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The Effect of Turkmenistan Energy Management, Innovation on Carbon Neutrality

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Abstract: By offering empirical research on the connection between Turkmenistan's energy management practices and carbon neutrality, we add to the body of knowledge on the country's energy management practices. In the topic of Turkmenistan Energy Management, we used data collected from 221 respondents. Our study demonstrates that the presence of state-of-the-art technology within the energy sector plays a beneficial role in advancing Turkmenistan's journey towards achieving carbon neutrality. Turkmenistan may advance more quickly by putting in place efficient energy management plans and encouraging innovation. In addition to fostering research collaboration, financing, and sustainable energy initiatives, our recommendation include improving energy efficiency, switching to clean energy sources, lowering dependency on fossil fuels, and all of the aforementioned.

Keywords*:* energy management practices, carbon neutrality, innovation, Turkmenistan, carbon emissions,

I. Introduction

Turkmenistan, a nation in Central Asia, has been growing its energy industry quickly recently. Natural gas resources are abundant in the nation, which has been growing oil and gas production to strengthen its economy [1]. However, worries regarding the nation's carbon footprint and environmental effect have been raised due to its significant reliance on fossil fuels. Turkmenistan has worked towards energy management, innovation, and carbon neutrality in response to these worries [2]. To encourage the use of renewable energy, energy efficiency, and sustainable development, the government has launched a number of projects and laws. For instance, the nation has set a goal to reach a 10% renewable energy share in its energy mix by 2020 [4].

Turkmenistan has been funding energy innovation in addition to encouraging renewable energy. To enhance sustainable energy technologies, like as solar and wind power, the nation has built research and development centres[3]. These initiatives are anticipated to minimise the nation's carbon footprint and open up new prospects for the energy sector's economic expansion and employment development. It is impossible to overestimate the value of energy management, innovation, and carbon neutrality for Turkmenistan's economy. The country's energy industry contributes significantly to its economic growth and makes up a sizeable share of its GDP [5] .

Large confirmed fossil fuel reserves are present in Turkmenistan. With resources that make up around 5.51% of the world's total, it is among the top countries in terms of natural gas reserves. Additionally, according to the International Energy Statistic of 2002, its contribution of world crude oil reserves is at 0.035%. According to recent statistics from 2022, gas dominates conventional proven reserves in terms of tonnes of oil equivalent with 90.2%, followed by oil with 0.8% [6].

Table 1: The fossil fuel reserves in Turkmenistan.

Resource /Explanations	Crude oil*	Natural gas*	Coal	Tight Oil	Shale Gas
Value	0.6 (0.035%)	400 (5.51%)	-	-	-
Unit	billion barrels	Tcf	-	-	-
Year	2021	2020	-	-	-

Source: [7]

Turkmenistan has a significant potential for renewable energy sources due to its favourable meteorological and geographic characteristics, but the country has yet to develop a market for these sources, and the industry is just now beginning to take shape. With wind speeds exceeding 7.5 m/s at a 50 m height.The most favorable conditions for wind energy development are found in the western regions along the Caspian Sea and the Garabogaz Bay within the Balkan region.[6].

Turkmenistan also has an average solar Global Horizontal Irradiance (GHI) of 4.6 to 5.1 and more than 300 bright days per year. The possibility to use solar energy in the nation is enormous given the amount of sunlight [6].

Table 2: Turkmenistan's renewable energy potentials

Resource/ explanations	Solar Potential (DNI)*	Wind Potential (50 м)*	Bio Potential (agricultural area)	Bio Potential (forest area)	Municipal Solid Waste
Value	4.6 -5.1	6.0-7.5	72.0	8.8	0.27
Unit	kWh/m²/day	m/s	% of land area	% of land area	kg/per capita/day
Year	2020	2020	2020	2020	2018

Source: [7]

The difficulties associated with the global energy transition, such as lowering greenhouse gas emissions and promoting novel carbon-neutral technology, necessitate focus. Given its advantageous position and abundant energy resources, Turkmenistan's investigation into energy management, innovation, and carbon neutrality research is an attractive field of study and application. Turkmenistan is transitioning towards renewable energy sources, underscoring the importance of conducting a comprehensive assessment of its economic implications and potential benefits. This might entail increased energy security, a decrease in reliance on fossil fuel exports, and the development of jobs in the renewable energy sector. However, there may also be economic and societal costs to take into account, as with any significant infrastructure construction and change. The International Renewable Energy Agency has stated that thorough planning and a whole-systems approach are necessary for a successful energy transition [8]. These stakeholders should include the government, business, academic institutions, and local communities.

Despite the fact that Turkmenistan's energy industry has grown significantly over the past ten years, worries about carbon emissions and sustainability have taken on more significance. The nation must overcome formidable obstacles to manage its energy sector, foster innovation, and diversify its economy. Turkmenistan's high reliance on fossil fuels also poses a huge barrier to the country's environmental aspirations as the globe advances towards carbon neutrality. Despite tremendous progress in Turkmenistan's energy industry during the previous ten years, issues with sustainability and carbon emissions have taken on a greater significance. In order to manage its energy sector, foster innovation, and diversify its economy, the nation must overcome formidable obstacles. Additionally, Turkmenistan's high reliance on fossil fuels significantly challenges its sustainability ambitions as the globe works towards carbon neutrality.

The first of our three main study goals are to examine the current energy management practisesin Turkmenistan and gauge how they affect carbon emissions. The second goal is to investigate the value of innovation for Turkmenistan's energy industry and how it may help the country become carbon neutral. Finally, we want to evaluate how Turkmenistan's progress towards carbon neutrality will be impacted by the application of innovative energy management systems. This essay is divided into five sections. The introduction is covered in section 1, the literature review is covered in section 2, and the methodology is covered in section 3. The study's findings are presented in Section 4, while the discussion of the study's conclusions and suggestions is included in Section 5.

II. Theoretical Background and Research Hypothesis

2.1 The Current State of Energy Management In Turkmenistan

Natural gas, oil, and renewable energy sources like sun and wind are all abundant in Turkmenistan, a nation in Central Asia. The Turkmenistan economy depends heavily on the energy industry, which also contributes significantly to the GDP and export revenue of the nation. Turkmenistan is the fourth-largest natural gas producer in the world, and the energy industry contributes almost 40% of the nation's GDP, according to the International Energy Agency (IEA) [9].Turkmenistan's government oversees the energy industry through state-owned companies including Turkmennebit, Turkmengeologiya, and Turkmenneft. The management of oil and gas resources includes exploration, production, and transportation.

