Support to the Energy Sector Reform in Lesotho: Technical Guidelines for Off-Grid Products

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Disclaimer

This report is prepared by the Non Key Expert 2 (Mr Lucky Ngidi) based on information collected from various identified stakeholders and also provided by the Client (The Government of Lesotho), where necessary, third parties, as a result the report results and analysis will be based on that information (including the information sourced from various online sources and scholars).

The accuracy of the information provided may have an impact on the conclusions reached and on the accuracy of the recommendations. The higher degree of accuracy of the information provided will directly affect the certainty of the findings and recommendations provided in the Report.

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LIST OF ACRONYMS

IRENA	International Renewable Energy Agency
EIA	Environmental Impact Assessment
UNSD	United Nations Statistics Division
WB	World Bank
WHO	World Health Organisation
SHS	Solar Home System
SDG	Sustainable Development Goals
ESMAP	Energy Sector Management Assistance Program
LEC	Lesotho Electricity Company
LHDA	Lesotho Highlands Development Authority
REU	Rural Electrification Unit
DoE	Department of Energy
LEWA	Lesotho Electricity and Water Authority
NSDP	National Sustainable Development Plan
REFIT	Renewable Energy Feed In Tariff
LHWP	Lesotho Highlands Water Project
IFC	International Finance Corporation
UNIDO	United Nations Industrial Development Organization
IEC	International Electrotechnical Commission
REAP	Renewable Energy Access Project
GoL	Government of Lesotho
EMP	Energy Management Platform
SADC	Southern African Development Community
MEPS	Minimum Energy Efficiency Performance Standards
SEFA	Sustainable Energy For All
UNDP	United Nations Development Programme
REA	Rural Electrification Agency
LEGCO	Lesotho Electricity Generation Company

LSI	Lesotho Standards Institution
LNU	Lesotho National University
LNU-ERC	Lesotho National University Energy Research Centre
R&D	Research and Development
NGO	Non-Government Organisations
GEF	Global Environmental Facility
ACE	African Clean Energy
CIGS	Copper Indium Gallium Selenide
AC	Alternating Current
DC	Direct Current
Ni-Cd	Nickel-cadmium
LED	Light Emitting Diode
CCTV	Closed-Circuit Television
PV	Photovoltaic
LPG	Liquefied Petroleum Gas
SWH	Solar Water Heater
LERC	Lesotho Energy Research Centre
SACREEE	SADC Centre for Renewable Energy and Energy Efficiency.
SANS	South African National Standards
CEC	Clean Energy Credits
BESS	Battery Energy Storage System
EELSP	Energy Efficiency Labeling and Standards Program
GSA	Ghana Standards Authority

1 Executive Summary

Access to reliable and sustainable energy is a cornerstone of socio-economic development and improved quality of life. Lesotho, like many countries, faces the dual challenges of energy access and environmental sustainability. In response, the proposed technical standards and labelling system for off-grid energy solutions are designed to guide the Government of Lesotho in addressing these challenges.

Lesotho's energy landscape is characterized by a mix of on-grid and off-grid solutions, with significant portions of the population lacking access to the national electricity grid. Off-grid energy solutions, including solar home systems, mini-grids, and other renewable technologies, hold immense potential in addressing this energy access gap. However, ensuring the quality, performance, and environmental sustainability of these solutions is of paramount importance.

This assignment seeks to develop the Technical Guidelines or Standards for Labelling Off-Grid Solutions. The Specific Objectives of the assignment are outlined below:

- Engage stakeholders to understand the current state of labels and standards and make recommendations on the same;
- Review the energy related standards in general and specifically;
- Review, harmonize and adopt for Lesotho (where relevant) the SADC member States' Minimum Energy Performance Standards (MEPS) specifying all necessary performance requirements for an energy-using device, that effectively limits the maximum amount of energy that may be consumed by a product in performing a specified task;
- Review and improve existing practices in the development and adoption of labels and standards, and develop new ones where none exist;
- Review existing standards and their implementation including proposing changes to them and support their upgrading; and
- Develop and adopt standards based on best practices including advising on the harmonization at regional, continental, and global levels.

The proposed technical standards and labelling system for off-grid energy solutions in Lesotho hold the potential to address energy access challenges, promote environmental sustainability, and stimulate market growth. This initiative will require collaboration among government agencies, regulatory bodies, industry stakeholders, and consumer advocates to ensure its successful implementation. Below is the executive summary of the assignment outcomes aligning to each specific objective.

1.1 Stakeholder Engagements of the current state of labels and standards

The Stakeholder Engagements on the current state of the labels and standards in Lesotho was physically done from 10 to 15 September, some of the meetings were done virtually. One of the key findings was that there are no labelling standards currently available in Lesotho, more specifically for off-grid products, and that also includes a fully established regulatory framework to enforce compliance on off-grid products. The report has identified some gaps

and made recommendations for various government ministries, agencies, as well as the market participants as follows:

- **Comprehensive Off-Grid Energy Policy:** Lesotho needs to develop a comprehensive off-grid energy policy that outlines clear goals, strategies, and timelines for the development and implementation of technical standards and labelling for off-grid solutions. This policy should encompass a broad spectrum of off-grid technologies, including solar home systems, mini-grids, and other renewable energy solutions;
- **Stakeholder Engagement:** There must be engagements with a wide range of stakeholders, including government agencies, industry associations, manufacturers, consumers, and development partners. Collaborative efforts are essential for the successful development and implementation of technical standards and labelling programs;
- **Regulatory Framework:** The Government of Lesotho must establish a clear regulatory framework that defines the roles and responsibilities of regulatory bodies, enforcement agencies, and other relevant entities. This framework should include procedures for the development, review, and enforcement of technical standards and labelling requirements;
- **Harmonization with Regional Standards:** Align Lesotho's technical standards and labelling requirements with regional and international best practices to facilitate trade and ensure compatibility with products from neighboring countries. The Southern African Development Community (SADC) standards can serve as a useful reference;
- **Capacity Building and Training:** Invest in capacity building and training programs for regulatory authorities and local manufacturers. Building technical expertise is crucial for the development, enforcement, and compliance monitoring of standards and labelling;
- **Consumer Awareness and Education:** Implement consumer awareness and education programs to inform the public about the benefits of off-grid solutions, products and how to interpret energy labels. Educated consumers are more likely to make informed choices and embrace off-grid products;
- **Data Collection and Reporting:** Develop a robust system for data collection, analysis, and reporting on the energy performance of off-grid technologies. This data will be instrumental in assessing the impact of technical standards and labelling, enabling evidence-based policy adjustments;
- **Incentives and Penalties:** Consider introducing incentives for manufacturers and consumers to promote compliance with technical standards and labels, such as tax incentives or subsidies for energy-efficient products. Simultaneously, establish penalties for non-compliance to deter the distribution of substandard products;
- **Review and Revision:** Periodically review and update the technical standards and labelling requirements to keep pace with technological advancements and changing market dynamics. Regular consultation with stakeholders is essential in this process; and

- **Sustainability and Inclusivity:** Ensure that the development of technical standards and labelling promotes sustainability and inclusivity, addressing gender disparities and environmental considerations. These aspects should be integrated into the overall policy framework.

1.2 Review the energy related standards in general and specifically

Implementing technical standards and labelling for off-grid energy solutions in Lesotho is essential to ensure the quality, safety, and performance of these technologies. To successfully integrate these measures into Lesotho's energy landscape, the following recommendations should be considered:

- **Develop Comprehensive Technical Standards:** Lesotho should develop detailed technical standards specific to off-grid energy solutions, addressing components, system design, and performance metrics. These standards should align with international best practices and consider local conditions. Through the assignment, the Government of Lesotho is going the right way as this is yielding a technical guideline which can be later adopted as a standard by the Lesotho Standards Institution;
- **Establish Regulatory Framework:** Create a regulatory framework that outlines the roles and responsibilities of various stakeholders, including government agencies, regulatory bodies, and industry associations. This framework should detail the approval process for off-grid products and systems;
- **Capacity Building:** The Government of Lesotho should invest in training programs and capacity building for government officials and technicians involved in testing, inspection, and certification of off-grid technologies. This will ensure that they have the necessary expertise to enforce technical standards;
- **Accreditation of Testing Laboratories:** Develop a system for accrediting testing laboratories to ensure the accuracy and reliability of performance tests. Accredited labs can provide unbiased and credible assessments of off-grid products, fostering consumer trust;
- **Consumer Education and Awareness:** Launch consumer education campaigns to increase awareness of the benefits of off-grid energy solutions and the importance of choosing products with quality labels. Educated consumers are more likely to make informed choices;
- **Market Surveillance and Enforcement:** Implement a robust market surveillance and enforcement program to monitor compliance with technical standards and labelling requirements. This should include random product sampling and inspections to identify non-compliant products;
- **Incentives for Compliance:** Introduce incentives for manufacturers and distributors who consistently comply with technical standards and labelling requirements. Incentives may include expedited approvals or access to financial support for product development;
- **Collaboration with International Partners:** Collaborate with international organizations and neighboring countries to harmonize technical standards and

labelling schemes. This will facilitate cross-border trade of off-grid products and ensure consistency in quality;

- **Pilot Programs:** Launch pilot programs to assess the feasibility and effectiveness of implementing technical standards and labelling in specific regions or sectors. These pilot programs can serve as valuable learning experiences before full-scale implementation;
- **Monitoring and Evaluation:** Establish a monitoring and evaluation mechanism to assess the impact of technical standards and labelling on the off-grid market. Regularly review and update standards to keep pace with technological advancements and changing consumer needs;
- **Research and Development Incentives:** Encourage research and development in off-grid technologies by providing incentives, such as tax breaks or grants, to manufacturers and innovators. This will drive the development of more efficient and cost-effective solutions;
- **Public-Private Partnerships:** Foster collaboration between government agencies and private sector stakeholders, including manufacturers, distributors, and industry associations. Public-private partnerships can accelerate the adoption of standards and labels

1.3 Gap Analysis Report

The chapter on Gap Analysis Report endeavours to cast a spotlight on the landscape of off-grid products and services currently available in Lesotho. It examines the existing products, technologies, and initiatives designed to alleviate energy poverty and their distribution and adoption across the nation. Furthermore, it delves into the regulatory and policy frameworks governing the off-grid energy sector, assessing their efficacy and potential for improvement. The report also scrutinizes the environmental and socio-economic impacts of off-grid solutions in the Lesotho context, emphasizing the need for sustainability.

As Lesotho embarks on its journey towards universal energy access, this Gap Analysis Report aims to elucidate the challenges and constraints that currently impede progress. It will outline the gaps and deficiencies in off-grid energy products and services that must be addressed. Equally important, it will underscore the successes and innovations that can be built upon to pave the way forward.

The report draws upon a comprehensive analysis of data, consultations with stakeholders, and a synthesis of international best practices to provide recommendations for policymakers, development partners, investors, and the private sector. These recommendations are geared towards fostering an enabling environment for the growth of off-grid energy solutions in Lesotho and ensuring that the benefits of reliable, clean energy are realized by all, regardless of their geographic location.

This Gap Analysis Report represents a critical step towards the attainment of sustainable energy access in Lesotho. By identifying and addressing the existing gaps in the off-grid energy sector, the Government of Lesotho can work collectively to illuminate homes, empower businesses, and energize communities throughout the Kingdom. The future of Lesotho's

energy landscape is one of progress, and this report serves as the map to guide us on this transformative journey.

The gap analysis approach for the purposes of this report is based on the following factors:

- Energy Policy
- Environmental Policy
- Trade and Industry Policy
- Regulation
- Market Participants
- Lesotho Electricity Company
- Lesotho Electricity Generation Company
- Lesotho Grid Code
- Research and Development
- Education
- Communities

The analysis provides a detailed synopsis on the gaps identified in Lesotho's off-grid products market, it made critical recommendations on the gaps identified with proposed solutions to improve those shortcomings for the Government of Lesotho and relevant stakeholders. At high level, the findings reveal insufficient participation and collaboration regarding off-grid products. It was also noted that there is non-existence of financial models from the banking institutions to increase access to the products for the less fortunate.

1.4 Review, harmonize and adopt for Lesotho (where relevant) the SADC member States' Minimum Energy Performance Standards (MEPS)

As part of the assignment, the GoL has recently adopted the SADC MEPS, and needed a review to align with the context of the country and to identify any deficiencies that needs to be addressed in the implementation of the MEPS. The MEPS review for the context of Lesotho indicated that the document lays a good foundation for energy performance of the products, the document may need to be reviewed annually assessed to be abreast of the technology developments. The Lesotho Government will need to develop a framework for operationalizing the MEPS in the country as it has already been adopted as a country standard. There needs to be development of procedures for certification of buildings and products for energy efficiency minimum requirements. The procedures must include the training and development requirements for the locals to do the certifications, monitoring and evaluation.

The challenges and areas for improvement for the MEPS are:

- Enforcement and Compliance
- Consumer Awareness
- Data Collection and Reporting
- Product Availability and Affordability

Some general recommendations regarding the implementation of MEPS in Lesotho based on best practices and the importance of energy efficiency standards are:

- Harmonize with Regional Standards
- Regular Updates and Reviews
- Enforcement and Compliance
- Public Awareness and Education
- Capacity Building
- Labeling Programs
- Incentives and Financing
- Research and Development
- Collaboration with Industry
- Monitoring and Evaluation.

The SADC Minimum Energy Performance Standards if implemented correctly and diligently may present a significant step in promoting energy efficiency within the Lesotho. While there have been positive outcomes, including energy savings and reduced environmental impact, challenges related to enforcement, consumer awareness, data collection, and product availability may persist. Implementing the recommendations provided can help strengthen MEPS and further enhance energy efficiency efforts within the Kingdom of Lesotho.

1.5 Review and improve existing practices in the development and adoption of labels and standards, and develop new ones where none exist

Following a thorough assessment and evaluation of information available, as well as various industry stakeholder engagement, it was reported that Lesotho subscribes to IEC standards, but it was evident that there was no formal process for adoption of labels that is documented in the country, as a result, part of ensuring that the outcomes of this work are abreast of the prevailing developments internationally and regionally, the case studies from four (4) countries was used to provide a valuable approach to a broader perspective and enhance the depth of recommendations to be made. Due to the time limitations of the assignment, case studies will be chosen from 4 countries, these are South Africa, Liberia, Ghana and Australia. This exercise assisted in providing a vast knowledge and perspectives from various regions and globally, to ensure that that the proposed guidelines are aligned with the international practices. Some results drawn from the case studies are as follows:

South Africa: South Africa has made significant progress in implementing labelling standards for off-grid technologies. The Energy Efficiency Labeling and Standards Program (EELSP) has been instrumental in raising consumer awareness and incentivizing the purchase of energy-efficient products. To maintain this momentum, it is crucial for South Africa to continue strengthening the enforcement of standards, expanding the range of labeled products, and fostering partnerships with manufacturers and retailers.

Liberia: In Liberia, labelling standards for off-grid technologies are still in their early stages. However, the Liberia Electricity Corporation (LEC) has started implementing energy labeling for appliances, and this initiative holds promise for enhancing energy efficiency and reducing

electricity consumption. To ensure the effectiveness of labelling standards in Liberia, the government should continue to support this program, conduct public awareness campaigns, and promote the adoption of energy-efficient products.

Ghana: Ghana has also recognized the significance of labelling standards and has implemented the Ghana Standards Authority (GSA) Energy Efficiency Label. This initiative is crucial in promoting energy efficiency and reducing energy costs for consumers. Ghana's government should focus on regular monitoring and enforcement of standards, as well as expanding the labeling program to cover a wider range of appliances. In addition, awareness campaigns should be conducted to educate consumers about the benefits of energy-efficient products.

Australia: Australia stands as an example of a country with well-established and comprehensive labelling standards through programs like the Energy Rating Label. The Australian experience demonstrates that strong labelling standards are effective in influencing consumer choices and driving market transformation toward energy-efficient products. To maintain this success, Australia should continue to update and expand the standards to reflect technological advancements, conduct consumer education programs, and encourage innovation in energy-efficient technologies.

Lessons were drawn from these cases to adopt an approach to the framework used for the proposed technical guideline for off-grid products in Lesotho.

1.6 Review existing standards and their implementation including proposing changes to them and support their upgrading

Following a thorough assessment and evaluation of information available, as well as various industry stakeholder engagement, it was evident that there were no standards available at this point, the Lesotho Government subscribes to the IEC standards and used them for some of the requirements for electrical and energy equipment. Therefore, this proposed technical guideline will serve as a basis of the standards to be adopted locally as a National Standard for Labelling of the Off-Grid Solutions.

1.7 Develop and adopt standards based on best practices including advising on the harmonization at regional, continental, and global levels.

In developing the Technical Guideline for Labelling Off-Grid Solutions a framework to be used was followed based on various international practices such as the EU regulations for energy labeling and were also informed by a case study on Australia, Ghana, Liberia and South Africa. The proposed framework is as follows:

The Proposed Technical Standards:

The proposed technical guideline for Lesotho encompass the establishment of clear and comprehensive guidelines for off-grid energy solutions in Lesotho. This guideline covers a range of key components, including:

- **Product Quality and Performance:** Setting criteria for the quality and performance of off-grid technologies, ensuring that they meet safety and efficiency and performance standards;
- **Environmental Sustainability:** Incorporating environmental considerations, such as product lifecycle assessments and adherence to sustainable practices, to mitigate the ecological impact of off-grid technologies;
- **Safety and Durability:** Ensuring the safety of off-grid solutions during operation, maintenance, and disposal, with a focus on safeguarding both consumers and the environment; and
- **Consumer Information and Education:** Mandating the provision of clear and concise information for consumers, including energy labels that explain product performance and energy efficiency.

Proposed Labelling System:

The proposed labelling system complements the technical standards by providing consumers with accessible information about the off-grid energy solutions they purchase. Key features of the labelling system include:

- **Performance and Efficiency Labels:** A standardized labeling system that informs consumers about the energy efficiency and performance of off-grid products, allowing them to make informed choices.
- **Product Identification:** Clear identification of the manufacturer, product model, and a unique product identifier for tracking and compliance purposes.
- **Energy Performance Metrics:** Inclusion of key performance metrics, such as energy consumption, energy generation, and product lifecycle emissions, to guide consumers in selecting the most suitable off-grid technologies.

Benefits and Implications:

The proposed technical standards and labelling system offer several significant benefits and implications for Lesotho:

- **Energy Access:** Improved access to reliable off-grid solutions, especially in remote and underserved areas, leading to enhanced living standards for off-grid population.
- **Environmental Sustainability:** Mitigation of environmental impacts through the promotion of energy-efficient and sustainable off-grid solutions, contributing to climate change mitigation.
- **Market Development:** Encouragement of innovation, competitiveness, and growth in the off-grid technology market, benefiting consumers and manufacturers.

- **Consumer Empowerment:** Empowering consumers with information to make informed choices, reduce energy costs, and select products that align with their energy needs.

1.8 Recommendations for the Government of Lesotho

Policy and Regulatory Considerations

Promoting sustainability in the off-grid energy sector in Lesotho requires the development of robust technical standards and labelling mechanisms. These recommendations offer guidance on policy and regulatory considerations to effectively implement and enforce technical standards and labelling for off-grid energy solutions in Lesotho.

- Comprehensive Off-Grid Energy Policy;
- Conduct proper Stakeholder Engagement;
- Establish a fully-fledged Regulatory Framework for off-grid products;
- Ensure harmonization with Regional Standards;
- Engage on Capacity Building and Training of government employees and communities;
- Ensure Consumer Awareness and Education;
- Develop and establish a robust Data Collection and Reporting;
- Introduce Incentives and Penalties schemes in the regulatory framework;
- Periodically review and update the technical standards and labelling requirements to keep pace with technological advancements and changing market dynamics; anf
- Ensure that the development of technical standards and labelling promotes sustainability and inclusivity, addressing gender disparities and environmental considerations.

Considerations for the Lesotho Standards Institute (LSI)

Implementing technical standards and labelling for off-grid energy solutions in Lesotho is essential to ensure the quality, safety, and performance of these technologies. To successfully integrate these measures into Lesotho's energy landscape, the following recommendations should be considered for the LSI:

- Develop Comprehensive Technical Standards;
- Establish Regulatory Framework and create a regulatory framework that outlines the roles and responsibilities of various stakeholders, including government agencies, regulatory bodies, and industry associations;
- Invest in training programs and capacity building for government officials and technicians involved in testing, inspection, and certification of off-grid technologies;
- Develop a system for accrediting testing laboratories to ensure the accuracy and reliability of performance tests. Accredited labs can provide unbiased and credible assessments of off-grid products, fostering consumer trust;

- Launch consumer education campaigns to increase awareness of the benefits of off-grid energy solutions and the importance of choosing products with quality labels;
- Implement a robust market surveillance and enforcement program to monitor compliance with technical standards and labelling requirements;
- Introduce incentives for manufacturers and distributors who consistently comply with technical standards and labelling requirements;
- Collaboration with international partners to harmonize technical standards and labelling schemes;
- Launch pilot programs to assess the feasibility and effectiveness of implementing technical standards and labelling in specific regions or sectors.
- Establish a monitoring and evaluation mechanism to assess the impact of technical standards and labelling on the off-grid market;
- Encourage research and development in off-grid technologies by providing incentives, such as tax breaks or grants, to manufacturers and innovators; and
- Foster collaboration between government agencies and private sector stakeholders, including manufacturers, distributors, and industry associations.

Considerations for Private Sector

Private sector engagement is crucial for the successful implementation of proposed technical standards and labelling for off-grid energy solutions in Lesotho. To ensure effective compliance and foster innovation, below are detailed recommendations for private sector stakeholders in Lesotho:

- Towards adherence to standards, private sector companies should align their products and services with the proposed technical standards for off-grid energy solutions in Lesotho;
- Invest on product innovation and R&D to make input into the development and maturing of the market;
- Promote Energy-Efficient and Products compliance to the labelling guideline;
- Implement Stringent Quality Control: Companies should establish robust quality control mechanisms to ensure that products meet the proposed technical standards consistently;
- Support the Labelling System by embracing the labelling system, using labels to communicate energy performance to consumers effectively;
- Promote local manufacturing by encouraging the establishment of local manufacturing or assembly units for off-grid products;
- Efficient Supply Chain Management by streamlining supply chain processes to ensure timely delivery, reliable product availability, and effective after-sales services to meet consumer needs and expectations;

- Collaborate with Government and NGOs by engaging in partnerships with government agencies and non-governmental organizations to leverage resources and support in reaching underserved populations and remote areas;
- Private companies should explore financing options and partnerships to offer consumers affordable payment plans and financing solutions, making it easier for them to adopt off-grid technologies;
- Invest in the training and development of local technicians and professionals who can install, maintain, and repair off-grid systems. This ensures the sustainability of the sector and creates job opportunities;
- Participate in regulatory discussions by actively participating in discussions with regulatory bodies to provide input and feedback on the proposed technical standards, ensuring that they are practical and feasible for implementation;
- Continuously monitor and assess the Lesotho market to identify emerging trends, consumer demands, and opportunities for expanding the off-grid energy sector; and
- Embrace eco-friendly and sustainable practices in product design and manufacturing. This includes responsible disposal and recycling practices for end-of-life products.

Considerations for Lesotho Communities and Consumers

These set of recommendations below aims to guide Lesotho communities and consumers on the proposed technical standards and labelling for off-grid energy solutions:

- Communities and consumers should familiarize themselves with energy labels on off-grid energy products;
- Prioritize the purchase of energy-efficient off-grid products with higher energy efficiency ratings. These products not only reduce energy consumption but also lower long-term operating costs;
- Ensure that off-grid energy solutions conform to the proposed technical standards in Lesotho. Products that meet these standards are more likely to be safe, reliable, and energy-efficient;
- Look for off-grid energy products that have been certified by recognized quality assurance organizations or institutions;
- Compare different off-grid energy solutions, considering not only energy efficiency but also other features such as battery life, ease of maintenance, and warranty periods;
- Participate in consumer awareness programs and workshops organized by government agencies, non-governmental organizations, or industry associations. These programs provide valuable information on the benefits of energy-efficient off-grid technologies;
- Whenever possible, support local businesses and entrepreneurs involved in the distribution and maintenance of off-grid energy solutions;

- Communities and consumers should actively provide feedback and report cases of non-compliance with technical standards and labelling to relevant authorities. This helps maintain the quality and safety of off-grid products;
- Invest in improving energy literacy by seeking information on the benefits of off-grid energy solutions, energy conservation practices, and sustainable energy use in daily life; and
- Encourage community participation by promoting community participation in renewable energy projects and off-grid solutions. Collective action can drive the adoption of sustainable energy practices and technologies.

Considerations for the Academic Institutions

The Lesotho Energy Research Centre (LERC) plays a crucial role in guiding Lesotho's energy sector towards sustainability and access. In the context of proposed technical standards and labelling for off-grid energy solutions, the following recommendations are offered to strengthen the impact of LERC's efforts:

- LERC should conduct in-depth market research to understand the current status of off-grid energy solutions in Lesotho;
- LERC should work in collaboration with relevant stakeholders, including manufacturers, government agencies, and international organizations, to develop locally relevant technical standards for off-grid energy solutions. These standards should consider the specific environmental conditions and needs of Lesotho, such as extreme temperatures and high-altitude locations;
- Introduce a User-Friendly Labeling System: LERC should design an easy-to-understand labelling system for off-grid products. The labels should convey important information about product performance, energy efficiency, and durability. Moreover, efforts should be made to make the labels available in local languages to ensure accessibility;
- To ensure the successful adoption of labelling standards, LERC should conduct public awareness campaigns. These campaigns should educate consumers on the benefits of choosing energy-efficient off-grid products and how to interpret the labels. Collaboration with local communities, schools, and media outlets is essential;
- LERC should engage with local and international manufacturers to encourage the production of energy-efficient off-grid products that meet the proposed standards. Incentives, such as tax breaks or grants, can be offered to manufacturers who comply with the standards;
- It is essential for LERC to work with relevant government agencies to strengthen enforcement mechanisms. This includes conducting regular product inspections and imposing penalties for non-compliance. A well-regulated market will help protect consumers and maintain the integrity of labelling standards;
- LERC should establish a monitoring and evaluation system to track the effectiveness of the labelling standards. Regular assessments will help identify areas for

improvement and ensure that the standards continue to meet the evolving needs of the off-grid market;

- LERC should encourage research and innovation in off-grid technologies. This can be achieved by collaborating with universities and research institutions to develop and test new products that are both energy-efficient and locally adapted. Supporting local inventors and entrepreneurs is also crucial;
- LERC should explore financing options to support consumers in purchasing energy-efficient off-grid solutions. This can include microfinance schemes, subsidies, or partnerships with financial institutions to make these products more accessible to underserved populations; and
- LERC should engage with regional and international organizations and share best practices and lessons learned. Collaboration can help Lesotho benefit from the experiences of other countries in developing and implementing labelling standards for off-grid solutions.

2 Background

Rural Africa is positioned at the epicenter of the global energy access predicament. Current estimations suggest that as of 2017, approximately 840 million individuals globally were devoid of electricity, with a significant 573 million of them residing in Sub-Saharan Africa(IRENA,2017). Projections indicate that by 2030, the global count of individuals without access to electricity will reduce to 650 million, yet a staggering 90% of these will persist in Sub-Saharan Africa, with 80% located in rural areas, World Bank, 2017). In these remote regions, the primary reliance for power is expected to rest on decentralized sources due to vast rural areas in the topography of these countries including Lesotho, such as mini-grids and solar home systems (SHSs). It is anticipated that by 2030, these decentralized systems could potentially cater to the energy needs of over 130 million people in Africa (IEA, 2017). This development would mark an unparalleled utilization of distributed power, necessitating the deployment of tens of millions of SHSs and the establishment of 100,000 or more mini-grids (World Bank, 2017). Governments and international donors have launched a series of initiatives in response to this critical issue, with the goal of addressing the energy access challenge.

The Sustainable Energy for All (SEforAll) initiative, introduced in 2011, set a paramount objective to achieve universal access to electricity by 2030. This ambition gained further recognition in 2015 when it was integrated into the United Nations' Sustainable Development Goals (SDGs). Significantly, numerous African nations have included comprehensive plans for expanding electricity access as part of their commitments to the 2015 Paris Climate Agreement. Additionally, international donors have played an active role in advancing this

cause. The World Bank's Energy Security Management Assistance Program (ESMAP) has been offering technical assistance to developing countries for several years. The United States Government initiated "Power Africa" in 2013 to bolster electricity access efforts, and in 2017, the African Development Bank unveiled its "New Deal on Energy for Africa," pledging a substantial $12 billion investment in enhancing energy access.

