International Journal of Financial Management and Economics

**P-ISSN:** 2617-9210
**E-ISSN:** 2617-9229
IJFME 2025; 8(1): 98-102
www.theeconomicsjournal.com
Received: 24-11-2024
Accepted: 28-12-2024

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# The role of technology in promoting sustainable development

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**DOI:** https://doi.org/10.33545/26179210.2025.v8.i1.457

**Abstract**
The advancement of sustainable development (SD) heavily relies on technology which allows for implementation of renewable energy solutions. Renewable energy solves major worldwide issues which combine climate change with security of energy supplies and economic progress. The shift from traditional energy sources to sustainable options becomes possible through wind turbines alongside solar panels and decentralized energy systems which help nations achieve both environmental pollution reduction and natural resource conservation. The sustainable development goals (SDGs) can be achieved through renewable energy strategies because countries including China, United States, Norway and Brazil successfully develop power by utilizing their natural resources alongside green technologies. The worldwide push to extract renewable energy upgrades has expanded because people have learned more about global warming and demand more secure energy supply. People in communities support sustainability through the adoption of environmentally friendly technologies that belong in each household. Renewable energy technology systems allow governments to minimize environmental impacts while using enhanced economic development and better energy access and climate change adaptation for better global sustainability goals.

**Keywords:** Technology, sustainable development, environmental, rrenewable energy

## 1. Introduction
Many countries face environmental threats to sustainable development because their fast-growing populations and expanding human activities in environmental and economic and social domains (Schoor *et al*., 2023; Ramakrishna & Jose, 2022) [1, 2]. People frequently engage with discussions about sustainable development. The complete understanding of sustainable development demonstrates how this concept achieves present human requirements through measures that defend future peoples' needs without harming environmental stability and system integrity (Colglazier, 2015; Omer *et al*., 2008) [3, 4]. The concept stresses environmental resilience which is about natural systems maintaining essential services for present and upcoming populations as they adapt to and resist changes (Sharma *et al*., 2021; Schoor *et al*., 2023) [5, 1].
After the United Nations (UN) World Commission on Environment and Development published the Brundtland Report in 1987 sustainable development and its objectives received heightened worldwide interest. Sustainable development depends on three fundamental pillars including environmental sustainability together with social sustainability and economic sustainability (Secundo *et al*., 2020) [7]. The 2030 Agenda for Sustainable Development by the United Nations generated wide interest in 2015 as it introduced global social and environmental and economic guidelines (Ugurluay & Kirikkaleli, 2022; Borowski, 2021) [8, 9]. The UN calls for nations along with governments and civil society organization and public sector and private sector entities to join forces in attaining a balanced relation between these targets by 2030 (Secundo *et al*., 2020) [7]. Human actions that modify Earth systems create extensive difficulties for sustainable development while it faces these challenges. Together with climate change and global warming and environmental pollution and biodiversity loss and threats to food security these issues persist as difficult and urgent matters (Schoor *et al*., 2023; Leal Filho *et al*., 2019) [1, 10].
The path to sustainable development requires people to modify their lifestyle activities and actions within several domains like energy usage and food selections and action reduction

that diminishes global warming and environmental contamination (Leal Filho *et al*., 2019; Tremblay *et al*., 2020) [10, 11]. The behavioral changes integrate technology innovation to minimize environmental effects and promote sustainability according to Filho *et al*. (2019) [10]. Our survival relies on solving complicated worldwide issues because they determine both the quality of life and human health. Sustainable development promotion can be achieved through innovative technological applications that span economic and environmental and social sectors according to Ugurluay & Kirikkaleli (2022) [8] and Stuermer *et al*. (2017) [12].

The advancement of renewable energy solutions and waste management systems and innovations for agricultural improvement have made sustainability fundamental to technological development (Al-Emran & Griffy-Brown, 2023) [13]. Sustainability technology implements scientific knowledge alongside engineering solutions and tools which develop answers for handling environmental issues while fulfilling current social requirements while protecting future resource availability (Al-Emran & Griffy-Brown, 2023; Secundo *et al*., 2020; Grybauskas *et al*., 2022) [13, 7]. The promotion of sustainable development depends heavily on renewable sources because they reduce environmental destruction and achieve fair resource sharing and protect natural ecosystems and enhance both social development and economic prosperity (Al-Emran & Griffy-Brown, 2023; Ugurluay & Kirikkaleli, 2022) [13, 8].

