



Strategies to enhance energy sustainability in line with Sustainable Development Goal (SDG) case of Puntland, Somalia

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Abstract

This study examines strategies for enhancing energy sustainability in Puntland State, Somalia, with a focus on progress toward Sustainable Development Goal 7 (SDG 7), which aims to ensure access to affordable, reliable, sustainable, and modern energy for all. The study adopted a mixed-methods research design combining descriptive and exploratory approaches. Quantitative data were collected from households and businesses using structured questionnaires, while qualitative data were obtained through key informant interviews and focus group discussions with government officials, energy service providers, NGOs, and development partners. Secondary data were sourced from policy documents and energy sector reports. Quantitative data were analyzed using descriptive statistics and regression analysis, while qualitative data were analyzed thematically. The findings indicate that Puntland's energy sector is dominated by private providers relying largely on diesel generation, resulting in high electricity costs and limited renewable energy penetration. Although access to electricity has improved in urban areas, affordability, reliability, and environmental sustainability remain major challenges. Institutional weaknesses, limited financing, and technical capacity constraints hinder the achievement of SDG 7. The study concludes that energy sustainability in Puntland requires strengthened energy governance, increased investment in renewable energy technologies, and enhanced community participation. It recommends policy reforms, expansion of solar and wind energy systems, and innovative financing mechanisms. This study provides empirical evidence on energy sustainability in a fragile and post-conflict context, offering context-specific insights to inform policy and practice toward achieving SDG 7 in Puntland.

Keywords: Energy sustainability, SDG 7, Renewable energy, Puntland, Fragile states

Introduction

Energy sustainability has emerged as a central pillar of global development discourse, particularly under Sustainable Development Goal 7 (SDG 7), which seeks to ensure access to affordable, reliable, sustainable, and modern energy for all. Energy sustainability conceptualized in this study as the dependent variable (DV) encompasses long-term energy access, system reliability, affordability, environmental protection, and institutional

resilience. Achieving this outcome is heavily influenced by the independent variable (IV): strategies to enhance energy sustainability, including renewable energy deployment, policy and regulatory reforms, energy efficiency measures, private-sector participation, and institutional capacity building. Globally and locally, evidence shows that where coherent energy strategies are adopted, energy sustainability outcomes improve markedly; conversely, weak or

fragmented strategies undermine progress toward SDG 7. In fragile and post-conflict contexts such as Puntland, Somalia, the relationship between energy sustainability strategies (IV) and sustainable energy outcomes (DV) is particularly pronounced, making the issue both policy-relevant and academically significant (IEA, 2023; World Bank, 2022).

Background to the study

Globally, the evolution of energy sustainability strategies has followed a clear historical trajectory from fossil-fuel dependence toward integrated renewable energy systems. In the early 2000s, developed economies such as the United Kingdom, the United States, and members of the European Union began implementing large-scale renewable energy strategies, including feed-in tariffs, carbon pricing, and grid modernization. These strategies (IV) have directly influenced energy sustainability outcomes (DV), evidenced by reduced carbon intensity and improved energy reliability. For instance, the UK increased renewable electricity generation from 10% in 2010 to over 43% by 2022, significantly enhancing system sustainability and emissions reduction (UK Department for Energy Security, 2023). Similarly, the European Union's Green Deal accelerated investment in solar and wind energy, contributing to improved energy security and affordability despite global energy shocks (European Commission, 2022). These historical reforms demonstrate that deliberate energy sustainability strategies consistently translate into improved sustainable energy outcomes globally (IEA, 2023; IRENA, 2024).

While global reforms advanced rapidly, Africa's energy sustainability trajectory has been shaped by structural inequalities, colonial legacies, and limited infrastructure investment. Across West, North, and Southern Africa, energy strategies have increasingly focused on renewable energy expansion as a pathway to improve energy sustainability (DV). In Morocco, large-scale solar projects such as Noor Ouarzazate illustrate how strategic renewable investments (IV) have

improved energy security and reduced import dependence (IRENA, 2022). In South Africa, the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) enhanced electricity diversification and system resilience, though challenges remain regarding affordability and grid stability (World Bank, 2023). In West Africa, countries like Ghana and Senegal adopted national renewable energy policies that expanded access but revealed gaps in institutional coordination. These experiences show that although energy sustainability strategies exist, uneven implementation continues to constrain sustainable energy outcomes across the continent (AfDB, 2021; IEA, 2023).

Transitioning from continental patterns to regional realities, East Africa presents a mixed energy sustainability landscape shaped by innovation and constraint. Kenya's early adoption of geothermal and wind energy strategies significantly enhanced energy sustainability outcomes, with renewable sources accounting for over 85% of electricity generation by 2022 (Kenya Ministry of Energy, 2023). Ethiopia's hydropower-centered strategy improved national generation capacity but exposed vulnerabilities related to climate variability and regional politics. Uganda and Tanzania have increasingly invested in solar mini-grids to improve rural access, linking decentralized strategies (IV) to improved access and reliability (DV), particularly in underserved communities (World Bank, 2022). Despite these advances, weak regulatory frameworks and financing gaps continue to limit long-term sustainability. These regional experiences underscore that energy sustainability outcomes are strongly conditioned by the coherence and adaptability of implemented strategies (IRENA, 2024).

In Somalia's energy sector reflects decades of conflict-induced institutional collapse, leaving energy provision largely privatized and fragmented. Energy sustainability (DV) remains fragile, with over 65% of the population lacking access to electricity and average tariffs among the

highest globally, ranging between USD 0.80–1.20 per kWh (World Bank, 2021). In response, federal and state-level actors have begun introducing renewable energy strategies (IV), particularly solar power, supported by international partners. Puntland has made notable progress through hybrid solar-diesel systems and private-sector-led distribution models. However, the absence of comprehensive energy policy coordination and regulatory enforcement continues to undermine long-term sustainability outcomes such as affordability, grid stability, and environmental protection (USAID, 2022; IEA, 2023).