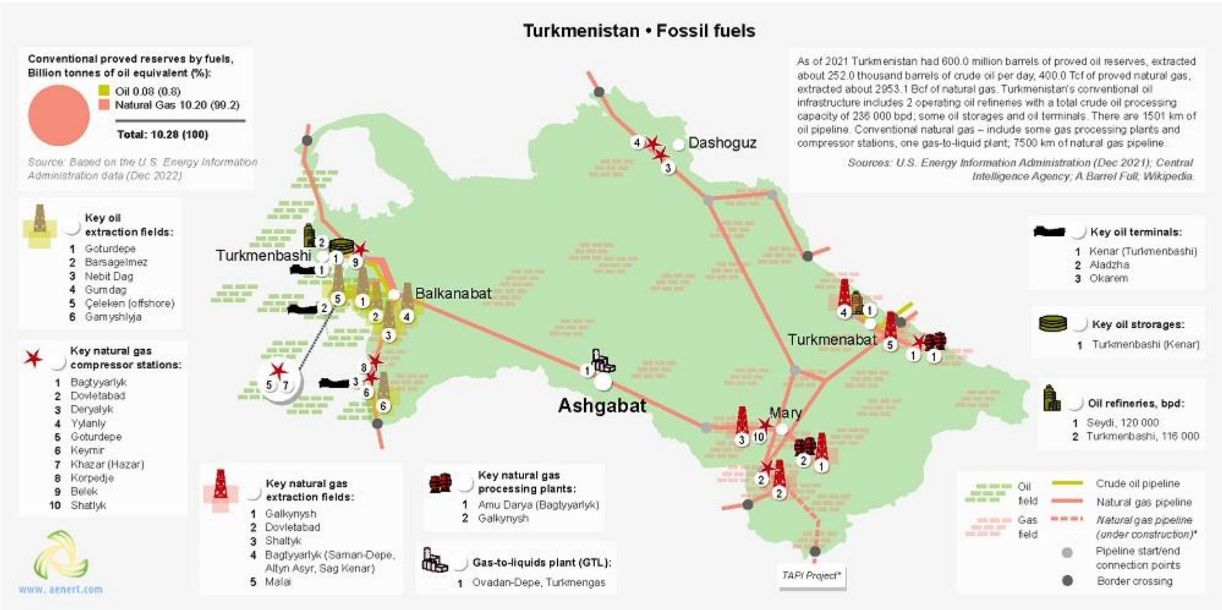

Figure 1: The foundational infrastructure supporting Turkmenistan's fossil fuel sector.

Based on information from the International Energy Statistics for 2022, Turkmenistan produced 3.696 billion British thermal units (Btu) of primary energy in 2021, while using 1.895 billion Btu of energy [7]. As a result, domestic consumption accounted for 51.27% of the output of primary energy. Regardless of the form of its energy consumption, Turkmenistan is a nation independent of energy imports thanks to its self-sufficiency in energy consumption. Turkmenistan's primary energy consumption in 2021 was 1.60 exajoules, with natural gas predominating at 82.5% and oil coming in second at 17.5%, according to BP's Statistical Review of World Energy 2022 [10].

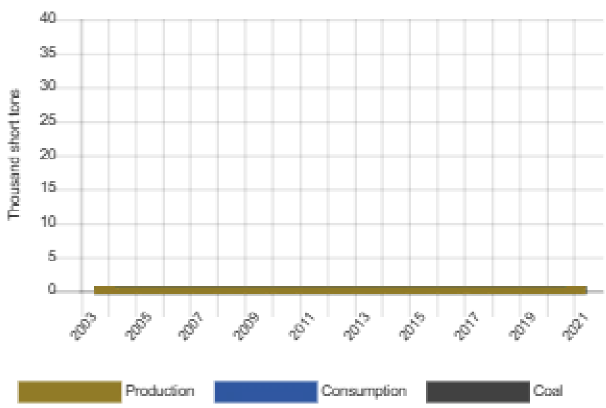

Figure 2: The Production and Consumption of Coal

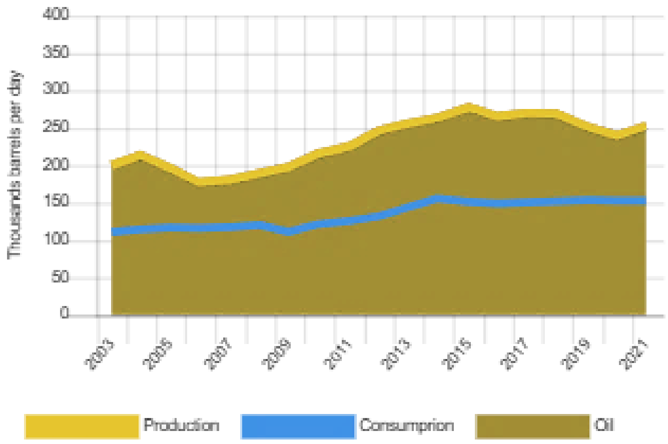

Figure 3: The Production and Consumption of Oli

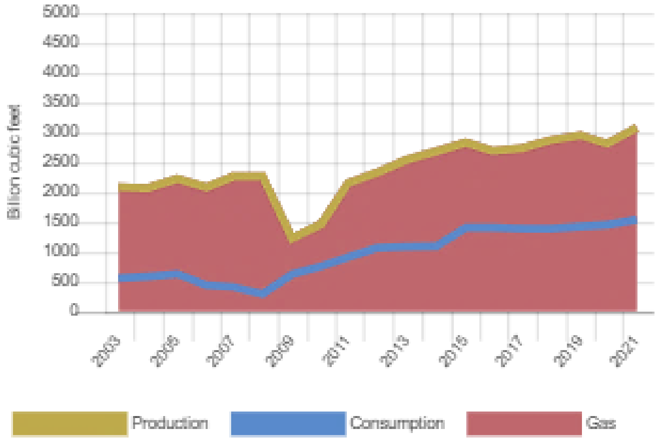

Figure 4: The Production and Consumption of Gas

The aforementioned graphs show that Turkmenistan's natural gas output has increased steadily over the previous ten years, virtually tripling the country's domestic use. Additionally, the nation produces around one-third more oil than it consumes.

The overall amount of power produced in Turkmenistan has significantly increased by more than 35% during the past 10 years. In 2021, the vast majority of energy production relied on fossil fuel-based power stations, with the predominant use of natural gas as their primary fuel source.Even if there are a few little solar power plants, their contribution to the total electricity output is still quite minor. There isn't much hydroelectric power production in Turkmenistan.

Turkmenistan is able to export excess power since local demand exceeds production. However, it is critical to recognise that the deteriorated state of the electricity infrastructure contributes to significant power losses that total more than 2.892 billion kWh yearly (per the Central Intelligence Agency) [7].

