal enerjinin Batı Anadolu başta olmak üzere birçok alanda yayılım gösterdiğini ifade etmek mümkündür. Hayvansal ve bitkisel atıklara bağlı biyokütle enerjisi de yenilenebilir enerji üretimi açısından önemli bir kaynak olmaktadır.

Yenilenebilir enerjideki çeşitliliğe rağmen enerji dönüşümüne imkân sunan başlangıç yatırımlarının yüksekliği, finansal kaynaklara erişim zorluğu, teknik altyapı yetersizliği, yatırımların karlılığa dönüşme hızının uzunluğu ve belirsizliği, bürokratik engeller yatırım iştahını büyük oranda azaltmaktadır. Bu nedenle yenilenebilir enerji yatımları konusunda özel sektör son derece çekimser kalmaktadır. Yenilenebilir enerji arzını artıracak girişimlerin kamu tarafından desteklenmesi ihtiyacı doğmaktadır. YEKDEM, YEKA ve Yerli Aksam Teşvikleri bu doğrultuda devreye alınan programlar arasında sıralanmaktadır. Bu destekleme mekanizmaları vergi muafiyetleri, satın alım garantisi, şebekeye bağlanan enerjide öncelik, lisans işlemlerinde indirim gibi bir dizi kolaylaştırıcı müdahalede bulunmaktadır. Sivil toplumun, üniversitelerin, özel sektörün ve kamunun eşgüdüm

içerisinde hareketine imkân sunan bilgi ve teknoloji transferinin sağlanması ve toplumsal katılımın teşvik edilmesi de dönüşüm sürecinde önemli olmaktadır.

Sonuç olarak Türkiye'de yenilenebilir enerji potansiyeli oldukça yüksektir. Bu zenginlik enerji bağımsızlığını artırma ve çevresel hedeflere ulaşma açısından oldukça umut vericidir. Uygun stratejik hedefler ve destek mekanizmaları ile Türkiye'nin yenilenebilir enerji alanındaki ilerlemesi, sürdürülebilir ekonomi ve sürdürülebilir çevre koşullarının yaratılmasına imkân sunacaktır.

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