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RENEWABLE ENERGIES IN THE TECHNOLOGICAL AGE AND SUSTAINABLE INVESTMENT SOLUTIONS FOR THE "SMART FUTURE"

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ABSTRACT

Objectives: *Modern trends clearly reflect the increasing adoption of renewable energy technologies and their integration into smart systems. This scientific paper aims to assess the effectiveness of sustainable investment decisions in renewable energy in the face of the challenges posed by technological progress.*
Methods/Approach: *To achieve (or solve) the set goal, the following scientific research methods were used:*
- Analytical: for collecting and summarizing statistical information and processing scientific literature on renewable energy;
- Abstract-logical: for determining the factors influencing investment decisions in this field;
- Quantitative: for determining the cause-and-effect relationship between investments, technological progress, and investment decisions using correlation coefficients;
- Generalization: This is used to formulate conclusions based on the research results.
Results: *The correlation between technological progress, renewable energy, and investment decisions is established. Factors affecting public attitude towards renewable energy are identified, and the transformational impact of innovations on the effective integration and use of renewable resources is assessed.*
Conclusions: *International experience and current trends indicate that the convergence of renewable energy and technologies is a wise decision for creating a "smart future" and fostering better development. By reducing the world's reliance on fossil fuels and minimizing our carbon footprint, adopting renewable energy is crucial for mitigating climate change and preserving ecosystems. Incorporating renewable energy technologies into regional planning not only increases energy efficiency but also contributes to the development of a resilient, intelligent urban environment. Effective implementation of sustainable investment solutions requires a collective commitment to overcoming challenges, sharing best practices, and developing innovations with advanced renewable energy technologies.*

Keywords: *Renewable Energy, Smart Technology, Environmental Innovation, Investment decisions, Correlation, "Green economy"*

JEL classification: E22; Q42; Q57; P28; P18; G11; R11
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INTRODUCTION

In today's global era, characterized by rapid technological advancements and escalating environmental challenges, making sustainable decisions is crucial for shaping a technologically advanced and environmentally clean future—a "smart future". (Iliev et al., 2023; Ramazanov & Petrova, 2020; Shopova et al., 2023; Dorokhova et al., 2024; Petrova & Tairov, 2022). Climate change has become a primary driver for the promotion of renewable energies.

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Utilizing new energy sources is a key component of the energy sector. Given the global need to reduce carbon emissions and transition to clean energy alternatives, making sustainable investment decisions in renewable energy sources will help alleviate the world's environmental problems.

Energy is a primary resource for a country's economy and an integral part of societal life. It plays a crucial role in using other resources during the production process, thus placing a double burden on energy resources. Renewable energies, being inexhaustible, offer significant benefits. Sustainable investment decisions in this sector can lead to job creation, cost reduction, environmental protection, improved human health, regional development, and infrastructure enhancement.

This research explores various renewable energy sources, such as solar, wind, hydro, and geothermal, examining their viability, scalability, and potential to transform the energy paradigm. The goal of this scientific work is to investigate the possibilities, challenges, and issues related to renewable energy in Georgia, considering the complex interplay between sustainable renewable practices and the growing global technological landscape. By conducting a correlational analysis of technological progress and investments in renewable energy sources, we will evaluate the advantages and disadvantages of renewable energies. The study will also draw on the experiences of leading countries and compare renewable energy sources in Georgia, aiming to provide key directions and recommendations for effectively integrating renewable energy within our technological framework.

It is also important to note that the synergistic effect between renewable energy and smart technologies—ranging from intelligent grid systems to advanced energy storage solutions - not only yields positive economic outcomes but also enhances a country’s energy independence. This synergy illustrates how innovation and strategic investment decisions contribute to sustainability and efficiency, including effects such as innovation and stimulation.

As we navigate the crossroads of technological evolution and environmental protection, fostering sustainable investment decisions, we advocate for a future where technology and renewable energy advance harmoniously toward a smarter, greener, and more sustainable tomorrow. An empirical analysis of data from leading countries in Europe and other regions enables us to accurately assess the state's role in supporting policies, incentives, and the stimulation of energy technology innovation. This analysis highlights the necessity of further development in the green economy. In addition, the South Caucasus region is part of the energy-rich Caspian area, making it advantageous for Europe to diversify its energy resources and partners in the long term. This perspective adds extra impetus to Georgia's development as a trade transit corridor (Abuseridze et al, 2022).

Opinions of scientific economists on the role of renewable energy in the age of technology

For this scientific work, various sources have been utilized, including manuals and scientific articles, official data from the National Statistics Service of Georgia, the Ministry of Economy and Sustainable Development of Georgia, and reports, studies, and periodicals published by the World Bank. Additionally, foreign publications on renewable energy sources and investment decisions have been referenced.