2.2 Challenges Facing The Turkmenistan Energy Sector

Inadequate regulatory frameworks, out-of-date technology, and a lack of infrastructure investment are just a few of the difficulties Turkmenistan's energy sector is now facing [11]. The nation's energy infrastructure has to be upgraded and made more efficient because it is outdated [12]. A lack of transparency and accountability in the energy industry is also a result of the regulatory framework's incomplete development [11].

Turkmenistan's energy industry faces serious challenges due to the nation's inability to properly use its abundant energy resources due to a lack of infrastructure investment [11]. Turkmenistan has the fourth-largest natural gas reserves in the world, but it has had trouble luring foreign investment in its energy industry, making it difficult to fund the construction of infrastructure [7]. This has led to an underutilization of energy resources, which is preventing economic development and growth [12].

As a result, Turkmenistan's energy industry exhibits antiquated technology, which further hinders the nation's capacity to properly develop and harness its energy resources [11]. Energy infrastructure around the nation that were constructed during the Soviet era now require modernisation[7]. Turkmenistan's energy exports are less competitive on the world market due to inefficiencies and increased costs caused by the use of outmoded technologies [11].

The energy sector in Turkmenistan confronts significant challenges that necessitate substantial investments and policy reforms for resolution.Turkmenistan will continue to have trouble effectively using its energy resources and reaping the potential advantages for its economy and society if these issues are not addressed.

2.3 The Existing Innovations In The Turkmenistan Energy Sector

Enhancing energy efficiency, lowering costs, and fostering sustainable growth in the energy industry all depend on innovations. The energy industry has seen the introduction of a number of cutting-edge technologies and procedures in Turkmenistan, including the utilisation of renewable energy sources, the modernisation of existing infrastructure, and energy-efficient appliances.

The usage of solar energy is one of the cutting-edge technologies that has been developed in the energy industry. Turkmenistan is a bright nation with abundant solar radiation, making it ideal for producing solar electricity. The development of the nation's first solar power plant is only one of the solar projects in which the Turkmen government has recently made investments. The capital city of Ashgabat is home to the 10 MW solar power plant, which was constructed in 2019 [13]. The facility has assisted in reducing the nation's reliance on natural gas and has helped to diversify the nation's energy supply.

Turkmenistan has also used cutting-edge technologies in the modernisation of its energy infrastructure. The Turkmen government has carried out a number of modernisation initiatives to boost the effectiveness of the energy industry. For instance, the government's attempts to update the energy infrastructure may be seen in the Turkmenistan-Afghanistan-Pakistan-India (TAPI) gas pipeline project. The project will need the building of a contemporary gas pipeline and will carry natural gas from Turkmenistan to the four nations indicated above [14].

Despite the advances already in place, Turkmenistan's energy industry nevertheless faces a number of obstacles. The absence of infrastructure investment is one of the major problems. The Turkmen government's meagre financial resources for energy-related investments have led to obsolete technologies and insufficient infrastructure. Furthermore, the country's regulatory system is unsound, which results in a lack of incentives for private sector investment in the energy industry. The usage of renewable energy sources and the modernisation of existing infrastructure are only two examples of the cutting-edge technologies and procedures the Turkmenistan energy industry has encountered. To improve the efficiency and sustainability of the business, problems including insufficient infrastructure investment, out-of-date technology, and lax regulatory frameworks must be addressed.

2.4 Implications Turkmenistan's Shift Towards Renewable Energy Sources

Due to its ability to lower greenhouse gas emissions and solve concerns about energy security, renewable energy sources have grown in significance in the world's energy balance. Being an energy-rich nation, Turkmenistan has been thinking about switching to renewable energy sources.

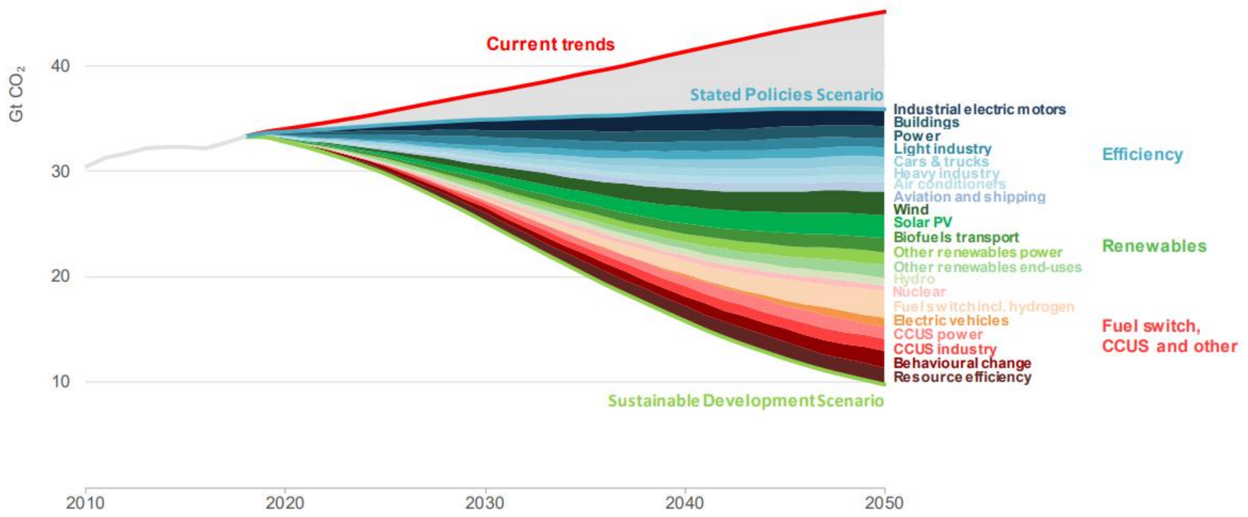

Figure 5: CO2 emissions linked to energy and reductions in CO2 emissions through various measures in the SDS.

Turkmenistan has been actively working towards adopting renewable energy sources as part of its sustainable development strategy. This empirical literature review explores the initiatives, projects, and policies in Turkmenistan's journey towards renewable energy adoption and their implications. The United Nations Development Programme (UNDP) has played a pivotal role in advancing renewable energy and energy efficiency in Turkmenistan (UNDP, 2022) [15]. Through collaborative efforts with the Ministry of Agriculture and Environmental Protection of Turkmenistan, UNDP initiated the project titled "Sustainable Cities in Turkmenistan: Integrated Green Urban Development in Ashgabat and Avaza" (UNDP, 2022) [15]. This project has been instrumental in conducting training seminars to introduce international best practices, regulatory frameworks, and technical documents for renewable energy promotion (UNDP, 2022) [15].