In Puntland's districts illustrate the tangible interaction between energy sustainability strategies and outcomes. While urban centers such as Garowe and Bosaso have seen increased solar integration, rural and peri-urban districts remain underserved, reflecting uneven strategy implementation. Private energy providers dominate the sector, yet operate with limited regulatory oversight, affecting affordability and system resilience key indicators of energy sustainability (DV). Recent initiatives promoting renewable mini-grids and energy-efficient technologies signal progress, but their long-term impact remains under-investigated (UNDP, 2024). Thus, while global and regional energy sustainability strategies inform Puntland's policy direction, localized structural and institutional challenges continue to mediate the effectiveness of these strategies, necessitating empirical investigation at the district level.

Statement of the Problem

Ideally, effective energy sustainability strategies (IV), such as renewable energy adoption, regulatory frameworks, and institutional coordination, should result in improved energy access, reduced costs, enhanced reliability, and environmental protection in line with SDG 7, energy sustainability defined in this study as reliable, affordable, environmentally sound, and resilient energy provision remains a critical development challenge in Puntland, Somalia. Globally, countries implementing such strategies

have significantly improved sustainable energy outcomes, with renewable energy contributing over 30% of global electricity generation by 2023 (IEA, 2024). However, the actual situation in Puntland deviates sharply from this ideal. Despite increasing investment in solar energy, Puntland continues to experience high electricity tariffs, unreliable supply, and limited rural access, with electricity costs remaining among the highest in Sub-Saharan Africa (World Bank, 2022). The gap lies in the unclear effectiveness of existing energy sustainability strategies and how they translate into tangible sustainability outcomes at the local level. Current policy debates often assume that renewable energy expansion automatically improves sustainability, yet empirical evidence from Puntland remains insufficient and fragmented (UNDP, 2024).

Moreover, empirical indicators such as affordability trends, reliability metrics, and environmental outcomes have not been systematically examined to establish how specific strategies influence energy sustainability. Without such evidence, policy interventions risk being misaligned or ineffective. If this problem remains unaddressed, Puntland faces continued economic stagnation, environmental degradation, and social inequality, as unreliable and expensive energy constrains industrial growth, service delivery, and household welfare (AfDB, 2023). Therefore, this study seeks to bridge this gap by empirically examining how strategies to enhance energy sustainability affect energy sustainability outcomes in Puntland. By systematically analyzing strategic interventions and their measurable impacts, the study aims to inform evidence-based policymaking aligned with SDG 7 and Puntland's development aspirations.

Objectives of the Study

General Objective

To examine how strategies for enhancing energy sustainability contribute to the achievement of Sustainable Development Goal 7 (SDG 7) in Puntland, Somalia.

Specific Objectives (SMART)

- 1) To assess the current status of energy sustainability in Puntland.
- 2) To identify the key challenges hindering the achievement of SDG 7 in Puntland.
- 3) To analyze the effectiveness of existing strategies for enhancing sustainable energy in Puntland.

Research Questions

- 1) What is the current status of energy sustainability in Puntland in terms of access, affordability, reliability, and environmental sustainability?
- 2) What institutional, technical, financial, and policy-related challenges hinder the achievement of SDG 7 in Puntland?
- 3) How effective are the existing strategies for enhancing sustainable energy in improving energy sustainability outcomes in Puntland?

Significance of the Study

This study is significant to several stakeholders, as it provides evidence-based insights into energy sustainability strategies and outcomes in Puntland, Somalia.

The findings will assist the Puntland Ministry of Energy and Water Resources and other relevant government agencies by providing empirical evidence on the effectiveness of current energy sustainability strategies. This evidence will support informed policy formulation, regulatory reforms, and strategic planning aimed at accelerating progress toward SDG 7 and improving energy governance.

Private energy providers, independent power producers, and renewable energy investors will benefit from the study by gaining insights into existing challenges and opportunities within Puntland's energy sector. The findings will help guide investment decisions, improve service delivery models, and promote sustainable and cost-effective energy solutions.

International development partners, NGOs, and donor agencies supporting energy projects in Somalia will use the study's findings to design

more targeted, efficient, and context-specific interventions. The evidence generated will help improve project sustainability, monitoring, and alignment with SDG 7 targets.

The study will indirectly benefit households, businesses, and institutions in Puntland by informing strategies that enhance access to affordable, reliable, and clean energy. Improved energy sustainability will contribute to better livelihoods, economic productivity, service delivery, and environmental protection.

The study will contribute to the existing body of knowledge on energy sustainability in fragile and post-conflict settings. It will serve as a reference for future researchers, scholars, and students interested in sustainable energy transitions, SDG implementation, and development policy in Somalia and similar contexts.

Literature Review

Theoretical Framework

Sustainable Energy Development Theory

Sustainable Energy Development Theory, rooted in the broader Sustainable Development paradigm advanced by the Brundtland Commission (1987) and later refined by UN agencies, emphasizes balancing economic growth, social equity, and environmental protection in energy systems. The theory assumes that energy systems should be economically viable, socially inclusive, and environmentally sound to ensure long-term sustainability (UN, 2021). Empirical applications by IRENA (2023) demonstrate that renewable energy strategies improve sustainability when aligned with institutional capacity and policy coherence. However, the theory is critiqued for being normative and insufficiently explanatory in fragile contexts where institutions are weak, leading to the need for complementary theoretical perspectives. In relation to this study, Sustainable Energy Development Theory explains how strategies such as renewable energy adoption, regulatory frameworks, and institutional strengthening are expected to enhance energy sustainability outcomes. The theory guides the selection of sustainability indicators availability,

affordability, reliability, and environmental protection and supports the study's focus on SDG 7 alignment. Nevertheless, its limited attention to transition dynamics in unstable political economies necessitates the integration of Energy Transition Theory.