Despite concerted efforts, achieving universal electricity access in rural Africa presents a formidable challenge. A significant barrier revolves around securing the necessary investments. According to the International Energy Agency (IEA) report in 2020, an estimated $84 billion was allocated for expanding electricity access in Africa between 2017 and 2030. However, to meet the ambitious goal of universal electricity access by 2030, an additional annual investment of approximately $26 billion is deemed necessary, with the bulk of this amount earmarked for off-grid and mini-grid systems (IEA, 2017).

The international community has a role to play, but the challenge lies in the fact that this sum surpasses more than 50% of the total official development assistance allocated to sub-Saharan Africa for all purposes. It seems unlikely that donors will either increase their assistance to meet this demand or divert such a substantial amount from other development priorities. Moreover, Africa's existing electrical utilities are not financially equipped to support this expansion, with a World Bank study from 2016 revealing that 37 out of 39 utilities analyzed were struggling to cover their existing costs (Kojima & Trimble, "Making Power Affordable," 2016).

To bring power to rural Africa, it is imperative to attract private sector investments and establish commercially viable models for providing electricity to some of the world's most economically challenged households (Dowdy, 2021).

2.1 The Lesotho Energy Sector

In Lesotho, the electricity supply sector is primarily under the control of two government-owned entities. The Lesotho Electricity Company (LEC) holds a monopoly over the transmission, distribution, and supply of electricity, while the Lesotho Electricity Generation Company plays a central role in electricity generation, operating the 'Muela Hydro Power Station. This power station is an integral component of the Lesotho Highlands Water Project (lewa.org.ls.nd).

Significant changes occurred in the electricity industry during the post-2000 period. As part of its initiative to restructure state-owned assets, the government opted to privatize LEC.

Simultaneously, the 'Muela hydro generation remained within LHDA, with the aim of ensuring transparency in cost management (lewa.org.ls.nd).

The government's policy agenda in Lesotho places strong emphasis on accelerating electrification programs. LEC is tasked with overseeing electrification within its designated service area. Beyond the LEC's jurisdiction, efforts to electrify rural areas are coordinated by the Rural Electrification Unit (REU) within the Department of Energy (DoE). To support these initiatives, the Lesotho Electricity and Water Authority (LEWA) has established a Universal Access Fund, which has alLeady commenced its operations. By 2011, over ten electrification projects had received funding from this Fund (lewa.org.ls.nd).

The total primary energy supply for Lesotho in 2020 was dominated by traditional biomass with its share representing about 57%. Modern forms of energy, such as petroleum products, coal, electricity and LPG, constitute the remaining 43%, the demand for which has been on the rise. Electricity only accounted for 7% of the consumed energy in Lesotho in 2020 (Lesotho Energy Policy 215-2025, DoE, . Domestic sector is the biggest electricity consumer at 54.3% followed by manufacturing sector at 24.4%. The annual per capita electricity consumption is 253 kWh, significantly below the Africanaverage of 579 kWh and the world average of 2,777 kWh. The household electrification rate is approximately 51%. About 60% of households in the country use biomass for space heating, water heating and cooking *(Country Indicators and SDG's, IRENA, 2023).*

2.2 Lesotho Energy Policy 2015 – 2025

The Lesotho Energy Policy 2015-2025 was adopted in March 2015 and is the overarching sector document that guides specific sector policies development and implementation. It addresses almost all key changes needed in the sector and brings certainty in decision-making and in the role of private sector stakeholders in the energy sector. It targets three distinct, yet supportive functions (policy design to provide strategic framework of operation, implementation of policy andregulation of policy) and it also reviews institutional responsibilities from policy design to regulationof single policies.

The Lesotho Energy Policy 2015-2025 serves as a comprehensive framework policy that delineates the strategic trajectory of the nation's energy sector. This policy is in alignment with the Vision 2020 and the National Strategic Development Plan (NSDP). Its central objectives include the advancement of cleaner, environmentally sustainable renewable energy sources and an augmentation of their proportion in the national energy portfolio.

One of the primary objectives of this policy is to escalate electricity accessibility, targeting a 40% coverage of the population by 2020, a substantial increase from the 5% level recorded in 2000. Renewable energy sources are identified as pivotal tools in achieving this objective, playing a significant role in elevating the electrification rate throughout the country. Furthermore, the policy outlines plans for establishing a Renewable Energy Feed-In-Tariffs (REFIT) program, designed to incentivize investments in the renewable energy sector. The policy also makes specific objectives and strategies for off-grid solutions. It aims to establish technical standards and quality assurance for the purchase, installation, and maintenance of electricity production and energy storage facilities used for self-supply. It also plans to impose and collect levies on energy services and products (Lesotho Energy Policy 2015-2025).

The Lesotho Energy Policy 2015-2025 envisions universal and sustainable energy access while keeping affordability and environmental impact in mind. The overarching objectives are to enhance livelihoods, foster economic growth and investment, ensure energy security, and protect the environment. The policy outlines specific statements, each accompanied by distinct objectives and strategies, including the establishment of institutional and regulatory frameworks, data availability and updates on energy resources, sustainable bioenergy supply, improved access to renewable energy services, energy efficiency promotion, reliable electricity supply, enhanced transmission network efficiency, increased electricity access across sectors, competitive electricity market operations, greater electricity usage, secure petroleum product supply, equitable distribution, wider access, investment attraction, and transparent energy pricing. Additionally, the policy incorporates a visual model for the energy sector and the roles of related institutions[1].

Lesotho primarily relies on a mix of energy sources to meet its electricity needs. Historically, the country's energy sector has been heavily dependent on hydroelectric power. The Lesotho Highlands Water Project (LHWP) is a critical component of this, with a series of dams and hydroelectric plants built to harness water resources for both electricity generation and water supply. These plants include the Katse Dam and Mohale Dam, which collectively contribute a significant portion of Lesotho's electricity supply[2].

The Lesotho Energy policy 2015-2025, further states that in recent years, Lesotho has sought to diversify its energy sources to reduce its dependency on hydropower, particularly in the face of climate change and water scarcity concerns. Initiatives to harness solar energy and

[1] Lesotho Energy Policy 2015-2025
[2] Lesotho Energy Policy 2015-2025

wind power have gained traction. The country's favorable climatic conditions for solar power and wind patterns for wind energy have made these renewable sources attractive options. These efforts are aimed at enhancing energy security and reducing greenhouse gas emissions.

Challenges in Energy Sector

According to the Lesotho Policy 2015 – 2025, the challenges in the sector are as follows**:**

- **Energy Access:** Limited access to electricity is a critical issue in Lesotho, particularly in rural areas, where a significant portion of the population lacks reliable electricity access. This issue hampers economic development, education, healthcare, and overall quality of life for the people of Lesotho;
- **Funding Constraints:** Developing energy infrastructure, such as expanding the electricity grid and constructing new power generation facilities, requires substantial financial resources. Lesotho faces challenges in securing the necessary funding for these critical projects;
- **Climate Vulnerability**: Lesotho's energy sector is vulnerable to the effects of climate change, particularly in terms of hydropower generation. Prolonged droughts and irregular rainfall patterns can significantly reduce the availability of water for electricity production, thus affecting the reliability of the power supply; and
- **Technical and Operational Challenges:** Maintaining and upgrading the existing energy infrastructure in Lesotho presents technical and operational challenges. Additionally, addressing skills and knowledge gaps within the energy workforce is essential for the effective operation and development of the energy sector in the country.

2.3 Lesotho Rural Electrification

Lesotho recognizes the importance of addressing its energy challenges and has taken several initiatives to improve energy access and reliability through the Energy Policy 2015-2025. The government has initiated programs to extend the electricity grid to remote and underserved rural areas. The goal is to connect more households, schools, and healthcare facilities to the grid, ultimately improving the living standards and economic prospects of these communities[3].

In addressing the rural electrification challenge in Lesotho, several interconnected issues demand thorough analysis and resolution. These include the country's mountainous terrain, the need for a supportive policy framework, and a shift in attitudes towards cleaner energy sources. Firstly, Lesotho's landscape is characterized by rugged mountains, with altitudes

[3] Lesotho Energy Policy 2015-2025

ranging from 1,500 to 3,482 meters[4]. This geographical configuration significantly influences population distribution and, consequently, access to electricity services. Rural electrification in Lesotho is a critical component of the country's energy development and access agenda. Despite its small size and population, Lesotho faces unique challenges when it comes to providing electricity to its rural areas[5].

Rural Electrification Challenges: Lesotho's mountainous terrain and scattered rural settlements pose significant challenges to electrification efforts. A substantial portion of the population resides in remote areas, making it logistically challenging and costly to extend the national grid. As a result, access to electricity in rural regions has historically been limited, impacting various aspects of life, including economic opportunities, education, healthcare, and overall quality of life[6].

Government Initiatives: The government of Lesotho has recognized the importance of rural electrification and is actively working to improve access to clean and affordable energy. The Lesotho Energy Policy 2015-2025, aligned with the Vision 2020 and the National Strategic Development Plan (NSDP), underscores the importance of expanding electrification to rural areas and promoting the use of cleaner energy sources.

Renewable Energy Integration: To address the challenges associated with rural electrification, Lesotho has been exploring renewable energy sources, particularly hydropower. The 'Muela Hydro Power Station, as part of the Lesotho Highlands Water Project, has been a notable source of clean energy, but climate vulnerability due to factors like prolonged droughts presents challenges.

International Support: International organizations and donors, such as the World Bank and the United Nations Development Programme, have been supporting rural electrification projects in Lesotho. These efforts aim to improve infrastructure and energy services in remote areas, contributing to economic development and improved living standards

Rural Electrification Strategy: Lesotho's Rural Electrification Unit (REU), operating within the Department of Energy, plays a pivotal role in managing rural electrification projects. The

[4] Rural Household Electrification in Lesotho, M. Mpholo, M. Meyer-Renschhausen, R. I. Thamae, T. Molapo, L. Mokhuts'oane, B. M. Taele & L. Makhetha, (2018)

[5] Rural Household Electrification in Lesotho, M. Mpholo, M. Meyer-Renschhausen, R. I. Thamae, T. Molapo, L. Mokhuts'oane, B. M. Taele & L. Makhetha, (2018)

[6] Lesotho Energy Policy 2015-2025

government has also established a Universal Access Fund to support electrification initiatives in underserved areas.

Sustainable Energy Goals: Lesotho is committed to achieving Sustainable Development Goal 7 (SDG 7) - ensuring access to affordable, reliable, sustainable, and modern energy for all. Rural electrification plays a central role in advancing this goal.

Rural electrification in Lesotho remains a significant challenge due to its mountainous terrain and scattered population. The government, along with international support, is actively working on the reform initiatives and policies to improve access to electricity in rural areas. The integration of renewable energy sources and efforts to enhance infrastructure are essential steps towards achieving universal and sustainable energy access in the country.

2.4 The Standards and Guidelines for the Lesotho Sector

Lesotho is a subscriber member of the International Organization of Standardization. The legal framework for standards certification has been formed, the Standards and Quality Assurance Department of the Ministry of Trade and Industry, Cooperatives and Marketing was established as the national standards body in January 2000 and subsequently the Lesotho Standards institute was formed. At the point there are no standards for any energy technologies for Lesotho[7].

Access to affordable, reliable, sustainable and modern energy is a key Sustainable Development Goal, part of Global Goal 7. Achieving it requires scale up of the manufacture and distribution of new energy technologies, in this instance off-grid technologies, but not all technology is created equally. Ensuring that new solutions deliver on their promises to improve health, livelihoods and the environment requires appropriate international standards[8]. Designing those standards requires new approaches and a deep understanding of market needs. Any developing market needs to be enabled to have orderly development through minimum requirements which are achieved by having standards in place[9].

As part of the Lesotho Energy Policy objectives for policy design and its implementation including regulation thereof, the development of standards and guidelines for new technologies to regulate orderly development of the market for various types of energy technologies and solutions is urgent. As a result, the development of the Technical Guideline

[7] https://www.commonwealthofnations.org/sectors-lesotho/business/standards_and_regulation/
[8] https://sdgs.un.org/goals/goal7
[9] https://sdgs.un.org/goals/goal7

and Labelling for Off-Grid Solutions, will eventually form part of the policy and standards framework of the Kingdom of Lesotho.

3 Introduction

Sustainable development is not possible without sustainable energy, so many basic needs depend on reliable energy[10]. Extending the national grid would ensure a satisfying quality of power to rural communities in Africa. But the solution often remains expensive for remote areas who lack existing infrastructure and are located at the edge of the electric grid, sometimes called the 'last mile'. In areas like this where grid extension is not economically feasible, electrification through decentralized renewable-based solutions have gained momentum as a means of achieving universal energy access.

According to *Off Grid EN - Sustain Solar* Off-grid, or off-the-grid Solutions), refers to the absence of access to the main electrical grid as a source of power which is usually as a result of the economic conditions Leading to energy poverty and the need for off-grid solutions for the affected communities. Off-grid systems include solar home systems for individual or household use. These systems are competitive with fossil fuel, and have been the most widely deployed technology. They are made affordable to even the poorest communities, mostly through the emerging informal and formal traders as it is in the Kingdom of Lesotho.

There are various technologies available to replace charcoal, wood, or other polluting fuels for cooking. These include electric, solar, biogas, liquefied petroleum gas, and natural gas. Improved cookstoves for cleaner and more efficient combustion of biomass and solid fuels are also a promising and low-cost opportunity[11].

The innovative ideas of off-grid solutions has been introduced as a way for customers to buy clean off-grid technology solutions and are placed inside local convenience stores close to people's homes and villages in developing countries[12].

As a result of the low access to electrification through the main national grid, the proliferation of the Off-grid solutions and systems increase exponentially and the flooding of Off-Grid technologies is being driven by affordability levels of those communities who do not have access to power. The affordability levels also give rise to the increase of the formal and informal traders of solutions which as much as they are cheap, but are not reliable, do not

[10] https://www.devex.com/news/sustainable-development-is-not-possible-without-sustainable-energy-78002
[11] https://www.stantec.com/en
[12] https://www.stantec.com/en

provide longevity of operating as well a low or no quality at all to the products that floods into the Lesotho economy and market.

The Government of Lesotho has realised through the feedback from the communities that they are receiving technologies of sub-standards from the market which have not gone through any vetting or regulatory processes, as a result affecting the economy and the citizens negatively.

3.1 Why Technical Guideline and Labelling for Off-Grid Solutions in the Kingdom of Lesotho?

Standards and guidelines are published documents that establish technical specifications and procedures designed to maximize the reliability of the materials, products, methods, and/or services people use every day. A standard can be thought of as an agreed-upon norm used by people, industry, and government that outlines the best way to complete a task, whether it's about developing a product, providing a service, controlling a process, or interacting with the world. Technology standards can also provide a framework that enables devices from different manufacturers to communicate with one another. In the process, standards provide a stable but continually evolving foundation that enables entire industries to develop and thrive formally and orderly. By following standards, manufacturers get highly detailed information about how devices identify one another, how data flows between them, and how it's kept secure, to name just a few examples.

Standards and guidelines form the fundamental building blocks for product development by establishing consistent protocols that can be universally understood and adopted. This helps fuel compatibility and interoperability and simplifies product development, and speeds time-to-market. Standards also make it easier to understand and compare competing products. As standards are globally adopted and applied in many markets, they also fuel international trade.

Meanwhile, when consumers and businesses and communities are confident that products will work as expected, they're far more likely to buy them. Standards-based interoperability also gives them the freedom to mix and match different manufacturers' products.

Standards and labeling for off-grid technologies play a crucial role in ensuring the quality, performance, and safety of these products. They provide several benefits for both consumers and the industry. Below are some reasons why standards and labeling are important for off-grid technologies.

- **Quality Assurance:** Standards help establish minimum quality requirements for off-grid technologies, ensuring that products are reliable and meet performance expectations. (IEC,2018);
- **Consumer Confidence:** Labelling provides consumers with information about the product's quality and performance, helping them make informed purchasing decisions. (Clean Energy Solutions Center, 2017);
- **Safety Assurance:** Standards include safety requirements, which are critical for off-grid technologies to prevent accidents and hazards. (World Bank Group, 2018)

- **Interoperability:** Standards promote compatibility and interoperability between different off-grid products and systems, making it easier to integrate them into existing systems. (IEC, 2021).
- **Market Growth:** Standards and labeling can facilitate market growth by instilling confidence among investors and manufacturers, which can Lead to increased investment and innovation in the off-grid sector (IFC, 2017).
- **Regulatory Compliance:** Standards help manufacturers and suppliers ensure compliance with national and international regulations, facilitating market access and trade (UNIDO, 2019).
- **Energy Efficiency:** Standards often include energy efficiency criteria, encouraging the development and adoption of energy-efficient off-grid technologies (Global REAP, 2017).
- **Environmental Impact:** Standards may address environmental considerations, such as the responsible disposal of off-grid technology components, reducing their environmental footprint.(UNEP, 2020).
- **Investment Attraction:** Having well-defined standards and labeling mechanisms can attract investment in the off-grid technology sector, which is critical for expanding access to clean and sustainable energy (The World Bank, 2015).
- **Monitoring and Evaluation:** Standards and labeling can be used for monitoring and evaluation purposes, allowing governments and organizations to assess the performance and impact of off-grid technologies (Energy 4 Impact, 2018).

In summary, standards and labeling for off-grid technologies are essential for ensuring quality, safety, consumer confidence, and overall market development. They provide a framework for innovation and growth in the off-grid energy sector, which is critical for increasing access to clean and sustainable energy solutions, particularly in regions without reliable grid infrastructure.

The proposed Technical Guideline and Labelling for Off-Grid Solutions will be based on the solutions identified during the consultations of the various stakeholders in Lesotho, which includes Government, Private Sector and traders of off-grid technology in Lesotho.

The original intention from the Ministry of Energy was to develop the Standard and Labelling for Off-Grid Solutions, after deliberations with relevant local industry actors, it was recommended that the initial product be the Technical Guideline, as opposed to the Standard. This was mainly due to the fact that Lesotho has a Standards Institute, which is responsible and has an authority to develop standards. The mandate lies with this institute, as a result the assignment will seek to develop a technical guideline which can be later adopted as a standard using the Lesotho standards development framework, led by the Standards Institute.

4 Objective of the Assignment

As per the terms of reference, the overall objective of this assignment is improved access for the people of Lesotho and the private sector to modern, clean, affordable and reliable energy supply, including better enabling environment for large up-scaling under a follow-up phase II, which will be focusing on energy access for the rural areas and energy efficiency improvement in various economic sectors.

4.1 Specific objective(s)

- The specific objective of this assignment is to develop standards and labelling for off-grid solutions;
- This tool shall be used by the Government of Lesotho (GoL) and developers to standardize the off-grid solutions and
- The tool shall allow developers in the off-grid electrification field to enhance the trust in their technology and financial models by adhering to and/or aligning with international standards - not only pure technical standards for the diverse technical components of their energy delivery infrastructure, but also on common indicators that can facilitate investors in the sector to compare off-grid companies to each other.

This assignment will contribute towards the achievement of one of the Key Outputs under the energy reform programme which is “Operationalization of the Energy Policy through legislation and regulations” . Lesotho’s Ministry of Trade, Industry, Business Development and Tourism hosts the Lesotho Standards Institute body which is the country’s standards’ body. Through this organization, Lesotho seeks to adopt best practices in the world of off grid products and systems to support the country’s economic development and industrialization efforts. One such best practice is the development and adoption of standards and labelling requirements to support both the use, export and import of off grid systems and products into Lesotho. These standards and labelling requirements will also ensure that Lesotho determines the quality of products imported into its own borders, thus enable the country to tailor standards to the needs of its people.

The development of standards will also enable Government of Lesotho (GoL) to attract funding from development partners to fulfil the EMP, since they’ll provide confidence in the country’s electricity sector. Standards and labelling for off-grid are also needed to guide the scale up of “small-scale projects” and will create an environment that will provide clear guidelines to participating players from the private sector. Work under this scope should therefore identify and propose solutions that can enable the development and adoption of standards for off grid in Lesotho.

4.2 Specific Duties and Responsibilities

- Engage stakeholders to understand the current state of labels and standards and make recommendations on the same;
- Review the energy related standards in general and specifically;
- Review, harmonize and adopt for Lesotho (where relevant) the SADC member States' Minimum Energy Performance Standards (MEPS) specifying all necessary performance requirements for an energy-using device, that effectively limits the maximum amount of energy that may be consumed by a product in performing a specified task;
- Review and improve existing practices in the development and adoption of labels and standards, and develop new ones where none exist;
- Review existing standards and their implementation including proposing changes to them and support their upgrading; and
- Develop and adopt standards based on best practices including advising on the harmonization at regional, continental, and global levels.

5 The Approach to the Assignment

The deliverables were estimated to be completed within working 30 days after inception of the assignment. The required level of input is estimated to be 30 person-days. The assignment commenced on the 10th September 2023.

Table 1: Approach of the assignment

Deliverable	Deadline
Inception meeting and inception report	1 week from commencement
Consultation meetings with relevant stakeholders	2 weeks from commencement
Gap analysis report	3 weeks from commencement
Development of labels	3 weeks from commencement
Review and development of Technical Guideline	4 weeks from commencement
Dissemination workshop	
Draft and Final Report	

Figure 1 below depicts the approach to the assignment as per the terms of reference.

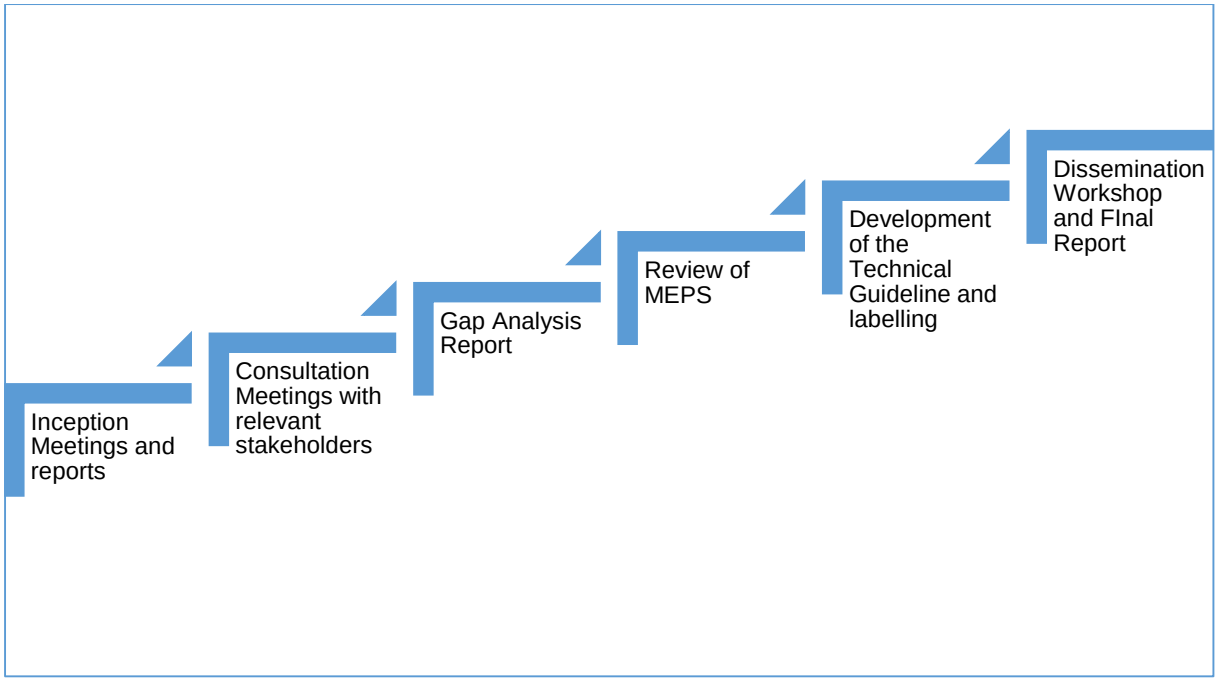

Figure 1: Approach to the Assignment

5.1 Inception meetings and inception report

The main objective of the inception report (which considers the inception meetings conducted with several key stakeholder) was to demonstrate the expert's understanding of the scope, set out the conceptual framework, key questions and methodology to deliver the work, also includes the basis of the information to be used including data sources and collection. According to the work schedule in the terms of reference, this report was to be delivered a week from commencement of the contract (10 September 2023), the report was submitted on 22 September 2023. The validation of the inception report by the DoE on 06 October 2023 led to embarking on the main deliverable which is the report entailing the Technical Guidelines and Labelling for Off-Grid Solutions. The guideline will be later adopted as a national standard using the Lesotho Standards development process, led by the Lesotho Standards Institute.

5.2 Consultation meetings with relevant stakeholders

The development of Technical Guidelines and labelling for off-grid solutions requires the inputs and collective wisdom of all relevant stakeholders in the energy sector identified by the Ministry. The major stakeholders which were identified and met for the information collection and inputs are outlines below:

5.2.1 Ministry of Natural Resources

The Ministry of Natural Resources in Lesotho is a vital government department responsible for the stewardship, management, and sustainable development of the country's natural resources. Lesotho, a landlocked nation in Southern Africa, is known for its rich natural landscapes, including mountains, rivers, and fertile valleys. The Ministry plays a crucial role in preserving and leveraging these resources for the well-being of the country's population. This report provides an overview of the Ministry of Natural Resources in Lesotho, its key

responsibilities, and its efforts to manage and protect the nation's natural wealth. During the consultations, some of the key discussions held with the ministry were:

- The mandate of the Ministry and relevance to the energy sector which is to reduce energy dependency and promote sustainable energy solutions, the Ministry has been involved in promoting and regulating renewable energy projects, but has not been actively in the defining of the sustainable off-grid technologies and their standards; and
- The department has been active in formulating and implementing environmental policies and regulations in the country. The Environmental Impact Assessment (EIA) system, for instance, helps ensure that development projects consider their environmental and social implications. For off-grid technologies, this would mean the Ministry will be interested in the regulations on the environmental sustainability of the products including requirements for safe disposal of the products which must still protect the environment

While renewable energy sources and off-grid solutions offer numerous benefits, including reduced greenhouse gas emissions and energy diversification, they also come with various environmental considerations. Here are some key environmental considerations of renewable energy technologies in Lesotho:

- **Land Use and Habitat Impact:** Large-scale renewable energy projects, such as wind and solar farms, can require significant land use. This may impact local habitats and ecosystems (SEFA, 2019);
- **Biodiversity Conservation:** The development of renewable energy projects must consider potential impacts on local biodiversity. Careful site selection and environmental impact assessments are crucial to mitigate negative effects (Lesotho Biodiversity Strategy and Action Plan, 2016);
- **Water Usage:** Some renewable energy technologies, such as hydropower, can have water requirements. Managing water resources sustainably is essential to avoid negative effects on water availability. (UNDP, 2020 Lesotho's National Adaptation Plan);
- **Visual and Aesthetic Impact:** Wind turbines and solar panels can change the visual landscape, impacting the aesthetics of the environment. Community perceptions and preferences should be considered. (SEFA,2019);
- **Noise and Disturbance:** Wind turbines, in particular, can generate noise and vibrations that may disturb local communities and wildlife. Proper siting and noise mitigation measures are important. (WHO,2018);
- **Waste Management:** Solar panels and wind turbine blades have a finite lifespan. Proper disposal and recycling of these components are essential to prevent environmental pollution (IRENA, 2016);
- **Erosion and Land Degradation:** The construction of renewable energy infrastructure can Lead to soil erosion and land degradation. Implementing erosion control measures is vital (UNDP, 2017);

- **Impact on Air Quality:** Biomass and biogas projects can affect air quality due to emissions from combustion. Proper design and emission control technologies are necessary (IEA, 2018);
- **Climate Resilience:** Lesotho's vulnerability to climate change requires that renewable energy projects consider their resilience to extreme weather events, such as floods and droughts (Lesotho Meteorological Services, 2019); and
- **Social and Cultural Considerations:** Engaging with local communities and respecting cultural values and traditions is crucial to ensure renewable energy projects are socially acceptable and environmentally sustainable (UNDP, 2019).

Incorporating these environmental considerations into the planning, design, and operation of sustainable energy projects and products is essential to ensure that the transition to clean energy sources in Lesotho is ecologically sustainable and benefits both the environment and local communities.

5.2.2 Department of Energy

The Lesotho Department of Energy plays a significant role in promoting and facilitating the adoption of off-grid technologies in the country. As part of the government's efforts to expand access to clean and sustainable energy sources, the department is responsible for formulating policies, regulations, and initiatives to support the development and deployment of off-grid solutions.