The primary objectives of the Sustainable Cities project are to inform stakeholders about the emerging renewable energy sector, study global experiences in renewable energy regulatory development, and promote innovative energy-efficient technologies in the electric power industry (UNDP, 2022) [15]. Funded by the Global Environmental Fund (GEF) and UNDP, this project aligns with Turkmenistan's commitment to sustainable urban development and reducing the adverse impacts of rapid urbanization (UNDP, 2022) [15].

The collaborative efforts between UNDP and Turkmenistan in developing renewable energy sources and adopting energy-efficient technologies contribute significantly to reducing greenhouse gas emissions (UNDP, 2022) [15]. This aligns with Turkmenistan's international obligations under the Paris Climate Agreement (UNDP, 2022) [15].

Turkmenistan has further solidified its commitment to renewable energy through the approval of the "National Strategy for the Development of Renewable Energy of Turkmenistan for the Period until 2030" by the President's Decree (UN Turkmenistan, 2021) [16]. Additionally, the Mejlis of Turkmenistan passed the "Law of Turkmenistan on Renewable Energy Sources" (UN Turkmenistan, 2021) [16]. These strategic documents provide a roadmap for Turkmenistan's systematic shift towards renewable energy sources.

Turkmenistan is reaping numerous advantages from its transition to renewable energy. The country’s concerted efforts to develop renewable energy sources and introduce cutting-edge energy-efficient technologies in the power sector are paving the way for a reduction in greenhouse gas emissions. This, in turn, is bolstering Turkmenistan’s commitment to meeting its international obligations under the Paris Climate Agreement.[17], [18].

Indeed, the adoption of renewable energy sources provides a viable solution to the issue of import dependency. This allows nations to diversify their economies and safeguard them from the volatile price fluctuations associated with fossil fuels. Furthermore, it fosters inclusive economic growth, job creation, and poverty reduction.[19]. Model projections indicate that, between 2020 and 2030, economic benefits amounting to as much as $6.4 billion (in discounted terms) could be achieved. This is possible through more efficient utilization of the region's hydro potential and thermal generation, shared planning reserve margin, reduction in unmet electricity demand, and fuel cost savings resulting from the transition from gas to hydropower generation.[20].

The process of developing regulatory documents is ongoing, with the UNDP project lending its support to the creation of 10 additional legal acts that will further bolster the use of renewable energy sources in the country. The UNDP's Sustainable Cities project is implementing and planning practical steps in several areas to promote renewable energy use in Turkmenistan and introduce innovative energy-efficient technologies in the power sector.

Ongoing efforts are dedicated to the development of regulatory documents, with the backing of the UNDP project, aiming to create ten additional legal acts that facilitate the utilization of renewable energy sources within Turkmenistan [21]. Furthermore, practical initiatives, both currently underway and planned within the UNDP's Sustainable Cities project, are focused on advancing the adoption of renewable energy and the introduction of innovative, energy-efficient technologies in various sectors [21].

2.5 Theoretical Review

There are several relevant theories that could help in understanding Turkmenistan's energy management, innovation, economy, and carbon neutrality research.

2.5.1 The Sustainable Development Theory

The Brundtland Commission report from 1987 is when the sustainable development idea was originally presented. According to this theory, development plans must balance economic, social, and environmental factors. According to the hypothesis, if handled effectively, economic growth and environmental conservation may reinforce one another. According to the United Nations (1987), development should accommodate current requirements without jeopardising the capacity of future generations to do the same[22].

A key idea in the fields of energy management, innovation, economy, and carbon neutrality research, sustainable development theory offers a framework for comprehending how economic growth may be attained while safeguarding the environment for future generations. In the Brundtland Report from the World Commission on Environment and Development (WCED) in the 1980s, the term "sustainable development" was first used. According to the WCED, sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs"[22].

The sustainable development idea places a strong emphasis on the necessity of striking a balance between social responsibility, environmental conservation, and economic prosperity. The study of energy management in Turkmenistan is particularly pertinent to this idea since the nation aims to grow its energy industry while lowering its carbon impact and advancing social and economic well-being. Sustainable development theory underscores the importance of intergenerational equity, emphasizing the fair distribution of both the costs and benefits of economic progress among different generations.

The sustainable development theory may be used by academics and decision-makers to pinpoint locations where economic development and environmental preservation can coexist, as well as to create strategies and policies that support sustainable development. Investing in renewable energy sources, increasing energy efficiency, supporting sustainable agriculture, and tackling social and economic inequality are a few examples of how this might be done in Turkmenistan. Turkmenistan can accomplish economic growth and social advancement while safeguarding the environment for coming generations by using a sustainable development approach to energy management.

The sustainable development theory is extremely pertinent to studies on energy management, innovation, the economy, and carbon neutrality in Turkmenistan. The nation's energy industry makes a major contribution to the economy but also has an impact on the environment. Turkmenistan must take into account the economic, social, and environmental ramifications of its policies and practises as it works to diversify its energy mix and switch to cleaner sources.

The sustainable development theory is criticised for emphasising economic growth too much and failing to sufficiently address the underlying causes of social inequality and environmental deterioration [23]. They contend that the theory is too nebulous and provides insufficient specific instructions for achieving sustainable development [23]. Other detractors contend that the sustainable development paradigm overemphasises economic expansion while failing to effectively address concerns of social justice and fairness.

The sustainable development theory continues to be a crucial paradigm for comprehending the intricate relationships between economic development, social progress, and environmental preservation notwithstanding these challenges. With Turkmenistan navigating the difficulties of sustainable energy development, its emphasis on balancing conflicting interests is particularly pertinent.

2.5.2 The triple bottom-line theory

In order to gauge a company's sustainability, John Elkington initially proposed the triple bottom line idea in 1994. According to the principle, a company should also consider its social and environmental impacts in addition to its financial success. In other words, a company must take responsibility for its effects on customers, the environment, and its bottom line [24].

The triple bottom line theory emphasises the value of striking a balance between economic growth and social and environmental responsibility, making it extremely important to the study of Turkmenistan's energy management, innovation, economics, and carbon neutrality research. This is crucial in the context of Turkmenistan, where the energy industry plays a vital role in economic development while also having substantial social and environmental effects.

The triple bottom line approach is criticised for putting too much emphasis on assessing effect and not enough on enhancing sustainability. Some contend that the idea is oversimplified and that organisations should instead concentrate on more comprehensive approaches to sustainability since it simplifies sustainability to a checklist of three elements [25].

The triple bottom line idea continues to be a useful paradigm for organisations and governments wanting to integrate sustainability into their operations despite its critiques. The triple bottom line theory can offer a helpful framework for evaluating the social, environmental, and economic ramifications of Turkmenistan's attempts to switch to renewable energy sources and become carbon neutral.

2.6 Research Hypotheses

Based on the objectives of the study, the following research hypothesis stated in the null form will be tested:

H1: Improved energy management practices in Turkmenistan will result in a reduction of carbon emissions.

