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Energy Indicators for Sustainable Development in Sierra Leone: A Review

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Abstract

This review examines the application, challenges, and policy implications of energy indicators for sustainable development in Sierra Leone. The country continues to experience persistent energy access shortages and a high reliance on biomass as its primary energy source. Although global interest in monitoring progress toward Sustainable Development Goal 7 (Affordable and Clean Energy) is growing, the application of energy indicators to Sierra Leone's planning systems remains relatively narrow. The review, following PRISMA 2020 guidelines, synthesizes evidence from 63 peer-reviewed articles, policy briefs, and institutional documents from the period 2000-2025. The synthesis is based on a tripartite framework that considers the economic, social, and environmental dimensions of sustainability. The results reveal significant gaps in data, institutional capacity, and the absence of integrated monitoring frameworks. Even though national plans like the National Renewable Energy Action Plan and the Energy Sector Policy articulate sustainable energy targets, no specific performance measurement measures have been outlined. Evidence from other sub-Saharan countries, as well as international agencies such as the IAEA, IEA, and UNDESA, indicates that the adoption of a consistent yet context-appropriate energy indicator framework can improve the evidence-based formulation of energy policy. The review concludes with pragmatic recommendations that focus on institutionalizing energy indicators, simplifying data collection processes, and aligning Sierra Leone's energy policy with global sustainability standards.

Keywords: Energy: Sustainable Development: Economic: Environmental: Social: Sierra Leone.

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1.0 Introduction

Access to sustainable, modern, and dependable energy is essential for promoting economic development, alleviating poverty, enhancing health and educational outcomes, and ensuring environmental sustainability. This concept is highlighted in Sustainable Development Goal 7 (SDG 7), which aspires to achieve universal access to affordable, reliable, sustainable, and modern energy by the year 2030. Energy access serves as a crucial enabler that supports nearly every aspect of human and economic progress [1,2].

The significance of energy in promoting inclusive and low-carbon development has been underscored by various international organizations, including the International Atomic Energy Agency (IAEA), the World Bank, and the International Renewable Energy Agency (IRENA), through their support for Energy Indicators for Sustainable Development [3,4,5]. Sierra Leone, a West African country bordered by Guinea, Liberia, and the Atlantic Ocean, remains one of the nations with the lowest rates of electricity electrification globally. It is classified as a low-income country, with its economic framework heavily dependent on subsistence agriculture and the extraction of natural resources [6,7]. As of 2023, the electrification rate in the country was only 26%, with rural areas experiencing rates below 10%, which indicates that the majority of the population relies on traditional biomass for cooking [1,8].

The African Development Bank ranked Sierra Leone 46th out of 54 African countries on the Africa Infrastructure Development Index and 44th on the Electricity Access Index. This ranking reflects significant deficiencies in infrastructure, energy access, and reliability [9,10]. Despite the development of several national energy strategies, including the Energy Sector Reform Strategy, the National Renewable Energy Action Plan (NREAP), and the Integrated Resource and Resilience Plan (IRRP), there is little evidence that these plans are guided by standardized, disaggregated, or internationally recognized energy indicators [11,7]. This limitation prevents the country from assessing the effectiveness of its policies, tracking progress towards Sustainable Development Goal 7 and related energy indicators [12,13].

Moreover, research indicates that Sierra Leone lacks essential energy indicators related to affordability, efficiency, environmental impacts, and gender equity [4,14]. These deficiencies are not unique to Sierra Leone; however, they are particularly urgent given the country's vulnerable energy infrastructure and high levels of energy poverty. This review paper offers a comprehensive overview of the current status, shortcomings, and potential pathways for the implementation of Energy Indicators for Sustainable Development (EISD) in Sierra Leone, a country characterized by limited energy access and inadequate data infrastructure [17,18]. The paper aims to assess the application of EISD at the national level, pinpoint institutional, policy, and data-related constraints, examine lessons learned from successful implementations in comparable countries, and suggest strategic recommendations for the incorporation of EISD into the energy policy and planning frameworks of Sierra Leone [19,20].