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In his work, *Renewable Energy and Sustainable Development*, Ibrahim Dincher highlights the need for long-term actions to address environmental problems and underscores the importance of sustainable development. He emphasizes the critical role of renewable energy sources and concludes that there is a strong connection between renewable energy and sustainable development. (Dincer, 2024).

Like other sectors, investments in renewable energy experienced a decline during the pandemic. Authors Menghan Li, Nawzad Majeed Hamawandy, Fazle Wahid, Husam Rjoub, and Zongke Bao observe that "Continuous investment in renewable energy, energy efficiency, and other green initiatives decreased dramatically in 2020-21 due to the COVID-19 outbreak and the global economic crisis. The pandemic, along with economic downturns, led to a significant drop in oil and gas prices. Lower fossil fuel prices undermine the development of renewable energy projects, making solar, wind, and other renewable sources less economically competitive. This reduction in investment interest jeopardizes the Paris Climate Agreement and numerous Sustainable Development Goals (SDGs)."(Menghan et al, 2021).

In their work, Foreign Direct Investments in the Conditions of the COVID-19 Pandemic: Georgia-EU Relations, Ramin Tsinaridze and Giorgi Rizhvadze emphasize that "to attract investments in the service sector, it is essential to introduce new technologies rapidly." One key recommendation they make is to accelerate the transition to 5G technology. This advancement will encourage local and foreign startups to pursue business projects centered on technology and innovation. (Tsinaridze et al., 2023).

Although China is currently a technologically advanced country, it remains committed to investing in the "green economy" and believes that "green finance" will address economic, financial, and environmental (ecological) challenges. In the current economic environment, financial inclusion is crucial for a nation's wide, inclusive, and sustainable growth (Todorov, Aleksandrova & Ismailov, 2023). It has been observed that investment in renewable energy plays a crucial role in green finance. Therefore, policies should be designed to enhance renewable energy development, contributing to a more sustainable environment. This approach encourages the creation of innovative policies to expand the use of renewable energy sources as alternatives to fossil fuels. Thus, improving green finance should be a key consideration in policy formulation to increase renewable energy production and investment. Implementing such measures is expected to mitigate uncertainties across economic, financial, and environmental domains. (Bei et al, 2023).

For countries, investing in renewable energy sources has become crucial for maintaining the balance between energy, economy, and ecology (Shalbayeva et al. 2024). "Renewable energy sources are eco-friendly as they do not emit carbon into the atmosphere. Additionally, they play a key role in enabling countries to produce their energy resources. Although investments in this area have been increasing recently, the production capacity of these resources is still insufficient, and full efficiency has not yet been achieved due to the high level of technical knowledge required for renewable energy technologies." (Zhong et al., 2020).

Recently, the Indian economy has been characterized by rapid economic growth. Over the long term, the group of authors suggests that it is essential to utilize renewable energy sources alongside mining and oil. "By 2040, India's energy consumption is expected to grow the fastest among all major economies, with coal

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meeting most of this demand, followed by renewable energy. By 2020, renewables had become the second most significant source of domestic power production, surpassing gas and oil. The demand for renewables in India is projected to increase dramatically, reaching 256 Mtoe by 2040, up from 17 Mtoe in 2016." (Kumar et al., 2020).

In the paper *"How Does Artificial Intelligence Affect High-Quality Energy Development? Achieving a Clean Energy Transition Society"* by Bo Wang, Jianda Wang, Kangyin Dong, and Rabindra Nepal, the authors explore how artificial intelligence (AI) contributes to high-quality energy development (HED) in China. They discuss the transition from qualitative improvements to quantitative changes in energy development, highlighting that high-quality energy development is a critical strategy for the Chinese government. AI, as an emerging technology, is seen as a key enabler of this transition, enhancing energy security and strengthening the overall process.

The paper examines the relationship between AI and HED using the HED index and evaluates AI development across 30 Chinese provinces from 2007 to 2017. It also investigates the marginal effect of the digital economy on the relationship between AI and HED. The results indicate that AI has a positive impact on HED in China; specifically, "a 1% increase in AI development is associated with a 0.032% increase in the HED index." Additionally, AI indirectly enhances the HED index by fostering green innovation and increasing R&D intensity. The study also finds that the level of development of the digital economy influences the impact of AI on HED, with AI having a more significant positive impact in emerging digital economy sectors. The authors offer practical advice and recommendations for agencies aiming to achieve a clean energy transition and leverage AI to support high-quality energy development. (Wang et al., 2024).