H2: The presence of innovative technologies and solutions in the energy sector of Turkmenistan will positively impact the country's journey toward carbon neutrality.

H3: Implementation of effective energy management strategies combined with innovation will accelerate

Turkmenistan's progress in achieving carbon neutrality.

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H1: Improved Energy Management Practices
     |
     |----> Reduction of Carbon Emissions ----> Progress Towards Carbon
Neutrality
     |          ^
     |          |
H2: Presence of Innovative Technologies and Solutions
     |
     |----> Positive Impact on Journey Towards Carbon Neutrality
             ^
             |
H3: Implementation of Effective Energy Management Strategies Combined with
Innovation
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Figure 6: Theoretical model

In this framework:

Hypothesis 1 (H1) suggests that improved energy management practices in Turkmenistan will lead to a reduction in carbon emissions, which in turn contributes to the country's progress towards carbon neutrality.

Hypothesis 2 (H2) posits that the presence of innovative technologies and solutions in Turkmenistan's energy sector will have a positive impact on the country's journey towards carbon neutrality.

Hypothesis 3 (H3) proposes that the implementation of effective energy management strategies combined with innovation will accelerate Turkmenistan's progress in achieving carbon neutrality. This hypothesis essentially combines H1 and H2, indicating that both improved energy management practices and innovative technologies and solutions are necessary for accelerating progress towards carbon neutrality.

2.6 Summary and Gap in Literature Review

Although research has been conducted on the energy sector of Turkmenistan, a gap exists in synthesizing the current state of energy management, analyzing existing innovations, and examining their impact on the economy. There is insufficient research available that comprehensively analyzes the current state of the Turkmenistan energy sector as it relates to energy management, innovative practices, and economic development. Therefore, this study aims to reduce this gap in the literature by synthesizing existing research on these three areas and conducting an analysis of their interrelationships.

In conclusion, the existing empirical literature on Turkmenistan's energy management, innovation, economy, and carbon neutrality is limited. The studies available suggest that Turkmenistan faces significant challenges in each of these areas, but also present opportunities for improvement. Future research should continue to explore these issues in more detail, using a variety of research approaches to provide a comprehensive understanding of the challenges and opportunities facing Turkmenistan's energy sector.

III. Research Design

3.1 Data Collection

A survey was conducted to gather data in Turkmenistan, utilizing questionnaire methods for data collection. The study focused on employees working in Turkmenistan's energy sectors. Probability sampling was employed, which involves selecting a non-random sample from the target population. The study's results are expected to be applicable to the entire population, meaning that the findings can be generalized without the need to collect data from every individual. A probability random sampling approach was used, resulting in a sample size of 300 respondents.To distribute the 300 questionnaires, they were sent via email to Turkmenistan. A group of knowledgeable individuals and colleagues assisted in printing and disseminating the questionnaires to employees across various businesses in Turkmenistan, with a significant portion being from companies like Buried Hill Energy and Dragon Oil PLC. Subsequently, after the questionnaires were distributed, approximately 270 employees participated and returned the completed questionnaires. The completed questionnaires were then transported from Turkmenistan to China using a courier delivery service.

3.2 Measures

3.2.1 Energy Management Policies(EMP) Scale
The scale used to assess Energy Management Policies was created through the development of self-designed questionnaires, informed by a comprehensive review of relevant literature in the field.The questionnaire has 10 items (1) The current energy management practices in Turkmenistan prioritize sustainability and energy security. (2) Turkmenistan has made significant progress in reducing carbon emissions through its energy management policies. (3) The government of Turkmenistan is committed to promoting renewable energy sources as part of its energy management policies. (4) Energy management policies in Turkmenistan are effectively balancing the country's economic development goals with its environmental and sustainability goals. (5) There is a need for greater public awareness and engagement on energy management issues in Turkmenistan. (6) Turkmenistan's energy management policies prioritize energy efficiency measures and conservation practices. (7) The government of Turkmenistan is effectively implementing its energy management policies and regulations [30]. (8) Energy management policies in Turkmenistan adequately address the country's energy security challenges. (9) Turkmenistan has adequate institutional capacity to implement and monitor its energy management policies. (10). The current energy management practices in Turkmenistan are adequately preparing the country for a transition to a low-carbon energy system. Cronbach's Alpha was 0.897 for this scale's reliability.

3.2.2 Innovation in Turkmenistan's Energy (ITE) Scale
The Innovation in Turkmenistan's Energy scale was constructed based on an extensive review of various pieces of literature. The scale was formatted using a 5-point Likert scale and comprises 10 items. These questionnaire items include: (1) Turkmenistan's innovation policies and strategies effectively promote economic growth and diversification. (2) The government of Turkmenistan provides sufficient financial support to innovators and entrepreneurs in the country. (3) Turkmenistan's innovation policies and strategies adequately address the country's economic challenges and opportunities. (4) There is a need for greater collaboration between academia, government, and industry to foster innovation in Turkmenistan. (5). The current innovation policies and strategies in Turkmenistan are adequately preparing the country for a transition to a knowledge-based economy. (6) Turkmenistan's innovation policies and strategies prioritize the development and adoption of new technologies. (7) Turkmenistan has a supportive regulatory environment that encourages innovation and entrepreneurship. (8) The current innovation policies and strategies in Turkmenistan adequately address the needs and challenges of small and medium-sized enterprises (SMEs). (9) The government of Turkmenistan provides sufficient support to the development of research and development (R&D) in the country. (10). Turkmenistan's innovation policies and strategies are effectively promoting the development of local innovation ecosystems. The coefficient α for this scale of 0.749

3.2.3 Achieving Carbon Neutrality (CN) Scale
The scale used to gauge carbon neutrality was developed internally through a review of pertinent literature. It was structured as a 5-point Likert scale with 5 items. The items on the scale encompass: (1) Achieving carbon neutrality is crucial for the long-term sustainability of Turkmenistan's energy sector. (2) Turkmenistan has made significant progress in achieving carbon neutrality and reducing its carbon emissions. (3) Turkmenistan's current efforts towards carbon neutrality are sufficient and promising for the country's sustainable and economic development. (4) Renewable energy sources, such as wind and solar, are effective ways of achieving carbon neutrality in Turkmenistan. (5) Embracing carbon-neutral initiatives will negatively affect the Turkmenistan economy and impact on the country's long-term growth. Cronbach's Alpha was 0.660 for this scale's reliability.