The analysis is structured around four primary research questions that address the present condition of energy indicators, challenges in implementation, exemplary practices globally, and the potential for establishing a national EISD framework by the IAEA and Tracking SDG 7 methodologies [3,2,21]. This study is both

pertinent and timely, as it addresses a significant knowledge deficiency in the literature concerning energy governance case studies for Sierra Leone and provides a systematic method for evaluating advancements towards energy-related Sustainable Development Goals [22,23]. Furthermore, it promotes evidence-based decision-making by presenting actionable recommendations to enhance energy data infrastructure, strengthen institutional coordination, and align national energy policies with global sustainability objectives [24,25]. Additionally, the research delineates the comprehensive developmental application of Energy Indicators for Sustainable Development (EISD) by connecting energy indicators to climate resilience, equitable energy access, and inclusive development, particularly for rural communities and women [26,27,28]. By providing analysis tailored to specific contexts and offering recommendations relevant to policy, this review aids in the realization of Sierra Leone's Nationally Determined Contributions (NDCs), Agenda 2063, and the ECOWAS Renewable Energy Policy (EREP) [29,30,31]. Consequently, the article acts as a vital resource for national energy planners, development agencies, and academic researchers, effectively bridging the gap between global energy tracking efforts and their application at the national level in low-income countries [32,33,34].

1.1 Overview of Energy Indicator for Sustainable Development (EISD)

Energy Indicators for Sustainable Development (EISD) serve as frameworks designed to assess the sustainability of energy systems across economic, social, and environmental dimensions. This EISD framework was collaboratively developed by the International Atomic Energy Agency (IAEA), the International Energy Agency (IEA), and the United Nations Department of Economic and Social Affairs (UNDESA) to assist policymakers in tracking advancements towards Sustainable Development Goal 7 (SDG 7) and related sustainability objectives [3,2,1]. The Energy Indicators for Sustainable Development (EISD) encompass key metrics related to energy access, affordability, energy efficiency, the proportion of renewable energy resources, greenhouse gas emissions, and energy tariffs. These indicators form the essential basis for informed decision-making, ensuring that energy policies foster both developmental progress and environmental sustainability [4,5,35].

1.2 Relevance of EISD to SDG 7 and broader sustainability

SDG-7, centered on affordable and clean energy, directly, curtails reliance on costly and polluting fuels, thereby addressing poverty (SDG-1), while facilitating clean energy for healthcare services (SDG-3) and sustainable urbanization (SDG-11) through reliable infrastructure and power. It also aligns with responsible consumption and production (SDG-12), with lesser consumption of resources and reduced negative effects on ecosystem. Indirectly, SDG-7 supports all kinds of agricultural practices that promotes sustainability (SDG-2), elevates educational quality (SDG-4), empowers women by creating Jobs (SDG-5), facilitates clean water access (SDG-6), drives economic expansion (SDG-8), spurs technological innovation (SDG-9), advances social equality (SDG-10), aids climate change mitigation (SDG-13), safeguards biodiversity (SDG-14, SDG-15), and fosters peace, justice, and collaborative partnerships (SDG-16, SDG-17). This interconnectedness underscores the importance of SDG-7 [74]. Access to and the sustainability of energy are intrinsically linked to various Sustainable Development Goals (SDGs). Specifically, SDG 7 aims for universal access to energy that is affordable, reliable, and clean, while also providing significant co-benefits for health (SDG 3), education

(SDG 4), gender equality (SDG 5), and climate action (SDG 13) [13,12]. EISD offers a crucial framework for tracking progress and ensuring that national initiatives are in harmony with global objectives [16,36]. Research has demonstrated that EISD frameworks enable countries to achieve greater policy coherence, enhance data quality, and improve investment planning [37,38]. Indicators such as energy intensity relative to GDP, emissions per unit of energy, and household energy expenditure ratios serve to illuminate inefficiencies and social inequalities [4,8]. Electricity expansion through mini-grids or stand-alone systems could help developing countries to address electricity access challenges in a climate-friendly manner and sustain livelihoods. Like other types of infrastructure, however, modern electrical capacity (grid, off-grid, and mini-grid) is vulnerable to climate change to varying extents [19].

1.3 Global Applications of EISD: Case Studies

In Mexico, EISD indicators were aligned with national development plans to assess energy intensities, emissions, and energy affordability and revealed transport and household energy consumption structural inefficiencies [38].

In Brazil, the Energy Indicators for Sustainable Development (EISD) approach was implemented to diversify the energy mix by optimizing the utilization of hydropower and biofuels, while also improving energy efficiency and cost-effectiveness [36]. Researchers also identify that a number of energy policy options on both demand and supply sides, on the demand side, policy options for energy efficiency and end-use efficiency include reduction of energy intensity in the industrial sector, and transport efficiency. They also discuss the potential impact of a fund to improve energy affordability for the poor. Supply side policy options for Brazil include: small-scale hydroelectric; wind power; solar photovoltaic; ethanol (as automotive fuel); sugarcane bagasse cogeneration; and natural gas-fired combined heat and power (CHP) plants. Moreover, the indicators highlight interlinkages among energy, economic, social and environmental data in a coherent way. The authors use time-series and cross-sectional data to support their analyses and assessments [75].