Sustainability technology comprises extraction methods and systems together with programs and tools for production and consumption and elimination that function as direct enablers of sustainable development (Beder, 1994; Habanik *et al*., 2019; Weaver *et al*., 2017) [15, 16, 17]. The research evaluates key technological domains that promote sustainable development by means of environmental protection and renewable energy innovations along with innovative agricultural safety methods. The achievement of sustainability depends significantly on technology because it protects natural resources while ensuring environmental equilibrium according to multiple scientific studies.

## 2. Literature Review

The field of digital systems and programs alongside technological development has substantially contributed to sustainability through its multiple positive effects on sustainable development (Ahmad *et al*., 2023; Al-Emran & Griffy-Brown, 2023) [18, 13].

Multiple contemporary investigations show that tech advancements alongside digital transformation help decrease environmental risks through their efforts toward sustainable development in economic, environmental, social aspects (Ahmad *et al*., 2023, Anadon *et al*., 2016, Omri, 2020, Corsi *et al*., 2020) [18, 19, 21].

Technological innovation companies operating in advanced nations support their clients to combine advanced technologies with societal needs while preserving sustainability (Omri, 2018) [22].

The Sustainable Development Goals (SDGs) show how vital it is to tackle worldwide air pollution through changes between conventional energy systems toward sustainable power resources (Nguyen *et al*., 2023) [23]. Renewable energy serves as an established solution which addresses environmental issues together with economic development and nationwide energy distribution (Wrigley, 2013; Voumik *et al*., 2023; Lawal *et al*., 2023) [24, 25, 26]. Several nations currently invest their resources into developing renewable energy technologies while deploying initiatives for extracting renewable power. The related goals can be achieved through these efforts which work to reduce environmental degradation while protecting natural resources and enabling sustainable development (Anghelache *et al*., 2023) [27]. Renewable energy technology use leads to sustainable development through two key benefits including air pollution reduction and health protection (Sasmaz *et al*., 2020) [29]. According to Cheng *et al*. (2021) [33] renewable energy serves as an important resource to resolve multiple critical issues in which sustainable energy systems secure access for all while boosting economic productivity and fighting climate change. The technology enables both the advancement of SD goals and their successful accomplishment.

## 3. Data and Methodology

This study derives its data from existing research documents and statistical records of Germany and the United States along with Brazil China India Norway New Zealand Denmark and Portugal. Literary material was used to extract additional information about the growing technological dependence in the studied fields. The study incorporated information from both the Renewable Energy Agency (IRENA) as well as the Organization for Economic Cooperation and Development (OECD). The analysis of relevant studies and necessary indicators in specified areas supported the hypothesis that technology drives sustainable development.

## 4. Results and Discussion

The International Renewable Energy Agency shows China leads the world in renewable energy use while the United States stands in second position (Table 1). The study confirms that China extensively utilizes renewable energy resources including solar power and hydropower and wind power and bioenergy to generate electricity and reduce pollution (Jiang & Raza, 2024) [30]. Chinese leaders understand that sustainable energy production fulfills multiple SDGs while demonstrating their commitment to SD development as part of global efforts. A wide range of green technology strategies are being implemented by China together with other nations demonstrating their commitment to SD progress (Su & Fan, 2022; Jiang & Raza, 2024; Zhang *et al*., 2015) [31, 30, 32].

United States has achieved substantial progress in renewable energy utilization because of its climate emission reduction objectives along with its goal to establish a sustainable power system (Ullah *et al*., 2023) [41]. The nation possesses several renewable energy resource types which include wind energy together with solar power and hydropower as well as geothermal and biomass options. The implementation of wind and solar energy systems grew at the fastest rate during recent years due to technological developments and decreasing prices and government backing programs. Texas holds the leading position in wind energy production but California stands at the forefront for solar power use (Ullah *et al*., 2023) [41]. The power generation system which uses flowing water remains a fundamental energy source for regions that have ample water supplies. Renewable energy infrastructure investment by the United States maintains its purpose in achieving clean energy targets through

sustainable policies to secure energy security and reduce climate change impacts in creating a future sustainable ecosystem.

**Table 1:** Presents the top countries with the highest total renewable energy capacity.

| Country | Capacity (GW) |
|---|---|
| China | *1*,020 |
| United States | 325 |
| Brazil | 160 |
| India | 150 |
| Germany | 140 |

**Source:** International Renewable Energy Agency (IRENA)

Table 2 with Figure 1 shows that Norway together with Brazil are major global players when it comes to producing electricity from renewable sources. The countries enjoy plenty of sustainable natural resources which they utilize using green energy technologies for their power generation needs. Technology stands as a vital catalyst for sustainability advancement in developed nations based on Marco-Lajara *et al* (2023) [34] as well as Rahman *et al* (2024) [35].