3.3 Analytic strategy
3.3 Structural Equation Model (SEM)
To examine the relationships between improved energy management practices (EMP), innovative technologies (IT), and the journey toward carbon neutrality (CN), a structural equation model (SEM) was employed. SEM is a technique for analyzing complex relationships among constructs and indicators using multivariate data (Hair et al., 2021). It has been applied in various fields, such as ecology, where it can help to test hypotheses, evaluate causal mechanisms, and account for measurement errors (Grace et al., 2016). SEM can also be used in medical research, where it can examine the effects of latent variables, test mediation and moderation effects, and compare models across groups (Kline, 2010).

The SEM will allow us to assess the direct and indirect effects of EMP and IT on CN, as well as the combined effect of EMP and IT on CN.
Where:
EMP: Improved energy management practices
IT: Innovative technologies
CN: Carbon neutrality

The SEM can be used to estimate the relationships between these variables, including the direct path coefficients (representing direct effects) and the indirect path coefficients (representing indirect effects). The model can also incorporate error terms for each variable to account for measurement error.

Hypotheses H1, H2, and H3 can be tested by examining the significance and magnitude of the path coefficients in the SEM.

For H1, we would expect a negative direct path coefficient between EMP and CN.
For H2, we would expect a positive direct path coefficient between IT and CN.
For H3, we would expect a positive combined effect of EMP and IT on CN.

The economic interpretation process involved three key stages. Firstly, since the data was obtained from independent sources, the likelihood of common method variation was deemed minimal. Nevertheless, to further mitigate potential source bias, the statistical approach proposed by Podsakoff et al. (2003) was applied. Additionally, following the guidelines of Podsakoff and Organ (1986) for reducing typical method bias, the survey data was arranged in a random order, and subsequently, Harman's one-factor test was conducted.

Secondly, the analysis encompassed descriptive statistics along with correlations. Descriptive statistics were employed to provide an overview and summary of the characteristics of the sample or dataset. This included metrics such as mean, standard deviation, and the frequency distribution of variables. Inferential statistics were subsequently used to gain a deeper understanding of the collective attributes of the constituents within the data sample.

Third, we conducted a structural equation model (SEM) to analyze the relationships between a set of variables. SEM is a multivariate analysis that incorporates both factor analysis and regression analysis to test a theoretical model of hypothesized relationships among variables. SPSS 26.0 was used for the analysis.

IV. Results

4.1 Profile of the Respondents

The demographic characteristics of the participants in the study of Turkmenistan Energy Management were analyzed. The sample included a total of 221 respondents, distributed across various age groups and work sectors. As shown in Appendix 1. Regarding age, the majority of participants were in the 30-35 years age group (n = 100, 45.3%), followed by 26-30 years (n = 70, 31.7%) and 31-35 years (n = 28, 12.7%). A few respondents were above 45 years (n = 12, 5.4%), and 15-18 years (n = 2, 0.9%), with only nine respondents (4.1%) in the 36-40 years age group. In terms of gender, more female respondents (n = 135, 61.1%) participated in the study compared to male respondents (n = 86, 38.9%). Regarding work sectors, the highest number of respondents were working in the Manufacturing industry (n = 72, 32.6%), followed by oil and gas (n = 57, 25.8%), Renewable Energy (n = 51, 23.1%), Agriculture (n = 36, 16.3%), and Water Management (n = 5, 2.3%). Concerning seniority level at work, most respondents were Senior Staff (n=130, 58.8%), and a smaller number of participants were Junior Staff (n = 41, 18.6%).

4.2 Descriptive Statistics and Correlation

Table 3 displays the Pearson's correlations, means, and standard deviations for the variables: CAN (Carbon neutrality), EMP (Improved energy management practices), and ITE (Innovative technologies). The mean for CAN is 3.844 with a standard deviation of 0.752. The mean for EMP is 3.882 with a standard deviation of 0.741. The mean for ITE is 3.797 with a standard deviation of 0.702. These descriptive statistics offer an overview of the central tendency and variability of the variables in the study.

The correlation coefficient between CAN and EMP is 0.619. This correlation suggests a positive relationship between carbon neutrality and improved energy management practices. The correlation coefficient between CAN and ITE is 0.639, indicating a positive relationship between carbon neutrality and innovative technologies. Finally, the correlation coefficient between EMP and ITE is 0.750, indicating a positive relationship between improved energy management practices and innovative technologies.

Our findings suggest that there are significant positive correlations between carbon neutrality and both improved energy management practices and innovative technologies. Additionally, there is a positive correlation between improved energy management practices and innovative technologies. Suggesting that the presence of innovative technologies in the energy sector may contribute to improved energy management practices and progress towards carbon neutrality.

Table 3: Descriptive Statistics and Correlation

Variable	Mean	SD	CAN	EMP	ITE
CAN	3.844	0.752	-		
EMP	3.882	0.741	0.619**	-	
ITE	3.797	0.702	0.639**	0.750**	-

****. Correlation is significant at the 0.01 level (2-tailed).**
a. Listwise N=221, EMP: Energy Management Practices, ITE: Innovative Technologies, CAN: Carbon Neutrality

4.3 Model Fit indices the Structural Equation Modelling

On Table 4 we displayed the various fit indices used to assess the goodness of fit for Model 1. Fit indices are statistical measures that evaluate how well the proposed model fits the observed data. Higher values of these indices indicate a better fit between the model and the data. The Comparative Fit Index (CFI) for Model 1 is 0.979, indicating a high level of fit. Similarly, the Tucker-Lewis Index (TLI) and Bentler-Bonett Non-normed Fit Index (NNFI) have values of 0.976, suggesting a strong fit between the model and the data. The Bentler-Bonett Normed Fit Index (NFI) has a value of 0.969, indicating a good fit. The Parsimony Normed Fit Index (PNFI) has a lower value of 0.852, suggesting a slightly poorer fit in terms of model parsimony. Additionally, Bollen's Relative Fit Index (RFI) has a value of 0.965, indicating a good fit. The Bollen's Incremental Fit Index (IFI) and Relative Noncentrality Index (RNI) both have values of 0.979, reflecting a high level of fit. It is worth noting that the T-size CFI, computed for $\alpha = 0.05$, has a value of 0.973. The T-size equivalents of the conventional CFI cut-off values for Model 1 are poor $< 0.857 <$ fair $< 0.918 <$ close. These values provide a benchmark for evaluating the model's fit, with the obtained T-size CFI falling within the "fair" range. The fit indices suggest that Model 1 exhibits a good to excellent fit with the observed data, indicating that the proposed model adequately represents the underlying relationships between the variables.