Key Responsibilities of the Lesotho Department of Energy:

- **Policy Formulation:** The department is responsible for developing energy policies and strategies that promote the deployment of off-grid technologies, such as solar home systems, mini-grids, and small-scale hydroelectric projects;
- **Regulatory Framework:** It establishes and enforces regulations for the off-grid energy sector, ensuring that off-grid technologies meet quality and safety standards;
- **Promotion and Incentives:** The department supports and incentivizes the use of off-grid technologies by offering financial incentives, subsidies, and tax breaks to encourage investment and consumer adoption;
- **Technical Assistance:** It provides technical guidance and support to off-grid technology developers and investors, facilitating project implementation and reducing barriers to entry;
- **Data Collection and Analysis:** The department collects and analyzes data on energy access, off-grid technology adoption, and energy demand to inform policy decisions and project planning;
- **Collaboration:** The department collaborates with international organizations, NGOs, and development partners to access funding and technical expertise for off-grid technology initiatives; and

- **Capacity Building:** It is involved in capacity-building efforts, including training and skill development programs, to enhance the capabilities of the local workforce in the off-grid energy sector.

Efforts and Initiatives in relation to off-grid programmes:

- **National Energy Policy and Strategy:** The Lesotho Department of Energy has developed and implemented the National Energy Policy and Strategy, which highlights the importance of off-grid technologies in addressing energy access challenges (GoL,2016);
- **Renewable Energy Promotion:** The department actively promotes the use of renewable energy sources in off-grid solutions, with a focus on solar power and small-scale hydropower projects (GoL,2016);
- **Off-Grid Electrification Programs:** It has initiated rural electrification programs aimed at extending access to off-grid electricity to remote and underserved areas, improving the quality of life and economic opportunities for rural communities (GoL,2016);
- **Technical and Financial Support:** The department provides technical assistance and financial support to off-grid technology developers and entrepreneurs to encourage investment in this sector (GOGLA,2017); and
- **Energy Access Data Collection:** The government, in collaboration with international partners, conducts surveys and data collection activities to assess energy access and off-grid technology adoption, helping to identify areas in need of intervention (World Bank Group, 2017).

Rural electrification in Lesotho remains a significant challenge due to its mountainous terrain and scattered population. The government, along with international support, is actively working on initiatives and policies to improve access to electricity in rural areas. The integration of renewable energy sources and efforts to enhance infrastructure are essential steps towards achieving universal and sustainable energy access in the country. Also the proliferation of the Off-grid market to the access challenges, calls for orderly development of the market which must be regulated and controlled through standards and guidelines.

5.2.3 Lesotho Electricity Company

The Lesotho Electricity Company (LEC) is the state-owned electric utility responsible for the generation, transmission, and distribution of electricity in Lesotho. In a country where access to electricity can be challenging due to its mountainous terrain and dispersed population, the LEC plays a significant role not only in expanding grid-based electrification but also in facilitating off-grid technologies to improve energy access. This section provides an overview of the Lesotho Electricity Company's role in off-grid technologies, as per the consultation meetings held in September 2023.

- **Grid Electrification and Coverage Expansion:** LEC's primary responsibility is to develop, operate, and maintain the national electricity grid. The company has been

actively involved in expanding the grid to reach underserved and remote areas of Lesotho, increasing access to electricity (LEC, 2021, Corporate Overview);

- **Off-Grid Electrification Initiatives:** Recognizing the need to go beyond grid extension, LEC has been involved in implementing off-grid electrification projects. This includes deploying renewable energy solutions like solar home systems and mini-grids in areas where grid connection is not feasible (LEC Annual Report 2019);
- **Rural Electrification Program:** LEC's Rural Electrification Program aims to extend electricity access to rural and remote communities. The program includes the installation of off-grid solar power systems and other decentralized energy solutions to reach areas that are not connected to the main grid (LEC, Rural Electrification Program 2020);
- **Off-Grid Power Generation:** LEC has explored the development of off-grid power generation projects, including small-scale hydropower and solar installations. These projects can serve as standalone systems or be integrated into the grid (LEC, Strategic Plan, 2019);
- **Energy Access Partnerships:** LEC collaborates with international organizations, government agencies, and non-governmental organizations to implement off-grid energy projects and improve energy access in Lesotho. These partnerships often involve funding and technical support (SEFA), 2019);
- **Regulatory Framework for Off-Grid Technologies:** LEC plays a role in setting and implementing regulatory frameworks for off-grid technologies. This includes standards, licensing, and quality control measures to ensure the reliability and safety of off-grid energy solutions (Ministry of Energy and Meteorology, 2016);
- **Community Engagement:** LEC actively engages with local communities to identify their energy needs and preferences. This community-based approach helps tailor off-grid solutions to the specific requirements of different regions (LEC Customer Service Charter, 2017); and
- **Capacity Building and Training:** LEC invests in building local capacity and training programs to empower communities and ensure the sustainability of off-grid energy projects in Lesotho (LEC Skills Development Policy, 2018).

The Lesotho Electricity Company is a key player in the development and deployment of off-grid technologies in Lesotho. By leveraging their expertise in the energy sector and working in collaboration with various stakeholders, LEC will contribute to improving energy access and promoting sustainable, decentralized energy solutions in the country. The recommendations section will guide how can LEC be further directly involved in the off-grid solutions market.

5.2.4 Lesotho Electricity and Water Authority

The Lesotho Electricity and Water Authority (LEWA) is the regulatory body responsible for overseeing and regulating the electricity and water sectors in the Kingdom of Lesotho. LEWA plays a vital role in ensuring the provision of reliable and affordable services to the population. In recent years, the authority has also taken on the responsibility of promoting and regulating off-grid technologies to enhance energy access in remote and underserved areas. This section

provides an overview of LEWA and its evolving role in the promotion and regulation of off-grid technologies.

As per its website and the meeting held with the authority, the key responsibilities of the Lesotho Electricity and Water Authority (LEWA) are:

- **Regulation**: LEWA is responsible for regulating the electricity and water sectors, ensuring compliance with industry standards and policies;
- **Licensing**: The authority issues licenses to electricity and water service providers, overseeing their operations to ensure quality and reliability;
- **Tariff Regulation**: LEWA sets tariffs for electricity and water services to ensure affordability while allowing for cost recovery and sustainability;
- **Consumer Protection**: The authority safeguards consumer interests, ensuring that service providers meet quality standards and addressing complaints and disputes.
- **Infrastructure Development**: LEWA plays a role in planning and coordinating infrastructure development projects in the energy and water sectors; and
- **Renewable Energy Promotion**: In line with national energy policies, LEWA is increasingly involved in promoting and regulating off-grid and renewable energy technologies to extend access to electricity.

Role of LEWA in Off-Grid Technologies:

LEWA has begun to play an active role in the promotion and regulation of off-grid technologies to address energy access challenges in Lesotho:

- **Rural Electrification**: LEWA, in collaboration with the Ministry of Energy and Meteorology, has initiated rural electrification programs to extend the electricity grid and promote off-grid solutions such as solar home systems and mini-grids in remote areas (LEWA, Annual Report, 2020);
- **Licensing Off-Grid Operators**: The authority issues licenses and provides regulatory oversight to off-grid operators, including those involved in mini-grid projects and the distribution of solar home systems;
- **Quality Standards**: LEWA sets quality and performance standards for off-grid technologies to ensure that products and services meet minimum requirements and provide reliable energy access (Lesotho Solar Home Systems Standards, 2018);
- **Tariff Approval**: The authority approves tariffs for off-grid services to ensure that they remain affordable for rural and underserved populations while allowing for the sustainability of off-grid operators; and
- **Consumer Education**: LEWA is actively involved in consumer education and awareness programs to inform the public about off-grid technology options, their benefits, and how to access them.

LEWA's evolving role in promoting and regulating off-grid technologies is essential for addressing energy access challenges in Lesotho, particularly in remote and rural areas where

grid connectivity is limited. The authority's efforts are critical in ensuring that off-grid solutions are reliable, affordable, and accessible to all citizens, contributing to improved living standards and economic development in the country.

5.2.5 Rural Electrification Unit

The Lesotho Rural Electrification Unit (REU) is a government entity in the Kingdom of Lesotho responsible for planning, coordinating, and implementing electrification projects across the country. As Lesotho aims to increase access to electricity, especially in remote and off-grid areas, REU plays a critical role in facilitating the expansion of off-grid technologies. This report provides an overview of the Lesotho Rural Electrification Unit and its key responsibilities in advancing off-grid solutions, supported by relevant references.

Key Responsibilities of the Lesotho Rural Electrification Unit (REU):

- **Electrification Planning and Coordination:** REU is responsible for developing and updating national electrification plans, which include strategies for extending access to electricity, especially in underserved and off-grid areas (REU, 2017).
- **Off-Grid Electrification Projects:** REU oversees and manages off-grid electrification projects, including the deployment of mini-grids and standalone systems such as solar home systems and small wind turbines in areas where grid extension is not feasible (REU Annual Report, 2020).
- **Promotion of Renewable Energy:** REU encourages the use of renewable energy sources, such as solar and wind, in off-grid applications. This includes supporting initiatives to develop and install renewable energy systems in remote areas (2016, Lesotho Renewable Energy and Energy Efficiency Policy and Strategy).
- **Access to Finance:** REU collaborates with financial institutions, development partners, and the private sector to mobilize funding for off-grid electrification projects and provide financial solutions to support access to electricity for underserved populations (REU, Project Financing and Investment Guidelines, 2018)..
- **Technical Support and Capacity Building:** The agency provides technical assistance, training, and capacity-building programs for local communities and stakeholders involved in off-grid energy projects to ensure effective implementation and maintenance (REU Training and Capacity Building Programs, 2019).
- **Regulatory and Policy Support:** REU collaborates with government departments to develop and implement policies and regulations that promote off-grid electrification, including the establishment of appropriate standards for off-grid technologies. (2016, Lesotho Renewable Energy and Energy Efficiency Policy and Strategy).

Initiatives and Achievements as per the discussion at the consultation meetings:

- **Rural Electrification:** REU has been instrumental in extending the electricity grid to rural and off-grid areas, improving the quality of life, education, and healthcare services for residents.

- **Solar Home Systems:** The unit has implemented initiatives to distribute solar home systems in remote areas, providing clean and reliable electricity to households without access to the grid.
- **Mini-Grids:** REU has supported the development of mini-grids powered by renewable sources, offering a sustainable solution for communities located far from the main grid.
- **Partnerships:** The agency has established partnerships with development organizations, including the World Bank and United Nations, to secure funding for off-grid electrification projects.
- **Community Involvement:** REU encourages community participation in the planning and decision-making process of off-grid projects, ensuring that solutions are tailored to local needs.

The Lesotho Rural Electrification Unit's efforts to promote and support off-grid technologies are instrumental in addressing energy access challenges in rural and remote areas, contributing to sustainable development and improved living standards for the country's citizens.

5.2.6 Lesotho Electricity Generation Company

The Lesotho Electricity Generation Company plays a significant role in the development and promotion of off-grid technologies in Lesotho. As a state-owned entity responsible for electricity generation, and actively engaged in initiatives to expand energy access, particularly in remote and off-grid areas of Lesotho. This section outlines the Company's role in off-grid technologies and references supporting its efforts.

Role of Lesotho Electricity Generation Company:

- **Hydropower Generation:** The company is primarily known for its involvement in the Lesotho Highlands Water Project (LHWP), which encompasses a series of dams and hydropower plants. These plants contribute a significant portion of Lesotho's electricity supply. In addition to supplying electricity to the national grid, the company's hydropower facilities play a critical role in providing off-grid power to some remote areas (Lesotho Highlands Development Authority. (2020);
- **Renewable Energy Development:** The generation company is actively exploring and investing in renewable energy projects, including mini-grids and small-scale off-grid systems. This includes harnessing solar and wind energy sources to electrify off-grid communities (SEFA, 2019);
- **Grid Extension and Rural Electrification:** The generation company, in collaboration with the Lesotho Electricity Company (LEC), is involved in extending the electricity grid to underserved rural areas. This initiative is critical in providing electricity access to remote communities and off-grid regions (LEC, 2020);
- **Energy Policy and Regulation:** The generation company plays a role in shaping national energy policy and regulation, advocating for the integration of off-grid

technologies into Lesotho's energy landscape. This includes formulating policies that encourage the adoption of off-grid and decentralized energy solutions (Ministry of Energy and Meteorology, 2020); and

- **Capacity Building and Skills Development:** The generation company is involved in initiatives aimed at building the capacity of local communities and individuals to install, operate, and maintain off-grid energy systems. These efforts contribute to local job creation and the sustainability of off-grid technologies (UNDP,2018).

The generation company's involvement in off-grid technologies can be part of Lesotho's broader efforts to enhance energy access and address the energy needs of its remote and underserved communities. Their participation in renewable energy projects and grid extension initiatives is pivotal for achieving these goals while contributing to the country's economic and social development.

5.2.7 Ministry of Trade, Industry, Business Development and Tourism

The Ministry of Trade, Industry, Business Development, and Tourism in Lesotho plays a pivotal role in promoting economic growth and development by fostering a conducive environment for businesses and industries. In the context of off-grid technologies, the Ministry is involved in facilitating and regulating the development and deployment of off-grid solutions. This report provides an overview of the Ministry's role in supporting off-grid technologies and references to support the information provided.

Key Functions of the Ministry:

According to the 2021 Ministry of Trade, Industry, Business Development, and Tourism, National Industrial Policy, the ministry is responsible for the following:

- **Policy Formulation**: The Ministry is responsible for developing and implementing policies that encourage investment and innovation in the field of off-grid technologies. These policies are crucial for creating a favorable regulatory environment for businesses operating in the off-grid sector;
- **Investment Promotion**: The Ministry works to attract both domestic and foreign investment in the off-grid energy and technology sectors. Investment incentives and promotion strategies are vital in fostering growth in these areas;
- **Regulatory Frameworks**: Establishing and enforcing regulatory frameworks for off-grid technologies, including product standards and licensing requirements, falls under the Ministry's purview. These regulations help ensure product quality, safety, and compliance with industry standards;
- **Business Development and Support**: The Ministry provides support and resources for entrepreneurs and businesses involved in off-grid technology solutions. This includes access to funding, training, and technical assistance; and
- **Tourism Promotion**: In the broader context of tourism, the Ministry's efforts can indirectly benefit the off-grid sector, as tourism often requires sustainable and reliable

off-grid energy solutions, such as solar power for remote lodges and eco-tourism facilities.

Possible role in Off-Grid Technologies:

- **Off-Grid Energy**: The Ministry promotes off-grid energy solutions, such as solar and small-scale hydropower, to help rural and remote communities access electricity. By fostering a supportive environment, the Ministry encourages businesses to invest in and provide off-grid energy services to underserved areas (National Industrial Policy, 2021);
- **Technology Innovation**: The Ministry supports innovation in off-grid technologies, which can include efficient cooking stoves, solar lanterns, and other clean energy solutions. Encouraging innovation in these areas contributes to energy access and environmental sustainability (UNIDO, 2017);
- **Business Incubation**: Through business development programs and incubation centers, the Ministry must help entrepreneurs and startups in the off-grid technology sector by providing training, mentorship, and access to resources and markets (Small and Medium Enterprise Policy, 2021);
- **Product Standards and Quality**: The Ministry must work with the LSI to establish and enforce product standards for off-grid technologies. This ensures that products entering the market meet quality and safety criteria (LSI,2020); and
- **Tourism Infrastructure**: As tourism is a key economic sector in Lesotho, the Ministry indirectly supports off-grid technologies by promoting the development of eco-friendly tourism facilities, often powered by renewable energy sources.

The Ministry of Trade, Industry, Business Development, and Tourism's multifaceted role in Lesotho's economic development makes it a key player in fostering the growth of off-grid technologies and other industries, which can significantly contribute to energy access, sustainability, and economic development in the country.

5.2.8 Lesotho Standards Institute

The Lesotho Standards Institute (LSI) is a key institution in Lesotho responsible for the development, promotion, and implementation of national standards across various sectors, including the field of off-grid technologies. LSI plays a crucial role in ensuring that off-grid technologies meet the necessary quality and safety standards, fostering innovation, and facilitating market access. This report provides an overview of LSI and its possible role in regulating and promoting off-grid technologies, supported by relevant references.

The Lesotho Standards Institute, established under the Lesotho Standards Act of 2016, is the primary organization responsible for standardization and quality assurance in Lesotho. LSI's mandate extends to various industries, including manufacturing, energy, and services, with a focus on setting and upholding national standards to promote economic growth and consumer protection.

Role in Off-Grid Technologies:

LSI must play a crucial role in the off-grid technology sector by performing several key functions as outlined below:

- **Standards Development:** developing and publishing national standards related to off-grid technologies. These standards must cover aspects such as product quality, performance, safety, and environmental impact;
- **Certification and Testing:** The LSI must provide certification and testing services to ensure that off-grid technologies meet the established standards. This certification process helps consumers identify reliable and safe products while supporting manufacturers in complying with regulatory requirements;
- **Quality Assurance:** LSI's activities will also contribute to improving the quality and reliability of off-grid technologies, which is essential for enhancing the overall energy infrastructure in Lesotho. Quality assurance measures also foster confidence among consumers and investors;
- **Market Access:** By establishing and promoting standards for off-grid technologies, LSI must facilitate market access for manufacturers and suppliers. This will help attract investments and encourages the growth of the off-grid technology sector in Lesotho;
- **Consumer Protection:** The LSI must do this by ensuring that off-grid technologies meet the prescribed standards protects consumers from substandard or unsafe products. This, in turn, contributes to the safety and well-being of the population of Lesotho;
- **Regulatory Compliance:** LSI's standards and certification processes will assist businesses in complying with regulatory requirements, which is vital for manufacturers and suppliers of off-grid technologies; and
- **Innovation Support:** By engaging with industry stakeholders and experts, LSI will contribute to the development of innovative and sustainable off-grid technologies that can address energy access challenges in the country.

The LSI is relatively new and has not adopted any standards in relation to energy technologies. The recommendations section of this report will propose various functions which must be done by the LSI where the Off-grid market is concerned.

LSI's role in the off-grid technology sector is pivotal for fostering a sustainable, reliable, and safe energy supply in Lesotho. The development and implementation of national standards for off-grid technologies contribute to the country's energy security, environmental sustainability, and economic growth.

5.2.9 Lesotho National University Energy Research Centre

According to the discussions with the institution, the Lesotho National University Energy Research Centre (LNU ERC) must play a pivotal role in the development, research, and implementation of off-grid and renewable energy technologies in the Kingdom of Lesotho. As

an academic and research institution, LNU ERC is dedicated to addressing energy challenges and promoting sustainable solutions. This report provides an overview of the LNU ERC's activities and their significance in the context of off-grid and renewable energy technologies, supported by references.

Role and Significance:

According to the Lesotho National University website (https://erc.nul.ls/), the role of the ERC is entrenched in its mandate to perform the following tasks:

- **Research and Development (R&D):** LNU ERC is at the forefront of research into off-grid and renewable energy technologies. The center conducts studies on solar power, wind energy, and other sustainable sources, exploring their viability and applicability in Lesotho's context. Their R&D efforts aim to identify the most effective technologies and solutions for the country;
- **Capacity Building:** The center plays a vital role in training and capacity building. By offering courses, workshops, and educational programs related to renewable energy, LNU ERC equips local professionals, students, and technicians with the knowledge and skills needed to work in the renewable energy sector;
- **Technical Assistance and Consulting:** LNU ERC collaborates with government agencies, NGOs, and private enterprises to provide technical expertise and advice on renewable energy projects. Their assistance helps in the design, implementation, and evaluation of off-grid and renewable energy initiatives;
- **Innovation and Technology Transfer:** The center fosters innovation by supporting local inventors and entrepreneurs. They help identify promising technologies and facilitate technology transfer, enabling the adoption of innovative solutions in the country's energy landscape; and
- **Data Collection and Analysis:** LNU ERC collects and analyzes data related to energy generation, consumption, and trends in Lesotho. This data is essential for informed decision-making by the government and stakeholders in the energy sector.

Projects and Initiatives:

- **Off-Grid Electrification Programs:** LNU ERC is actively involved in the development and evaluation of off-grid electrification programs, particularly in remote and rural areas where grid access is limited. They collaborate with partners to identify the most suitable off-grid solutions, such as solar home systems and microgrids (UNDP, 2019);
- **Renewable Energy Feasibility Studies:** The center conducts feasibility studies for renewable energy projects, including wind farms, solar installations, and small hydropower plants. These studies provide essential insights into the technical and economic viability of such projects (SEFA,2019);
- **Energy Efficiency Promotion:** LNU ERC is dedicated to promoting energy efficiency in both residential and industrial settings. They conduct research on energy-efficient

technologies and provide recommendations to reduce energy consumption (GEF,2017); and

- **Collaboration with Stakeholders:** According to the 2017 Lesotho Renewable Energy and Energy Efficiency Capacity Development Support Project The center collaborates with government ministries, development agencies, and the private sector to align their research and initiatives with national energy policies and priorities.

5.2.10 Lerotholi Polytechnic Institution

According to its course brochure of 2021, Lerotholi Polytechnic is one of Lesotho's premier technical and vocational training institutions. Established in 1988, it plays a vital role in the country's development by providing education and training in various technical and engineering disciplines. In recent years, Lerotholi Polytechnic has taken significant steps to promote off-grid and renewable energy technologies to address energy access challenges and foster sustainable development in Lesotho.

Key Initiatives and Role in Off-Grid and Renewable Energy Technologies:

According to the Lerotholi Polytechnic course programs of 2021 and annual reports of 2020 the roles and initiatives are outlined below:

- **Renewable Energy Education:** Lerotholi Polytechnic offers educational programs and training in renewable energy technologies. These programs equip students with the knowledge and skills necessary to work with solar, wind, and other renewable energy systems. They also promote the integration of renewable energy solutions in various sectors (Lerotholi Polytechnic, 2021). Course Brochure);
- **Research and Development:** The institution is actively involved in research and development activities related to renewable energy technologies. It collaborates with government agencies, non-governmental organizations, and industry partners to explore innovative solutions for Lesotho's energy challenges. Research efforts include improving the efficiency and reliability of off-grid energy systems (Lerotholi Polytechnic. (2020). Research and Development Projects);
- **Community Outreach:** Lerotholi Polytechnic engages with local communities to raise awareness about the benefits of renewable energy and off-grid solutions. It conducts workshops, training sessions, and outreach programs aimed at promoting clean and sustainable energy practices, especially in rural areas where access to electricity is limited (Lerotholi Polytechnic. (2019). Annual Report);
- **Technology Transfer:** The institution facilitates the transfer of renewable energy technologies and knowledge to local entrepreneurs and businesses. This helps stimulate the growth of the renewable energy sector, creating job opportunities and fostering economic development (Lerotholi Polytechnic. (2022). Technology Transfer Program);
- **Partnerships:** Lerotholi Polytechnic collaborates with national and international organizations to further its off-grid and renewable energy initiatives. These partnerships bring in expertise, funding, and resources to support projects and

programs aimed at improving access to clean and reliable energy (Lerotholi Polytechnic. (2021). Collaborations and Partnerships); and

- **Capacity Building:** The institution conducts training programs and workshops for technicians, engineers, and other professionals working in the renewable energy sector. These programs aim to enhance the skills and knowledge of the workforce, thereby contributing to the growth of the industry (Lerotholi Polytechnic. (2020). Capacity Building Initiatives).

Lerotholi Polytechnic Institution in Lesotho serves as a valuable resource for promoting off-grid and renewable energy technologies in the country. By offering education, research, community outreach, technology transfer, and capacity-building initiatives, the institution plays a crucial role in addressing energy access challenges and advancing sustainable development. Its efforts align with the broader goal of providing clean and reliable energy to the people of Lesotho, particularly in remote and underserved areas.

The institution must continue to offer and introduce the skills for Off-grid in Lesotho, to ensure that the installers and providers of the solutions are localized.

5.2.11 Solar Lights

According to the consultation meeting, Solar Lights is a home solar light company based in Lesotho, dedicated to improving energy access and sustainability in the region. Founded with a mission to address the energy challenges faced by off-grid communities in Lesotho, Solar Lights specializes in the development, distribution, and maintenance of solar-powered lighting solutions and renewable energy technologies.

Key Activities according to the meeting held on 13 September 2023:

- **Solar Lighting Solutions:** Solar Lights provides a range of solar lighting products designed to meet the unique needs of off-grid and remote communities in Lesotho. These products include solar lanterns, home lighting systems, and streetlights. They offer a clean, affordable, and sustainable source of lighting, improving the quality of life for residents without access to the grid;
- **Renewable Energy Awareness:** The company is actively involved in raising awareness about the benefits of renewable energy technologies. Through community engagement and educational programs, they aim to promote the use of solar and other clean energy sources as a means to reduce environmental impact and enhance energy resilience;
- **Microgrid Development:** Solar Lights collaborates with local communities to design and implement microgrid projects. These microgrids are powered by renewable sources like solar and wind, providing electricity to underserved areas where grid connectivity is challenging; and
- **Energy Efficiency Solutions:** In addition to providing clean energy, the company focuses on energy efficiency. They offer energy-efficient appliances and conduct

energy audits to help households and businesses maximize the use of renewable energy.

5.2.12 African Clean Energy

African Clean Energy (ACE) is an organization that plays a crucial role in advancing off-grid and renewable energy technologies in Lesotho. As Lesotho seeks to address energy access challenges and promote sustainable development, ACE's innovative solutions have been instrumental in providing clean energy solutions to the country. This section highlights ACE's role and contributions to Lesotho's off-grid and renewable energy sector as per the meetings that took place on 12 September 2023.

African Clean Energy is a social enterprise that focuses on providing clean, renewable energy solutions to off-grid and energy-poor communities in developing countries. Founded in 2011, ACE has gained recognition for its clean cooking and off-grid energy products. Their flagship product, the ACE 1, is a clean and efficient cookstove that uses a combination of biomass pellets and solar power to provide clean cooking solutions. Moreover, ACE has been working on expanding its product range to include off-grid electricity solutions, aligning with Lesotho's commitment to promoting renewable energy[13].

ACE's Contributions to Lesotho's Off-Grid and Renewable Energy Sector:

- **Clean Cooking Solutions**: ACE's ACE 1 clean cookstove has had a significant impact on the lives of many Basotho households. It reduces indoor air pollution, which is a major health concern associated with traditional cooking methods. This contributes to improved respiratory health and overall well-being among the local population;
- **Solar Power Integration**: ACE's products incorporate solar power, which aligns with Lesotho's efforts to harness its solar energy potential. The combination of solar and biomass pellets enhances the efficiency and sustainability of the energy source;
- **Environmental Impact**: ACE's clean cooking solutions reduce the reliance on traditional biomass fuels, thereby mitigating deforestation and reducing carbon emissions. This aligns with Lesotho's environmental goals and commitment to combat climate change;
- **Community Engagement**: ACE is known for its community engagement and capacity-building initiatives. They not only provide products but also educate users on their benefits and proper use. This empowers local communities to make the most of clean energy technologies**; and**
- **Partnerships**: ACE collaborates with local and international organizations, government agencies, and NGOs in Lesotho to expand their reach and promote clean energy solutions effectively.

African Clean Energy (ACE) can play a significant role and input in setting and promoting standards for off-grid products in Lesotho in several ways. It can collaborate with local regulatory bodies, governments, and international organizations to establish and adhere to

[13] https://africancleanenergy.com/about-us/ ,

rigorous quality and safety standards for off-grid products, particularly clean cooking stoves and energy solutions. This ensures that products meet certain quality benchmarks and are safe for use.

ACE can also advocate for and implement environmental standards, ensuring that off-grid products are designed and produced with sustainability in mind. This might include promoting energy-efficient technologies and reducing carbon footprints.

In terms of education of customers ACE can continue to actively educate consumers and the public about the importance of choosing products that meet certain standards. This can help raise awareness about the benefits of high-quality off-grid products and encourage informed purchasing decisions.

The private sector also has a role to participate in the capacity building of Lesotho citizens. It can provide training and capacity-building programs for local manufacturers and producers of off-grid products. By improving the skills and knowledge of local producers, ACE can indirectly contribute to the adoption of high standards within the industry.

In terms of advocacy and policy influence, ACE can engage with policymakers to advocate for regulations and policies that support and encourage the adoption of high standards for off-grid products. They can share their expertise and research to influence policy decisions.

On Research and Development, ACE can invest in research and development to improve existing off-grid technologies and to create new, innovative solutions. By pushing the boundaries of what's possible, they can set benchmarks for the industry.

ACE can contribute to the development and promotion of high standards for off-grid products in Lesotho. This not only benefits consumers by ensuring they have access to safe, efficient, and sustainable energy solutions but also helps drive the growth of the off-grid sector and contributes to broader sustainability goals.

6 Identifying and Defining Off-Grid Products for Kingdom of Lesotho

Access to reliable and affordable energy is a fundamental driver of socio-economic development and improved quality of life. In Lesotho has, the challenge of providing electricity to remote and off-grid areas is particularly acute due to the country's rugged terrain and dispersed population.