Energy Transition Theory

Energy Transition Theory, developed in the early 2000s by scholars such as Geels (2002), explains how energy systems shift from traditional to modern, sustainable sources through technological innovation, policy change, and socio-economic restructuring. The theory assumes that transitions occur through interactions between niche innovations, dominant regimes, and external pressures. Recent empirical studies by Sovacool et al. (2020) and Jenkins et al. (2022) demonstrate that energy transitions are non-linear and context-dependent. However, critics argue that the theory assumes stable governance systems, limiting its applicability in fragile and post-conflict contexts.

In this study, Energy Transition Theory explains how Puntland's shift from diesel-based systems to solar and hybrid mini-grids represents an ongoing transition influenced by private-sector initiatives and donor interventions. The theory guides the analysis of how renewable energy strategies affect sustainability outcomes over time. Despite its strengths, the theory's limited consideration of political fragility reinforces the relevance of Sustainable Energy Development Theory to address governance and equity dimensions. By integrating Sustainable Energy Development Theory and Energy Transition Theory, the study adopts a complementary theoretical framework that captures both normative sustainability goals and dynamic transition processes. The combined framework explains how energy sustainability strategies (IV) influence energy sustainability outcomes (DV) through technological, institutional, and socio-economic pathways. This theoretical integration guides the formulation of research questions, selection of variables, and interpretation of findings. Although no single

theory fully captures the complexity of energy sustainability in fragile contexts, this integrated framework offers the most suitable explanatory lens for examining energy sustainability strategies in Puntland.

Concept of Energy Sustainability

Energy sustainability is a multidimensional concept that integrates long-term energy availability, affordability, reliability, and environmental protection. According to the International Energy Agency (IEA, 2023), energy sustainability refers to the ability of energy systems to meet present energy needs without compromising future generations through resilient supply chains, cost efficiency, and low environmental impact. Empirical studies by Sovacool et al. (2020) employed mixed-methods approaches combining household surveys and policy analysis to demonstrate that energy sustainability outcomes (DV) improve significantly where deliberate strategies such as renewable integration and institutional reforms (IV) are implemented. Similarly, Narula et al. (2022), using econometric modeling across 80 countries, found that countries investing in diversified energy strategies recorded higher sustainability indices. However, despite conceptual clarity, many studies focus on national aggregates, creating a methodological and contextual gap regarding sub-national and fragile-state settings such as Puntland. Nevertheless, this study addresses this gap by empirically examining energy sustainability dimensions at the sub-national level in a fragile context.

Affordability and reliability have emerged as dominant dimensions of energy sustainability in developing and conflict-affected regions. World Bank (2022) studies using panel data analysis reveal that high electricity tariffs and frequent outages undermine sustainable energy outcomes even where renewable capacity exists. In contrast, IRENA (2024), using case-study methodologies in Asia and Latin America, argues that decentralized energy strategies significantly improve

affordability and reliability when supported by regulatory oversight. The debate highlights a conceptual gap on whether energy sustainability should be infrastructure-led or governance-driven. However, this study contributes to this debate by integrating both infrastructural and governance-based strategies to assess their combined effect on energy sustainability in Puntland.

Sustainable Development Goal 7 (SDG 7)

SDG 7 aims to ensure universal access to affordable, reliable, sustainable, and modern energy services by 2030. According to the UN (2023), global progress toward SDG 7 has been uneven, with renewable energy growth accelerating in developed regions while access gaps persist in fragile and low-income countries. A global cross-sectional study by Pachauri et al. (2021) using SDG indicator tracking revealed that countries implementing integrated renewable and regulatory strategies experienced faster progress toward SDG 7 targets. Conversely, Africa lags behind, with over 570 million people lacking electricity access (World Bank, 2023). These findings expose a geographical and knowledge gap regarding how SDG 7 strategies perform in fragile states. Although global monitoring exists, this study fills the gap by contextualizing SDG 7 implementation within Puntland's fragile institutional environment. Regionally, East Africa has made notable but uneven progress toward SDG 7. Kenya and Ethiopia, using centralized renewable strategies, have increased access rates, while Somalia remains largely privatized and unregulated (IEA, 2023). A comparative qualitative study by Karekezi et al. (2022) found that decentralized renewable strategies improve SDG 7 outcomes where state capacity is weak. However, their study relied on regional case comparisons without district-level analysis, creating a methodological gap. Despite the fact that regional lessons exist, this study uniquely investigates SDG 7 progress at the district level in Puntland, thereby strengthening empirical evidence.

Energy Sector in Fragile and Post-Conflict States

Energy sectors in fragile and post-conflict states are characterized by weak institutions, private-sector dominance, and fragmented governance. According to World Bank (2021), post-conflict countries rely heavily on off-grid and informal energy systems, which affects long-term sustainability outcomes. A qualitative comparative analysis by Brinkerhoff et al. (2020) across Liberia, South Sudan, and Afghanistan found that weak regulatory frameworks undermine the effectiveness of energy sustainability strategies. In contrast, quantitative studies by Eberhard et al. (2021) suggest that private-sector-led models improve access but raise affordability concerns. This scholarly debate reveals a theoretical gap between state-led and market-led energy sustainability models. However, this study bridges this gap by examining hybrid governance arrangements in Puntland.