The impact of renewable energy sources (RESs) on GDP and employment is noteworthy. Various studies have been analyzed to assess this issue, with findings reconciled using the example of Greece. The conclusion is that investing in renewable energy contributes to economic growth. According to the authors, "Studies have employed a wide range of methodological frameworks and empirical tools to quantify the macroeconomic effects of RESs, focusing primarily on two key economic indicators: GDP and employment effects. Future research could benefit from applying a suitably modified methodological approach to explore the structural effects of investment in supporting activities, such as grid improvements, efficiency enhancements, and weatherization, which are often pursued alongside RES investments." (Stamopoulos et al., 2021).

The scientific research conducted by the following group of authors highlights the need for investments in renewable energy sources (RESs) and the improvement of local spatial policies. They argue that "the problem with the Polish spatial planning system is the inadequate planning and legal framework for RES investments. This inadequacy leads to some investments being blocked and increases terminological confusion, creating barriers. Moreover, in the case of higher-capacity RESs, there is a risk of excessive localization in certain areas. In nearly 50% of municipalities, RESs are not included in strategic spatial planning tools. It is important to note that in Poland, the implementation of renewable energy in spatial planning is significantly lacking, particularly in rural areas. This issue is especially pronounced in the northern part of the country, where the

dispersion of settlements and the need for RESs is highest, particularly in regions with low emissions from wood and coal-fired boilers and stoves." (Blaszke et al., 2021).

Amid the contemporary challenges of globalization and the expansion of international business, the significance of the "green economy" is primarily centered on reducing environmental risks. However, beyond this primary ecological aim, investments in renewable energies also address socio-economic inequalities, enhance well-being, and contribute to economic development. According to the scientific article by M. Gelashvili, "The green economy mitigates the slowdown in economic growth by fostering economic development through the adoption of new consumer products and the improvement of existing ones. This results in increased public comfort and enhanced well-being. Understanding the essence, importance, and characteristics of the green economy requires recognizing its role in economic development. It is through innovation that the economic growth rates can be aligned with natural reproduction processes." (Gelashvili, 2023).

In reviewing both Georgian and international literature, the role and importance of renewable energy for a "smart future" have been emphasized. While studies, statistical analyses, and correlations from various countries yield differing results, addressing the modern global economic, social, and environmental challenges requires a significant increase in investments in renewable energy sources. Energy independence and security remain major challenges for Georgia's economy. Since gaining independence, the country's economy has been heavily reliant on investments, and this trend should continue with a focus on attracting additional foreign investments in high-tech sectors and utilizing alternative energy sources.

METHODOLOGY

The scientific and intellectual contributions from Georgian and international researchers in the field of renewable energies form the methodological foundation of this work. It is based on statistical data, research, and periodicals from the National Statistical Service of Georgia, the Ministry of Economy and Sustainable Development of Georgia, and the World Bank regarding investment decisions in renewable energy sources. The study employs correlation analysis, along with quantitative and statistical methods.

The materials for the conducted correlation analysis were taken from the above sources for the period of 2018 – 2023.

RESULTS

Basic decisions and Analysis of statistical indicators of investments in renewable energy sources

Researching the rapidly evolving technological landscape and making sustainable investment decisions are increasingly essential for leveraging renewable energy sources and addressing environmental challenges. This scientific paper explores the relationship between renewable energy and technology, considering the context in Georgia and the need to develop a "smart future" with sustainable solutions.

Economic and inclusive solutions are strategies, policies, and practices to address financial challenges while ensuring inclusivity, equity, and social well-being. These solutions are designed to promote sustainable

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economic development that benefits all segments of society, irrespective of socioeconomic status, ethnicity, gender, or other factors. Below is a breakdown of the main elements:

1. **Economic Decisions:**

Sustainable Growth: Economic decisions should promote growth that is environmentally sustainable and does not compromise the well-being of future generations. This involves adopting cleaner and more efficient production methods, utilizing renewable energy sources, and embracing circular economy principles to minimize waste.

Innovation and Technology: Integrating innovation and technology is a critical aspect of economic decisions. Technological advancements can enhance productivity, create jobs, and diversify the economy.

Financial Stability: Maintaining financial stability through sound fiscal and monetary policies is essential. This includes managing inflation, stabilizing the currency, and implementing effective financial regulations to mitigate economic volatility.

2. **Inclusive Solutions:**

Social Equity: Inclusive solutions aim to achieve social equity by addressing disparities in access to income, education, health, and opportunities. Policies and initiatives are designed to distribute the benefits of economic development more fairly, reducing social inequality.