This section explores the landscape of off-grid technologies and solutions which are available Lesotho, highlighting the importance of identifying and implementing sustainable energy solutions to address energy access gaps.

Lesotho, with a population of approximately 2.2 million, faces significant challenges in ensuring widespLead access to electricity. The majority of its population, particularly in rural and remote regions, lacks access to the national electricity grid. This energy access gap is a barrier to socio-economic development, healthcare, education, and overall quality of life (World Bank, 2020). Additionally, the vulnerability of the energy sector to climate change impacts, particularly on hydropower generation, further complicates the situation (UNDP, 2018).

Off-grid technologies and solutions play a pivotal role in addressing energy access challenges in Lesotho. These solutions are designed to provide decentralized, stand-alone, or mini-grid systems that can bring electricity to areas beyond the reach of the centralized grid. Off-grid technologies encompass a wide range of options, including:

Further to what has been identified during the stakeholder meetings, the following off-grid products recommended for inclusion to the technical guideline and labelling of off-grid solutions are as follows:

Figure 2: Lesotho Identified Off-Grid Solutions to be defined

6.1 Solar Photovoltaics

In Lesotho, as in many other regions, solar panels are a popular and environmentally sustainable way to generate electricity from the sun's energy. There are several types of solar panels commonly used, each with its own advantages and applications. Below different types of solar panels suitable for use in Lesotho, will be defined. Table 2 below shows minimum specifications that must be visible and labelled on all solar panels which may be adopted by the Lesotho Market:

Table 2: Minimum Specification required for Solar Panels in Lesotho Off-grid Market (Source: US Department of Energy, Selecting Solar Panels)

Name of the Off-Grid Product	**Solar Photovoltaic**
Item	**Description**
Solar Panel Type	The type of solar cell technology used in the panel impacts efficiency, aesthetics, and cost.
Efficiency	This percentage indicates how much sunlight the panel can convert into electricity. Higher efficiency panels generate more power in the same amount of space.
Power Output:	**Wattage or Kilowatt Rating**: This represents the maximum power output of the panel. Choose panels with wattage appropriate for your energy needs.
Temperature Coefficient:	**Temperature Coefficient of Pmax**: This value measures how the panel's efficiency decreases as the temperature rises. Lower coefficients are better for hot climates.
Tolerance:	**Power Tolerance**: Indicates how closely the panel's actual output matches its rated output. Smaller tolerance percentages signify better quality.
Frame and Durability:	**Frame Material**: Panels come with aluminum or steel frames. Aluminum is more common due to its corrosion resistance. **Durability**: Look for panels with strong frames and certifications for wind and snow loads.
Warranty:	Product and Performance Warranty: Panels typically come with a product warranty (e.g., 10-25 years) and a performance warranty guaranteeing a minimum output (e.g., 25 years).
Operating Conditions:	**Temperature Range**: Panels should operate within a specified temperature range, with some models designed for extreme conditions. Nominal Operating Cell Temperature, which estimates panel performance at specific conditions.
Certifications:	Look for certifications such as IEC and any other widely recognized certifications
Degradation Rate:	Manufacturers often specify the rate at which their panels degrade over time (typically 0.3%-0.8% per year). Lower degradation rates mean longer-lasting efficiency.
Aesthetics:	Panel appearance may be important, especially for residential installations. Black or all-black panels are less obtrusive.
Mounting Orientation and Angle:	Consider the panel's recommended orientation (e.g., south-facing) and angle (e.g., 30 degrees) for optimal performance.
Compatibility:	Ensure the panels are compatible with your inverter and mounting system.

6.1.1 Monocrystalline Solar Panels

Monocrystalline solar panels are a type of photovoltaic technology that is highly regarded for its exceptional efficiency and aesthetics. These panels are constructed from single-crystal silicon, which results in a uniform and smooth appearance, making them a popular choice for both residential and commercial solar installations[14]. Monocrystalline solar cells are known for their high efficiency ratings, often exceeding 20%, which means they can convert a greater portion of sunlight into electricity[15]. This increased efficiency is advantageous for areas with limited rooftop space or where maximizing energy generation is a priority. Monocrystalline panels are also renowned for their longevity and durability, typically coming with warranties of 25 years or more and they are an excellent choice for those looking to harness solar energy while maintaining a sleek and visually appealing appearance on their properties[16]. Figure 3 below shows the Monocrystalline Solar Panels pictures.

Figure 3: Monocrystalline solar panels (Source: Sollatek.com)

Monocrystalline solar panels offer a promising solution for Lesotho's energy needs, with their high efficiency and reliability. The efficiency of monocrystalline panels ensures that even in less-than-optimal sunlight conditions, they can generate a substantial amount of clean energy. Furthermore, the durability of monocrystalline panels makes them suitable for Lesotho's rugged terrain and extreme climate, providing a sustainable energy solution for the long term.

6.1.2 Polycrystalline Solar Panels

Polycrystalline solar panels are cost-effective and widely used. They are made from multiple crystal structures and offer good performance in various weather conditions. They are suitable for a range of applications (Renewable Energy World, 2019).

These solar panels are a commonly used type of photovoltaic technology known for their cost-effectiveness and widespLead availability. These panels are constructed from multiple silicon crystals, making them less efficient compared to monocrystalline panels. However, they are more economical to produce, making them a practical choice for a wide range of applications, especially where space is not a limiting factor. Polycrystalline solar panels are recognized for

[14] solarreviews.com.n.d
[15] EnergySage.com.n.d.
[16] Sunpower.com.n.d

their reliable performance and durability, making them a popular choice for residential and commercial installations[17].

Figure 4 below depicts a polycrystalline solar panel:

Figure 4: Polycrystalline Solar Panel (Source: https://www.indiamart.com/)

Polycrystalline solar panels have found significant utility in Lesotho, contributing to the nation's sustainable energy landscape. They have become a viable choice for harnessing solar energy in this region due to their cost-effectiveness, durability, and moderate efficiency levels, making them a suitable option for various applications (World Bank, 2020)

Lesotho's geography, characterized by its high altitude and abundant sunshine, complements the use of polycrystalline solar panels. The panels are capable of converting ample sunlight into electricity, which can be harnessed for both residential and commercial purposes, thereby reducing the nation's reliance on fossil fuels (Lesotho Energy Policy, 2016).

Moreover, the adaptability of polycrystalline panels to diverse environments and weather conditions makes them well-suited for Lesotho's variable climate (Lesotho Meteorological Services, 2020). By incorporating these panels into the energy mix, Lesotho can not only reduce greenhouse gas emissions but also increase access to electricity, particularly in underserved rural areas (LEC.n.d.).

6.1.3 Thin-Film Solar Panels

Thin-film solar panels are lightweight and flexible, making them suitable for irregular surfaces or portable applications. While they are less efficient than crystalline panels, they can be advantageous in specific situations (Solar Power World, 2020).

Thin-film solar panels are known for their adaptability to a variety of environmental conditions, which makes them a potential option for Lesotho's varying weather patterns and altitudes. They tend to perform well in diffuse light and high-temperature conditions, which can be advantageous in Lesotho's climate[18].

Thin-film panels are typically lighter and more flexible than traditional crystalline silicon panels. This flexibility can be beneficial in rural or remote areas in Lesotho, where the terrain may be

[17] US, Energy.gov, n.d
[18] "Advantages of Thin-Film Solar Panels." SolarPowerWorld. solarpowerworldonline.com.

challenging or where off-grid installations are require[19]. These panels are often less expensive to produce than crystalline silicon panels, which can make them a cost-effective choice for both grid-connected and off-grid solar installations in Lesotho[20].

One drawback of thin-film panels is their relatively lower efficiency compared to monocrystalline or polycrystalline silicon panels. This means that more surface area may be required to generate the same amount of electricity, which could be a limitation in areas with limited available space[21].

Thin-film panels can be well-suited for large-scale solar farms, which may be developed in Lesotho to generate renewable energy for export or local consumption[22]. To determine the feasibility of thin-film panels in Lesotho, it's important to assess the specific energy needs, available space, and economic considerations. Factors like government incentives and policies supporting solar energy adoption should also be considered[23].Figure 5 depicts a picture of the thin film solar panels.

Figure 5: Thin Film Solar Panels (Source: https://www.azocleantech.com/)

In conclusion, thin-film solar panels offer certain advantages, such as adaptability to varying conditions and cost-effectiveness, which can make them a viable option for Lesotho's energy needs. However, their lower efficiency and evolving technology should be taken into account when considering their use in solar projects in the region.

6.1.4 Bifacial Solar Panels

Bifacial solar panels can capture sunlight from both sides, increasing their energy generation. They are often used in installations where sunlight can be reflected onto the rear side of the panel[24].

[19] "Thin Film vs. Crystalline Silicon: The Advantages and Disadvantages." Solar.com. solar.com.
[20] "The Pros and Cons of Thin Film Solar Panels." EnergySage. energysage.com.
[21] "Comparing Thin-Film to Crystalline Silicon Panels." Energy.gov. energy.gov.
[22] "Large Scale Thin-Film Solar Power Plants." Solar Choice. solarchoice.net.au.
[23] "Factors to Consider When Evaluating Solar Panel Types." EnergySage. energysage.com
[24] Solar Builder. (2019). What You Should Know About Bifacial Solar Panels. Retrieved from SolarBuilderMag.com

Bifacial solar panels are designed to capture sunlight from both the front and rear sides, increasing their overall energy generation. This dual-sided capability can be particularly beneficial in regions with variable weather conditions, like Lesotho, where cloud cover and snowfall can affect solar energy production.

Lesotho's snow-covered landscapes during winter can enhance the albedo effect, which is the reflection of sunlight off the ground. Bifacial panels can capture some of this reflected light, further improving energy yield[25]. Bifacial panels are known for their ability to perform well in low light conditions. In Lesotho, where weather patterns can change rapidly, this resilience can be advantageous, ensuring a more consistent energy supply[26].

By producing more energy from the same land area, bifacial panels can help reduce the environmental impact associated with solar energy production, such as land use and materials[27]. Given the specific climatic and geographical conditions in Lesotho, it would be beneficial to conduct research and monitoring to assess the performance of bifacial solar panels in the region. This data can help optimize their use and ensure maximum benefits. Below figure 6 depicts a typical picture of bifacial solar panels:

Figure 6: Bifacial Solar Panels (Source: Solarreviews.com)

Bifacial solar panels offer a promising solution for Lesotho's energy needs, given their enhanced efficiency, adaptability to varying conditions, and potential for increased energy output. However, practical implementation and localized research are essential to fully understand their benefits in the unique context of Lesotho.

6.1.5 Copper Indium Gallium Selenide (CIGS) Solar Panels

CIGS solar panels are a type of thin-film technology. They are known for their flexibility, making them suitable for curved or irregular surfaces. They are also lightweight and can perform well in low-light conditions[28].

[25] Aidan Wang, Chief Marketing Officer of LONGi Solar, "Bifacial Solar Technology: Understanding the Albedo Effect," LONGi Solar Blog
[26] Jifan Gao, President of Trina Solar, "The Bifacial Advantage: Unlocking the Full Potential of Solar Panels," Trina Solar Blog.
[27] Rik De Doncker, "Bifacial Solar Modules—An Opportunity in Utility-Scale PV Plants," IEEE Xplore.
[28] Solar Magazine. (2021). CIGS Solar Panels: Characteristics, Advantages, and Manufacturers. Retrieved from SolarMagazine.com

Copper Indium Gallium Selenide (CIGS) solar panels are a thin-film photovoltaic technology that has gained attention in recent years due to their potential advantages and suitability for specific applications.

These solar panels have shown promise in terms of efficiency, with the potential to convert a high percentage of sunlight into electricity. Their thin-film design allows them to perform well even in low-light conditions, making them suitable for regions with varying weather patterns, such as Lesotho[29]. CIGS panels are lightweight and can be manufactured in flexible form factors. This flexibility can be advantageous for various applications, including off-grid and portable solar solutions, which can be particularly useful in Lesotho's remote and rural areas[30].

The production of CIGS solar panels has the potential to be more cost-effective than traditional silicon-based panels. The establishment of local manufacturing or assembly facilities could contribute to affordability and accessibility for Lesotho's residents[31].

While CIGS panels offer several benefits, they can be less durable than traditional crystalline silicon panels, especially in harsh environmental conditions. It is essential to consider the local climate and environmental factors in Lesotho, which may impact the long-term performance and maintenance of CIGS panels[32]. Lesotho may benefit from staying updated on these advancements and potential collaborations with research institutions[33]. Below figure 7 depicts a picture of typical CIGS solar panels.

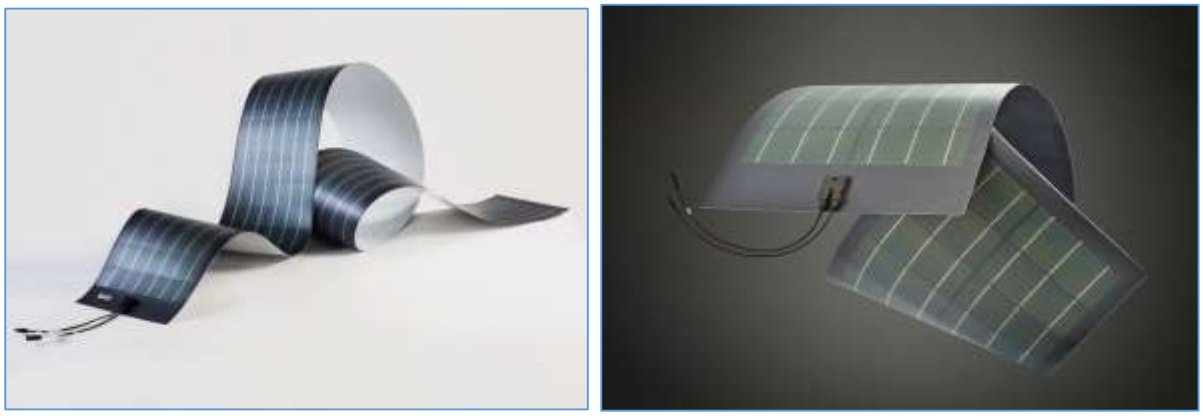

Figure 7: CIGS solar panels (Source: dsisolar.com)

CIGS solar panels hold promise for Lesotho, particularly for off-grid and portable solar applications. However, careful consideration should be given to local environmental factors and the need for ongoing maintenance.

6.1.6 Amorphous Silicon (a-Si) Solar Panels

Amorphous silicon solar panels are another thin-film type. They are known for their low cost and the ability to perform well in low-light conditions. They are used in a variety of applications, including small electronic devices. Amorphous silicon solar panels, often referred to as thin-

[29] "CIGS Solar Cells: A Technology Overview" - National Renewable Energy Laboratory (NREL)
[30] Flexible and Lightweight CIGS Solar Modules" - Solar Power World
[31] "Comparing the Costs of Thin-Film and Silicon Solar Panels" - Solar Reviews
[32] "Advantages and Disadvantages of Thin-Film Solar Panels" - EnergySage
[33] "CIGS Solar Cell Efficiency Breaks World Record" - PV Magazine

film solar panels, offer a distinct set of advantages and considerations when evaluating their potential use in Lesotho.

The Amorphous silicon panels are known for their versatility in terms of form and aesthetics. They can be integrated into various surfaces and structures, making them suitable for a range of applications in both urban and rural settings (IRENA, 2015).[34]

Amorphous silicon panels typically have lower efficiency compared to crystalline silicon panels. However, they have an advantage in low-light conditions, making them suitable for areas with variable weather patterns or high cloud cover, which can be relevant in Lesotho [35].

The manufacturing process for amorphous silicon panels is generally less expensive than that of crystalline silicon panels. This could make them an economically viable option for Lesotho, especially in distributed and off-grid installations (IRENA, 2015). Regular maintenance and monitoring would be necessary to ensure optimal performance in the Lesotho climate[36].

To effectively utilize amorphous silicon panels in Lesotho, it would be essential to develop local expertise for installation, maintenance, and repair. This can create opportunities for skills development and job creation (IRENA, 2015). Figure 8 below depicts the Amorphous silicon panels.

Figure 8: Amorphous silicon solar panels (Source: pv-magazine.com/)

The adaptability, cost-effectiveness, and resilience to low-light conditions may be particularly advantageous for these panels in this region, provided that local expertise and support mechanisms are established.

6.2 Inverters

In Lesotho, as in many parts of the world, inverters play a crucial role in the generation, conversion, and distribution of electrical power. Inverters are devices that convert direct current (DC) electricity, often generated by solar panels or batteries, into alternating current (AC) electricity that can be used in homes and businesses. Different types of inverters are

[34] IRENA 2015 - Innovation Outlook: Thin-film Solar Photovoltaics
[35] U.S. Department of Energy - Thin-Film Solar Cells
[36] SolarPowerWorld - Thin-Film Solar Panels: Do They Make Sense for You?

used depending on the specific application and requirements. Table 3 is indicative of minimum specifications that must be visible on the inverters market, and maybe adopted in Lesotho:

Table 3: Minimum Specification requirements for Inverters (Source: IEC 62109)

Name of the Off-Grid Product	**Solar Inverters**
Item	**Description**
Inverter Type:	Inverters come in various types, including string inverters, microinverters, and power optimizers. The choice depends on the design and requirements of your solar system.
Power Rating:	The inverter's power rating, typically measured in watts (W) or kilowatts (kW), should match or slightly exceed the total capacity of the solar panels in your system.
Efficiency:	Inverter efficiency indicates how effectively it converts DC power into AC power. Look for a high efficiency rating, which minimizes energy losses in the conversion process.
Voltage Range:	Check the inverter's input voltage range to ensure it is compatible with the voltage output of your solar panels.
Maximum Power Point Tracking (MPPT):	MPPT technology optimizes the inverter's performance by tracking the maximum power point of the solar array to maximize energy production, especially in varying weather conditions.
Number of MPPT Trackers: .	Some inverters have multiple MPPT trackers, allowing for more flexibility in system design and accommodating panels with different orientations or shading issues
Grid Compatibility:	Ensure the inverter is compatible with your local grid voltage and regulations. Some regions may require specific grid support functions, such as anti-islanding protection.
Monitoring and Data Communication:	Look for inverters with built-in monitoring systems and data communication capabilities. These features allow you to track system performance and identify issues in real-time.
Warranty:	Inverters typically come with warranties that vary in length. A longer warranty period provides added peace of mind. Ensure you understand the warranty terms and what it covers.
Compliance with Standards:	Verify that the inverter complies with relevant industry standards and certifications, such as IEC (International Electrotechnical Commission) and any other internationally recognized standards
Remote Control and Smart Features:	Some inverters offer remote control and smart features that allow you to adjust settings, monitor performance, and receive updates through a mobile app or web interface.
Build Quality and Durability:	Consider the inverter's build quality, protection against environmental factors, and its expected lifespan

Name of the Off-Grid Product	Solar Inverters
Item	**Description**
Safety Features:	Check for safety features such as overvoltage protection, overcurrent protection, and arc-fault protection to ensure the safety of your solar PV system.

6.2.1 Off-Grid Inverters

Off-grid or stand-alone inverters are used in systems that are not connected to the grid. They convert DC power from batteries or other sources into AC electricity for local use[37]. These inverters play a crucial role in providing reliable and efficient electrical power in regions like Lesotho, where access to the centralized grid is limited. Here are some remarks on off-grid inverters and their potential for use in Lesotho:

Off-grid inverters are essential in expanding energy access in remote and off-grid areas of Lesotho. They can convert DC power from renewable sources like solar panels or small wind turbines into AC power for use in homes and businesses (IRENA - Off-grid Renewable Energy Systems, 2020), they also contribute to energy independence, reducing dependence on traditional and often unreliable energy sources, such as kerosene lamps or diesel generators. This is critical in areas where grid electricity is scarce. (World Bank - Energy Access, 2021).

With battery storage these inverters can provide a reliable power supply, ensuring that residents in Lesotho have electricity even during periods of grid outages or intermittent power supply. This can be a game-changer for healthcare facilities, schools, and businesses.

Off-grid inverters are compatible with clean and sustainable energy sources, such as solar and wind power. By utilizing these technologies, Lesotho can reduce its carbon footprint and promote environmental sustainability[38].

These energy solutions, when paired with microfinance and entrepreneurship programs, can stimulate economic development in Lesotho. Small businesses can benefit from consistent and affordable electricity, creating new opportunities for growth[39]. Figure 9 below depicts a typical modern off-grid inverter.

[37] R. Ramachandran, et al., "Design and Implementation of an Off-Grid Photovoltaic System with MPPT," in IEEE Transactions on Sustainable Energy, 2019.
[38] UNDP - Renewable Energy for Rural Communities
[39] SE4All - Off-Grid Solutions.n.d.

Figure 9: Modern Off-grid Inverters (Source:Voltacon.com)

It would be important to acknowledge the challenges in deploying off-grid inverters in Lesotho. These challenges may include initial investment costs, maintenance, and ensuring proper training for local communities to manage and maintain the systems effectively. For the successful implementation of off-grid inverters in Lesotho, government support, policies, and international partnerships are crucial. Public-private partnerships and donor programs can help fund and facilitate the adoption of off-grid solutions.

The potential for off-grid inverters in Lesotho is significant, offering the promise of improved energy access, reliability, and sustainability. However, the successful deployment of these solutions requires careful planning, community involvement, and continued support from various stakeholders, both domestic and international.

6.3 Batteries

In Lesotho, electrical power batteries can play a crucial role in supporting various applications, from off-grid energy solutions to backup power systems. Understanding the different types of electrical power batteries is essential for effectively deploying sustainable and reliable energy storage solutions. Here, we define several types of electrical power batteries suitable for use in Lesotho. Table 4 outlines the minimum specification requirements for batteries that may be adopted by Lesotho:

Table 4: Minimum Specification Requirements for Batteries (Source: IEC Standards)

Name of the Off-Grid Product	**Batteries**
Item	**Description**
Battery Type:	The choice of battery chemistry should align with the application. Common types include lead-acid, lithium-ion, and flow batteries. Relevant standards and guidelines can vary based on the specific battery chemistry.
Capacity (Ah or kWh):	Battery capacity, typically measured in ampere-hours (Ah) or kilowatt-hours (kWh), defines the total energy storage capacity of the battery. Reference standards include IEC 62619 for lithium-ion batteries or IEC 61427 for lead-acid batteries.

Name of the Off-Grid Product	Batteries
Item	**Description**
Voltage (V):	The battery's nominal voltage, which can vary based on the specific application and battery chemistry. Relevant standards include IEC 60095 for lead-acid batteries and IEC 62660 for lithium-ion batteries.
Cycle Life:	The number of charge and discharge cycles a battery can undergo while maintaining its performance. For example, IEC 62660 provides guidelines for cycle life testing of lithium-ion batteries.
Depth of Discharge (DoD):	The percentage of a battery's capacity that can be safely discharged without damaging the battery. DoD limits can vary by battery chemistry and technology.
Round-Trip Efficiency: .	The efficiency of energy conversion in the battery, often measured as a percentage. IEC 62933 provides a framework for assessing and reporting energy storage system efficiency.
Self-Discharge Rate:	The rate at which a battery loses charge when not in use. This parameter can vary by battery chemistry and is often specified by manufacturers.
Operating Temperature Range:	The range of temperatures within which the battery can safely and effectively operate. Reference standards may include IEC 62619 for lithium-ion batteries or IEC 61427 for lead-acid batteries.
Safety and Certification:	Batteries should conform to safety standards and may require certification. For example, UN 38.3 is a set of guidelines for the safe transport of lithium-ion batteries, while IEC 62133 addresses safety aspects of lithium-ion batteries.
Environmental Impact:	Consider the environmental impact, such as recyclability and disposal, in line with relevant regulations and guidelines. For lithium-ion batteries, IEC 62603 provides guidance on environmental aspects.
Communication and Monitoring: .	Some batteries come with built-in communication interfaces and monitoring capabilities, which can be essential for system integration.
Warranty:	The terms and conditions of the battery warranty, which can vary by manufacturer. Review warranty documents provided by the manufacturer for details.
Grid Compatibility: .	For batteries intended for grid-tied systems, ensure they comply with grid code requirements and relevant grid connection standards, which can vary by region and utility

6.3.1 Lead-Acid Batteries

Lead-acid batteries are a well-established technology known for their affordability and reliability. They are commonly used in off-grid solar systems and backup power applications in Lesotho's rural and remote areas (Shukla, A. K. et al. (2019). Figure 10 shows an example of Lead- Acid Batteries:

.Figure 10: Lead-Acid Battery (Source: https://www.Leadacid-batteries.com/products/)

6.3.2 Lithium-Ion Batteries

Lithium-ion batteries offer high energy density and longer lifespan compared to Lead-acid batteries. They are suitable for various applications, including grid stabilization, renewable energy integration, and electric vehicle charging infrastructure in urban and peri-urban areas of (Lesotho Scrosati, B., & Garche, J, 2010). Figure 11 shows an example of Lithium-Ion Batteries.

Figure 11: Lithium Ion Battery (Source: https://www.lithiumion-batteries.com/products/)

6.3.3 Nickel-Cadmium (Ni-Cd) Batteries

Ni-Cd batteries are known for their robustness and ability to withstand extreme temperatures, making them suitable for off-grid and industrial applications in Lesotho, particularly in regions with harsh environmental conditions (Linden, D., & Reddy, T. B. (Eds.), 2002). Figure 12, depicts a typical picture of a Nickel-Cadmium Battery.

Figure 12: Nickel-Cadmium Battery (Source: Batteryguy.com)

6.3.4 Nickel-Metal Hydride (Ni-MH) Batteries

Ni-MH batteries offer a good balance between energy density and environmental sustainability. They are commonly used in portable electronics and backup power systems, and can be a benefit to Lesotho's urban and rural areas (Pistoia, G. (Ed.), 2005). Figure 13 shows an example of typical Nickel-Metal Hydride Batteries.

Figure 13: Nickel-Metal Hydride Batteries (Source: BatteryGuy.com)

6.3.5 Flow Batteries

Flow batteries are ideal for large-scale energy storage applications and grid-level renewable energy integration projects in Lesotho. Their scalability and long cycle life make them suitable for managing fluctuating energy demands (Skyllas-Kazacos, M., et al, 2011). Figure 14 shows an example of typical Flow Batteries.

Figure 14: Flow Batteries (Source: Solarreviews.com)

6.3.6 Sodium-Sulfur Batteries

Sodium-sulfur batteries, known for their high energy density and efficiency, are suitable for grid-scale energy storage applications in Lesotho. They are often used in stabilizing renewable energy sources and managing peak energy demands (Lu, X., et al, 2013). Figure 15 shows an example of typical Sodium Sulphur Batteries.

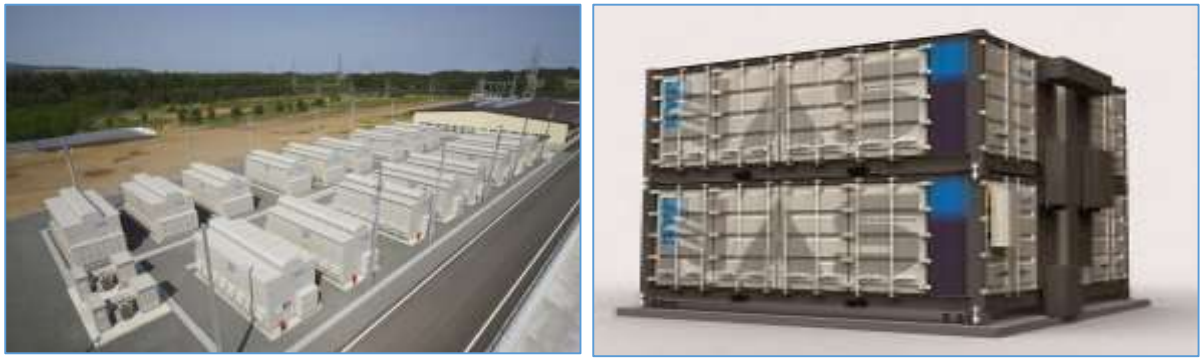

Figure 14: Sodium Sulphur Batteries (Source: basf.com)

6.3.7 Zinc-Bromine Batteries:

Zinc-bromine batteries are well-suited for off-grid and remote area applications in Lesotho, providing reliable and long-duration energy storage solutions. They are known for their low cost and high energy density (Skyllas-Kazacos, M., et al, 1986). Figure 16 shows an example of typical Zinc Bromine Batteries.

Figure 16: Zinc Bromine Batteries (Source:Stockhea.co.au)

Understanding the unique characteristics and applications of these different types of electrical power batteries is crucial for designing effective and sustainable energy storage solutions tailored to meet the diverse energy needs of Lesotho's population, both in urban and remote areas.