**Table 2:** Shows the countries with the highest share of renewable energy used in electricity generation.

| Country | Percentage (%) |
|---|---|
| Norway | 98.3 |
| Brazil | 89.3 |
| New Zealand | 87.6 |
| Denmark | 87.2 |
| Portugal | 75.5 |

The two world-leading nations Norway and Brazil support renewable energy by employing their distinct natural resources to achieve environmental sustainability. Norway depends on hydropower for its electricity needs since this renewable energy source covers almost all of its power consumption thanks to its extensive water supplies and sophisticated infrastructure according to Malka *et al*. (2023) [39]. Due to its commitment Norwegian infrastructure supports low greenhouse gas emissions production without sacrificing domestic energy requirements. Brazil achieved major progress in renewable energy by maximizing both bioenergy and hydropower (Pelkmans, 2021) [40]. Brazil obtains a considerable portion of its energy from sugarcane ethanol biofuels and other biofuels while generating power through its extensive river systems (Pelkmans, 2021) [40]. Renewable energy demonstrates the ability of economic growth to coexist with environmental conservation in these two nations who serve as sustainability examples for other countries working toward green energy systems.

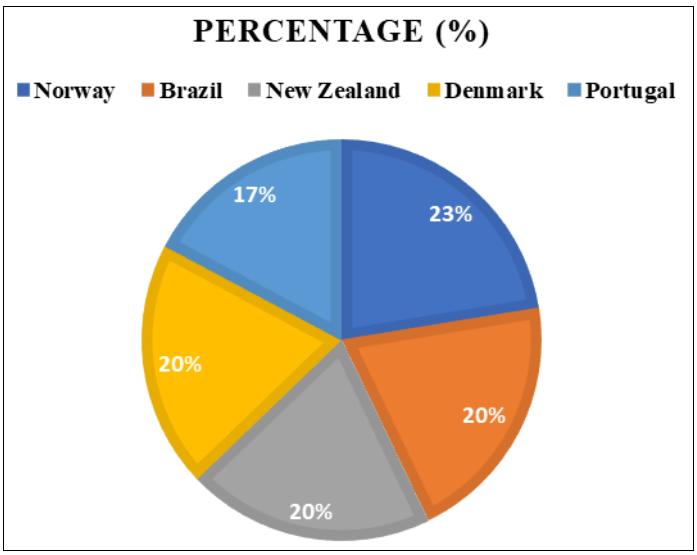


**Fig 1:** Shows the countries with the highest share of renewable energy used in electricity generation.

People simultaneously implement renewable energy solutions because of increased climate change awareness while using technological approaches to secure energy security according to Al-Shetwi (2022) [36] and Bassey (2023) [37]. The basic principle of technological advancement serves to create progress toward SD. Many nations together with their developed members reach multiple SDGs through their implementation of green technology combined with key indicator monitoring systems. Through renewable energy implementation projects societies gain economic growth while establishing global environmental sustainability together with climate change reduction. The public within communities shows improved understanding about how technology enables

sustainable development. Wind turbines and solar panels within decentralized energy systems became standard for residential power generation because people worldwide began adopting these systems (Chwieduk *et al*., 2020) [38]. Sustainable operations result from systems which integrate environmental attention with energy-efficient operations to prevent contamination of environmental energy sources.

## 5. Conclusion

Technology innovation stands as the essential key component to drive sustainable development and ranks among the most vital contemporary life-changing subjects. Research and political discussions now focus on this subject because it has become a prominent area of scientific and academic investigation. Research has shown how technology supports sustainability through its use of renewable power systems as a single target of investigation. Statistical data and research findings revealed that developed nations have leveraged their resources to adopt renewable energy through the implementation of green technologies. These efforts have significantly contributed to reducing pollution and mitigating climate change while simultaneously driving economic growth. Although our study primarily focused on one aspect of sustainability, it confirmed the decisive role of technological advancements in promoting sustainable development. Technological progress has evident impacts—both positive and negative—on sustainability. Therefore, it is essential for policymakers, institutions, and communities to intensify their efforts in harnessing technologies and programs to achieve all sustainable development goals.

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