Job Creation: Strategies for inclusive economic growth emphasize job creation, particularly for low-income communities. This involves supporting sectors with high employment potential and implementing training programs to enhance workforce skills.

Access to Basic Services: Inclusive solutions aim to ensure universal access to essential services such as health, education, and housing. This ensures that everyone in society has the opportunity to lead a dignified and fulfilling life.

Community Involvement: Involving communities in the decision-making process is a key aspect of inclusiveness. Empowering local communities to participate in developing policies that directly affect them fosters a sense of ownership and ensures that diverse perspectives are considered.

3. **Resource Conservation:**

Economic and inclusive solutions recognize the finite nature of resources and promote sustainable resource management. This involves adopting practices that minimize environmental impact, such as reducing carbon emissions, protecting biodiversity, and conserving water resources.

Greenhouse Gas Emissions: The increasing trends in global climate change highlight that the primary contributors to greenhouse gas emissions are still high-economy countries. These countries bear significant responsibility in addressing this critical issue. Greenhouse gas emissions are a major driver of global climate change and continue to rise annually with no signs of diminishing. According to the Intergovernmental Panel on Climate Change (IPCC), human activities are responsible for nearly all of the increase in greenhouse gases since the mid-20th century. Consequently, the concentrations of carbon dioxide, methane, nitrogen oxides, and other trace gases have risen dramatically during this period.

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Table 1. Greenhouse Gas Emissions by Country

№	Country	CO_2 Emissions	Air Pollution
1	People' 's Republic of China	10,667.89 Mt	30.6 µg/m^3
2	United States of America	4,712.77 Mt	8.9 µg/m^3
3	India	2,441.79 Mt	53.3 µg/m^3
4	Russia	1,557.14 Mt	11.2 µg/m^3
5	Japan	1,030.78 Mt	9.1 µg/m^3
6	Iran	745.04 Mt	32.5 µg/m^3
7	Germany	644.31 Mt	11 µg/m^3
8	Saudi Arabia	625.51 Mt	41.5 µg/m^3
9	Sous Korea	597.61 Mt	18.3 µg/m^3
10	Indonesia	598.5 Mt	30.4 µg/m^3

Source: Greenhouse Gas Emissions by Country. (Wisevoter, 2024)

Global greenhouse gas emissions increased by approximately 70% from 1970 to 2018 and continue to rise, despite significant efforts to reduce them in recent years. This increase is largely driven by the growing economies of countries such as China and India, expanding energy demand across transport, industry, buildings, and households. Total greenhouse gas emissions vary widely between countries, with China remaining the world's largest emitter, followed by the US and India. However, when considering emissions per capita - taking population size into account - smaller countries like Qatar and Luxembourg often lead the list. In the case of Georgia, CO2 emissions amount to 9.97 Mt, placing it 104th in the world, while its air pollution index stands at 17 µg/m³, positioning it 59th globally.

Climate Change Resilience: Inclusive solutions also address the impact of climate change on vulnerable communities. Strategies are focused on building resilience and adaptive capacity to ensure that all segments of society can cope with and recover from climate-related challenges.

In summary, economic and inclusive solutions are comprehensive approaches that balance economic development with social inclusion, environmental sustainability, and long-term resilience. By addressing the interconnected challenges societies face, these solutions strive to create a fairer and more sustainable future for all.

Renewable energy is crucial in addressing environmental problems and implementing sustainable measures. Here are some key aspects highlighting the connection between renewable energy and environmental considerations:

Reducing Carbon Emissions: Clean Energy Sources: Unlike fossil fuels, renewable energy sources such as solar, wind, hydropower, and geothermal do not emit greenhouse gases during energy production. The widespread adoption of renewable energy significantly reduces carbon emissions, mitigates climate change, and decreases air pollution.

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Improving Air and Water Quality: Reducing Air Pollution: Traditional energy sources like coal and natural gas release pollutants that negatively impact air quality. Transitioning to renewable energy sources helps reduce air pollution, creating a cleaner and healthier environment for human populations and ecosystems.

Sustainable Use of Water: Unlike conventional power plants that require substantial water for cooling, many renewable energy technologies, such as solar and wind, have minimal water consumption. This contributes to more sustainable water management practices.

Biodiversity Conservation:

Reduced Habitat Disruption: The extraction and use of fossil fuels often lead to habitat destruction and fragmentation. Renewable energy projects, especially those designed with ecosystems in mind, reduce habitat disturbance and help maintain biodiversity.