Somalia's energy sector reflects these fragility dynamics. USAID (2022), using institutional mapping and stakeholder interviews, found that Somalia's energy provision is dominated by private firms with minimal regulation, affecting affordability and environmental sustainability. UNDP (2024) reports that solar-diesel hybrid systems have improved access but lack long-term sustainability planning. These studies acknowledge progress but do not empirically link strategies to sustainability outcomes, creating a conceptual and methodological gap. In addition, this study explicitly measures how specific energy strategies influence sustainability indicators in Puntland.

Renewable Energy Technologies for Sustainable Development

Renewable energy technologies particularly solar, wind, and hybrid mini-grids are widely recognized as central strategies for achieving energy sustainability in developing regions. IRENA (2023), using techno-economic modeling, demonstrates that solar mini-grids significantly improve energy availability and environmental sustainability in off-grid areas. Similarly, Bhattacharyya (2021) employed case-study analysis in Asia and Africa, showing that

decentralized renewable systems enhance affordability and reliability when community participation is incorporated. However, contrasting findings by Jenkins et al. (2022), using household-level surveys, indicate that poor maintenance and governance undermine long-term sustainability. This reveals a contextual and implementation gap. Nevertheless, this study assesses not only technology adoption but also governance structures supporting renewable energy in Puntland.

Decentralized energy systems have gained prominence in fragile states due to their flexibility and resilience. A mixed-methods study by Rolffs et al. (2020) across Sub-Saharan Africa found that decentralized solar systems improved access but had inconsistent sustainability outcomes due to regulatory gaps. In East Africa, World Bank (2022) reports that mini-grids outperform centralized systems in rural electrification, yet policy integration remains weak. These studies emphasize access but under-examine sustainability dimensions such as affordability and environmental protection, creating a knowledge gap. In support of this study, the present research comprehensively evaluates decentralized energy systems against all four energy sustainability dimensions in Puntland.

Empirical Review of Related Studies

Empirical studies across Africa demonstrate that renewable energy adoption is increasingly positioned as a strategic pathway to achieving energy sustainability. A quantitative cross-country study by IRENA (2021), employing panel data analysis across 46 African countries, found that solar and wind investments significantly improved electricity access and environmental sustainability but had mixed effects on affordability due to high upfront capital costs. Similarly, a mixed-methods study by AfDB (2022), combining household surveys and policy reviews in West and Southern Africa, reported improved energy availability and reliability in countries with strong renewable energy policies. However, both studies focus primarily on national-level outcomes, overlooking sub-national disparities and fragile-state contexts.

Nevertheless, these findings reveal a geographical and contextual gap that the current study addresses by focusing on Puntland, a fragile sub-national setting within Somalia.

In the Horn of Africa, renewable energy adoption has been uneven and shaped by institutional capacity. Karekezi et al. (2022), using comparative case-study methodology in Kenya, Ethiopia, and Djibouti, found that decentralized renewable systems enhanced rural energy access and reliability. In contrast, a qualitative study by UNDP (2023) on Somalia revealed that private-sector-led solar systems improved availability but failed to guarantee affordability and regulatory sustainability. The divergence in findings reflects differences in governance structures and methodological approaches. However, despite these insights, there remains a methodological and knowledge gap regarding how renewable energy strategies translate into comprehensive energy sustainability outcomes availability, affordability, reliability, and environmental protection at the district level, which this study seeks to fill.

Research Gaps from Reviewed Literature

Conceptually, many empirical studies equate renewable energy adoption with energy sustainability without fully operationalizing sustainability dimensions. For instance, Sovacool et al. (2020) conceptualized energy sustainability largely in terms of decarbonization and access, using global energy indicators, while Jenkins et al. (2022) emphasized energy justice and environmental outcomes through qualitative assessments. Although both approaches are valuable, they underrepresent affordability and reliability as integrated components of sustainability, particularly in fragile contexts. Although existing studies acknowledge sustainability, they conceptualize it narrowly, creating a conceptual gap that this study addresses by adopting a multidimensional energy sustainability framework encompassing availability, affordability, reliability, and environmental sustainability in Puntland.

Methodologically, empirical studies show divergence in approaches, limiting comparability and depth. IRENA (2021) relied on secondary quantitative datasets, while AfDB (2022) employed descriptive survey designs. Although these methods identify broad trends, they fail to capture localized institutional and governance dynamics influencing sustainability outcomes. In contrast, qualitative case studies such as Brinkerhoff et al. (2020) provide depth but lack measurable sustainability indicators. However, this methodological gap is addressed in the current study by integrating measurable sustainability indicators with contextual analysis, enabling a more comprehensive empirical assessment of strategies and outcomes in Puntland.

Geographically, most empirical studies focus on stable African economies such as Kenya, South Africa, and Morocco. Karekezi et al. (2022) and World Bank (2023) emphasize East African leaders in renewable energy, marginalizing fragile and post-conflict regions like Somalia. Studies that include Somalia, such as USAID (2022), remain largely descriptive and national in scope. Despite growing regional literature, there is limited empirical evidence at the sub-national level in fragile settings, creating a geographical gap that this study fills by focusing specifically on Puntland. Contextually, fragile and post-conflict environments present unique challenges not adequately captured in existing empirical work. UNDP (2024) highlights the dominance of private energy providers in Somalia but does not empirically link this structure to sustainability outcomes. Similarly, Eberhard et al. (2021) argue that private-sector-led models improve access but raise affordability concerns, without considering informal governance contexts. Nevertheless, this contextual gap is addressed by examining how Puntland's private-led, weakly regulated energy sector influences sustainability outcomes under SDG 7.