In Lesotho, as in many other places, various types of electrical power batteries may be used for different applications. These batteries serve critical roles in providing backup power, supporting renewable energy systems, and enabling electrification in off-grid areas.

6.4 Solar Home Lights

Solar home lights are another proof to the power of innovation and renewable energy technologies. These systems harness the abundant sunlight that graces the nation throughout the year, converting it into clean and sustainable electricity. They have become an indispensable part of everyday life for thousands, lighting up homes, powering small appliances, and even enabling children to study after dark, thus contributing to educational and economic empowerment. Table 5 outlines the typical minimum specification requirements for solar home lights that maybe adopted by Lesotho:

Table 5: Minimum Specification Requirements for Solar Home Lights (Source: IEC 62509)

Name of the Off-Grid Product	**Solar Home Lights**
Item	**Description**
Solar Panel:	Power Rating: Typically ranging from 5 watts to 50 watts or more, depending on the system's capacity. Type: Monocrystalline, polycrystalline, or thin-film solar panels.
Battery:	Type: Rechargeable battery (e.g., lead-acid, lithium-ion, or LiFePO4). Capacity: Varies from 7Ah to 50Ah, depending on the system's energy storage needs.
Lighting Fixtures:	• Type: LED (Light Emitting Diode) lights are common due to their energy efficiency. • Number of Bulbs: Typically 2 to 4 LED bulbs or more. • Brightness: Lumens rating, often ranging from 200 to 1,000 lumens per bulb. • Lighting Hours: The number of hours the lights can operate on a full charge.
Control Unit:	• Charge Controller: To regulate the power flow from the solar panel to the battery and prevent overcharging. • Inverter: If AC (alternating current) power is needed for appliances, a small inverter may be included.
Mobile Charging:	USB Ports: Many solar home systems include USB ports for charging mobile phones and small electronic devices.
Indicator and Controls:	• Battery Status: LED indicators to show the battery's charge level. • On/Off Switch: To control the lighting system. • Remote Control: Some systems come with remote controls for convenience.
Power Source Options:	• Solar Charging: The primary source of energy. • Grid Charging: Some systems may have the option to charge from the grid in case of extended cloudy days.

Name of the Off-Grid Product	Solar Home Lights
Item	**Description**
Mounting and Installation:	• Wall-mounted or ceiling-mounted fixtures. • Portable or fixed installation options.
System Protection:	• Overcharge and over-discharge protection for the battery. • Short-circuit protection for safety.
Warranty:	Manufacturer's warranty covering the solar panel, battery, and other components. Warranties typically range from 1 to 5 years or more.
Compliance with Standards:	Ensure that the solar home lighting system complies with relevant national or international standards for safety, performance, and quality.
Size and Weight:	Dimensions and weight of the system for transportation and installation considerations.
Operating Environment: .	The system should be designed to withstand environmental conditions, including temperature ranges, humidity, and exposure to the elements.

6.4.1 Solar Lanterns

Solar lanterns are compact, portable lighting devices equipped with built-in solar panels. They are suitable for individual use and can be carried or hung indoors or outdoors. Solar lanterns provide a few hours of illumination on a single charge. Solar lanterns are practical for rural households and businesses in Lesotho, especially in areas without access to the grid. They offer affordable and reliable lighting, supporting education and livelihood activities[40]. Figure 17 shows an example of typical solar lanterns.

Figure 17: Solar Lanterns (Source: www.lights.com)

6.4.2 Solar Garden Lights

Solar garden lights are decorative lighting fixtures used in gardens, parks, and landscaping. They consist of small solar panels, LED bulbs, and rechargeable batteries. Solar garden lights

[40] United Nations Foundation. (2016). Pico Solar Market Assessment for the People of Lesotho.

automatically turn on at dusk. Solar garden lights can enhance the aesthetics of outdoor spaces in homes, public gardens, and recreational areas in Lesotho. They provide ambient lighting and reduce the need for traditional grid-powered lighting[41] . Figure 18 shows an example of typical solar garden lights.

Figure 18:Solar Garden Lights (Source:homedecorideas.uk)

6.4.3 Solar Portable Lights

Solar portable lights are small, versatile lighting devices with integrated solar panels. They are designed for individual use and can be carried, hung, or mounted as needed. Solar portable lights are commonly used as task lights or flashlights. Solar portable lights are suitable for various applications, including Leading, cooking, and outdoor activities. They offer convenient and reliable lighting for off-grid households and individuals[42]. Figure 19 shows an example of typical solar portable lights.

Figure 19: Solar Portable Lights (Source:www.aleiexpress.com)

6.5 Solar Street Lights

Solar street lights are standalone lighting systems designed for outdoor use in streets, roads, and public areas. They consist of high-capacity batteries, Light Emitting Diode (LED) lamps, and solar panels. Solar street lights are equipped with sensors for automatic dusk-to-dawn operation. Solar street lights are ideal for illuminating public spaces, streets, and pathways in both urban and rural areas. They offer energy-efficient lighting while reducing operational costs and reliance on grid electricity.

[41] SolarReviews. (2021). The Best Solar Garden Lights for 2021.
[42] Practical Action. (2018). Solar Lighting for Rural Areas: A Comparison of Four Products.

There are several types of solar street lights available, each with its unique features and applications. In Lesotho, the choice of solar street lights should consider factors such as local weather conditions, lighting requirements, and budget constraints. Common types include:

- **All-in-One Solar Street Lights:** All-in-one solar street lights integrate the solar panel, LED lamp, battery, and charge controller into a single unit. They are compact and easy to install[43];
- **Split Solar Street Lights:** Split solar street lights have a separate solar panel that is connected to the light fixture through wires. This design offers flexibility in positioning the solar panel for maximum sunlight exposure[44];
- **Integrated Solar Street Lights:** Integrated solar street lights are similar to all-in-one lights but may have a separate solar panel connected by a short cable. They are known for their high efficiency and ease of installation[45];
- **Solar Street Light Poles:** Solar street light poles are traditional street light fixtures equipped with an integrated solar panel, LED lamp, and battery. They replace existing grid-connected lights and are suitable for locations with existing poles[46];
- **High-Lumen Solar Street Lights:** High-lumen solar street lights are designed to provide exceptionally bright illumination and are suitable for areas where high visibility is critical, such as major roadways[47]; and
- **Decorative Solar Street Lights:** Decorative solar street lights are aesthetically designed fixtures that are often used in urban and commercial areas to enhance the ambiance. They combine functionality with visual appeal[48].

Figure 20 below shows an example of various types of solar streetlights as discussed in this chapter.

[43] United Nations Development Programme (UNDP). (2020). Installation of All-in-One Solar Street Lights in Maseru.
[44] Ministry of Energy and Meteorology, Lesotho. (2019). Solar Street Lighting Program in the Kingdom of Lesotho.
[45] United Nations Industrial Development Organization (UNIDO). (2019). Solar Street Lighting System for Public Places.
[46] Lesotho Electricity Company. (2021). Solar Street Lighting
[47] International Renewable Energy Agency (IRENA). (2017). Roadway and Street Lighting: Market Analysis.
[48] Sustainable Energy Fund for Africa (SEFA). (2019). Solar Street Lighting Investment Opportunities in Lesotho.

Figure 20: Various Types of Streetlights (kcdlights.com)

The adoption of solar street lights in Lesotho holds great potential for improving public safety and energy efficiency. Selecting the right type of solar street light depends on factors like local conditions, lighting requirements, and aesthetic considerations. With various options available, Lesotho can make informed choices to promote sustainable and reliable street lighting solutions. Table 6 outlines the minimum specification requirements for street lights which may be adopted by the Lesotho guideline for Off-grid projects:

Table 6: Minimum Specification Requirements for Streetlights (Source: IEC 62509)

Name of the Off-Grid Product	**Solar Street Lights**
Item	**Description**
Solar Panel:	• Type: Monocrystalline or polycrystalline. • Wattage: Typically 30W to 150W, depending on the lighting requirements. • Efficiency: Minimum efficiency based on the manufacturer's datasheet. • Refer to IEC 61215 for solar panel standards.
Battery:	• Type: Lithium-ion or lead-acid, with preference for lithium-ion due to higher efficiency and longer lifespan. • Capacity: Sufficient to store energy for multiple nights of operation. • Lifespan: Manufacturer's specifications for cycle life.
LED Luminaire:	• Type: High-efficiency LED. • Wattage: Appropriate wattage for the required light output. • Color Temperature: Warm or cool white, depending on project preference.

Name of the Off-Grid Product	Solar Street Lights
Item	**Description**
	• Lumen Output: Complies with project illumination standards..
Controller/Charge Regulator:	• Type: PWM (Pulse Width Modulation) or MPPT (Maximum Power Point Tracking) controller. • Functions: Dusk-to-dawn operation, battery protection, and charge control.
Pole Height and Material:	• Height: As per project requirements, typically 4-8 meters. • Material: Galvanized steel or aluminum for durability.
Autonomy Days	• Number of days the system can operate without sunlight, typically 2-5 days.
Solar Panel Tilt Angle:	• Adjustable or fixed tilt angle for optimal solar exposure.
Light Distribution Pattern:	• Type: Asymmetrical or symmetrical, as per project and road layout. • Reference: IESNA RP-8 for street lighting distribution.
Operating Temperature Range:	Suitable for the local climate and environmental conditions.
Warranty:	Manufacturer's warranty for the entire system, including solar panels, battery, and LED luminaire.
Compliance with Standards:	Ensure compliance with local electrical and safety standards and regulations.
Remote Monitoring and Control:	Optional: Remote monitoring and control capabilities for system performance tracking and maintenance.
Operating Environment: .	The system should be designed to withstand environmental conditions, including temperature ranges, humidity, and exposure to the elements.

6.6 Solar Flood Lights:

Solar flood lights are powerful outdoor lighting systems with high-intensity LED lamps and large solar panels. They are designed to provide focused and bright illumination for a wide range of applications, including security, landscape lighting, and event lighting. Solar flood lights are useful for enhancing security and visibility in residential and commercial areas, as well as for illuminating outdoor events and public spaces, especially in regions with limited access to electricity [49].In Lesotho, where access to electricity can be limited, solar flood lights offer a sustainable and reliable source of illumination. Below are different types of solar flood lights suitable for use in Lesotho:

- **Stand-Alone Solar Flood Lights:** Stand-alone solar flood lights are self-contained systems that include a solar panel, battery, LED light, and a controller. They can be installed easily and are independent of the grid, making them suitable for remote areas in Lesotho[50];

[49] Licwshi. (2021). Remote Control Solar Outdoor Lights.
[50] SEPCO. (2021). Stand Alone Solar Lighting - Solar Power Solutions.

- **Solar Flood Lights with Motion Sensors:** Solar flood lights with motion sensors are equipped with sensors that detect movement and activate the lights. These lights are energy-efficient and ideal for security and lighting pathways[51];
- **Dusk-to-Dawn Solar Flood Lights:** Dusk-to-dawn solar flood lights are designed to automatically turn on at dusk and off at dawn. They are suitable for continuous outdoor lighting, such as in parking lots and driveways[52];
- **Remote-Controlled Solar Flood Lights:** Remote-controlled solar flood lights allow users to adjust the brightness, timing, and modes using a remote control. These lights offer flexibility and customization in lighting[53];
- **Solar Flood Lights with Multiple Heads:** Solar flood lights with multiple heads have two or more adjustable light heads. They can illuminate different directions, making them ideal for wide-area lighting and security applications[54];
- **Solar Flood Lights with Battery Backup:** Solar flood lights with battery backup store excess solar energy in a battery, ensuring continuous operation during cloudy days or nighttime. This feature enhances reliability in areas with inconsistent sunlight[55];
- **Solar Flood Lights with Integrated CCTV:** Some solar flood lights come equipped with integrated closed-circuit television (CCTV) cameras for enhanced security. These lights can capture video footage while providing illumination[56];
- **High-Intensity Solar Flood Lights:** High-intensity solar flood lights are designed to provide extremely bright illumination. They are suitable for large outdoor spaces or areas where high visibility is essential[57];
- **Compact Solar Flood Lights:** Compact solar flood lights are smaller and more portable, making them suitable for camping, emergency lighting, and accent lighting in gardens and patios[58]; and
- **Solar Flood Lights with Remote Monitoring:** Some advanced solar flood lights offer remote monitoring capabilities, allowing users to check the system's status, adjust settings, and receive alerts using a mobile app or online platform[59]. Figure 21 depicts various types of solar floodlights that can be used in Lesotho.

[51] Sunforce. (2021). Solar Motion Security Light.
[52] LEONLITE. (2021). 5000K LED Dusk to Dawn Light.
[53] Licwshi. (2021). Remote Control Solar Outdoor Lights.
[54] RuggedGrade. (2021). Adjustable Solar Wall Mount LED Floodlight.
[55] Bestqool. (2021). Bestqool Solar LED Light.
[56] Ring. (2021). Ring Floodlight Camera
[57] LOVUS. (2021). LOVUS Commercial Solar Flood Lights.
[58] URPOWER. (2021). Solar Lights
[59] Solar Street Lights USA. (2021). Smart Solar Lighting: Remote Management and Monitoring.

Figure 21: Types of Solar Flood Lights (Source: Amazon.ca)

Specifications for solar floodlights may vary depending on the specific model, brand, and intended use. However, in Table 7 are some common specifications and features to consider when evaluating solar floodlights and may be adopted in Lesotho:

Table 7: Minimum Specification Requirements for Solar Floodlights (Source: IEC 62509, IEC 62257, IEC 60598)

Name of the Off-Grid Product	**Solar Floodlights Lights**
Item	**Description**
Solar Panel:	The wattage of the solar panel determines how quickly the floodlight's batteries can charge. Higher wattage panels charge faster. Look for specifications like "X watts monocrystalline solar panel."
Battery:	Battery capacity is usually measured in ampere-hours (Ah) or watt-hours (Wh). Higher capacity batteries can store more energy and provide longer lighting durations. For example, "Li-ion battery with 3.7V, 6000mAh."Capacity: Varies from 7Ah to 50Ah, depending on the system's energy storage needs.
Lighting (Lumens)	Lumens measure the brightness of the light. Higher lumens indicate a brighter floodlight. Look for

Name of the Off-Grid Product	Solar Floodlights Lights
Item	**Description**
	specifications like "1,000 lumens" or more for a floodlight.
Color Temperature	Color temperature indicates the warmth or coolness of the light. For outdoor applications, a "cool white" (around 5,500K) is common for floodlights
Lighting Mode	Floodlights may offer different lighting modes, such as motion sensor, dusk-to-dawn, or continuous lighting. Check for specifications like "3 lighting modes."
Motion Sensor Range	If equipped with a motion sensor, consider the range at which it can detect motion. For example, "motion sensor with a range of 10 meters."
IP Rating	The Ingress Protection (IP) rating indicates the floodlight's resistance to dust and water. For outdoor use, look for a high IP rating like "IP65" for water and dust resistance.
Material and Durability:	Check the construction material, such as aluminum, for durability and resistance to weather conditions.
Installation Options:	Consider whether the floodlight can be wall-mounted, pole-mounted, or ground-mounted, and if the necessary hardware is included.
Remote Control:	Some models come with remote controls for adjusting lighting modes and brightness.
Charging Time:	The time required for a full charge can vary. It may range from a few hours to a full day of sunlight.
Working Time:	The working time is how long the floodlight can operate on a full charge. Look for specifications like "8-10 hours on a full charge."
Certifications	Some solar floodlights may have certifications for quality and safety

6.7 Hybrid Stoves (Biomass & Solar)

Lesotho, a country characterized by rugged terrain and varying energy needs across different regions, presents a unique challenge in achieving sustainable and efficient cooking solutions. Hybrid stoves that integrate both solar and biomass technologies offer a promising way to address these needs. This report defines and identifies different hybrid stoves suitable for use in Lesotho.

Hybrid Stoves are a category of cooking appliances that combine multiple energy sources to improve cooking efficiency and reduce environmental impact. In the context of Lesotho, the primary sources are solar and biomass. Solar energy can be harnessed for cooking through solar thermal technology, while biomass, including wood, crop residues, and animal dung, is the traditional and Leadily available energy source. Below are different Hybrid Stove Types for uses in Lesotho:

- **Solar-Biomass Hybrid Cookstoves:** These stoves integrate a solar thermal component, typically in the form of a solar collector, with a traditional biomass stove. Solar energy is used for preheating water or air, which is then combined with biomass combustion for cooking[60];
- **Solar-Electric-Biomass Hybrid Stoves:** These stoves combine a solar thermal component with a small electric generator, such as a thermoelectric generator or a photovoltaic (PV) panel, to power a more efficient biomass stove or electric heating elements. This combination can provide cooking options during both sunny and cloudy days[61];
- **Solar-Assisted Improved Biomass Stoves:** These stoves are designed to enhance the efficiency of biomass combustion by incorporating solar assistance. Solar energy can be used for preheating combustion air, reducing fuel consumption and emissions[62];
- **Solar Box Cookers with Biomass Backup:** Solar box cookers are passive solar cooking devices that use reflected sunlight to heat an insulated box, where food is placed for cooking. In areas with intermittent sunlight, a biomass backup option is included to ensure continuous cooking [63]; and
- **Pico Solar Stoves with Biomass Support:** Compact, portable solar stoves are designed for individual or small-scale cooking needs. Biomass can complement solar energy during adverse weather conditions or for cooking tasks requiring higher temperatures[64] .

Figure 22, represents various types of hybrid stoves used in Lesotho.

[60] Tripathi, A., et al. (2017). Solar Biomass Hybrid Cook Stove. Energy Procedia, 138, 845-850.
[61] Boudou, J. P., & Duffau, B. (2018). Solar Electric and Biomass Hybrid Stove. Journal of Solar Energy Engineering, 140(2), 021001.
[62] Naphade, S., et al. (2018). Improved Biomass Cookstove with Solar Assistance. Journal of Energy Resources Technology, 140(7), 071103.
63 Shinde, M., & Charfi, A. (2017). Solar Box Cooker with Biomass Backup. Solar Energy, 159, 1104-1115.
64 Chandran, K. M., et al. (2018). Pico Solar Stoves with Biomass Support. Solar Energy, 166, 29-40

Figure 22: Various types of hybrid stoves used in Lesotho (Source:.zimexapp.zw)

Hybrid stoves that combine solar and biomass technologies represent an innovative and sustainable solution to address cooking needs in Lesotho. These stoves provide a way to reduce biomass consumption, improve energy efficiency, and enhance energy security while minimizing environmental impacts. Identifying the right hybrid stove for specific applications in Lesotho can contribute to better livelihoods and sustainable development in this region.

Specifications for biomass hybrid stoves can vary based on factors such as the specific application, the type of biomass fuel used, and regional regulations. However, there are common specifications and standards that are often expected for these stoves. In Table 8 below are some minimum specifications that can be expected on these stoves,

Table 8: Minimum Specification Requirements for Hybrid Stoves (Source: ISO 19867-1:2018 and ISO 19867-2:2018)

Name of the Off-Grid Product	**Hybrid Stoves**
Item	**Description**
Fuel Stoves	Biomass hybrid stoves should be designed to use a variety of biomass fuels, including wood, crop residues, agricultural waste, and pellets. Reference: ISO 19867-1:2018, "Cookstoves and space heaters for use with solid biofuels - Part 1: General requirements."
Efficiency	Stoves should have a high thermal efficiency to maximize energy conversion from biomass to useful heat, thus reducing fuel consumption. Reference: ISO 19867-1:2018.
Emissions:	Biomass stoves should meet emission limits for harmful pollutants, such as particulate matter (PM), carbon monoxide (CO), and volatile organic compounds (VOCs).

Name of the Off-Grid Product	Hybrid Stoves
Item	**Description**
	Reference: ISO 19867-1:2018.
Safety	Stoves should be designed with safety features to prevent accidents, including measures to avoid burns and protect against tipping. Reference: ISO 19867-1:2018.
Heat Output	The stove should provide adequate heat output for its intended use, whether for cooking, heating, or both. Reference: ISO 19867-1:2018.
Durability	Stoves should be built to withstand the rigors of regular use and have a reasonable service life. Reference: ISO 19867-1:2018.
Ease of Use	Stoves should be user-friendly and easy to operate, with clear instructions for proper use. Reference: ISO 19867-1:2018.
Sustainability	Stove design should consider sustainability principles, such as using locally sourced materials and minimizing environmental impact. Reference: ISO 19867-1:2018.
Size and Weight	Biomass hybrid stoves should be compact and lightweight for easy transport and storage. Reference: ISO 19867-1:2018
Compatibility with Renewable Energy	Some hybrid stoves are designed to work in conjunction with solar panels or other renewable energy sources to enhance energy efficiency.
Certification	Stoves should be certified by relevant authorities or testing bodies to ensure compliance with safety and efficiency standards.
Cost-Effectiveness:	Stoves should offer a cost-effective solution for the target market, including affordability and fuel efficiency. Reference: ISO 19867-1:2018..

6.8 Solar Cellphone Chargers

Access to electricity remains a challenge in many parts of Lesotho, particularly in remote and rural areas. As a result, alternative sources of power, such as solar cellphone chargers, can be invaluable in ensuring that individuals stay connected and can access vital information.

Solar cellphone chargers are portable electronic devices that harness solar energy to charge mobile phones and other small electronic devices. They typically consist of photovoltaic (PV) panels that convert sunlight into electrical energy, which is then stored in an integrated battery or used directly to charge the connected devices. These chargers are designed for use in off-grid or remote areas where access to conventional electricity sources is limited. Types of Solar Cellphone Chargers are discussed below:

- **Solar Power Banks:** Solar power banks are compact, portable devices with integrated solar panels and internal batteries. They are designed to charge mobile phones and other small electronic devices on the go[65];
- **Foldable Solar Panels with USB Ports:** Foldable solar panels are larger and more powerful than solar power banks. They can be folded for easy transport and storage. These panels often have USB ports to charge mobile phones directly or to connect to external power banks[66];
- **Solar Charging Kits:** Solar charging kits are designed for off-grid households. They typically include a solar panel, a charge controller, and a battery. These kits can be used to charge multiple devices, including mobile phones[67]; and
- **Backpacks with Solar Panels:** Solar backpacks have built-in solar panels integrated into the fabric. They are designed for outdoor enthusiasts and students, allowing them to charge their devices while on the move[68].

Figure 23 represents the various types of Solar Cellphone Chargers:

Figure 23: Various types of Solar Cellphone Chargers (Source: Thegadgetflow.com)

[65] Jain, M., & Shrivastava, P. (2021). Solar Mobile Charger with Tracking System. International Journal of Recent Technology and Engineering, 9(3), 5402-5405

[66] Rahman, M. S., Emon, S. I., Siddique, N. H., & Islam, M. R. (2019). A Portable Solar Charger Design with High-Efficiency Sun-Tracking System. In 2019 International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST) (pp. 514-519). IEEE.

[67] Sathiya, A., & Prakash, B. (2019). Design and Development of Solar Mobile Charger. International Journal of Research in Engineering, Science and Management, 2(3), 13-17.

[68] M., & Sanga, C. (2019). Design and Implementation of a Solar Panel Integrated Bag for Charging Mobile Phones. International Journal of Emerging Technologies and Innovative Research, 6(6), 161-167.

In Lesotho, where rural electrification remains a challenge, solar cellphone chargers can be a valuable tool for ensuring that individuals in remote areas can stay connected and access vital services through their mobile devices. Table 9 below outlines the minimum specification requirements for Solar Cellphone Chargers which may be adopted by Lesotho.

Table 9: Minimum Specification Requirements for Solar Cellphone Chargers (Source: IEC 62619)

Name of the Off-Grid Product	**Solar Cellphone Chargers**
Item	**Description**
Solar Panel Capacity:	Solar cellphone chargers have different solar panel capacities, typically measured in watts (W) or milliwatts (mW). A higher capacity panel can generate more power. Look for panels that are efficient in converting sunlight into electricity..
Output Power and Voltage	Check the charger's output power, usually measured in watts (W) or milliwatts (mW), and its output voltage, typically 5V, which is standard for charging most cellphones.
Battery Capacity	Some solar chargers include an internal battery for energy storage. The capacity of this battery is usually measured in milliampere-hours (mAh) or watt-hours (Wh) and determines how much charge it can store.
USB Ports	The number and type of USB ports can vary. Ensure that the charger has the appropriate ports for your devices.
Charging Speed	Solar chargers may have different charging speeds based on the available sunlight and the capacity of the charger. Look for information on how long it takes to charge a typical cellphone.
Efficiency Ratings	Efficiency ratings, often represented as a percentage, indicate how effectively the solar panel converts sunlight into electricity. Higher efficiency means faster charging.
Durability and Build Quality	Solar chargers should be durable and weather-resistant. Look for products with durable materials and features like water resistance for outdoor use.
Portability and Size	Consider the size and weight of the charger. Portable chargers are easy to carry and may include features like foldable panels for compact storage.
Compatibility	Ensure that the charger is compatible with your specific cellphone model and any other devices you intend to charge.
Additional Features	Some solar chargers include extra features like built-in flashlights, multiple charging ports, or protective cases.
Certifications and Safety:	Look for certifications that indicate compliance with safety and performance standards.
Warranty	Check if the product comes with a warranty, as it can be an indicator of the manufacturer's confidence in the product's quality.

6.9 Solar Cookers or Ovens

Solar ovens, also known as solar cookers, are devices that use sunlight to cook or heat food. These eco-friendly devices harness solar energy, making them suitable for regions with abundant sunshine like Lesotho. The use of solar ovens in Lesotho can reduce reliance on

traditional biomass fuels, decrease deforestation, and improve access to clean cooking solutions. Figure 24 below are different types of solar ovens and their suitability for Lesotho:

Figure 24 Various types of Solar Ovens (Source: Summitzero.com)

Choosing the right solar oven for Lesotho depends on factors such as local cooking practices, food preferences, weather conditions, and available resources. It's essential to consider the specific needs of the communities and promote awareness and training for the effective use of these ovens to maximize their benefits. Table 10 below outlines the minimum specification requirements for the solar ovens which may be adopted by Lesotho:

Table 10: Minimum Specification Requirements for Solar Ovens (Source: ISO 19867-2:2018)

Name of the Off-Grid Product	**Solar Ovens**
Item	**Description**
Solar Collector Type:	Specify the type of solar collector used, such as parabolic reflectors, solar box cookers, or solar panel cookers. Different designs have varying heat capture and concentration capabilities.
Cooking Capacity	Define the cooking capacity in terms of the number of meals or the volume of food that the solar cooker should be able to handle. Consider the size of pots and pans that can fit inside the cooker.
Temperature Range	Specify the desired cooking temperature range based on the types of dishes to be prepared. Different recipes may require different temperatures.
Materials	Specify the materials used for the cooker's construction. Common materials include reflective materials (e.g., aluminum or stainless steel) for the reflectors, heat-resistant materials for the cooking chamber, and durable supports and stands.
Reflectors	Detail the size and quality of the reflectors. Larger and more reflective surfaces capture more sunlight and generate higher temperatures. Quality materials like anodized aluminum can enhance reflectivity.
Tracking Mechanism	If applicable, specify whether the solar cooker should have a sun-tracking mechanism to follow the sun's path throughout the day for optimal efficiency

Name of the Off-Grid Product	Solar Ovens
Item	**Description**
Cooking Time	Specify the estimated cooking time for different types of dishes, as it can vary based on the design and solar conditions.
Portability	Indicate whether the solar cooker should be portable or fixed in place. Portable cookers are useful for camping and outdoor activities..
Safety Features	Specify any safety features, such as temperature control mechanisms or built-in sun tracking systems, that enhance the usability and safety of the oven.
Warranty:	Define warranty terms and support services, including maintenance and repair options, to ensure the longevity of the solar cooker.
Compliance with Standards:	Ensure that the solar cooker complies with relevant international standards, such as the International Organization for Standardization (ISO) standards for solar cookers
Efficiency	Include efficiency standards or expectations, such as the cooker's ability to convert sunlight into usable heat and its cooking time compared to traditional methods.
Ease of Use .	Consider the ease of use, including setup and operation. User-friendly designs and clear instructions are essential, especially in regions with limited access to education.
Durability	Specify the expected lifespan of the solar cooker and any requirements for withstanding various weather conditions, such as rain, wind, and extreme temperatures.
Packaging and Transportation	Define requirements for packaging and transportation, which are essential for ensuring that the solar cooker reaches its destination in good condition.

6.10 Liquefied Petroleum Gas (LPG) Stoves

Liquefied Petroleum Gas (LPG) stoves are an essential and versatile cooking solution for both urban and rural areas, offering a cleaner and more efficient alternative to traditional solid fuel stoves. In rural Lesotho, where access to modern cooking methods is limited, LPG stoves have the potential to improve cooking practices, reduce indoor air pollution, and enhance the quality of life.