Land Use Efficiency:

Minimal Land Impact: While some renewable energy projects require land, technological advancements allow for more efficient land use. For example, solar panels can be integrated into existing infrastructure, and offshore wind farms utilize open waters without impacting land ecosystems.

Resource Conservation:

Resource Depletion: The extraction of fossil fuels depletes finite resources and can cause irreversible damage to ecosystems. In contrast, renewable energy technologies rely on abundant and renewable resources like sunlight and wind, reducing the strain on natural resources.

Waste Reduction and Recycling:

Low Environmental Impact: The production and operation of renewable energy systems generally produce less waste than traditional energy sources. Additionally, many components of renewable energy systems, such as solar panels and wind turbines, are recyclable, contributing to a more sustainable life cycle.

Climate Resilience:

Mitigation and Adaptation: Adopting renewable energy not only helps mitigate climate change but also enhances climate resilience. By reducing reliance on fossil fuels, societies become more adaptable to the impacts of climate change, including extreme weather events and rising sea levels.

Environmental Justice:

Equitable Distribution: Placing renewable energy projects can lead to a more equitable distribution of environmental benefits. This helps avoid the disproportionate ecological burdens often experienced by marginalized communities living near traditional energy facilities.

Global Policies and Agreements:

International Cooperation: Renewable energy aligns with global environmental agreements and initiatives to combat climate change. Agreements such as the Paris Agreement highlight the importance of transitioning to a low-carbon, sustainable energy future.

The integration of renewable energy into the energy mix is a fundamental aspect of sustainable development and environmental protection. Advances in technology and policies supporting clean energy sources are

expected to enhance the positive environmental impact of renewable energy, contributing to a more sustainable and resilient planet.

Notably, according to data from the National Statistics Service of Georgia, the energy sector is not among the top three industries receiving direct foreign investments. However, there is a clear upward trend in investments in renewable energy, as detailed in the accompanying table.

Table 2. Breakdown of FDI by economic sectors in 2018-2023 (million us dollars)

	2018	**2019**	**2020**	**2021**	**2022**	**2023***
Total	1 350.6	1 354.1	595.3	1 252.7	2 097.9	1 594.7
of which:						
Financial and insurance activities	273.6	285.3	409.4	472.1	538.0	630.1
Manufacturing	171.1	123.6	44.9	133.5	134.0	291.7
Transport	192.4	54.5	10.5	3.2	90.1	138.2
Trade	59.9	139.8	62.2	141.7	189.4	116.6
Energy	123.4	256.0	17.1	185.7	129.6	108.5
Information and communication	-12.7	89.9	74.1	-4.4	140.9	85.7
Real estate activities	21.3	-64.7	53.4	45.2	366.5	59.7
Arts, entertainment, and recreation	30.8	140.1	21.4	231.7	165.9	57.8
Hotels and restaurants	106.0	119.7	-246.6	-13.6	66.7	34.6
Education	13.3	4.1	10.2	15.3	12.4	18.2
Administrative activities	47.0	21.6	0.8	11.5	5.6	14.6
Human health activities	15.9	16.7	7.7	26.3	3.1	14.2
Professional, scientific, and technical activities	52.2	27.1	19.8	25.0	15.9	8.0
Mining and quarrying	59.5	51.7	98.9	-21.3	6.6	5.1
Construction	187.3	53.6	31.8	-11.4	34.4	3.1
Water supply; Waste management	5.9	8.3	-26.3	0.4	197.2	-0.9
Agriculture	-2.4	7.3	-1.6	1.9	4.7	-3.3
Other service activities	6.1	19.4	7.5	9.9	-3.2	12.7

Source: National Statistical Service of Georgia (2018-2023)

In 2023, the three main economic sectors accounted for 66.5% of foreign direct investment (FDI). The largest share of FDI was recorded in the financial and insurance activities sector, totaling $630.1 million (39.5%). This was followed by the manufacturing industry with $291.7 million (18.3%), and the transport sector with $138.2 million (8.7%).

To stimulate Georgia's development and enhance the multiplier effect of foreign direct investments on the country's economy, sustainable investment decisions must consider economic, social, and ecological factors. As noted, "The role of foreign direct investment is significant in developing national economies, making it

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even more valuable and contributing to the revitalization of the sector. Investments resulting from this are key levers for improving the country's economic situation. (Tsinaridze et al., 2023). Georgia's investment legislation, aiming to open the economy to increased international business activity and foreign investment, facilitates the entry of foreign investors by maintaining favorable regulatory conditions (Abuseridze, 2021).