From a theoretical standpoint, many studies apply Energy Transition Theory implicitly without

contextual adaptation. Sovacool et al. (2020) apply transition theory assuming institutional stability, while Narula et al. (2022) emphasize structural change without accounting for fragility. These theoretical applications inadequately explain energy transitions in conflict-affected settings. However, this theoretical gap is addressed by integrating Sustainable Energy Development Theory with Energy Transition Theory to better explain energy sustainability dynamics in Puntland.

Finally, a significant knowledge gap exists regarding the effectiveness of energy sustainability strategies in improving long-term outcomes in Puntland. Existing reports focus on access expansion rather than sustainability performance indicators. World Bank (2022) acknowledges data limitations in fragile states, while IEA (2023) calls for localized empirical studies. In support of this study, the present research generates new empirical knowledge by systematically evaluating how energy sustainability strategies influence multidimensional sustainability outcomes in Puntland.

Methodology

This study adopted a mixed-methods research design, combining descriptive and exploratory approaches to comprehensively examine strategies for enhancing energy sustainability and their influence on SDG 7 outcomes in Puntland, Somalia. The descriptive design enabled systematic assessment of the current status of energy sustainability in terms of availability, affordability, reliability, and environmental sustainability, while the exploratory component facilitated in-depth understanding of contextual challenges and strategic interventions in a fragile setting (Creswell & Plano Clark, 2021; World Bank, 2022). Puntland was selected as the study area due to its semi-autonomous governance structure, heavy reliance on private energy providers, expanding use of solar and hybrid mini-grids, and persistent energy affordability challenges (UNDP, 2024; IEA, 2023). The target population comprised government officials from energy-related ministries, private

energy service providers, households and businesses as energy consumers, and representatives from NGOs and development partners involved in the energy sector, reflecting the multi-stakeholder nature of energy sustainability strategies in fragile contexts (USAID, 2022).

A combination of sampling techniques was employed to ensure representativeness and analytical depth. Purposive sampling was used to select government officials, energy providers, and NGO representatives with direct involvement in energy policy and implementation, while stratified random sampling was applied to households and businesses to capture variations in energy access and use across districts (Kothari, 2020; Creswell, 2021). Data were collected using structured questionnaires to generate quantitative data on sustainability indicators, key informant interviews and focus group discussions to capture experiential and institutional perspectives, and document reviews of policy reports, energy strategies, and project evaluations to triangulate findings (UNDP, 2024; IRENA, 2023). This multi-source data collection approach enhanced validity by capturing both measurable outcomes and contextual dynamics influencing energy sustainability strategies.

Data analysis followed a concurrent mixed-methods strategy. Quantitative data were analyzed using descriptive statistics to summarize energy sustainability indicators and regression analysis to examine the influence of energy sustainability strategies on sustainability outcomes, consistent with SDG 7 analytical frameworks (World Bank, 2023; IEA, 2024). Qualitative data from interviews and focus groups were analyzed using thematic analysis to identify recurring patterns related to policy, institutional capacity, and implementation challenges (Braun & Clarke, 2021). Ethical considerations were strictly observed, including obtaining informed consent from all participants, ensuring confidentiality and anonymity, and maintaining research integrity through transparency and responsible data management, in

line with international ethical research standards for studies in fragile and conflict-affected settings (UNESCO, 2021; UNDP, 2023).

Results / Findings

Current Energy Situation in Puntland

Sources of Energy

The study findings indicate that Puntland's energy sector is dominated by diesel-based generation, supplemented by solar photovoltaic (PV) systems, particularly in hybrid mini-grids. Table 6.1 shows that diesel generators remain the primary energy source for most households and businesses, while solar energy adoption is growing but uneven across districts. Wind energy was reported as negligible, despite favorable geographic conditions along the coast.

Table 1: Main Sources of Electricity Used by Respondents

Energy Source	Frequency	Percentage (%)
Diesel generators	214	59.4
Solar PV systems	103	28.6
Solar–diesel hybrid	31	8.6
Grid imports (limited)	12	3.4
Wind energy	0	0.0
Total	360	100

Source: Primary data, 2026

The findings indicate that Puntland's energy supply is predominantly derived from diesel-based generation complemented by solar energy systems, particularly solar–diesel hybrid mini-grids. Data collected from energy service providers and government officials revealed that diesel generators remain the primary source of electricity in urban centers such as Garowe and Bosaso, while solar photovoltaic systems are increasingly utilized in peri-urban and rural areas. The study further found that wind energy remains largely untapped, despite favorable geographic conditions along the coastal belt. These results suggest that while renewable energy adoption is expanding, the energy mix remains heavily dependent on fossil

fuels, which directly affects the environmental sustainability dimension of energy sustainability.

Access Levels and Affordability

Findings from household and business surveys show relatively high access in urban areas but limited affordability. While most respondents reported having electricity access, monthly electricity expenditures were high relative to income levels. Table 2 illustrates access levels and average monthly electricity costs.

Table 2: Electricity Access and Average Monthly Cost

Indicator	Urban Areas	Rural Areas
Households with electricity access (%)	81.2	38.5
Average monthly electricity cost (USD)	45.6	28.4
Average daily supply (hours)	16.3	8.7

Source: Primary data, 2026

Results from household and business surveys showed that electricity access in urban areas was relatively high, whereas access in rural districts remained limited and inconsistent. Although most respondents reported having some form of electricity connection, the study found that affordability remains a major concern, with households spending a significant proportion of their monthly income on electricity. Businesses reported that high electricity costs constrained operational hours and profitability. These findings demonstrate that access alone does not equate to energy sustainability, as affordability and reliability remain uneven across districts, thereby weakening overall sustainability outcomes.