The recent history of Cuba, the largest Small Island Developing State, provides a rather unique case. After the dissolution in 1989 of Cuba's traditional trade agreements with the former Soviet Union, the country's favorable terms for importing crude oil and petroleum products ended [76]. The adjustments that Cuba had to make in its energy policies are detailed by D. Pérez, I. López and I. Berdellans [77]. The authors use the ISED to evaluate the effectiveness of energy policies, including measures to reduce energy import dependence, increase the share of renewable energy resources in the total supply mix, and improve energy efficiency.

Lithuania utilized EISD to reshape its energy policy in the wake of nuclear decommissioning, focusing on renewable energy sources and decreasing reliance on imports [37]. They provide an interesting illustration of a country faced with limited indigenous energy resources and an ageing nuclear power plant in an increasingly globalized economic environment. D. Streimikiene [37] describes efforts at applying the ISED methodology to analyze energy trends and to set energy priorities and goals. These applications result in interesting policy recommendations for Lithuania, suggesting how to reduce energy intensity and increase end-use efficiency, as well as guaranteeing energy security and reaching a balance between affordability for the poor and end-use

efficiency.

Slovakian used the ISED system to assess the country's energy system and to identify national energy priority areas. The trends resulting from energy policies implemented before the country's accession to the European Union in 2004 are analyzed in detail. The ISED implementation results in interesting policy recommendations for Slovakia, suggesting how to improve energy pricing policies, reduce energy intensity and guarantee energy security [78].

Ghana, Kenya, and Rwanda have also made significant progress by integrating EISD into their national planning processes, which has improved transparency and enhanced the attractiveness of green investments [15,16,13]

1.3 Energy Situation in Sierra Leone

Sierra Leone continues to be recognized as one of the most impoverished nations globally regarding energy access, with a national electrification rate of merely 26% and less than 10% in rural areas [1,8]. The heavy reliance on biomass and the high costs associated with importing fossil fuels lead to the use of inefficient and polluting energy sources, particularly in off-grid communities [7,14]. Several national initiatives, such as the Energy Sector Reform Strategy, the National Renewable Energy Action Plan (NREAP), and the Integrated Resource and Resilience Plan (IRRP), have been established to improve energy accessibility and sustainability; however, the absence of standardized energy indicators hampers effective monitoring and accountability [39,11,12]. The primary obstacle remains data collection, as institutional fragmentation restricts comprehensive cross-sectoral analysis. There is a significant lack of documentation regarding energy-related indicators within the country's development planning, and energy statistics are neither consistently updated nor disaggregated [10] [40]. Currently, Sierra Leone lacks a national framework for Energy Indicators for Sustainable Development (EISD), in contrast to its regional counterparts. The absence of indicators on clean cooking, gender-specific energy access, and household affordability hinders the implementation of evidence-based intervention [14,41,42].

2.0 Materials and Methods

This review employed a transparent and methodical strategy to assess the application and significance of energy indicators for sustainable development in Sierra Leone. The research design incorporated bibliometric screening, qualitative synthesis, and thematic content analysis to cultivate a comprehensive understanding of the subject matter. This mixed-methods strategy is particularly effective for investigating domains such as energy governance, sustainability, and policy performance [43]. The review adhered to a series of protocols grounded in the PRISMA 2020 guidelines, which advocate for transparency and systematic reporting in literature reviews [44]. The analytical framework was constructed upon the tripartite model of sustainable development, emphasizing the economic, social, and environmental dimensions [45,46]. The evaluation of energy indicators was associated with Sustainable Development Goal-7 (Affordable and Clean Energy) and pertinent national policy documents, including the National Renewable Energy Action Plan, the Energy Sector Policy, and Sierra Leone's Medium-Term National Development Plan (2019–2023) [11,47]. A comprehensive literature search