According to the Stanford Artificial Intelligence 2023 report, global AI investments will reach $91.9 billion in 2022, but this is only the tip of the iceberg. According to Goldman Sachs, global AI investment will reach $110.2 billion in 2023 and grow to $158.4 billion in 2025.

Thus, the interconnected nature of renewable energy and smart technologies is a transformative force in the global energy landscape. As these technologies continue to advance and converge, they offer unprecedented opportunities to create a more sustainable, resilient, and intelligent 'smart future'.

Now, in the global renewable energy rankings, the countries with the most renewable energy are Iceland, Norway, Sweden, Brazil, New Zealand, Denmark, Austria, Switzerland, Finland, and Colombia. Iceland has the most renewable energy and reports that 86.87% comes from renewable sources. Norway is the second largest renewable energy country, with 71.56% of its energy coming from renewable sources. Sweden is the third country with the most renewable energy generating 50.92% of sustainable energy. Brazil generates 46.22% of its energy from renewable sources. New Zealand is in fifth position with the most renewable energy, with 40.22% of its energy coming from renewable sources. Denmark is the sixth country with the most renewable energy, with 39.25% clean energy. Austria generates 37.48% of its energy from renewable sources. Switzerland is in eighth position with 36.72% of its renewable energy. Finland generates 34.61% of energy from renewable sources. Colombia is in the next position, with 33.02% of its energy coming from renewable sources, mainly hydropower (see Table 3).

Table 3. Renewable Energy by Country

№	Country	Renewable Energy Generation
1	Iceland	86.7%
2	Norway	71.56%
3	Sweden	50.92%
4	Brazil	46.22%
5	New Zeland	40.22%
6	Denmark	39.25%
7	Austria	37.48%
8	Switzerland	36.72%
9	Finland	34.61%
10	Colombia	33.02%
11	Portugal	32.7%
12	Ecuador	32.35%

Source: Wisevoter, 2024

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As for Georgia's global renewable energy ranking, unfortunately, it does not provide specific information, indicating that the country's utilization of renewable energy technologies is relatively low. This highlights the need for significant progress to achieve sustainable economic development. With the global average production of renewable energy at 17%, it is evident that many countries are not fully exploiting their renewable energy potential. Therefore, governments of developed nations and the private sector must collaborate to bridge this gap and encourage greater contributions from developing countries.

The relationship between renewable energy and smart technology is dynamic and synergistic, offering tremendous potential to create a more sustainable and efficient energy landscape. Here are some key aspects of this connection:

1. **Smart Grids: Enhanced Grid Management:** Smart grids utilize advanced communication and control technologies to optimize energy generation, distribution, and consumption. By integrating renewable energy sources into smart grids, real-time monitoring and management are possible, enhancing grid reliability and efficiency.
2. **Energy Storage Solutions: Balancing Fluctuations:** Renewable energy sources, such as solar and wind, can be intermittent. Smart energy storage solutions, including advanced batteries, efficiently store excess energy generated during peak periods. This stored energy can be used during low generation, ensuring a consistent and reliable power supply.
3. **Demand Response Systems: Adaptive Consumption**
4. Smart technology enables demand response systems that allow consumers to adjust their energy consumption in real time based on pricing and availability. This not only helps balance supply and demand but also encourages the use of renewable energy during peak times.
5. **IoT in Energy Management: Data-Driven Decision Making**
6. The Internet of Things (IoT) is crucial in integrating renewable energy by providing a network of interconnected devices that can collect and share data. In energy management, IoT enables smart meters, sensors, and devices to enhance energy consumption, identify inefficiencies, and promote energy savings.
7. **Distributed Energy Resources (DERs): Decentralized Power Generation**
8. Smart technology supports the integration of distributed energy resources, allowing small-scale renewable energy systems, such as rooftop solar panels, to contribute to the overall energy supply. This decentralization reduces transmission losses and enhances energy sustainability.
9. **Grid Stability and Security: Cyber-Physical Integration**
10. The combination of renewable energy and smart technologies strengthens the resilience and security of energy networks. Incorporating cyber-physical systems allows grids to detect and respond to disruptions, ensuring reliable power delivery even amid challenges.
11. **Energy Efficiency and Home Automation: Smart Home Systems**

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12. Smart technology extends to individual households through energy-efficient appliances, smart thermostats, and home automation systems that reduce energy consumption. These technologies align with the sustainability and conservation goals of adopting renewable energy.
13. **Innovation and Research Collaboration: Technological Advances**
14. The synergy between renewable energy and smart technologies fosters ongoing innovation. Collaborative research initiatives focus on developing new technologies and strategies to optimize the integration of renewable sources within smart grids, ensuring continuous improvement and evolution.