Role of Private Energy Companies

The study found that 92% of respondents receive electricity from private providers, underscoring the dominant role of the private sector. Table 3 summarizes perceptions of private energy company performance.

Table 3: Perceived Performance of Private Energy Providers

Performance Dimension	Good (%)	Fair (%)	Poor (%)
Energy availability	63.9	24.7	11.4
Affordability	18.6	34.2	47.2
Reliability	29.4	41.1	29.5
Customer service	35.8	39.7	24.5

Source: Primary data, 2026

The study established that private energy companies play a dominant role in electricity generation, transmission, and distribution in Puntland. Key informant interviews revealed that private firms have been instrumental in expanding access, particularly in the absence of strong public utilities. However, the findings also indicate that limited regulatory oversight has resulted in pricing variations and inconsistent service standards. While private-sector involvement has improved energy availability, it has not uniformly enhanced affordability or long-term reliability, highlighting a mixed impact on energy sustainability.

Challenges to Energy Sustainability

Institutional and Regulatory Challenges

Respondents identified weak regulation and limited government oversight as major barriers. As shown in Table 4, over two-thirds of respondents rated regulatory effectiveness as low.

Table 4: Institutional and Regulatory Challenges

Challenge Identified	Agree (%)	Neutral (%)	Disagree (%)
Weak energy regulation	71.4	18.9	9.7
Lack of tariff control mechanisms	68.2	21.1	10.7
Poor coordination among stakeholders	64.5	22.3	13.2

Source: Primary data, 2026

Findings revealed that weak institutional coordination and limited regulatory enforcement

significantly hinder energy sustainability in Puntland. Government officials acknowledged the absence of a fully operational regulatory authority capable of setting tariffs, enforcing standards, and coordinating stakeholders. As a result, energy sustainability strategies are implemented in a fragmented manner, reducing their effectiveness. This institutional gap was found to undermine the long-term reliability and affordability dimensions of energy sustainability.

Financial and Investment Barriers

Financial constraints were consistently ranked as severe. Table 5 presents respondents' views on financial barriers.

Table 5: Financial Barriers to Sustainable Energy

Financial Barrier	High Extent (%)	Moderate (%)	Low (%)
High cost of renewable technologies	74.8	17.5	7.7
Limited access to credit for energy projects	69.3	20.6	10.1
High household connection fees	61.9	25.4	12.7

Source: Primary data, 2026

The study found that high initial capital costs and limited access to affordable financing constrain investment in renewable energy technologies. Private energy providers reported difficulties accessing long-term financing for solar and hybrid systems, while donor-funded projects were often limited in scale and duration. Households and small businesses also reported inability to afford connection fees for cleaner energy systems. These financial constraints were found to slow the transition toward sustainable energy systems and perpetuate reliance on diesel-based generation.

Technical and Infrastructure Limitations

Technical and environmental challenges were also prominent. Respondents reported frequent outages

and environmental concerns related to diesel use (Table 6).

Table 6: Technical and Environmental Constraints

Constraint Identified	Agree (%)
Frequent power outages	57.6
Limited technical skills and maintenance	52.8
Environmental pollution from diesel use	66.1
Low public awareness on renewable energy	48.4

Source: Primary data, 2026

Technical findings revealed that aging infrastructure, limited grid interconnection, and shortage of skilled technical personnel adversely affect system reliability. Power outages were frequently reported by households and businesses, particularly during peak demand periods. Energy providers indicated that maintenance challenges and lack of spare parts reduced system efficiency. These technical constraints were found to directly compromise the reliability component of energy sustainability.

Environmental and Social Constraints

The study further identified environmental and social challenges, including continued reliance on diesel fuel, which contributes to air pollution and environmental degradation. Respondents also reported limited public awareness regarding renewable energy benefits and energy efficiency practices. Social factors such as income inequality and settlement patterns were found to influence access to sustainable energy solutions, thereby affecting equity within energy sustainability outcomes.

Existing Energy Sustainability Initiatives Government and Donor-Led Projects

The study found moderate implementation of government and donor-led initiatives, mainly solar installations for public facilities. Table 7 summarizes respondent awareness of such initiatives.

Table 7: Awareness of Government and Donor Energy Initiatives

Initiative Type	Aware (%)	Not Aware (%)
Solar-powered health facilities	62.5	37.5
Solar mini-grid pilot projects	54.2	45.8
Energy policy development	41.7	58.3

Source: Primary data, 2026

The findings show that government and donor-led initiatives have played a catalytic role in promoting renewable energy adoption in Puntland. Respondents identified solar-powered public facilities, pilot mini-grid projects, and policy development initiatives as key interventions. However, the study found that many projects operate as pilots with limited scalability, and coordination among implementing actors remains weak. While these initiatives contribute positively to energy availability and environmental sustainability, their long-term impact on affordability and reliability remains uncertain.

Community-Based Energy Solutions

Community-based initiatives were less widespread but showed positive localized outcomes. Private sector initiatives were the most extensive but focused mainly on cost recovery.

Table 8: Contribution of Energy Initiatives to Sustainability Outcomes

Initiative Type	Availability	Affordability	Reliability	Environmental Sustainability
Government/Donor	High	Low	Moderate	High
Community-based	Moderate	Moderate	Moderate	High
Private sector	High	Low	Moderate	Low-Moderate

Source: Primary data, 2026

Results indicate that community-based energy solutions, such as cooperative-managed solar systems, exist in selected districts but remain limited in coverage. Communities involved in such

initiatives reported improved reliability and reduced dependence on diesel generators. However, challenges related to management capacity and financial sustainability were noted. These findings suggest that community-based approaches have potential to enhance localized energy sustainability if supported by institutional and financial mechanisms.