Table 4: Model fit indices

Index	Value
Comparative Fit Index (CFI)	0.979
T-size CFI	0.973
Tucker-Lewis Index (TLI)	0.976
Bentler-Bonett Non-normed Fit Index (NNFI)	0.976
Bentler-Bonett Normed Fit Index (NFI)	0.969
Parsimony Normed Fit Index (PNFI)	0.852
Bollen's Relative Fit Index (RFI)	0.965
Bollen's Incremental Fit Index (IFI)	0.979
Relative Noncentrality Index (RNI)	0.979

Note. T-size CFI is computed for $\alpha = 0.05$

Note. The T-size equivalents of the conventional CFI cut-off values (poor < 0.90 < fair < 0.95 < close) are **poor < 0.857 < fair < 0.918 < close** for model: Model 1

4.4 Other Fit Measures

Table 5 presents other fit measures used to evaluate the goodness of fit for Model 1. These measures provide insights into the model's accuracy in representing the underlying data and relationships between variables. The Root Mean Square Error of Approximation (RMSEA) for Model 1 is 0.098. This value indicates a fair fit between the model and the observed data. The 90% confidence interval (CI) for RMSEA ranges from 0.089 to 0.108. The p-value associated with RMSEA is 0.000, suggesting that the model does not fit the data well. The T-size RMSEA, computed for α = 0.05, has a value of 0.108. The T-size equivalents of the conventional RMSEA cut-off values (close < 0.05 < fair < 0.08 < poor) are close < 0.062 < fair < 0.089 < poor for Model 1. Comparing these values, it can be concluded that the model's fit is fair, falling within the expected range. The Standardized Root Mean Square Residual (SRMR) for Model 1 is 0.077. This value indicates a reasonably good fit, as lower values of SRMR indicate a better fit between the model and the observed data. Hoelter's critical N values provide an indication of the minimum sample size required for a good fit. For α = .05, the critical N is 84.424, while for α = .01, it is 90.435. These values indicate that the sample size used in the analysis exceeds the minimum requirements for a good fit. The Goodness of Fit Index (GFI) has a value of 0.978, indicating a high level of fit between the model and the data. Overall, the fit measures suggest that Model 1 has a fair to reasonably good fit with the observed data.

Table 5: Other fit measures

Metric	Value
Root mean square error of approximation (RMSEA)	0.098
RMSEA 90% CI lower bound	0.089
RMSEA 90% CI upper bound	0.108
RMSEA p-value	0.000
T-size RMSEA	0.108
Standardized root mean square residual (SRMR)	0.077
Hoelter's critical N (α = .05)	84.424
Hoelter's critical N (α = .01)	90.435
Goodness of fit index (GFI)	0.978
McDonald fit index (MFI)	0.446
Expected cross validation index (ECVI)	

Note. T-size RMSEA is computed for $\alpha = 0.05$

4.5 Test of Hypotheses

H1: Improved energy management practices in Turkmenistan will result in a reduction of carbon emissions.

H2: The presence of innovative technologies and solutions in the energy sector of Turkmenistan will positively impact the country's journey toward carbon neutrality.

H3: Implementation of effective energy management strategies combined with innovation will accelerate Turkmenistan's progress in achieving carbon neutrality.

We conducted a structural equation modelling to examine the relationship between energy management practices in Turkmenistan (the independent variable), innovative technologies and achieving carbon neutrality (the dependent variable). Table 4, presents the results of our SEM regression analysis examining the relationship between Carbon Neutrality (CAN), Improved Energy Management Practices (EMP), and Innovative Technologies (ITE) as predictors of specific outcomes. Our analysis provides estimates (Estimate) and corresponding standard errors (Std. Error) for each predictor-outcome relationship. The z-value reflects the magnitude of the coefficient relative to its standard error, and p indicates the level of statistical significance.

For the relationship between Carbon Neutrality (CAN) and Improved Energy Management Practices (EMP), the regression coefficient (alpha) is estimated at 0.548, with a standard error of 0.028. The large z-value of 19.386 suggests a highly significant relationship ($p < .001$). The 95% confidence interval for this relationship ranges from 0.493 to 0.604, indicating that the true population value is likely to fall within this range. Hence, we accept the hypothesis that improved energy management practices in Turkmenistan will result in a reduction of carbon emissions.

Similarly, the relationship between Carbon Neutrality (CAN) and Innovative Technologies (ITE) shows a direct coefficient (direct) of 0.341, with a standard error of 0.050. The z-value of 6.754 indicates a significant relationship ($p < .001$). The 95% confidence interval for this relationship ranges from 0.242 to 0.439. therefore, we accept the hypothesis that the presence of innovative technologies and solutions in the energy sector of Turkmenistan will positively impact the country's journey toward carbon neutrality.

Furthermore, the relationship between Improved Energy Management Practices (EMP) and Innovative Technologies (ITE) has a beta coefficient of 0.799, with a standard error of 0.063. The z-value of 12.743 indicates a significant relationship ($p < .001$). The 95% confidence interval for this relationship ranges from 0.676 to 0.922. Therefore, the findings indicate a positive correlation between Improved Energy Management Practices (EMP) and Innovative Technologies (ITE) with Carbon Neutrality (CAN). This is supported by the statistically significant coefficients and their corresponding confidence intervals.We accept the hypothesis that the Implementation of effective energy management strategies combined with innovation will accelerate Turkmenistan's progress in achieving carbon neutrality. These findings highlight the potential effectiveness of EMP and ITE in promoting carbon neutrality initiatives.

Table 6: SEM Regression coefficients

							95% Confidence Interval	
Predictor	**Outcome**		**Estimate**	**Std. Error**	**z-value**	**p**	**Lower**	**Upper**
CAN	EMP	alpha	0.548	0.028	19.386	< .001	0.493	0.604
	ITE	direct	0.341	0.050	6.754	< .001	0.242	0.439
EMP	ITE	beta	0.799	0.063	12.743	< .001	0.676	0.922