was performed utilizing a variety of academic and institutional sources to collect both global and local perspectives. The academic databases that were explored included Scopus, Web of Science, ScienceDirect, Google Scholar, African Journals Online (AJOL), and PubMed, thereby ensuring a comprehensive coverage of various topics. Additionally, institutional repositories such as the World Bank Open Knowledge Repository, the International Energy Agency (IEA), the IRENA Statistics Database, the UN Data Portal, Sierra Leone's Ministry of Energy, and Statistics Sierra Leone were consulted to identify pertinent grey literature and policy documents [1,12,8]. The literature searches encompassed publications from January 2000 to April 2025. The keyword combinations utilized included phrases such as "energy indicators," "sustainable energy metrics," "sustainable development," "Sierra Leone," "West Africa," "SDG 7," "energy access," and "renewable energy," with Boolean operators employed to enhance the specificity of the results [48]. The inclusion criteria specified that articles and reports must: (1) concentrate on energy indicators relevant to sustainable development; (2) offer empirical data, conceptual analysis, or policy evaluations that apply to Sierra Leone or comparable sub-Saharan African contexts; (3) be published in English between 2000 and 2024; and (4) examine the interplay between energy systems and socio-economic or environmental outcomes. Documents were excluded if they were excessively technical without addressing sustainability, failed to mention energy indicators or development metrics, or were duplicates lacking accessible full texts [49] [50]. The screening procedure comprised four primary phases: identification, elimination of duplicates, screening of titles and abstracts, and comprehensive review of full texts. Reference management was conducted utilizing Zotero, which facilitated the efficient tracking and organization of the literature. Beginning with 412 records, duplicates and irrelevant entries were eliminated, culminating in 63 high-quality articles and reports for the final synthesis. This procedure adhered to rigorous screening protocols that conform to the best practices in systematic reviews [51,50]. Data extraction was performed using a structured coding framework to gather essential variables, including publication year, author(s), type of publication, types of energy indicators discussed, relevance to Sierra Leone's energy and policy context, the sustainability aspects addressed (economic, social, or environmental), linkages to the Sustainable Development Goals (SDGs), particularly SDG 7, and documented data limitations or policy implications. This methodology facilitated the comparison and organization of evidence based on the pillars of sustainable development. Indicators were assessed and mapped using widely recognized frameworks, especially those established by the IAEA (2005), UNDESA (2023), and IEA (2024), which are frequently employed in global and regional energy assessments [46,52,53]. To ensure quality and reliability, a quality appraisal was conducted using standard evaluation tools. Peer-reviewed journal articles were evaluated with the Critical Appraisal Skills Program (CASP) checklist, which examines research design, validity, and applicability (CASP, 2018). The evaluation of grey literature and institutional reports was conducted using the AACODS checklist [54], which examines factors such as authority, accuracy, coverage, objectivity, date, and significance. Only those sources that fulfilled the minimum quality criteria were retained, thereby ensuring that the evidence base of the review remained robust and pertinent to policy [55]. Ethical considerations were minimal since the study did not engage with human subjects or involve the collection of primary data. All utilized materials were sourced from publicly available and ethically published resources. Every intellectual and scholarly contribution has been appropriately cited throughout the review, adhering to the principles of academic integrity and transparency [56].

3.0 Results

Sierra Leone is a country with a rapidly growing economy and a population of over 7 million people. The country is heavily reliant on fossil fuels, particularly oil, which accounts for over 90% of its energy consumption. This reliance on fossil fuels has led to concerns about the country's energy security and the impact of climate change. Sierra Leone is an energy-dependent country and needs to put more effort into increasing energy security, energy efficiency, and renewable energy. Due to its almost complete energy dependent nature, the country is spending a lot of money on the importation of energy products, hence the Current Account Deficit (CAD) is very high, which affects the GDP of the country immensely. To a large extent, this affects the economy very badly. This indicator alone, Energy Security has indirect force on many other indicators such as energy efficiency (ECO 3), share of energy and electricity (ECO 13), and energy and user prices (ECO 14). Energy indicators play a fundamental role in tracking progress toward both global and national development targets, particularly Sustainable Development Goal 7, which emphasizes affordable and clean energy access [57] [53]. In Sierra Leone, however, the application of energy indicators remains fragmented and underdeveloped [47] [11]. While the government has introduced strategic frameworks such as the National Renewable Energy Action Plan and the Electricity Sector Reform Roadmap, these initiatives lack comprehensive, multidimensional indicator systems necessary for effective implementation and performance assessment [6] [58]. Current national reporting on energy tends to focus narrowly on electricity access, primarily household connection rates, while other critical dimensions, including energy affordability, reliability, sustainability, and equity, are insufficiently represented [13,59,21]. The absence of integrated indicators that capture environmental, economic, and social dimensions restricts Sierra Leone's ability to engage in evidence-based policymaking and conduct holistic evaluations of sustainability [60,61]. Furthermore, limited efforts to disaggregate energy data by region, gender, or income level weaken assessments of energy equity [62]. A review of over sixty peer-reviewed articles, technical reports, and national documents identified several key energy indicators essential for Sierra Leone: population level electricity access[8], the share of renewables in total energy consumption [13], per capita electricity consumption [53], energy intensity (MJ/USD of GDP) [63], electricity affordability relative to household income [12], system reliability such as power outage frequency and duration [40], and carbon dioxide emissions per kilowatt-hour [35]. These align with the Energy Indicators for Sustainable Development (EISD) framework and established monitoring tools such as the Multi-Tier Framework [64]. Despite this, the practical application of these indicators in Sierra Leone is inconsistent. Challenges include fragmented data sources, weak institutional collaboration, and limited technical expertise [2] [65]. For instance, while data on electricity access may be updated intermittently, information on system reliability and affordability is rarely gathered systematically [66] [67]. Many systemic barriers impede the implementation of energy indicators in Sierra Leone. First, there are significant deficiencies in data availability and quality: the country lacks real-time, disaggregated data on energy consumption, fuel sources, grid reliability, and emissions [59,13,1]. Second, institutional coordination is weak. Various entities, including the Ministry of Energy, Statistics Sierra Leone, the Electricity Distribution and Supply Authority (EDSA), and the Electricity Generation and Transmission Company (EGTC), operate with overlapping mandates and seldom share data or align their monitoring frameworks [11,58]. Third, there is a shortage of skilled professionals and financial resources necessary to establish and maintain robust energy data systems [18,47,68]. Fourth, energy indicators are rarely integrated into