LPG stoves, also known as gas stoves, are cooking appliances that use Liquefied Petroleum Gas as fuel. LPG is a hydrocarbon gas mixture primarily composed of propane and butane, stored in pressurized containers. LPG stoves utilize this gas for cooking by mixing it with air and igniting it through burners, providing a controlled and consistent flame for cooking purposes. Figure 25 below depicts various types of LPG Stoves for Rural Lesotho:

Figure 25: Various types of LPG Stoves for Rural Lesotho (Source:www.catro.co.za)

LPG stoves are a valuable cooking solution for rural Lesotho, offering cleaner and more efficient cooking practices, reducing indoor air pollution, and enhancing overall quality of life. By identifying the different types of LPG stoves available and understanding their benefits, rural communities in Lesotho can make informed decisions about the adoption of this technology to improve their cooking practices. Table 11 below outlines the minimum specification requirements for Liquefied Petroleum Gas stoves which may be adopted by Lesotho.

Table 11: Minimum Specification Requirements for LPG Stoves (Source: ISO 6400:1985)

Name of the Off-Grid Product	**LPG Stoves**
Item	**Description**
Burner Configuration	LPG stoves typically have multiple burners, with specifications regarding the number, size, and type of burners. Common configurations include two, three, or four burners.
Burner Materials	Burners are often made of materials like stainless steel or cast iron for durability and heat resistance.
Ignition System	LPG stoves may have electronic ignition systems for convenient and safe ignition without the need for external lighters.
Flame Control	LPG stoves should provide a range of flame control options to adjust heat intensity for various cooking needs.
Safety Features	Safety features should include flame failure protection to cut off the gas supply if the flame goes out, as well as gas leakage detection and overheat protection

Name of the Off-Grid Product	LPG Stoves
Item	**Description**
Fuel Type	Clearly specify that the stove is designed for LPG use, as different types of gas (e.g., natural gas or propane) may require different burner nozzles.
Gas Pressure	LPG stoves should be designed to operate at the appropriate gas pressure levels according to local regulations.
Control Knobs	Knobs should be ergonomically designed and easy to use for flame adjustment.
Cooktop Material	The cooktop surface is often made of materials like tempered glass or stainless steel, which are easy to clean and maintain.
Pan Support	Stoves may have pan supports or trivets to hold cookware securely over the burners.
Dimensions:	Specify the stove's dimensions, including width, depth, and height, to ensure it fits the intended kitchen space.
Oven and Grilling Features (If applicable)	Some LPG stoves come with ovens or grilling features, which should have their own specifications for temperature range, capacity, and additional features.
Fuel Efficiency	Provide information on the stove's fuel efficiency, including the number of hours of cooking it can provide on a specific LPG cylinder size.
Certifications	Ensure that the LPG stove complies with local and international safety and quality standards, such as ISO or regional safety certifications. Refer to the specific standards applicable in your region
Warranty	Specify the warranty period and terms for the stove to reassure customers of its quality and durability.
Maintenance and Cleaning Instructions	Include guidelines on how to clean and maintain the stove to ensure its longevity and safe operation.

6.11 Solar Water Heaters

Solar water heaters (SWHs) are devices that utilize energy from the sun to heat water for various domestic and industrial applications. In Lesotho, where access to hot water can be challenging, solar water heaters offer an energy-efficient and sustainable solution. There are different types of solar water heaters, and identifying the right one for use in Lesotho depends on factors such as climate, energy requirements, and available space including in some instances, the water pressure. Figure 25 below identifies various types of solar water heaters suitable for Lesotho.

Figure 25: Various types of solar water heaters(Source:FinancialTribune.com)

Selecting the most appropriate type of solar water heater for use in Lesotho depends on local conditions, energy needs, and budget constraints. With the right choice, these systems can offer reliable and sustainable hot water solutions while reducing energy costs and environmental impact. Table 12 outlines the minimum specification requirements for the solar water heaters, which can be adopted by Lesotho.

Table 12: Minimum Specification Requirements for Solar Water Heaters (Source: ISO 9806-1:2013)

Name of the Off-Grid Product	**Solar Water Heaters**
Item	**Description**
Collector Type	Solar water heaters can have different collector types, such as flat-plate collectors or evacuated tube collectors. The collector type affects efficiency and performance.
Collector Area	The collector area, usually measured in square meters, determines the amount of solar energy the system can capture. Larger collector areas can provide more hot water.
System Configuration	Solar water heaters can be passive or active systems. Active systems use pumps to circulate the heat transfer fluid, while passive systems rely on natural convection. Choose a configuration suitable for your needs
Tank Capacity	The size of the hot water storage tank is crucial. It's typically measured in liters or gallons. Larger tanks can store more hot water for use during cloudy days.
Insulation	The tank and piping should be well-insulated to minimize heat loss. Insulation material and thickness are essential specifications.

Name of the Off-Grid Product	Solar Water Heaters
Item	**Description**
Heat Transfer Fluid	Solar water heaters use a heat transfer fluid (e.g., antifreeze or water) to transfer heat from the collector to the tank. The type of fluid and its volume are important.
Mounting	Solar collectors can be roof-mounted, ground-mounted, or integrated into building designs. The choice depends on the available space and system design.
Climate Suitability	Consider the system's performance in your specific climate. Some systems are designed for cold or cloudy climates and are more efficient in those conditions.
Angle Orientation	The angle and orientation of the collector(s) impact efficiency. It should be set to maximize solar exposure in your location.
Backup Heating System	Solar water heaters may include a backup heating system (e.g., electric or gas) for cloudy days. Specifications for the backup system are important.
Warranty	Check the warranty provided by the manufacturer. It should cover the system components, collector, and tank for a reasonable duration.
Certification	Look for certifications from relevant standards organizations, such as the Solar Rating and Certification Corporation (SRCC) in the United States or equivalent organizations in other countries.
Maintenance Requirements	Understand the maintenance needs of the system, including the frequency of inspections, cleaning, and any part replacements.
Local Regulations	Ensure the solar water heater complies with local building codes and regulations. Different regions may have specific requirements

In conclusion, the identification of off-grid technologies and solutions in Lesotho underscores their importance in addressing energy access challenges and driving sustainable development. The integration of these technologies, along with coordinated efforts and policy support, can help bridge the energy access gap, stimulate economic growth, and enhance the overall well-being of Lesotho's population.

7 Gap Analysis Report

In the realm of sustainable energy access and rural electrification, the Kingdom of Lesotho stands as a nation facing both unique challenges and promising opportunities. The aspiration for universal access to reliable and affordable electricity services in Lesotho is one that carries immense significance for socio-economic development, public health, and environmental sustainability. In this context, the present report serves as a comprehensive Gap Analysis, intended to assess the current state of off-grid energy products and services within the country, identify areas where improvements are needed, and highlight opportunities for advancement.

Lesotho, nestled within the southern region of Africa, possesses a landscape marked by both breathtaking mountain ranges and remote, hard-to-reach communities. The country's rugged terrain, combined with a scattered population, has posed formidable challenges to extending the conventional grid infrastructure, leaving a substantial portion of the population in the dark. In

response to this, the pursuit of off-grid energy solutions has emerged as a beacon of hope for the people of Lesotho, offering a pathway to inclusive and sustainable development.

This Gap Analysis Report endeavors to cast a spotlight on the landscape of off-grid products and services currently available in Lesotho. It examines the existing products, technologies, and initiatives designed to alleviate energy poverty and their distribution and adoption across the nation. Furthermore, it delves into the regulatory and policy frameworks governing the off-grid energy sector, assessing their efficacy and potential for improvement. The report also scrutinizes the environmental and socio-economic impacts of off-grid solutions in the Lesotho context, emphasizing the need for sustainability.

As Lesotho embarks on its journey towards universal energy access, this Gap Analysis Report aims to elucidate the challenges and constraints that currently impede progress. It will outline the gaps and deficiencies in off-grid energy products and services that must be addressed. Equally important, it will underscore the successes and innovations that can be built upon to pave the way forward.

The report draws upon a comprehensive analysis of data, consultations with stakeholders, and a synthesis of international best practices to provide recommendations for policymakers, development partners, investors, and the private sector. These recommendations are geared towards fostering an enabling environment for the growth of off-grid energy solutions in Lesotho and ensuring that the benefits of reliable, clean energy are realized by all, regardless of their geographic location.

This Gap Analysis Report represents a critical step towards the attainment of sustainable energy access in Lesotho. By identifying and addressing the existing gaps in the off-grid energy sector, the Government of Lesotho can work collectively to illuminate homes, empower businesses, and energize communities throughout the Kingdom. The future of Lesotho's energy landscape is one of progress, and this report serves as the map to guide us on this transformative journey.

The gap analysis approach for the purposes of this report will be based on the following factors:

- Energy Policy
- Environmental Policy
- Trade and Industry Policy
- Regulation
- Market Participants
- Lesotho Electricity Company
- Lesotho Electricity Generation Company
- Lesotho Grid Code
- Research and Development
- Education
- Communities

The report intends to identify the recommendations on the gaps identified with the view to improve those shortcomings.

7.1 Gaps analysis in the Energy Policy

Lesotho, like many other developing countries, has recognized the importance of expanding off-grid solutions to reach underserved populations. However, regulating the off-grid market presents significant challenges. This report examines the regulatory gaps in Lesotho's off-grid market and suggests strategies to enhance the regulatory framework.

Lesotho's energy sector is regulated by the Ministry of Natural Resources, Energy, and Environment. The sector comprises a mix of on-grid and off-grid solutions, with off-grid products including solar home systems, mini-grids, and other renewable energy technologies. Lesotho has made efforts to encourage the use of off-grid solutions, particularly in rural areas where grid electrification is challenging. After several consultation meetings and information gathering on the Lesotho energy policy, the following gaps in Table 13, below were identified:

Table 13: Gaps in Energy Policy

Item	Identified Gaps	Recommendations
Policy Gaps	**Lack of a Comprehensive Off-Grid Policy:** There is a lack of a dedicated off-grid energy policy, making it challenging to coordinate and prioritize off-grid efforts .	Develop a comprehensive off-grid policy to provide a clear vision, set goals, and outline strategies for promoting off-grid solutions.
	Inadequate Incentives: There are limited incentives for private sector participation in the off-grid market	Create incentives for private sector participation, including tax breaks, import duty exemptions, and investment guarantees.
Legislation Gaps	**Regulatory Uncertainty:** The absence of clear regulatory mechanisms and standards for off-grid products creates uncertainty for investors and consumers, as a results there is slower market growth and limited investor interest due to regulatory uncertainties.	Strengthen regulatory mechanisms and standard enforcement to ensure the quality, safety, and performance of off-grid technologies.
Standardisation and Quality Assurance	**Lack of Standardization:** There is a lack of uniform quality standards for off-grid products, which can affect product quality and consumer trust	Strengthen regulatory mechanisms and standard enforcement to ensure the quality, safety, and performance of off-grid technologies.
	Insufficient Quality Control Measures: The capacity for regular inspections and quality control is inadequate	Invest in training and capacity building to address the shortage of skilled personnel to manage, maintain, and repair off-grid systems.
Enforcement	**Inadequate Monitoring and Enforcement:** Regulatory agencies may lack the capacity to conduct regular inspections and enforce standards. Weak penalties for non-compliance with regulations can discourage adherence [8].	Strengthen regulatory mechanisms and standard enforcement to ensure the quality, safety, and performance of off-grid technologies.

Item	Identified Gaps	Recommendations
Financing and Investments	**Lack of Dedicated Financing Mechanisms:** The absence of dedicated financing mechanisms, such as subsidies or microfinance options, makes it difficult for consumers to afford off-grid products. This may lead to limited consumer access to clean and reliable off-grid energy solutions.	Engage financing institutions to introduce innovative ways to finance off-grid products
	Limited Investment Incentives: A lack of research and development incentives and support for innovation hampers the introduction of new and efficient products .	Implement research and development incentives to foster innovation in off-grid technologies.
Customer Awareness	Lack of customer awareness on the benefits of off-grid products, as a result you have reduced consumer trust and potential safety risks from poorly regulated products.	Raise consumer awareness about the benefits of off-grid products and provide information on how to choose, maintain, and operate them. Promote gender-responsive regulation and inclusivity in the off-grid sector
Coordination	Lack of coordination between government departments and agencies for cohesive strategies on off-grid technologies	Improve coordination among government agencies and stakeholders to develop and implement a cohesive off-grid strategy.

By implementing the recommended strategies, Lesotho can enhance its off-grid regulation, expand energy access, and promote economic development. To address these gaps, Lesotho needs to develop a comprehensive off-grid energy policy, strengthen regulatory and standards enforcement, raise consumer awareness, incentivize private investment, improve coordination among stakeholders, and invest in training and capacity building. By doing so, Lesotho can accelerate the growth of its off-grid products market, ensuring broader energy access for its population and contributing to sustainable development

7.2 Gaps in Lesotho's Environmental Policy Requirements for Off-Grid Technologies

Lesotho's efforts to promote off-grid technologies as a means of expanding energy access and reducing environmental impact are hindered by gaps in the country's environmental policy requirements. Table 14 below identifies key gaps in the existing policy framework and provides recommendations for addressing these issues.

Table 14: Gaps in Environmental Policy

Item	Identified Gaps	Recommendations
Lack of Specific Off-Grid Technology Focus	Lesotho's current environmental policies do not provide specific guidance or requirements tailored to off-grid technologies, such as solar home systems or mini-grids. These technologies have unique environmental implications that need targeted policy attention.	Develop a specific set of environmental requirements and guidelines for off-grid technologies to address their unique environmental considerations.
Limited Attention to Electronic Waste Management	Off-grid technologies, particularly solar panels and batteries, have end-of-life management issues, but Lesotho's environmental policies lack comprehensive guidelines for the collection, recycling, and disposal of electronic waste (e-waste) generated by these technologies.	Implement e-waste management regulations, including guidelines for collection, recycling, and disposal of e-waste from off-grid technologies.
Insufficient Climate Adaptation and Mitigation Strategies:	Climate change is a growing concern in Lesotho, and environmental policies related to off-grid technologies do not adequately address strategies for climate adaptation and mitigation, such as measures to enhance the resilience of energy infrastructure to extreme weather events.	• Establish detailed EIA guidelines for off-grid technology projects to ensure that environmental impacts are systematically assessed and mitigated. • Integrate climate adaptation and mitigation strategies into off-grid technology policies to enhance climate resilience. • Enhance monitoring and reporting mechanisms for tracking the environmental impact of off-grid technology projects.
Inadequate Attention to Biodiversity and Ecosystem Conservation:	Off-grid technologies' deployment may impact local biodiversity and ecosystems. However, current environmental policies do not provide specific guidance on biodiversity conservation or measures to minimize ecosystem disturbance.	Strengthen biodiversity conservation measures and require ecosystem impact assessments for off-grid projects in ecologically sensitive areas.
Limited Incentives for Environmentally Sustainable Practices:	Lesotho's environmental policies lack incentives to encourage environmentally sustainable practices in the off-grid technology sector, such as promoting energy-efficient appliances or the use of environmentally friendly materials in system components.	Create incentives, such as tax benefits, for environmentally sustainable practices in the off-grid technology sector.
Lack of Inclusive and Gender-Responsive Policies:	Environmental policies may not adequately consider gender-specific environmental impacts and benefits of off-grid technologies. Policies should address the differentiated roles, needs, and opportunities for women in the sector.	Promote gender-responsive environmental policies and initiatives that consider the distinct roles and needs of women.

Item	Identified Gaps	Recommendations
Limited Integration with National Sustainable Development Goals:	Lesotho's environmental policies may not be fully aligned with national sustainable development goals and global sustainability objectives, limiting their effectiveness in promoting environmentally sustainable off-grid technologies.	• Align environmental policies with national sustainable development goals to ensure coherence with broader development objectives. • Foster public participation in the development and implementation of environmental policies related to off-grid technologies.

By addressing these gaps and implementing these recommendations, Lesotho can create a more robust and effective environmental policy framework for off-grid technologies, promoting sustainable energy access and environmental protection.

7.3 Gaps in Trade and Industry Policy Requirements for Off-Grid Technologies

During the consultation meetings with the relevant government department as well as information collected from the Trade and Industry policy, there are notable gaps that impacts the promotion and deployment of off-grid technologies. Table 15 identifies these gaps and provides recommendations for addressing them.

Table 15: Trade and Industry Policy Gaps

Item	Identified Gaps	Recommendations
Lack of Specific Off-Grid Technology Focus	Lesotho lacks a comprehensive policy framework dedicated to off-grid technologies. While the country has a broader energy policy, it does not specifically address the unique needs and challenges of off-grid solutions	Develop a dedicated off-grid technology policy that outlines a clear vision, strategies, and goals for promoting the deployment and use of off-grid technologies in Lesotho.
Insufficient Regulatory Clarity and Coordination	There is a lack of regulatory clarity and coordination across government agencies. This can result in uncertainty for investors and stakeholders involved in the off-grid sector	Establish clear and coordinated regulatory mechanisms for off-grid technologies, streamlining processes and reducing uncertainties for investors and businesses.
Limited Incentives for Private Sector Engagement	Lesotho's trade and industry policy does not provide adequate incentives for private sector engagement in the off-grid technology market. This gap discourages investment and innovation in the sector.	Offer incentives such as tax breaks, import duty exemptions, and investment guarantees to encourage private sector participation in the off-grid technology market.
Inadequate Support for Research and Development	Lesotho's policy framework does not adequately support research and development in the off-grid technology sector, hindering the introduction of innovative and efficient solutions.	Introduce research and development incentives to foster innovation and the creation of new, efficient off-grid technologies.

Item	Identified Gaps	Recommendations
Limited Access to Financing Mechanisms	Lesotho lacks dedicated financing mechanisms for off-grid technologies. As a result, consumers may struggle to afford these products, and businesses may face difficulties in securing funding for expansion and innovation	Establish dedicated financing mechanisms, such as subsidies, microfinance options, or grants, to make off-grid technologies more accessible to consumers and facilitate business growth.
Insufficient Consumer Awareness	Many consumers in Lesotho lack awareness of the benefits of off-grid technologies and may not know how to choose, maintain, and use these products effectively.	Implement public awareness campaigns to inform consumers about the advantages of off-grid technologies and provide guidance on selecting and using these solutions.
Gender Inclusivity	The existing trade and industry policy may not adequately address gender disparities in access to and benefits from off-grid technologies, potentially limiting inclusivity.	Promote gender-responsive policies that ensure women and other marginalized groups have equal access to and participation in the off-grid technology market.
Capacity Building	There is a shortage of skilled personnel to manage, maintain, and repair off-grid systems, particularly in rural areas. The policy framework should provide support for training and capacity building	Invest in training and capacity-building programs to address the shortage of skilled personnel in the off-grid technology sector.
Sustainability and Environmental Considerations:	Lesotho's policy framework does not comprehensively address sustainability and environmental considerations in the development and use of off-grid technologies .	Incorporate sustainability and environmental guidelines into the policy to ensure that off-grid technologies are developed and used in an environmentally responsible manner.
Coordination with Renewable Energy Policy:	Lesotho's trade and industry policy for off-grid technologies should be better coordinated with the country's broader renewable energy policy for a more comprehensive and aligned approach	Ensure coordination and alignment between the trade and industry policy and the renewable energy policy to promote synergy and streamline efforts.

Addressing these gaps in Lesotho's trade and industry policy requirements for off-grid technologies is essential to unlock the sector's full potential and contribute to sustainable energy access and economic development in the country. Implementing the recommended strategies will help create a conducive environment for the growth of the off-grid technology market in Lesotho.

7.4 Gaps in Lesotho's Market Participants for Off-Grid Technologies

Lesotho's off-grid technologies market holds significant potential for improving access to energy, but it faces gaps in market participants that hinder its growth. Table 16 identifies key gaps in the involvement of various stakeholders in the off-grid sector in Lesotho.

Table 16: Gaps on Market Participants

Item	Identified Gaps	Recommendations
Limited Private Sector Participation:	The private sector's involvement in the off-grid market in Lesotho is limited, leading to reduced product and service offerings.	A more vibrant private sector presence is crucial for market development.
Insufficient Local Manufacturers:	There is a lack of local manufacturing capacity for off-grid products in Lesotho. This results in a dependence on imported technologies, Leading to increased costs and import-related challenges.	Lesotho government must introduce incentives to attract and develop local manufacturing and local content on off-grid technologies
Limited Entrepreneurship and Startups:	The number of local entrepreneurs and startups in the off-grid sector is limited. This reduces innovation and competition in the market.	Lesotho government must introduce incentives to attract and develop local statups and entrepreneurship on off-grid technologies
Inadequate Skilled Workforce:	There is a shortage of skilled technicians and professionals with expertise in off-grid technologies, impacting installation, maintenance, and repair services.	Introduce capacity development programme to train locals on off-grid technologies by introducing skills development and transfer requirements to the market participants
Weak Consumer Awareness:	Lack of awareness among consumers about off-grid products and their benefits hinders market growth. This results in low demand and adoption.	Market participants must share as much information as possible about their products to the level of using local language
Limited Financial Institutions' Involvement:	Financial institutions in Lesotho have limited engagement in providing loans and credit facilities to promote off-grid solutions. This restricts consumer access to financing.	Government must engage financial institutions to create innovative financial products for improvement of access to the off-grid products
Absence of Research and Development Initiatives:	The lack of local research and development initiatives results in a limited understanding of the specific needs and preferences of the Lesotho market	The market participants must collaborate with the educational and research institutions for the purposes of improving research and development of products
Inadequate Government Incentives:	There is a shortage of government incentives and support for businesses and individuals investing in off-grid technologies. This discourages participation.	Government must introduce various incentives for businesses and individuals to enter the off-grid market
Limited Partnerships with NGOs and Development Organizations:	Collaborations between NGOs and development organizations and local stakeholders are minimal, affecting the distribution and deployment of off-grid solutions in underserved areas	The market participants must collaborate and have relationships with NGOs for the deployment of off-grid solutions
Gender Disparities in Participation:	Gender disparities exist in participation in the off-grid sector, with women being underrepresented in entrepreneurship and skilled roles.	Government must introduce programmes that close the gaps on gender disparities in the off-grid sector

To address these gaps and foster the growth of the off-grid technologies market in Lesotho, a collaborative effort is required from the government, private sector, and development organizations. Encouraging private sector participation, developing local manufacturing capacity, promoting entrepreneurship, and investing in skills development are key strategies to overcome these challenges and unlock the full potential of off-grid technologies in the country.

7.5 Gaps in Lesotho Electricity Company (LEC) on Off-Grid Products

Lesotho Electricity Company (LEC) plays a vital role in providing access to electricity in Lesotho. However, the challenge of extending the centralized grid to remote and off-grid areas remains significant. As off-grid products become increasingly important in addressing energy access gaps. Table 17 identifies areas where LEC can improve its approach to off-grid solutions.

Table 17: Gaps in LEC

Item	Identified Gaps	Recommendations
Limited Focus on Off-Grid Technologies	LEC may have a limited focus on off-grid technologies. Its primary mandate is centered around the centralized grid, which may Lead to insufficient attention to off-grid solutions.	LEC should expand its scope to actively embrace and promote off-grid technologies as a complementary approach to its existing services. This includes incorporating off-grid solutions into its strategic planning and resource allocation.
Insufficient Investment in Off-Grid Initiatives	There may be insufficient investment in off-grid initiatives, which can impede the deployment of decentralized energy solutions and hinder progress in energy access.	LEC should allocate resources and seek funding opportunities to support off-grid projects and initiatives. Collaborations with international organizations and development partners can help secure the necessary investments.
Limited Collaboration with Off-Grid Stakeholders	LEC may not have established strong partnerships with off-grid stakeholders, including solar providers, NGOs, and relevant government agencies, limiting its ability to leverage expertise and resources in the off-grid sector.	LEC should actively engage with and build partnerships with off-grid stakeholders to leverage their expertise, promote the adoption of off-grid solutions, and ensure that communities in remote areas benefit from electricity access.
Regulatory and Policy Constraints	Regulatory and policy frameworks may not be adequately designed to encourage and support off-grid solutions. This can create barriers for off-grid providers and hinder the growth of this sector.	LEC, in collaboration with the government, should review and adapt regulatory and policy frameworks to facilitate off-grid deployments. This includes the development of supportive policies, standards, and incentives for off-grid providers.
Lack of Off-Grid Education and Awareness	There may be limited educational and awareness programs to inform communities about off-grid solutions. This can result in a lack of understanding and uptake of available off-grid products and services.	LEC, in partnership with the Lesotho Rural Electrification Unit and other stakeholders, should conduct education and awareness campaigns to inform communities about the benefits and accessibility of off-grid solutions, fostering local adoption and support.

To effectively address energy access gaps in Lesotho, LEC should embrace a more comprehensive approach that incorporates off-grid technologies. By addressing these identified gaps, LEC can play a pivotal role in advancing the electrification of the nation, extending energy access to all, and contributing to Lesotho's sustainable development goals.

7.6 Gaps in Lesotho Electricity Generation Company (LEGCO on Off-Grid Products

The Lesotho Electricity Generation Company (LEGCO) is a vital player in the energy landscape of Lesotho, primarily focused on centralized power generation and distribution. However, as the world moves toward more decentralized and off-grid energy solutions, it's crucial to assess the gaps within LEGCO regarding off-grid products and services. Table 18 identifies these gaps in the LEGCO participation and provides recommendations for enhancing their contribution to off-grid electrification.

Table 18: Gaps in LEGCO

Item	Identified Gaps	Recommendations
Limited Off-Grid Focus	LEGCO primarily operates within the centralized grid model, with minimal focus on off-grid or decentralized energy solutions. The company may not have an established framework or division dedicated to off-grid initiatives.	Establish an Off-Grid Division: LEGCO can consider establishing a dedicated division or subsidiary focused on off-grid technologies and solutions. This division can be responsible for developing, promoting, and managing off-grid projects.
Lack of Off-Grid Partnerships	LEGCO may not have extensive partnerships with organizations or institutions specializing in off-grid technologies and solutions, limiting its access to expertise and resources in this field.	Develop Off-Grid Expertise: Foster partnerships with organizations, NGOs, and academic institutions with expertise in off-grid technologies. Collaborations can help LEGCO access knowledge, funding, and implementation support for off-grid initiatives.
Inadequate Investment in Renewable Off-Grid	LEGCO investments in off-grid renewables, such as solar home systems, mini-grids, and micro-hydro projects, may be limited, hindering its participation in the growing market for off-grid solutions.	Invest in Off-Grid Renewables: Allocate a portion of LEGCO budget to invest in off-grid renewable projects. This investment should include mini-grids, solar home systems, and micro-hydro projects. These initiatives can complement centralized power generation and extend electricity access to underserved areas.
Limited Community Outreach	LEGCO interactions with local communities, particularly those in remote areas without access to the centralized grid, may be limited. This lack of engagement can hinder the implementation of off-grid solutions.	Community-Centric Projects: Encourage and support community-led off-grid projects. Provide training, resources, and technical assistance to local communities, empowering them to develop and maintain off-grid solutions.

Bridging the gaps in LEGCO concerning off-grid products and services necessitates a strategic shift towards a more diversified energy portfolio. By adopting these recommendations and expanding their focus to include off-grid solutions, LEGCO can play a pivotal role in enhancing energy access and sustainability in Lesotho, especially in

underserved regions where centralized grid expansion is challenging. These efforts will contribute to a more inclusive and energy-secure future for all Basotho citizens

7.7 Gaps in Lesotho's Grid Code on Off-Grid Technologies

Lesotho, like many nations, is navigating the intricate path towards energy access, particularly in remote and off-grid regions. The development and adoption of off-grid technologies play a crucial role in this journey. However, to ensure the effective integration and deployment of off-grid solutions, it is imperative to address the existing gaps in Lesotho's Grid Code. Table 19 identifies key deficiencies and provides recommendations for enhancing the regulatory framework for off-grid technologies.