An important factor is the citation of existing data on the integration and development trends of artificial intelligence (AI), which underscores the significant role that smart technologies play in enhancing the potential for renewable energy adoption.

Correlational analysis of Renewable Energy Generation, Foreign Direct Investment, and Technological Progress

The impact of foreign direct investment (FDI) in renewable energy production, considering technological progress, is significant not only for economic indicators but also for environmental protection. This impact is particularly notable concerning the technological progress rating of installed renewable energy systems, such as solar generation. Therefore, it is logical to illustrate their interdependence and their level of influence on each other through correlation analysis.

For conducting research based on statistical indicators, determining the correlation between two or more variables is a robust method. Additionally, calculating and displaying the standard deviation can provide a clearer understanding of how closely FDI is related to developing renewable energy sources and alternative energy technologies.

In Georgia, from 2019 to 2023, there has been a significant increase in renewable energy technologies, specifically the number of solar panels. Concurrently, the amount of electricity produced by these solar panels has risen substantially. As of the latest data, solar panel production stands at 67,552 thousand kilowatts (Energy and Water Supply Regulatory National Commission of Georgia 2021 activity reports, 2023).

To determine the correlation, we utilized international ratings of technological progress for Georgia. In 2019, Georgia was ranked 48th (Georgia in the innovation index rank, 2021), whereas, based on the 2023 data, Georgia is ranked 65th (Georgia in the innovation index rank, 2023). This shift reflects the evolving landscape of technological progress and its implications for renewable energy development.

The COVID-19 pandemic and its challenges have called investments, international trade and related relationships into question (Abuseridze, 2021). Another crucial variable is the total foreign direct investments (FDI) made in Georgia. According to official data from the National Statistical Service of Georgia, FDI decreased to $595.3 million in 2020 due to the challenges posed by the global COVID-19 pandemic. However, in the subsequent years, FDI rebounded to pre-pandemic levels and has shown progressive growth (National Statistical Service of Georgia, Foreign Direct Investments, 2019-2023). For detailed data, please refer to the table below.

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Table 4. Georgia in global rankings, FDI, and renewable energy statistical data

years	Number of Stations Installed	Renewable Energy Solar Generation		Technological Progress Rating of Georgia	Direct Foreign Investments Made in Georgia (Million USD)
2019	155	3.52		48	1354.1
2020	246	4.093		63	595.3
2021	369	17.745		63	1252.7
2022	723	36.375		74	2097.9
2023	1143	67.552		65	1549.7

Source: The table was compiled by the authors based on statistical data

IBM SPSS Statistics software was used for correlation analysis, and the results shown in Table 5 were obtained based on the entered data. Based on the official data mentioned, we calculated the Pearson correlation between the relevant variables, as detailed in Table 5.

Table 5. Correlation analysis between RESs and other data

	Number of Stations Installed	Renewable Energy Solar Generation	Technological Progress Rating of Georgia	Direct Foreign Investments Made in Georgia (Million USD)
Number of Stations Installed	1.000	0.995**	0.591	0.562
Renewable Energy Solar Generation	0.995	1.000	0.532	0.572
Technological Progress Rating of Georgia	0.591	0.532	1.000	0.425
Direct Forei	0.562	0.572	0.425	1.000
**. Correlation is significant				

Source: The table is compiled based on our calculations

The final results of the study were formulated as follows:

1. Number of Installed Stations - Solar Energy Generation

Pearson Correlation: 0.995

There is an extremely high positive correlation (0.995) between the number of installed stations and solar energy generation. This indicates that as the number of renewable energy plants increases, so does the total solar power generation capacity. This relationship suggests that expanding renewable energy infrastructure directly enhances production capacity, reflecting the scalability of renewable energy projects.

2. Number of Installed Stations - Technological Progress Rating

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Pearson Correlation: 0.591

The correlation between the number of installed stations and the technological progress rating of Georgia is moderately positive (0.591). This indicates that technological advancements will likely support increased renewable energy plants. Improvements in technology can lead to the establishment of more renewable energy plants, contributing to cleaner and more sustainable energy generation.

3. Number of Installed Stations - Direct Foreign Investment

Pearson Correlation: 0.562

There is a moderate positive correlation (0.562) between the number of installed stations and direct foreign investment in Georgia. This suggests that foreign investment plays a significant role in developing and expanding renewable energy infrastructure. Foreign capital can provide the necessary resources and expertise to establish and operate new renewable energy plants, thus driving growth.