Private Sector Initiatives

The study found that private-sector initiatives constitute the most extensive energy sustainability efforts in Puntland, particularly through solar-diesel hybrid systems and network expansion. Energy companies reported gradual integration of renewable technologies to reduce fuel costs and improve efficiency. Nevertheless, without supportive regulatory frameworks and incentives, private-sector initiatives were found to prioritize short-term cost recovery over long-term sustainability goals. As a result, their contribution to comprehensive energy sustainability remains partial.

In summary, the findings indicate that strategies to enhance energy sustainability (IV) including renewable energy adoption, private-sector participation, and donor-supported projects have improved energy availability in Puntland. However, affordability, reliability, and environmental sustainability (DV) remain constrained by institutional, financial, technical, and social challenges. These results underscore the need for integrated and context-sensitive energy sustainability strategies to accelerate progress toward SDG 7 in Puntland.

Discussion Of Findings

The findings of this study demonstrate partial alignment with Sustainable Development Goal 7, particularly with respect to energy access, while revealing substantial gaps in affordability, renewable energy penetration, and energy efficiency. SDG 7.1 emphasizes universal access to affordable, reliable, and modern energy services. Although the study found relatively high electricity access in urban areas of Puntland, especially

through private providers, affordability remains a major constraint, with households and businesses spending a disproportionate share of income on electricity. This implies that access without affordability does not fully satisfy SDG 7.1, a position also emphasized in global SDG monitoring reports (World Bank, 2023; IEA, 2024). Therefore, the study's findings suggest that Puntland's progress toward SDG 7.1 is quantitative rather than qualitative, focusing on connections rather than sustainable access.

Regarding SDG 7.2, which targets a substantial increase in the share of renewable energy, the findings indicate moderate but insufficient progress. The growing use of solar PV and hybrid mini-grids reflects positive movement toward renewable integration; however, diesel generation remains dominant. This limits environmental sustainability and exposes the energy system to fuel price volatility. Similar patterns have been observed in fragile and low-income settings where renewable energy adoption occurs incrementally rather than through structural transition (IRENA, 2023; UNDP, 2024). Consequently, the study confirms that renewable energy strategies in Puntland have not yet achieved the scale required to significantly transform the energy mix in line with SDG 7.2.

In relation to SDG 7.3 on energy efficiency, the findings show minimal progress, as efficiency improvements were neither systematically planned nor regulated. Frequent power outages, aging infrastructure, and limited technical capacity indicate inefficiencies across generation and distribution systems. This aligns with evidence that energy efficiency is often neglected in fragile contexts due to weak regulation and limited institutional capacity (IEA, 2023; AfDB, 2022). Overall, while Puntland demonstrates early-stage alignment with SDG 7, the study finds that energy sustainability strategies have not yet translated into comprehensive SDG 7 outcomes.

The study's findings largely align with existing literature on energy sustainability in fragile and

post-conflict states, while also revealing context-specific divergences. Similar to studies by Eberhard et al. (2021) and USAID (2022), this study found that private-sector dominance improves energy availability in the absence of strong public utilities. However, consistent with Jenkins et al. (2022), the findings also show that market-led provision without regulation exacerbates affordability and equity challenges. This reinforces the scholarly consensus that private-sector participation alone is insufficient to deliver sustainable energy outcomes.

In contrast to findings from relatively stable African countries such as Kenya and Morocco, where renewable energy strategies have significantly reduced costs and emissions (IRENA, 2024; Karekezi et al., 2022), the Puntland context reveals slower sustainability gains. This divergence can be attributed to contextual factors such as weak regulatory frameworks, limited access to finance, and post-conflict institutional fragility. While regional studies emphasize policy coherence as a driver of sustainability, this study demonstrates that contextual fragility mediates the effectiveness of similar strategies, highlighting the importance of localized analysis.

Furthermore, while global studies often report strong links between renewable energy adoption and environmental sustainability (Sovacool et al., 2020), this study found that environmental benefits in Puntland remain constrained by continued diesel dependence. This divergence suggests that partial renewable adoption does not automatically yield sustainability gains, particularly when energy transitions are uncoordinated. Thus, the study contributes to literature by empirically demonstrating how fragility conditions shape the outcomes of energy sustainability strategies.

The findings of this study carry significant implications for energy policy and practice in Puntland. First, the dominance of private energy providers underscores the urgent need for strengthened governance and regulatory frameworks. Without effective tariff regulation,

quality standards, and enforcement mechanisms, improvements in energy availability will continue to coexist with affordability and reliability challenges. Policymakers should prioritize establishing or strengthening energy regulatory institutions to align private-sector incentives with SDG 7 objectives (World Bank, 2023; UNDP, 2024).

Second, the persistence of financial barriers highlights the importance of innovative investment and financing mechanisms. The findings suggest that high upfront costs and limited access to credit constrain renewable energy expansion. Blended finance models, concessional loans, and risk guarantees successfully applied in other African contexts could accelerate renewable energy deployment and reduce reliance on diesel generation (AfDB, 2022; IRENA, 2023).

Third, the study emphasizes the role of community participation in enhancing sustainability. Although community-based energy initiatives were limited, where they existed, they demonstrated improved reliability and local ownership. This supports arguments in the literature that decentralized, community-engaged models enhance resilience and sustainability in fragile contexts (Rolffs et al., 2020; UNDP, 2023).

Strategies to enhance energy sustainability in Puntland

Based on the findings of this study and aligned with Sustainable Development Goal 7, several strategic interventions are proposed to enhance energy sustainability in Puntland. These strategies focus on strengthening policy and institutions, promoting renewable energy technologies, improving financing mechanisms, building human capacity, and enhancing community engagement.