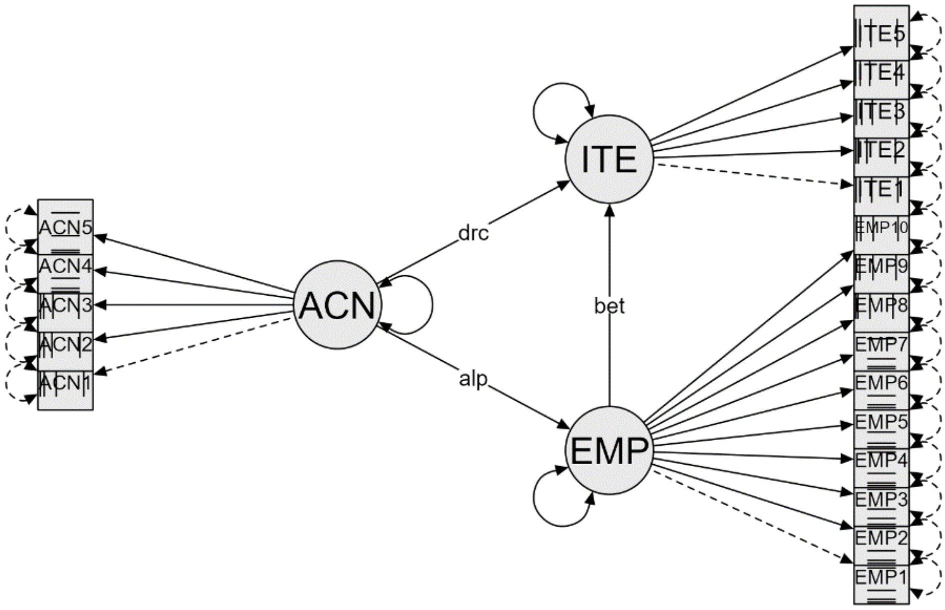

Figure 7: we present the Path diagram of the SEM

V. Discussion of Findings and Conclusion

5.1 Discussion of Research Findings

The findings of our study regarding the demographic characteristics of the participants suggest that our sample is diverse, with respondents from various age groups and work sectors. The majority of participants were in the 30-35 years age group, followed by the 26-30 years and 31-35 years age groups. Only a small number of respondents were above 45 years, and the 15-18 years age group had the least representation. Regarding gender, the study had a higher proportion of female respondents compared to male respondents. This finding is consistent with previous research studies that have reported a higher participation of women in research studies [28]. Regarding work sectors, the study had the highest number of respondents in the Manufacturing industry, followed by oil and gas, Renewable Energy, Agriculture, and Water Management. This finding is in line with the current economic structure of Turkmenistan, where oil and gas and manufacturing industries play a critical role in the economy [33]. Concerning seniority level at work, the majority of respondents were Senior Staff, while a smaller number of participants were Junior Staff. This finding suggests that the study had a representation of individuals with different levels of experience and expertise.

Our first objective was to analyze the current energy management practices in Turkmenistan and assess their impact on carbon emissions. The findings of the study suggest that improved energy management practices in Turkmenistan will lead to the reduction of carbon emissions. This conclusion is supported by previous research in the field. For example, a study by Yudelson[35] has found that implementing energy-efficient measures, improving energy management practices, and utilizing renewable energy sources can contribute to a significant reduction in carbon emissions. Similarly, another study by Biresselioglu and Cobanoglu [26] has examined the relationship between organizational energy management practices and carbon emissions reduction. Their findings also support a significant positive relationship between improved energy management practices and the reduction of carbon emissions. Moreover, the finding that the relationship between carbon neutrality and improved energy management practices is highly significant is also in line with previous research. For example, the International Energy Agency [9] has found that energy efficiency measures and improvements in energy management practices are essential to achieving carbon neutrality. Similarly, a study by Khan et al. [32] has examined the role of energy management practices in achieving carbon neutrality in developing countries. The authors conclude that improved energy management practices are critical for reducing carbon emissions and achieving carbon neutrality.

Our second objective is to investigate the role of innovation in the energy sector of Turkmenistan and its potential for achieving carbon neutrality. The presented findings suggest that innovative technologies and solutions in the energy sector have a positive impact on Turkmenistan's journey towards carbon neutrality. This conclusion is supported by research in the field. A study by Zaman et al. [36] has examined the relationship between the adoption of innovative technologies and carbon emissions reduction. The authors found that the adoption of innovative technologies can significantly reduce carbon emissions in the energy sector. Additionally, a study by Gholami et al. [29] has investigated the potential of renewable energy technologies in reducing carbon emissions. Their findings indicate that renewable energies such as solar and wind can play a significant role in reducing carbon emissions. Additionally, the discovery of a significant relationship between carbon neutrality and innovative technologies is consistent with findings in existing literature.A study by the International Renewable Energy Agency [8] highlights the importance of innovative technologies in the deployment of renewable energy and achieving carbon neutrality. The report highlights the role of innovative technologies in increasing energy efficiency, reducing costs, and overcoming technical challenges associated with renewable energy deployment.

Our third objective is to investigate the impact of implementing effective energy management strategies combined with innovation on Turkmenistan's progress toward achieving carbon neutrality. The findings of the study indicate that the implementation of effective energy management strategies combined with innovative technologies will accelerate Turkmenistan's progress toward achieving carbon neutrality. This conclusion is supported by previous research by the United Nations Industrial Development Organization (UNIDO) [34] that examined the relationship between energy management practices and innovation in improving resource efficiency. The report highlights the importance of both energy management practices and innovation in reducing energy consumption and carbon emissions. Furthermore, the finding that the relationship between improved energy management practices and innovative technologies is positively associated with carbon neutrality is also supported by A study conducted by Zhang and Zhao [37] that investigated the role of energy management practices and innovation in achieving carbon neutrality in China. The authors found that the adoption of energy-efficient technologies and improved energy management practices played a significant role in reducing carbon emissions. In addition, several studies have emphasized the importance of combining effective energy management practices with innovative technologies to achieve carbon neutrality. For instance, a study by the World Bank [5] suggests that innovative technologies, coupled with effective policies and regulations, can accelerate countries' progress towards achieving carbon neutrality.

5.2 Conclusion

Based on the study's results, it can be concluded that there is substantial evidence supporting the notion that enhanced energy management practices in Turkmenistan result in a reduction of carbon emissions.The adoption of innovative technologies also plays a crucial role in achieving this reduction, particularly in the energy sector. The study supports the hypothesis that the implementation of effective energy management strategies combined with innovation contributes positively to Turkmenistan's journey towards carbon neutrality.

5.3 Policy Recommendations

Based on the findings, we made the following recommendations were made:

1. **Promote Energy Efficiency Measures:** Implement policies and initiatives aimed at fostering energy-efficient practices across diverse sectors, including buildings, transportation, and industrial processes. These efforts may involve offering incentives, tax incentives, and educational campaigns to enhance public awareness regarding energy-saving techniques.
2. **Invest in Renewable Energy Sources:** Increase investments in renewable energy technologies, such as solar, wind, and geothermal power. Develop policies and financial mechanisms that facilitate the transition towards clean energy sources and reduce reliance on fossil fuels.
3. **Support Research and Development:** Allocate resources to research and development initiatives focused on developing innovative technologies and solutions for energy management and carbon emissions reduction. Encourage collaboration between academia, industry, and government agencies to foster innovation in the energy sector.
4. **Strengthen Policy Framework:** Enhance existing policies and regulations related to energy management and carbon emissions reduction. Implement stricter emission standards, enforce energy efficiency requirements, and establish mechanisms for monitoring and reporting carbon emissions.
5. **Promote Public-Private Partnerships:**Cultivate collaborations between the public and private sectors to

expedite the adoption of energy-efficient technologies and practices.Encourage collaboration on research, funding, and implementation of sustainable energy projects.

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