4. Renewable Solar Generation - Technological Progress Rating

Pearson Correlation: 0.532

There is a moderately positive correlation (0.532) between renewable solar generation and technological progress. This indicates that technological advancements contribute to more efficient and higher solar power generation. Advances in technology can improve solar panel production, enhance energy conversion efficiency, and improve the overall performance of solar power plants.

5. Renewable Energy Generation - Foreign Direct Investment (FDI)

Pearson Correlation: 0.572

There is a moderate positive correlation (0.572) between renewable solar generation and FDI. This relationship underscores the role of foreign capital in boosting solar power generation capacity. Foreign investments are crucial for installing new stations and upgrading existing infrastructure to increase energy production.

6. Technological Progress Rating - Foreign Direct Investment (FDI)

Pearson Correlation: 0.425

The correlation between technological progress rating and FDI is lower (0.425) than other variables but still indicates a positive relationship. This suggests that regions with higher technological progress tend to attract more foreign investment. This relationship highlights how technological advances can create a favorable investment climate, attracting additional foreign capital to the renewable energy sector.

DISCUSSION

The results of the study of the article are reflected in the following recommendations:

Policy support: Governments should introduce and implement policies that facilitate the adoption of renewable energy. These include subsidies, tax breaks, and regulations encouraging the development and integration of clean energy technologies.

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Investment in Research and Development: Increased investment in research and development is critical to advancing renewable energy technologies. Governments, private sector entities, and philanthropic organizations must allocate resources to support innovative solutions that improve efficiency and reduce costs.

Education and awareness: Public awareness and education campaigns are essential to promote awareness of the benefits of renewable energy. This can foster community support and encourage individuals to make sustainable energy choices.

Infrastructure Development: Governments and the private sector must invest in developing strong infrastructure to support the integration of renewable energy. This includes the creation of smart grids, energy storage, and electric vehicle charging infrastructure.

International cooperation: Cooperation on a global scale is essential to address the challenges of renewable energy adoption. International agreements and partnerships will facilitate the sharing of best practices, technology transfer, and financial support for developing countries to implement sustainable energy solutions. Finally, combining renewable energy and technology offers a promising path toward a sustainable and smart future. Through strategic investments, policy support, and international cooperation, individuals, organizations, and institutions can harness the power of clean energy to meet the challenges of the 21st century.

CONCLUSION

The analysis reveals a significant interdependence between the development of renewable energy infrastructure in Georgia, technological progress, and foreign investment. Enhancing technological capabilities and attracting foreign investment are critical strategies for increasing renewable energy production. By utilizing this data, policymakers and stakeholders can formulate effective strategies to promote sustainable energy development and economic growth in Georgia.

As Georgia's technological progress rating improves, there is a strong tendency for an increase in installed stations. This indicates that technological advancement in Georgia is positively related to the expansion of station installations, potentially reflecting developments in infrastructure or technological applications.

These correlations provide insights into how these variables may influence each other and could be useful for strategic planning and policy development in Georgia's renewable energy and economic development sectors.

Based on the information, Georgia has significant energy potential and can lead future initiatives to expand renewable energy infrastructure and improve technological innovation, thereby contributing to sustainable economic development.

Integration of Renewable Energy: Integrating renewable energy sources is crucial for creating a sustainable and intelligent future. As technology advances, energy demand is expected to increase, and reliance on conventional, non-renewable sources will exacerbate environmental challenges.

Synergy Between Renewable Energy and Technology: The current technological era presents a unique opportunity to synergize renewable energy with innovative solutions. Smart grids, advanced energy storage,

and IoT-enabled systems can enhance the efficiency and reliability of renewable energy sources, making them more viable alternatives.

Economic Viability of Renewable Technologies: Continuous technological advances have significantly reduced the cost of renewable energy infrastructure. Governments, businesses, and individuals must recognize the financial benefits of investing in renewable technologies, both in the short and long term.

Protecting the Environment: The environmental benefits of renewable energy are substantial. By transitioning to clean energy sources, we can mitigate the effects of climate change, reduce air and water pollution, and preserve ecosystems for future generations.

Global Cooperation is Key: Achieving sustainable solutions requires international cooperation. Countries, industries, and research institutions should work together to share knowledge, experience, and resources for the development and implementation of renewable energy technologies.

Author Contributions:

Conceptualization, G.R.; methodology, R.T.; formal analysis, R.T.; investigation, G.R.; project administration, R.T.; data curation, R.T.; resources, G.R.; supervision, R.T.; validation, G.R.; writing- original draft preparation, G.R.; writing—review and editing, R.T.

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Conflict of interests

The authors declare no conflict of interest.

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