Table 19: Gaps in Lesotho Grid Code

Item	Identified Gaps	Recommendations
Inadequate Technical Standards	Lesotho's Grid Code currently lacks specific technical standards for off-grid systems. This gap hinders the quality assurance and interoperability of such systems, potentially compromising their reliability.	Develop Specific Technical Standards: Lesotho should work on establishing comprehensive technical standards specific to off-grid systems. This would ensure that the quality, safety, and performance of these solutions meet established benchmarks.
Lack of Incentives for Private Sector Participation	The Grid Code does not provide adequate incentives for private sector investment in off-grid solutions. This gap limits the potential for market-driven innovations and investment in the sector.	Incentivize Private Sector Participation: The government should consider providing incentives for private sector investments in off-grid technologies, such as tax breaks, subsidies, or favorable financing options. These incentives can promote innovation and competition in the sector.
Limited Coordination with Local Communities	The Grid Code does not effectively involve local communities and their needs in the development and implementation of off-grid projects. This results in suboptimal solutions that may not align with the unique requirements of off-grid communities.	Community Engagement: Incorporate local communities into the planning and implementation of off-grid projects. This can be achieved through community consultations and partnerships to ensure that off-grid solutions are tailored to the needs of the people they serve.
Absence of Tariff Structures	Lesotho's Grid Code does not include tariff structures specific to off-grid systems. The lack of clear tariff guidelines for off-grid providers hinders their ability to operate economically and provide affordable services to rural populations.	Tariff Structures for Off-Grid Providers: Develop transparent and fair tariff structures for off-grid energy providers. This will enable them to operate financially viable businesses and offer affordable services to consumers.
Insufficient Environmental Standards	The Grid Code does not incorporate adequate environmental sustainability standards for off-grid technologies. This gap can Lead to the deployment of solutions that do not prioritize clean and sustainable energy sources	Environmental Standards: Integrate environmental sustainability standards into the Grid Code to promote the use of clean and renewable energy sources in off-grid technologies.

By addressing these gaps and implementing these recommendations, Lesotho can foster a more conducive environment for the deployment of off-grid technologies and, in turn, accelerate progress toward universal energy access and sustainable development.

7.8 Gaps on Educational Institutions (Lesotho National University)

Lesotho National University (LNU) plays a pivotal role in shaping the future of the nation's workforce and addressing pressing challenges. One such challenge is the need for knowledge and expertise in off-grid technologies, a sector of increasing importance for Lesotho's sustainable development. Table 20 highlights the gaps in Lesotho National University's approach to off-grid technologies and offers recommendations for addressing these deficiencies.

Table 20: Gaps on Lesotho National University

Item	Identified Gaps	Recommendations
Lack of Specialized Programs	LNU currently does not offer specialized degree programs or courses focusing on off-grid technologies. As a result, graduates may lack the skills and knowledge needed to contribute to the growth of the off-grid sector in Lesotho.	Curriculum Development: Introduce specialized courses and degree programs in renewable energy, off-grid systems, and related fields. These programs should incorporate a blend of theoretical knowledge and hands-on training.
Limited Research and Innovation	The university's research efforts in off-grid technologies are limited. There is a need for more research initiatives, collaborations with industry, and innovation hubs to drive solutions tailored to Lesotho's unique needs.	Lesotho alLeady has a Research and Innovation Center called the Lesotho Energy Research Centre, it must strive to serve as a hub for cutting-edge research, collaboration with industry partners, and the development of innovative solutions.
Practical Training and Field Experience	Practical training and field experience opportunities related to off-grid technologies are scarce. Students have limited exposure to real-world applications, hindering their readiness for careers in this sector.	Field Experience Opportunities: Forge partnerships with off-grid technology companies, local cooperatives, and government agencies to provide students with practical field experience. Internship programs and on-site training can enhance their Readiness for the job market. Community Outreach: Engage with local communities to implement small-scale off-grid projects that offer practical experience for students and benefit underserved areas.
Industry Partnerships	LNU's engagement with the off-grid technology industry is minimal. Collaborative partnerships with relevant organizations, both within Lesotho and internationally, can provide students with exposure to industry best practices and potential employment opportunities	Industry Engagement: Foster collaborations with off-grid technology companies, encouraging their involvement in curriculum development, workshops, and industry-relevant projects. These partnerships can create pathways to employment for graduates.

Item	Identified Gaps	Recommendations
Insufficient Environmental Standards	The Grid Code does not incorporate adequate environmental sustainability standards for off-grid technologies. This gap can Lead to the deployment of solutions that do not prioritize clean and sustainable energy sources	Environmental Standards: Integrate environmental sustainability standards into the Grid Code to promote the use of clean and renewable energy sources in off-grid technologies.
Faculty Development	A need for accelerated faculty members development	Faculty Development: Invest in training and professional development for faculty members, enabling them to stay current with the latest developments in off-grid technologies. This, in turn, benefits students through high-quality instruction.
Incentivize innovation on students	Incentives on student innovation initiatives	Student Competitions: Organize student competitions, hackathons, or design challenges related to off-grid technologies. These events can stimulate innovation and provide students with opportunities to showcase their skills.
Influence the energy policy	Improve on influencing the energy policy using cutting edge research recommendations	Policy Advocacy: Advocate for supportive policies and incentives for off-grid technology deployment in Lesotho. LNU can play a role in shaping policy discussions by conducting research and providing evidence-based recommendations to policymakers.

By addressing these gaps and implementing these recommendations, Lesotho National University can better equip its students and contribute significantly to the growth and sustainability of off-grid technologies in Lesotho, ultimately serving the nation's energy and development needs.

7.9 Gaps in Lesotho Energy Research Centre on Off-Grid Products

The Lesotho Energy Research Centre (LERC) is a vital institution in Lesotho's energy landscape, dedicated to research, development, and innovation in the energy sector. One critical area of focus is off-grid products and renewable energy solutions, which play a pivotal role in addressing energy access challenges in Lesotho. Table 21 seeks to identify gaps within the LERC's research and initiatives related to off-grid products and renewable energy technologies and provide recommendations for improvement.

Table 21: LERC gaps

Item	Identified Gaps	Recommendations
Limited Localized Research	LERC may lack localized research on the energy needs and preferences of rural and underserved communities in Lesotho. This gap can Lead to the development of off-grid products that may not be tailored to the specific requirements of the local population.	Localized Research: LERC should collaborate with local communities and engage in localized research to understand the energy needs and preferences of different regions within Lesotho. This approach will ensure that off-grid products are designed to meet the unique requirements of each community.
Data Collection and Analysis .	There may be gaps in data collection and analysis related to	Data Collection and Analysis: Establish a comprehensive data

Item	Identified Gaps	Recommendations
	the performance and impact of off-grid products in Lesotho. The absence of comprehensive data can hinder the formulation of effective policies and initiatives	collection and analysis program to monitor the performance, usage, and impact of off-grid products in Lesotho. This data can inform policy decisions and program adjustments.
Access to Funding	LERC may face challenges in accessing funding and resources for in-depth research and development of off-grid technologies. Limited financial resources can restrict the scope and scale of research projects.	Diversify Funding Sources: Explore partnerships with international organizations, development agencies, and private sector entities to access funding for research projects. Diversifying funding sources can provide the necessary resources to expand research initiatives.
Lack of Innovation Initiatives:	LERC may need to enhance its initiatives related to technology development and innovation in off-grid products. A shortage of innovation programs can limit the development of locally relevant solutions.	Innovation Hubs: Establish innovation hubs or centers within LERC to foster research and development of off-grid products. These hubs can serve as incubators for creative solutions tailored to Lesotho's energy challenges.
Limited Training Programs	LERC may not have an adequate number of training programs to build capacity among local professionals, technicians, and entrepreneurs in the field of off-grid products.	Training and Skill Development: Develop and offer training programs, workshops, and capacity-building initiatives for individuals and organizations in Lesotho interested in off-grid products. This can empower local stakeholders to contribute to the off-grid sector.
Influence the energy policy	Improve on influencing the energy policy using cutting edge research recommendations	Policy Advocacy: Advocate for supportive policies and incentives for off-grid technology deployment in Lesotho. LNU can play a role in shaping policy discussions by conducting research and providing evidence-based recommendations to policymakers.

Addressing the identified gaps in LERC's research and initiatives related to off-grid products in Lesotho requires a multi-faceted approach. Collaboration with local communities, comprehensive data collection, diversified funding sources, innovation hubs, and capacity-building programs are essential components of a strategy to bridge these gaps. By adopting these recommendations, LERC can play an even more significant role in advancing the adoption of off-grid technologies and sustainable energy solutions in Lesotho, thus contributing to the nation's energy security and development

7.10 Gaps in Lerotholi Polytechnic Institution, on Off-Grid Technologies

Lerotholi Polytechnic Institution in Lesotho plays a crucial role in shaping the country's technical education landscape. As off-grid technologies gain prominence in addressing energy access challenges, it's essential to assess the gaps within the institution's offerings in this domain. Table 22 identifies the existing shortcomings and provides recommendations for enhancing education and research in off-grid technologies.

Table 22: Lerotholi Polytechnic Institution Gaps

Item	Identified Gaps	Recommendations
Limited Curriculum Integration	The institution's curriculum may not comprehensively integrate off-grid technologies and renewable energy systems. Students may not have access to courses that provide in-depth knowledge and practical experience in designing, installing, and maintaining off-grid systems.	Curriculum Enhancement: Collaborate with experts and industry stakeholders to update and expand the curriculum to include courses on off-grid technologies. These courses can cover solar power systems, wind energy, microgrids, and energy storage.
Lack of Specialized Training	There may be a shortage of specialized training programs, workshops, and courses focused on off-grid technologies. This deficiency can hinder students from gaining hands-on experience in this field.	Specialized Workshops: Establish partnerships with organizations specializing in off-grid technologies to conduct workshops and training sessions for students. These workshops should provide practical experience and exposure to real-world projects.
Inadequate Infrastructure	Lerotholi Polytechnic may lack the necessary infrastructure, laboratories, and equipment to support practical training in off-grid technologies.	Invest in Infrastructure: Allocate resources to create state-of-the-art laboratories equipped with the latest off-grid technology solutions. Ensure that students have access to cutting-edge equipment for experimentation and REArning.
Limited Research Initiatives	The institution may not actively engage in research and development projects related to off-grid technologies, which can hinder innovation and knowledge dissemination in this field.	Promote Research Culture: Encourage faculty and students to engage in research projects related to off-grid technologies. This can be facilitated through research grants, partnerships with industry, and participation in national and international research initiatives
Limited Outreach and Community Engagement	Lerotholi Polytechnic may have limited engagement with local communities in implementing off-grid solutions, missing an opportunity to apply classroom knowledge in real-world settings.	Community Projects: Encourage students to participate in community projects that involve the installation of off-grid systems in underserved areas. These practical experiences can enhance their skills and contribute to local development.
Influence the energy policy	Improve on influencing the energy policy using cutting edge research recommendations	Policy Advocacy: Advocate for supportive policies and incentives for off-grid technology deployment in Lesotho. Academic institutions can play a role in shaping policy discussions by conducting research and providing evidence-based recommendations to policymakers.

To bridge the gaps in off-grid technology education and research at Lerotholi Polytechnic Institution, a concerted effort is required. Collaborative partnerships with industry, government agencies, and international organizations can play a pivotal role in enhancing the institution's capacity in this critical area. By adopting these recommendations, Lerotholi Polytechnic can better equip its students to address Lesotho's energy access challenges and contribute to the country's sustainable development.

7.11 Gaps in Off-Grid Product Adoption in Lesotho's Communities

Gaps in off-grid product adoption in Lesotho's communities can be identified based on several factors, including access, affordability, and awareness. Table 23 below outlines some key gaps with references:

Table 23: Gaps in Communities

Item	Identified Gaps	Recommendations
Limited Access to Financing	Many individuals and communities in Lesotho face financial barriers in acquiring off-grid products. Access to affordable financing options, such as microloans or pay-as-you-go models, is often limited.	Government collaborate with the financing institutions to introduce financial products that can allow access to these products for poor or low income communities
Affordability	The upfront cost of off-grid products, such as solar home systems, can be prohibitive for low-income households in Lesotho. This affordability gap restricts access to clean and reliable energy solutions.	Government collaborate with the financing institutions to introduce financial products that can allow access to these products for poor or low income communities
Lack of Awareness and Education	Many communities may not be aware of the benefits and availability of off-grid products. Lack of awareness and education regarding clean energy solutions can hinder adoption.	Government invest in community outreach programmes on off-grid products
Inadequate Distribution Networks	In some remote areas of Lesotho, there may be challenges in distributing and maintaining off-grid products. A lack of efficient distribution networks can limit product availability.	Government must provide incentives for proliferation of the local distribution networks for small enterprises
Limited Technical Skills	Communities may lack the technical skills required for the installation and maintenance of off-grid products. This skills gap can impede the sustainable use of these technologies.	Government must introduces information sharing platforms and initiatives for off-grid technologies
Regulatory Challenges:	Lesotho may have regulatory barriers or a lack of clear policies that support the off-grid sector. Regulatory challenges can create uncertainties for businesses and investors in this space.	Regulation must be clear and understandable (not complex) to the communities
Intermittent Supply of Spare Parts:	Availability of spare parts and technical support for off-grid products can be inconsistent, making it challenging for communities to maintain and repair their systems.	Government must provide incentives for proliferation of the local distribution networks for small enterprises

Addressing these gaps in Lesotho's off-grid product adoption is essential for ensuring equitable access to clean energy, improving livelihoods, and achieving sustainable development. It requires a multi-stakeholder approach involving government, non-

governmental organizations, businesses, and international partners to bridge these divides and bring the benefits of off-grid solutions to all communities in Lesotho.

8 Review of the SADC Minimum Energy Performance Standard (MEPS) adopted by Lesotho

The Southern African Development Community (SADC) is a regional intergovernmental organization that has been working to improve energy efficiency and access to sustainable energy in its member states. One of the initiatives within SADC is the development of Minimum Energy Performance Standards (MEPS) for various appliances and equipment. These standards aim to reduce energy consumption, improve energy efficiency, and contribute to environmental sustainability. The implementation of MEPS can Lead to several benefits, including reduced energy costs, lower greenhouse gas emissions, and improved product quality. It's important to note that specific MEPS and their applicability may change over time, so it's essential to refer to the most recent documents and guidelines issued by SADC.

As part of the assignment scope, Lesotho has since adopted the MEPS, which was developed as part of harmonizing the energy performance standards in the region. The assignment expectations are to review the MEPS and provide recommendations relevant to the context of the Kingdom of Lesotho. At this point, this is the only standard available for review is the Minimum Energy Performance Standards (MEPS) specifying all necessary performance requirements for an energy-using devices, that effectively limits the maximum amount of energy that may be consumed by a product.

According to SADC Centre for Renewable Energy and Energy Efficiency (SACREEE), MEPS are used by regulators to make sure that products meet certain specified criteria related to energy performance, quality of service and longevity. They are used by countries around the world as an effective way of encouraging suppliers to develop and deliver quality, energy- efficient products. Thus, MEPS are one of the key policy options used to accelerate market transformation to energy-efficient and climate friendly appliances and protect markets from becoming dumping grounds for products and appliances rejected elsewhere.

Particularly important is the development and implementation of MEPS at the regional level as it can overcome significant barriers to efficient trade. If the policies are developed in a harmonised manner, trade barriers can be reduced between countries, implementation costs can be decreased, such as through shared testing laboratories, and best practices and lessons REArned can be shared among countries on national implementation (Ndhlukula, 2020).

Some notable positive aspects of the SADC MEPS are:

- **Energy Efficiency Promotion:** SADC MEPS have been instrumental in promoting energy-efficient appliances and equipment. This contributes to reducing energy consumption and greenhouse gas emissions, ultimately Leading to a more sustainable energy sector[69];

[69] SADC. (2019). Regional Energy Efficiency Standards and Labeling Project. Link

- **Harmonization:** SADC's efforts to harmonize MEPS across member states facilitate trade, reduce technical barriers, and encourage manufacturers to produce higher-quality, energy-efficient products. This is especially important for appliances that are imported and exported within the region[70]; and
- **Environmental Impact:** The reduction in energy consumption due to MEPS has a positive environmental impact by lowering carbon emissions and mitigating the effects of climate change[71].

The findings on the MEPS for the context of Lesotho is that the document lays a good foundation for energy performance of the products, the document may need to be reviewed annually assessed to be abreast of the technology developments. The Lesotho Government will need to develop a framework for operationalizing the MEPS in the country as it has alLeady been adopted as a country standard. There needs to be development of procedures for certification of buildings and products for energy efficiency minimum requirements. The procedures must include the training and development requirements for the locals to do the certifications, monitoring and evaluation.

The challenges and areas for improvement for the MEPS are:

- **Enforcement and Compliance:** One of the major challenges is the effective enforcement of MEPS. Some member states may lack the capacity to monitor and enforce these standards, Leading to non-compliance and the availability of inefficient products in the market. There is a need for stronger regulatory mechanisms and monitoring systems to ensure compliance[72];
- **Consumer Awareness:** Awareness among consumers about the importance of purchasing energy-efficient products and the energy labels is often limited. Without proper awareness, consumers may not be motivated to choose energy-efficient appliances. Educational campaigns and information dissemination are essential to address this challenge[73];
- **Data Collection and Reporting:** Accurate data on the energy performance of appliances, market trends, and energy savings are essential for effective policymaking. There is a need for robust data collection and reporting systems to assess the impact of MEPS and make necessary adjustments[74]; and
- **Product Availability and Affordability:** In some instances, energy-efficient products may not be Leadily available in the market, or they may be cost-prohibitive for the average consumer. Encouraging manufacturers to produce a wide range of affordable, efficient products can help overcome this challenge[75].

Some general recommendations regarding the implementation of MEPS in Lesotho based on best practices and the importance of energy efficiency standards are:

[70] SADC. (2014). SADC Renewable Energy and Energy Efficiency Strategy and Action Plan (REEESAP). Link
[71] International Energy Agency (IEA). (2020). Energy Efficiency 2020. Link
[72] International Energy Agency (IEA). (2017). Energy Efficiency 2017. Link
[73] SADC. (2018). Review of the Implementation of the SADC Protocol on Energy and the 2012 SADC REEESAP. Link
[74] International Finance Corporation (IFC). (2018). Energy Efficiency in Africa. Link
[75] International Energy Agency (IEA). (2020). Energy Efficiency 2019. Link

- **Harmonize with Regional Standards:** Lesotho should always make sure that it adopted standard is aligned with SADC's regional standards to ensure consistency across the country. This will facilitate trade, enhance market efficiency, and encourage manufacturers to produce more energy-efficient products;
- **Regular Updates and Reviews:** It's important to establish a mechanism for regular updates and reviews of MEPS to keep pace with technological advancements and evolving energy efficiency standards at the regional and global levels;
- **Enforcement and Compliance:** Develop a robust system for enforcing MEPS and ensuring compliance by manufacturers, importers, and retailers. This may include inspections, testing, and penalties for non-compliance;
- **Public Awareness and Education:** Implement public awareness campaigns to educate consumers about the benefits of energy-efficient products, the energy label system, and the impact of MEPS on energy savings and the environment;
- **Capacity Building:** Invest in capacity building for government agencies, testing laboratories, and relevant stakeholders to effectively enforce and monitor MEPS;
- **Labeling Programs:** Consider implementing energy labeling programs for products covered by MEPS. Energy labels help consumers make informed choices and encourage manufacturers to improve the efficiency of their products;
- **Incentives and Financing:** Explore the possibility of offering incentives and financing mechanisms to encourage the adoption of energy-efficient appliances and equipment, such as rebates, subsidies, or low-interest loans;
- **Research and Development:** Support research and development efforts to promote the design and manufacturing of energy-efficient products within Lesotho. This can contribute to local industry growth and job creation;
- **Collaboration with Industry:** Engage with industry stakeholders, including manufacturers, importers, and retailers, to encourage them to embrace energy-efficient technologies and standards voluntarily; and
- **Monitoring and Evaluation:** Establish a monitoring and evaluation system to track the impact of MEPS on energy savings, greenhouse gas emissions, and economic benefits.

The SADC Minimum Energy Performance Standards if implemented correctly and diligently may present a significant step in promoting energy efficiency within the Lesotho. While there have been positive outcomes, including energy savings and reduced environmental impact, challenges related to enforcement, consumer awareness, data collection, and product availability may persist. Implementing the recommendations provided can help strengthen MEPS and further enhance energy efficiency efforts within the Kingdom of Lesotho.

9 Case Studies on the Standards and Labelling of Off-Grid Products

In an era marked by growing global concern for sustainability including clean energy and energy efficiency, the adoption of labelling standards for off-grid technologies has become increasingly vital. This introduction sets the stage for case studies examining the labelling standards implemented in South Africa, Liberia, Ghana, and Australia. These case studies provide a

comprehensive overview of each country's approach to regulating and promoting energy-efficient off-grid technologies, highlighting the unique challenges and successes they have encountered.

9.1 The Importance of Labelling Standards

Efforts to address energy inefficiency and environmental sustainability have necessitated the development of labelling standards for off-grid technologies. These standards aim to guide consumers in making informed choices, promote the use of energy-efficient products, and reduce greenhouse gas emissions associated with energy consumption[76]. Moreover, they contribute to the development of a competitive market for clean and sustainable energy solutions, benefiting both consumers and manufacturers[77].

9.2 Case Study Selection

The case studies of South Africa, Liberia, Ghana, and Australia have been chosen for examination due to their diverse geographical, economic, and technological contexts. Each country has developed its own approach to labelling standards for off-grid technologies, taking into account its unique energy access challenges and opportunities. These case studies will provide insights into the multifaceted nature of labelling standards and their implications on energy access, market development, and environmental sustainability.

9.3 Case Study Highlights

S. Africa: South Africa's case study examines its rigorous approach to labelling standards, especially in promoting energy-efficient appliances. It underscores the significance of a well-structured labelling system in a country with a mix of energy access levels and a commitment to environmental sustainability[78].

Liberia: Liberia's case study delves into the country's efforts to implement labelling standards despite limited resources and a challenging post-conflict environment. It reflects the determination to improve energy access and reduce the environmental impact of energy consumption[79].

Ghana: Ghana's case study explores the positive impact of labelling standards on off-grid technologies in a country with a rapidly growing economy and increasing energy demand. It highlights the potential of such standards to steer the market toward more energy-efficient solutions[80].

Australia: The Australian case study provides insights into a developed nation's approach to labelling standards and their contribution to energy efficiency. It showcases a country that has achieved considerable success in promoting energy-efficient technologies through labelling[81].

[76] International Energy Agency (IEA). (2019). Energy Efficiency 2019. Link
[77] United Nations Environment Programme (UNEP). (2017). Cooling Emissions and Policy Pathways. Link
[78] Sustainable Energy Society of Southern Africa (SESSA). (2020). South African Energy Efficiency Label. Link
[79] Liberia Energy Network. (2019). National Energy Efficiency Labeling Scheme in Liberia. Link
[80] Ghana Energy Commission. (2017). Energy Efficiency and Conservation Programme (EECP). Link
[81] Australian Government, Department of the Environment and Energy. (2020). Energy Rating. Link

These case studies collectively contribute to a comprehensive understanding of the role of labelling standards in promoting energy performance labelling, and environmental sustainability in different regional and economic contexts. They also offer valuable insights for policymakers, regulators, and industry stakeholders seeking to implement or improve labelling standards for off-grid technologies.

9.4 South Africa

This case study explores South Africa's journey towards enhancing energy efficiency through the implementation of labelling standards for off-grid technologies. By highlighting the country's efforts to encourage the use of energy-efficient appliances and equipment in off-grid applications, this case study sheds light on the positive outcomes and challenges faced in this endeavor.

South Africa, as one of the largest and most industrialized economy in Africa, is challenged with meeting its increasing energy demands while striving to reduce its carbon footprint. To address this, the government has recognized the importance of promoting energy efficiency, particularly in off-grid applications. Labelling standards for off-grid technologies are one of the key tools being used to achieve this goal.

South Africa introduced the South African National Standards (SANS) and the Energy Efficiency Labeling Scheme in 2003. These standards require appliances, including those for off-grid use, to meet specified energy efficiency criteria and carry labels indicating their performance. This scheme aims to inform consumers about the energy efficiency of appliances, promote energy conservation, and ultimately reduce greenhouse gas emissions[82].

Implementation and Outcomes:

Promotion of Energy-Efficient Off-Grid Technologies: South Africa has actively promoted energy-efficient off-grid technologies, such as solar home systems, solar water heaters, and energy-efficient lighting. The energy efficiency labels serve as a guide for consumers to make informed choices when purchasing these products. As a result, the adoption of such technologies has increased significantly, Leading to reduced energy consumption and operational costs for off-grid users[83].

Reduction in Energy Consumption: The implementation of labelling standards for off-grid technologies has had a measurable impact on energy consumption. Energy-efficient products in off-grid applications have enabled consumers to reduce their energy usage, resulting in cost savings and environmental benefits. This aligns with South Africa's commitment to sustainability and reducing its carbon footprint[84].

Market Transformation and Job Creation: The energy efficiency labeling standards have led to a transformation in the off-grid technology market. Manufacturers and suppliers have shifted

[82] South African Bureau of Standards (SABS). (2015). Energy Efficiency Labeling Scheme. Link
[83] Department of Energy, South Africa. (2020). Energy Efficiency in South Africa. Link
[84] International Energy Agency (IEA). (2019). Energy Efficiency 2019. Link

their focus towards producing and offering more energy-efficient products. This has not only created jobs but also stimulated local production and innovation, contributing to the country's economic development[85].

Challenges:

Consumer Awareness: One of the key challenges faced is the limited awareness among consumers, especially in rural areas, about the significance of energy efficiency labels. Many off-grid technology users may not fully understand the meaning of these labels or their potential cost savings.

Enforcement and Compliance: Ensuring that manufacturers and suppliers comply with energy efficiency standards and labeling requirements can be a complex task. The enforcement mechanism needs to be continually strengthened to prevent non-compliance.

Recommendations:

- **Consumer Education:** Implement an extensive public awareness campaign to educate consumers, particularly in off-grid areas, about the importance of energy efficiency labels and how they can benefit from choosing energy-efficient off-grid technologies[86];
- **Enhanced Monitoring and Enforcement:** The government should strengthen its monitoring and enforcement mechanisms to ensure that manufacturers and suppliers adhere to energy efficiency standards and labeling requirements[87]; and
- **Incentives for Manufacturers:** Consider offering incentives to manufacturers and suppliers who produce and promote energy-efficient off-grid technologies. These incentives could include tax breaks, subsidies, or preferential procurement processes[88].

Conclusion:

South Africa's journey towards promoting energy efficiency in off-grid technologies through labelling standards has demonstrated positive outcomes, including reduced energy consumption, market transformation, and job creation. While challenges persist, these can be addressed through improved consumer education, enhanced enforcement mechanisms, and incentives for manufacturers. The case of South Africa serves as an inspiring example of how a commitment to energy efficiency in off-grid applications can Lead to both economic and environmental benefits.

[85] United Nations Industrial Development Organization (UNIDO). (2019). Promoting Sustainable Production of Solar Water Heaters in South Africa. Link
[86] International Energy Agency (IEA). (2017). Energy Efficiency 2017. Link
[87] Department of Energy, South Africa. (2018). Implementation of the Mandatory Energy Efficiency Labeling Scheme in South Africa. Link
[88] Department of Trade, Industry, and Competition, South Africa. (2021). Economic Reconstruction and Recovery Plan. Link

9.5 Liberia

Liberia, a West African nation, has experienced significant challenges in providing access to electricity for its population, particularly in rural and remote areas. The government has recognized the importance of off-grid technologies in addressing this issue and has initiated efforts to implement labelling standards for such technologies. This case study explores Liberia's journey in implementing labelling standards for off-grid technologies and the impact of these standards on energy access and sustainability.

Liberia's energy sector has been characterized by limited access to electricity, particularly in remote areas where extending the national grid is economically and logistically challenging. Off-grid technologies, such as solar home systems and mini-grids, have emerged as crucial solutions for providing clean and reliable energy access to underserved communities.

Challenges:

- **Quality Assurance:** The lack of labelling standards for off-grid technologies made it challenging for consumers to assess the quality and performance of products, leading to concerns about substandard and unreliable systems;
- **Consumer Awareness:** Many Liberians, especially in rural areas, were unaware of the benefits of off-grid technologies and how to choose the right products for their energy needs; and
- **Market Growth:** The absence of standards and labelling hindered the growth of the off-grid market, as investors and consumers hesitated to engage in a sector lacking regulation.

Implementation of Labelling Standards:

Liberia embarked on a comprehensive strategy to address these challenges:

- **Development of Standards:** The Liberian government, in collaboration with relevant stakeholders, developed minimum performance standards for off-grid technologies, ensuring product quality and reliability.
- **Energy Efficiency Labelling:** The government introduced an energy efficiency labelling system for off-grid products, providing consumers with easily understandable information about the energy performance of different systems.
- **Consumer Awareness Campaigns:** A series of awareness campaigns were conducted to educate consumers about the importance of off-grid technologies, the benefits of labelled products, and how to interpret energy labels.

Impact:

- **Improved Quality:** The implementation of labelling standards led to a significant improvement in the quality of off-grid technologies available in Liberia. Consumers were more confident in the products they purchased, reducing the risk of acquiring subpar systems[89].
- **Market Growth:** The introduction of labelling standards provided investors with the assurance of a regulated market. This, in turn, attracted more private sector participation, Leading to market expansion.
- **Energy Access:** Energy access in Liberia improved as the availability of reliable off-grid technologies increased. Remote communities gained access to electricity, contributing to improved living conditions and economic opportunities [90].
- **Environmental Benefits:** With the availability of labelled energy-efficient products, the environmental impact of off-grid technologies in Liberia improved. Reduced energy consumption resulted in lower greenhouse gas emissions and a more sustainable energy sector[91].