policy cycles, thereby limiting their influence on budgeting, regulation, and long-term planning [6,69]. These gaps mirror challenges observed in other low-income and fragile states [32,70].

4.0 Conclusion

Regionally, Sierra Leone lags behind several West African counterparts in institutionalizing robust energy monitoring frameworks. Ghana, for example, publishes comprehensive annual energy statistics and maintains a dedicated energy commission [71,47]. Kenya utilizes geospatial information systems for rural electrification planning [72], and Senegal's National Agency for Renewable Energies supports indicator-driven policy monitoring [13]. These countries benefit from international partnerships and targeted donor support, which have fostered technical capacity and the adoption of harmonized indicators [13,1]. To address these deficiencies, Sierra Leone needs to implement institutional reforms, enhance data governance, and develop the capacity to adapt global frameworks such as EISD. It is also important to develop policies on energy indicators of sustainable development in Sierra Leone. These policies should focus on promoting the use of renewable energy sources, such as solar, hydro, biomass, bio-fuel and encouraging energy efficiency measures. Additionally, policies should aim to reduce the country's reliance on fossil fuels and promote the development of a diversified energy mix. One potential policy is to establish a renewable energy fund to support the development of renewable energy projects in the country. This fund could be used to provide incentives for businesses and individuals to invest in renewable energy projects, such as solar panels or mini-hydro. Additionally, the fund could be used to support research and development of new renewable energy technologies. Another policy is to implement energy efficiency measures for buildings and industries. This could include providing incentives for businesses to invest in energy-efficient equipment and buildings, as well as implementing tax cuts on the importation of energy-efficiency equipment.

Finally, policies should aim to promote the development of a diversified energy mix, including the use of natural gas and other alternative energy sources. This could involve investing in infrastructure to support the development and upgrade of the transmission, distribution and supply of our energy systems, as well as promoting the use of alternative energy sources, such as biofuels. Insights from Rwanda and Ghana indicate that the success of adopting simplified dashboards and involving stakeholders from various sectors is vital [16] [15]. Internationally, advanced economies such as Sweden, Germany, South Korea, and Costa Rica have established energy indicator systems that encompass interrelated dimensions of energy efficiency, carbon intensity, equity, and sustainable development [53]. Sierra Leone's progress toward such integrated, evidence-based systems remains limited, with existing frameworks and good intentions often undermined by persistent implementation challenges. There remain challenges in providing a comprehensive overview of Sierra Leone's energy situation, highlighting the need for sustained efforts to enhance data quality, availability, reliability, and accessibility. To improve future projects, greater focus should be placed on expanding the coverage of household surveys primarily on energy to accurately capture the quality of electricity and clean cooking services. Equally important, Sierra Leone needs to strengthen its statistical capacity to produce accurate energy balances, especially given the challenges in capturing disaggregated data on energy intensity indicators. Enhancing data collection and analysis is crucial for improving energy planning and advancing sustainable energy development in the country.

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