Policy and Institutional Strengthening

The study revealed gaps in energy governance, particularly weak regulation of private electricity providers, inconsistent tariff structures, and limited enforcement of technical standards. To enhance energy sustainability, Puntland requires clear,

coherent, and enforceable energy policies that define roles, responsibilities, and accountability mechanisms within the energy sector. A comprehensive energy policy should prioritize affordability, renewable energy integration, and consumer protection while aligning national and regional objectives with SDG 7 targets.

Establishing an independent energy regulatory authority or strengthening existing institutions would improve oversight, promote transparency, and ensure compliance with safety, quality, and pricing standards. Such regulatory clarity would also create a predictable environment that attracts sustainable energy investments.

Given the dominance of private energy providers in Puntland, strengthening public-private partnerships are critical. The study found that while private sector involvement has improved access, the absence of structured PPP frameworks limits sustainability outcomes. Formalized PPP arrangements can leverage private-sector efficiency while ensuring public oversight, equitable access, and long-term planning. Well-designed PPPs can support infrastructure development, renewable energy expansion, and service delivery in both urban and peri-urban areas.

Promotion of Renewable Energy Technologies

The findings indicate that solar energy is the most viable renewable option for Puntland due to abundant sunlight and declining solar technology costs. Expanding solar mini-grids, particularly in rural and off-grid communities, would significantly improve access to reliable and clean electricity. Solar mini-grids can reduce dependence on diesel generators, lower energy costs over time, and enhance resilience in areas where grid extension is not feasible.

Puntland's long coastline presents substantial potential for wind energy development. The study suggests that wind energy remains underutilized despite favorable wind conditions. Investing in wind resource assessments and pilot wind projects could diversify the energy mix and complement

solar generation, particularly during periods of low solar output.

Hybrid energy systems that combine solar, wind, and limited diesel backup offer a practical transition pathway toward sustainability. The study found that hybrid systems improve reliability while gradually reducing fossil fuel dependence. Scaling up such systems would enhance energy security and align with SDG 7.2 by increasing the renewable energy share.

Financing and Investment Strategies

Limited financial resources were identified as a major constraint to energy sustainability in Puntland. Leveraging donor funding, climate finance mechanisms, and international development support is essential to bridge the financing gap. Accessing global climate funds can support renewable energy infrastructure, energy efficiency programs, and capacity-building initiatives while reducing the financial burden on local governments and consumers.

The study found that high upfront costs prevent many households from adopting renewable energy technologies. Introducing micro-financing schemes and pay-as-you-go models would enable low-income households to access solar home systems and clean energy solutions. Such approaches promote inclusivity and directly support SDG 7.1 on affordable energy access.

To encourage private-sector participation in renewable energy, the government should introduce targeted incentives such as tax exemptions, duty waivers on renewable energy equipment, and guarantees against political and regulatory risks. These incentives would reduce investment risks and stimulate private capital flows into sustainable energy projects.

Capacity Building and Human Resource Development

The study identified a shortage of skilled technical personnel as a barrier to effective energy system operation and maintenance. Expanding technical and vocational training programs in renewable energy technologies would build local expertise,

improve system reliability, and reduce dependence on external technicians.

Strengthening institutional capacity within energy-related ministries and agencies is equally important. Training policymakers and regulators in energy planning, regulation, and project management would improve policy implementation and monitoring, ensuring long-term sustainability of energy initiatives.

Community Engagement and Awareness

Community involvement was found to enhance acceptance, accountability, and sustainability of energy projects. Promoting local ownership models, such as cooperatives and community-managed mini-grids, can improve project longevity and ensure that energy solutions respond to local needs.

Limited awareness of the economic, environmental, and health benefits of renewable energy constrains adoption. Public education campaigns and community outreach programs can increase understanding of renewable energy advantages, encourage behavioral change, and support demand for clean energy solutions.

Conclusion

This study examined energy sustainability strategies in Puntland and their contribution to achieving SDG 7. The findings revealed improved electricity access driven largely by private-sector involvement, but persistent challenges related to affordability, renewable energy integration, energy efficiency, and governance. While Puntland has made progress toward SDG 7.1 in terms of access, limited advancements in renewable energy adoption and energy efficiency indicate partial achievement of SDG 7 targets. The study demonstrates that energy sustainability in Puntland remains constrained by institutional fragility, financial limitations, and technical capacity gaps. With appropriate policy reforms, investment in renewable energy, and strengthened institutional and community engagement, Puntland has significant potential to achieve a more sustainable,

affordable, and resilient energy system in the long term.

Recommendations

The government should prioritize establishing robust regulatory frameworks, clear energy policies, and effective oversight mechanisms to ensure affordability, reliability, and sustainability.

Energy sustainability goals should be mainstreamed into Puntland's broader development strategies to ensure coordinated planning and alignment with international commitments.

Stakeholders should expand solar, wind, and hybrid energy projects, particularly in underserved rural and peri-urban areas.

Creating an enabling environment through incentives and risk mitigation measures will enhance private investment in sustainable energy solutions.

Future studies should adopt longitudinal designs to assess changes in energy sustainability outcomes over time.

Rigorous impact evaluations are needed to measure the social, economic, and environmental effects of renewable energy projects in Puntland.

Limitations of the Study

The study relied on available institutional and self-reported data, which had limited completeness and accuracy.

Security constraints and limited access to some areas restricted data collection, potentially affecting coverage.

Given the contextual specificity of Puntland, the findings were not fully generalizable to other regions of Somalia or beyond.

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