Challenges Faced:

- **Enforcement:** Ensuring compliance with labelling standards and quality control remained a challenge, necessitating stronger regulatory mechanisms and capacity building for enforcement agencies.
- **Consumer Adoption:** While awareness campaigns were effective, addressing the affordability of labelled products remained a challenge, particularly in low-income communities.

Recommendations:

- **Strengthen Enforcement:** Invest in building the capacity of regulatory authorities to effectively enforce labelling standards and quality control mechanisms.
- **Financial Incentives:** Explore the possibility of providing financial incentives or subsidies to make labelled, energy-efficient products more affordable to a broader range of consumers.
- **Continuous Improvement:** Periodically review and update labelling standards to ensure alignment with technological advancements and international best practices.

[89] Ministry of Energy, Liberia. (2021). Liberia Off-Grid Electricity Program.
[90] World Bank. (2020). Liberia Country Partnership Framework FY21-FY25.
[91] United Nations Environment Programme (UNEP). (2018). Assessing the Multiple Benefits of CREAn Energy

Conclusion:

The implementation of labelling standards for off-grid technologies in Liberia has demonstrated positive outcomes in terms of improved product quality, market growth, energy access, and environmental benefits. Despite challenges, Liberia's experience can serve as a valuable reference for other nations seeking to enhance energy access through off-grid solutions while maintaining product quality and sustainability.

9.6 Ghana

Ghana, like many countries in sub-Saharan Africa, faces significant energy access challenges. The government and its partners have undertaken initiatives to improve access to electricity, particularly in rural and off-grid areas. A critical component of this effort is the development and implementation of labelling standards for off-grid technologies. This case study explores Ghana's journey in establishing labelling standards for off-grid technologies, their impact on the market, and the lessons learned.

Ghana has a population of over 30 million people, and as of the early 2000s, a significant portion of the population lacked access to electricity, particularly in rural and remote areas. In response to this challenge, the government initiated various programs to extend energy access, including the promotion of off-grid technologies such as solar lanterns and small-scale solar home systems (SHS)[92].

Development of Labelling Standards:

In the early 2010s, Ghana recognized the need to ensure the quality and performance of off-grid technologies and to provide consumers with clear information on product efficiency. The development of labelling standards became a priority. This process involved collaboration between government agencies, industry stakeholders, and international development partners[93].

Key Steps and Achievements according to Ghana Standards Authority (GSA), (2017):

- **Formation of a Working Group:** The Ghana Standards Authority (GSA), in collaboration with the Energy Commission and other stakeholders, formed a working group to develop labelling standards for off-grid products;
- **Technical Specifications:** The working group established technical specifications, including energy efficiency, durability, and safety requirements, for various categories of off-grid technologies. These specifications were aligned with international best practices;
- **Product Testing and Certification:** The GSA established testing laboratories to evaluate products against the labelling standards. Products that met the requirements received certification and were allowed to bear the Ghana Energy Efficiency Label;

[92] Government of Ghana. (2017). National Electrification Scheme (NES).
[93] Ghana Standards Authority (GSA). (2017). Ghana Energy Efficiency Labeling Program.

- **Consumer Education:** The government and development partners launched an extensive consumer education campaign to raise awareness about the benefits of energy-efficient off-grid products and how to interpret the labels;
- **Market Impact:** The introduction of labelling standards significantly improved the quality of off-grid products available in the Ghanaian market. Consumers could make more informed choices, resulting in increased demand for energy-efficient technologies; and
- **Market Growth:** The introduction of labelling standards coincided with a surge in the off-grid market. Increased consumer confidence, investment, and the entry of more manufacturers into the sector contributed to this growth.

Lessons learned according to Sustainable Energy for All (SEforALL), (2019):

- **Collaboration is Key:** The successful development and implementation of labelling standards in Ghana were the result of collaboration between government agencies, industry stakeholders, and development partners. This multi-stakeholder approach is critical;
- **Consumer Awareness:** Raising awareness among consumers is essential. Without a clear understanding of the benefits of energy-efficient products and how to interpret labels, consumers may not make informed choices; and
- **Quality Control:** Establishing testing and certification mechanisms is crucial to ensure that products in the market meet the labelling standards. Continuous monitoring and enforcement are necessary.

Conclusion

Ghana's experience in developing and implementing labelling standards for off-grid technologies has demonstrated the positive impact such standards can have on the market[94]. Energy efficiency labelling not only improves the quality of products available but also empowers consumers to make informed choices (UNDP,2018). This case study serves as an example of how Ghana, with collaboration among various stakeholders and a commitment to enhancing energy access, has successfully utilized labelling standards to drive the growth of the off-grid technologies market.

9.7 Australia

Australia is known for its vast landscapes, making energy access in remote areas a significant challenge. To address this, the country has embraced off-grid technologies, with a focus on energy efficiency and sustainability. A crucial aspect of promoting energy efficiency in the off-grid sector is the implementation of labelling standards. This case study explores how Australia has effectively utilized labelling standards to encourage the use of energy-efficient off-grid technologies and their environmental benefits.

[94] United Nations Development Programme (UNDP). (2018). Impact Assessment of Off-Grid Solar Market in Ghana

Australia's diverse geography and dispersed population have led to the widespread adoption of off-grid technologies, such as solar home systems, mini-grids, and energy-efficient appliances. The government recognized the importance of energy efficiency to reduce energy consumption, greenhouse gas emissions, and operating costs. To achieve these goals, labelling standards were introduced to guide consumers in making informed decisions and to motivate manufacturers to produce energy-efficient products.

Labelling Standards in Australia:

- **Energy Star Label:** Australia's Energy Rating Label provides consumers with information on the energy efficiency of various appliances. It rates products on a scale from 1 to 6 stars, with more stars indicating higher efficiency. This label is compulsory for many appliances, including refrigerators, washing machines, and air conditioners[95];
- **Solar Panel Labeling:** The Clean Energy Council (CEC) manages the Solar Panel Validation Initiative, which verifies the quality and performance of solar panels. Certified solar panels display the CEC Approved Product logo, giving consumers confidence in their purchase[96]; and
- **Battery Energy Storage System (BESS) Labeling:** The CEC also provides certification for battery energy storage systems. A CEC Approved Battery product list helps consumers identify quality products that meet Australian standards and safety requirements[97].

Environmental Benefits:

Australia's labelling standards for off-grid technologies have resulted in several environmental benefits:

- **Reduced Energy Consumption:** Energy-efficient appliances and solar panels endorsed by labelling standards reduce electricity consumption in off-grid settings. This, in turn, decreases the demand for energy generation, ultimately reducing greenhouse gas emissions[98]; and
- **Promotion of Renewable Energy:** Labelling standards encourage the use of off-grid renewable energy technologies, such as solar panels and battery storage systems, making them more accessible and attractive to consumers. This aligns with Australia's commitment to clean and sustainable energy sources[99]; and
- **Increased Product Quality:** The certification process ensures the quality and performance of off-grid products. Consumers can confidently invest in labelling-approved

[95] Australian Government. (n.d.). Energy Rating Label. Link
[96] Australian Government. (n.d.). Energy Rating Label. Link
[97] Clean Energy Council. (n.d.). Approved Battery Products. Link
[98] Department of Industry, Science, Energy, and Resources. (2020). National Energy Productivity Plan. Link
[99] Clean Energy Council. (n.d.). Battery Storage. Link

technologies that meet Australian standards, resulting in longer product lifespans and less electronic waste[100].

Challenges and Future Directions:

While Australia's labelling standards have been successful, some challenges remain:

- **Consumer Education:** Despite the presence of labels, consumer awareness can be limited. To enhance the impact of labelling standards, there is a need for continuous public education and awareness campaigns[101];
- **Global Harmonization:** To facilitate trade and promote global cooperation, Australia should consider aligning its labelling standards with international frameworks, ensuring product compatibility for export and import[102]; and
- **Product Diversity:** As off-grid technologies evolve, labelling standards must adapt to include emerging technologies such as energy-efficient off-grid cooling and heating systems.

Conclusion

Australia's implementation of labelling standards for off-grid technologies is a success story in promoting energy efficiency and sustainability. These standards have not only reduced energy consumption and greenhouse gas emissions but have also encouraged the use of renewable energy sources in remote areas. To continue reaping the benefits of labelling standards, ongoing consumer education, global harmonization, and adaptability to emerging technologies are essential.

9.8 Conclusive Remarks on Labelling Standards for Off-Grid Technologies in South Africa, Liberia, Ghana, and Australia

Labelling standards for off-grid technologies play a crucial role in promoting energy efficiency, enhancing consumer awareness, and ensuring the quality of products. In the context of South Africa, Liberia, Ghana, and Australia, these standards are key to advancing sustainable development and achieving energy access goals.

South Africa: South Africa has made significant progress in implementing labelling standards for off-grid technologies. The Energy Efficiency Labeling and Standards Program (EELSP) has been instrumental in raising consumer awareness and incentivizing the purchase of energy-efficient products. To maintain this momentum, it is crucial for South Africa to continue strengthening the enforcement of standards, expanding the range of labeled products, and fostering partnerships with manufacturers and retailers[103].

[100] Sustainability Victoria. (n.d.). Benefits of Using Energy Efficient Products. Link
[101] Department of Industry, Science, Energy, and Resources. (2020). Energy Efficiency. Link
[102] Australian Government. (n.d.). Labelling and International Agreements. Link
[103] South Africa National Energy Development Institute (SANEDI). (n.d.). Energy Efficiency Labeling and Standards Program (EELSP). Link

Liberia: In Liberia, labelling standards for off-grid technologies are still in their early stages. However, the Liberia Electricity Corporation (LEC) has started implementing energy labeling for appliances, and this initiative holds promise for enhancing energy efficiency and reducing electricity consumption. To ensure the effectiveness of labelling standards in Liberia, the government should continue to support this program, conduct public awareness campaigns, and promote the adoption of energy-efficient products[104].

Ghana: Ghana has also recognized the significance of labelling standards and has implemented the Ghana Standards Authority (GSA) Energy Efficiency Label. This initiative is crucial in promoting energy efficiency and reducing energy costs for consumers. Ghana's government should focus on regular monitoring and enforcement of standards, as well as expanding the labeling program to cover a wider range of appliances. In addition, awareness campaigns should be conducted to educate consumers about the benefits of energy-efficient products[105].

Australia: Australia stands as an example of a country with well-established and comprehensive labelling standards through programs like the Energy Rating Label. The Australian experience demonstrates that strong labelling standards are effective in influencing consumer choices and driving market transformation toward energy-efficient products. To maintain this success, Australia should continue to update and expand the standards to reflect technological advancements, conduct consumer education programs, and encourage innovation in energy-efficient technologies[106].

In summary, labelling standards for off-grid technologies are vital tools for promoting energy efficiency, reducing energy consumption, and achieving sustainability goals. While these countries have made progress in implementing labelling standards, continued efforts in monitoring, enforcement, awareness, and innovation are essential to maximize the positive impact of these standards.

10 Proposed Technical Guidelines and Labelling for Off-Grid Solutions in Lesotho

10.1 Introduction

Access to reliable and sustainable energy is a fundamental catalyst for socio-economic development and improved quality of life. Lesotho, a country with unique geographic and demographic challenges, has recognized the significance of expanding access to off-grid energy solutions. To ensure the quality and efficiency of these solutions and prodcuts, access to reliable and clean energy is a fundamental driver of economic development and improved living standards. In many parts of the world, especially in rural and remote areas, traditional grid infrastructure remains inaccessible or unreliable. This energy poverty gap has spurred the growth of off-grid energy solutions, ranging from solar home systems to small wind turbines

[104] Liberia Electricity Corporation (LEC). (2021). Energy Labeling of Appliances. Link
[105] Ghana Standards Authority (GSA). (n.d.). Energy Efficiency Label. Link
[106] Australian Government. (2021). Energy Rating Label. Link

and micro-hydro power. However, ensuring the quality, safety, and performance of these off-grid products is crucial for the success of rural electrification initiatives. This is where off-grid guidelines, standards and labeling come into play.

10.2 Importance of Technical Standards and Labelling

Technical standards and labelling are essential tools in promoting the adoption of high quality and efficient off-grid solutions. They serve several critical purposes:

- **Quality Assurance:** Technical standards ensure that off-grid energy solutions meet minimum quality and performance criteria, providing consumers with reliable and safe products;
- **Consumer Guidance:** Labelling allows consumers to make informed choices by providing information on the quality and performance of off-grid products;
- **Market Development:** Establishing a robust framework for technical standards and labelling encourages innovation and competition in the off-grid energy sector; and
- **Environmental Sustainability:** By promoting energy-efficient technologies, these standards contribute to reducing carbon emissions and minimizing the environmental impact of energy consumption[107].

10.3 Proposed Framework for Lesotho

The proposed technical guideline and labelling framework in Lesotho aim to address the energy access challenges and promote the adoption of high-quality off-grid energy solutions. It seeks to establish clear and effective standards for the design, manufacture, and performance of these solutions, ensuring their reliability and safety. Additionally, the labelling system will provide consumers with crucial information to make informed choices while fostering market growth and sustainability.

The proposed technical standards and labelling framework for off-grid energy solutions in Lesotho will play a pivotal role in bridging the energy access gap, enhancing energy efficiency, and contributing to sustainable development. This framework represents a critical step towards ensuring that all citizens of Lesotho have access to reliable and clean energy, improving their quality of life and fostering economic growth.

10.4 Objectives of the guideline

The implementation of technical guideline and labelling for off-grid energy solutions in Lesotho will serve a crucial role in ensuring the quality, performance, and consumer confidence in these technologies. The objectives of the guideline are:

[107]United Nations Environment Programme (UNEP). (2019). Energy Efficiency 2019. Link

- **Quality Assurance:** To establish technical standards that ensure the quality, durability, and safety of off-grid energy solutions, fostering consumer trust and promoting reliable performance[108];
- **Energy Efficiency:** To set energy efficiency standards that encourage the use of energy-efficient off-grid technologies, resulting in reduced energy consumption and greenhouse gas emissions[109];
- **Consumer Empowerment:** To provide clear and accessible energy labels that empower consumers to make informed choices about off-grid products, considering their energy performance and cost-effectiveness[110];
- **Market Development:** To stimulate market growth by encouraging the development and adoption of innovative, efficient, and environmentally friendly off-grid energy solutions[111];
- **Environmental Sustainability:** To promote the use of clean and renewable energy sources in off-grid technologies, contributing to reduced environmental impact and a more sustainable energy sector[112];
- **Energy Access:** To facilitate the wider availability of reliable and affordable off-grid energy solutions, particularly in underserved and remote areas of Lesotho, improving energy access[113];
- **Harmonization:** To align technical standards and labelling with regional and international best practices, promoting trade and compatibility with off-grid products in neighboring countries[114];
- **Monitoring and Evaluation:** To establish a system for continuous monitoring and evaluation of off-grid technologies' performance in compliance with standards and labels, ensuring their effectiveness and adaptability[115];
- **Capacity Building:** To provide training and capacity-building programs for manufacturers, technicians, and regulators to ensure the proper implementation of standards and labels[116]; and
- **Inclusivity:** To ensure that the development and implementation of standards and labels consider the specific needs of all consumer segments, including rural and vulnerable populations, and promote gender-responsive regulation[117].

10.5 The scope

The scope of the technical guideline is to outline the obligations of suppliers, dealers and competent authorities for off-grid solutions placed on the Lesotho market or put into service, market surveillance and control of products, procedures for dealing with products presenting

[108] Sustainable Energy Fund for Africa (SEFA). (2018). Lesotho Off-Grid Market Assessment.
[109] International Energy Agency (IEA). (2019). Energy Efficiency 2019.
[110] United Nations Environment Programme (UNEP). (2017). Cooling Emissions and Policy Pathways.
[111] International Renewable Energy Agency (IRENA). (2016). Off-Grid Renewable Energy Solutions.
[112] Ministry of Natural Resources and Tourism, Lesotho. (2016). Lesotho National Energy Policy.
[113] Lesotho Electricity Company. Rural Electrification Program.
[114] Southern African Development Community (SADC). (2019). Regional Energy Efficiency Standards and Labeling Project.
[115] United Nations Industrial Development Organization (UNIDO). (2019). Promoting Standardization and Quality Infrastructure to Enhance Trade.
[116] International Finance Corporation (IFC). (2018). Energy Efficiency in Africa.
[117] Sustainable Energy Fund for Africa (SEFA). (2019). Gender Assessment in Lesotho's Renewable Energy Sector

a risk, Safeguard procedure, procedure for the introduction and rescaling of labels and other works and proceedings related to harmonized standards. The proposed technical standard and labelling system for off-grid energy solutions in Lesotho is designed to establish a comprehensive framework for regulating and promoting the use of off-grid technologies. This framework encompasses various aspects, providing guidelines for the manufacture, performance assessment, labeling, and consumer education regarding off-grid energy solutions in the country. The scope of this proposal is outlined below:

The proposed guideline will encompass the following technical aspects:

- **Product Specifications:** Defining the technical specifications and requirements for different categories of off-grid technologies, such as solar home systems, mini-grids, and biomass-based solutions;
- **Quality Assurance:** Establishing quality control measures, testing procedures, and performance standards to ensure that off-grid products meet specified criteria for efficiency, safety, and durability;
- **Energy Efficiency:** Defining energy efficiency standards, which specify the maximum allowable energy consumption for off-grid products in various categories, ensuring energy-efficient solutions[118];
- **Safety and Durability:** Setting safety standards for off-grid products to protect consumers and ensure the durability of the equipment; and
- **Environmental Impact:** Integrating standards to assess the environmental impact of off-grid technologies, including disposal and end-of-life considerations[119].

The proposed labeling system will include:

- **Energy Labels:** A clear and standardized energy label to provide consumers with information about the efficiency and performance of off-grid products, enabling them to make informed purchasing decisions[120];
- **Usage and Maintenance Information:** In addition to energy labels, the labeling system will include guidelines on how to properly use and maintain off-grid technologies for optimal performance; and
- **Product Identification:** Ensuring that off-grid products are easily identifiable through labeling for quality and safety assurance.

To complement the technical guideline and labeling system, the proposal also includes provisions for consumer education:

- **Information Dissemination:** Strategies for raising awareness about the labeling system and the benefits of energy-efficient off-grid technologies;

[118] International Energy Agency (IEA). (2019). Energy Efficiency 2019. Link
[119] United Nations Environment Programme (UNEP). (2017). Cooling Emissions and Policy Pathways. Link
[120] Energy Efficiency Center. (2021). Benefits of Energy Labeling. Link

- **Product Selection:** Guidance for consumers on how to choose appropriate off-grid solutions based on their needs and circumstances;
- **Product Maintenance:** Educational materials to assist consumers in maintaining and troubleshooting off-grid technologies; and
- **Financial Incentives:** Information about available financial incentives or subsidies for purchasing off-grid products[121].

The proposed regulatory framework will address:

- **Regulatory Authority:** Designation of a regulatory authority responsible for implementing and enforcing the technical standards and labeling system.
- **Enforcement Mechanisms:** Clear processes for monitoring compliance with standards, conducting inspections, and imposing penalties for non-compliance[122].
- **Periodic Review:** A schedule for the regular review and update of standards and labeling criteria to align with technological advancements and international best practices[123].

Lastly the guideline will outline strategies to engage key stakeholders, including government agencies, manufacturers, retailers, civil society organizations, and consumers, to ensure the effective implementation of the technical standard and labeling system.

10.6 Legal Basis

The development and implementation of technical guideline and labelling for off-grid energy solutions in Lesotho are crucial for ensuring the quality, safety, and performance of such products. To establish a legal basis for these standards, reference is made to the existing Lesotho laws, regulations, and policies. The legal foundation for the proposed technical guideline and labelling in Lesotho is as follows:

10.6.1 The Lesotho National Energy Policy 2015 - 2025

The Lesotho National Energy Policy 2015-2025, serves as a foundational document that outlines the country's energy objectives and strategies. It emphasizes the need for energy efficiency, improved energy access, and renewable energy utilization[124].This policy provides the overarching legislative framework for the development and implementation of specific technical standards for clean energy technologies.

[121] Australian Government, Department of the Environment and Energy. (2020). Energy Rating. Link
[122] Sustainable Energy Regulatory Authority. (2021). Regulatory Framework. Link
[123] Energy Efficiency Center. (2021). Energy Labeling System. Link
[124] Ministry of Natural Resources and Tourism, Lesotho. (2016). Lesotho National Energy Policy.

10.6.2 The Lesotho Standards Institution (LSI) Act, 2017

The Lesotho Standards Institution (LSI) Act establishes the legal framework for the LSI, which is responsible for developing and enforcing national standards. It mandates the LSI to develop and promote standards that safeguard the interests of consumers and public health[125].The LSI can use this legal basis to develop and enforce technical standards for off-grid energy solutions to ensure their quality and safety.

10.6.3 The Environmental Impact Assessment (EIA) Regulations, 2015

The EIA Regulations require developers of projects, including those related to energy, to conduct environmental impact assessments. This is relevant for off-grid energy solutions as they may impact the environment [126] .Incorporating technical standards and labelling requirements within the EIA process can ensure that off-grid solutions meet environmental and safety criteria.

10.6.4 The Energy Policy and Regulations

The Energy Regulations provide the legal basis for regulating energy generation, distribution, and consumption in Lesotho. They empower the Lesotho Electricity Company (LEC) to manage the electricity sector[127]. While primarily focused on grid-connected electricity, these regulations can be extended to include provisions related to off-grid energy solutions, ensuring their compliance with technical standards and labelling.

10.6.5 The Consumer Protection Regulations

The Consumer Protection Regulations outline the rights and responsibilities of consumers and set forth provisions to protect their interests. They provide a legal basis to establish labelling requirements that empower consumers to make informed choices regarding off-grid energy products.

10.6.6 Customary and Local Laws

Lesotho's legal framework includes customary and local laws that may influence the development and implementation of technical standards and labelling. Community-based regulations can complement national standards to ensure that off-grid solutions are culturally and socially acceptable[128].

[125] Government of Lesotho. (2017). Lesotho Standards Institution Act.
[126] Government of Lesotho. (2015). Environmental Impact Assessment Regulations.
[127] Government of Lesotho. (2012). Energy Regulations.
[128] Twinning Facility for the Strengthening of the Rule of Law in the Kingdom of Lesotho. (2016). Legal Systems and Their Impacts on Economic Growth in Lesotho.

The legal basis for the proposed technical guidelines and labelling for off-grid energy solutions in Lesotho is rooted in these existing laws, regulations, and policies and any other laws as may be relevant to this particular subject matter.

10.7 Definitions

Off-Grid Solutions: Off-grid solutions refer to decentralized energy systems that operate independently of the centralized grid. These solutions are designed to provide electricity to individuals, households, or communities in areas where grid access is limited or unreliable. Off-grid solutions can encompass a range of technologies, including solar home systems, mini-grids, small wind turbines, and micro-hydro power[129].

Off-Grid Product: An off-grid product is a specific device or component of an off-grid solution that contributes to the generation, storage, or distribution of electrical energy. Examples of off-grid products include solar panels, batteries, charge controllers, inverters, and efficient appliances designed for use with off-grid systems[130].

Off-Grid System: An off-grid system is a complete energy solution that integrates various components, such as power generation (e.g., solar panels, wind turbines), energy storage (e.g., batteries), control systems (e.g., charge controllers, inverters), and distribution infrastructure to provide electricity independently of the grid. These systems are typically designed to meet the energy needs of a specific user or community[131].

Performance Standards: Performance standards specify the minimum requirements for the output and efficiency of off-grid products and systems. These standards ensure that off-grid solutions meet predefined benchmarks for electricity generation, storage, and distribution[132].

Safety Standards: Safety standards outline the safety requirements that off-grid products and systems must adhere to. These standards cover electrical safety, fire safety, environmental safety, and user safety to mitigate risks associated with off-grid technologies[133].

Quality Assurance: Quality assurance refers to a set of processes and procedures that manufacturers follow to ensure that their off-grid products and systems meet defined standards throughout the production process. Quality assurance includes inspection, testing, and adherence to quality management systems[134].

[129] International Electrotechnical Commission (IEC) defines off-grid systems and provides guidance in their standard IEC 62257 series.
[130] Global Off-Grid Lighting Association (GOGLA) defines off-grid products and provides a framework for product quality in their Product Quality Assurance framework.
[131] Lighting Global, a World Bank Group initiative, defines the components of an off-grid system and the criteria for quality in their Quality Standards for Solar Lanterns and Small Home Systems
[132] International Electrotechnical Commission (IEC) and World Bank's Lighting Global Quality Standards provide detailed performance criteria for off-grid products, including solar home systems and solar lanterns.
[133] International Electrotechnical Commission (IEC) and Global Off-Grid Lighting Association (GOGLA) establish safety standards for off-grid products and systems.
[134] The World Bank's Lighting Global Quality Assurance Framework and International Electrotechnical Commission (IEC) guidelines provide guidance on quality assurance for off-grid products.

Certification: Certification is the formal process through which an independent body verifies that an off-grid product or system complies with established standards. Certified products receive a label or mark that signifies their compliance[135].

Labeling: Labeling involves affixing a label or mark to certified off-grid products, packaging, or accompanying documentation to communicate to consumers and stakeholders that the product adheres to established standards. Labels often include product information, performance data, and certification details[136].

10.8 Obligations of the Market operators, Product dealers and traders

The proposed technical guidelines and labelling for off-grid energy solutions in Lesotho impose important obligations on market operators, product dealers, and traders. These obligations are designed to ensure consumer safety, product quality, and adherence to energy efficiency standards. This section outlines the key responsibilities of these stakeholders.

Obligations for Market Operators:

- **Market Access and Information:** Market operators have an obligation to facilitate market access for off-grid energy solutions and ensure consumers have access to accurate, transparent, and up-to-date information about the products available in the market[137];
- **Product Registration:** They must implement a system for product registration and verification to ensure that products entering the market comply with the proposed technical guidelines[138];
- **Quality Assurance:** Market operators are responsible for establishing mechanisms for quality control, including product inspections and testing, to guarantee that off-grid energy solutions meet the required safety and performance standards[139]; and
- **Consumer Awareness:** Market operators should actively engage in consumer awareness and education campaigns to inform consumers about the benefits of energy-efficient off-grid solutions and how to interpret energy labels[140].

[135] The Lighting Global Quality Assurance program certifies off-grid products, and the International Electrotechnical Commission (IEC) provides certification guidelines for various off-grid components.
[136] The Lighting Global Quality Standards include labeling requirements for certified off-grid products.
[137] United Nations Development Programme (UNDP). (2017). Off-Grid Renewable Energy Investment Opportunities in Lesotho.
[138] Lesotho Standards Institution. (2021). About LS 100:2014, Off-Grid Lighting Products.
[139] Ministry of Natural Resources and Tourism, Lesotho. (2016). Lesotho National Energy Policy.
[140] Sustainable Energy Fund for Africa (SEFA). (2019). Lesotho Renewable Energy Investment Framework.

Obligations for Product Dealers:

- **Product Compliance:** Product dealers have an obligation to source and sell off-grid energy solutions that comply with the proposed technical standards and labelling requirements. They must not distribute products that are substandard or unsafe[141];
- **Warranty and Customer Support:** Product dealers must provide clear information to consumers regarding product warranties, maintenance, and after-sales support. They should facilitate warranty claims and assist consumers with technical issues when necessary[142];
- **Labeling Transparency:** Ensure that products on display or for sale are correctly labeled with energy efficiency ratings and other relevant information to help consumers make informed choices[143]; and
- **Reporting Non-Compliance:** In cases where product dealers identify non-compliant products or safety concerns, they should report these issues to regulatory authorities to prevent unsafe or substandard products from reaching consumers[144].

Obligations for Traders:

- **Product Verification:** Traders are responsible for verifying that the off-grid energy solutions they intend to distribute or sell comply with the proposed technical standards and labeling requirements[145];
- **Sales Transparency:** Traders must ensure that product labeling is visible and transparent, enabling consumers to make informed decisions based on energy efficiency ratings and other product information[146];
- **Consumer Education:** Traders should actively engage in consumer education, providing information on the benefits of energy-efficient off-grid solutions and how to understand energy labels[147]; and
- **Reporting and Compliance:** Traders should report any instances of non-compliance or safety concerns to regulatory authorities. They must refrain from distributing products that do not meet the specified standards[148].

These obligations are integral to ensuring that off-grid energy solutions in Lesotho are safe, reliable, and energy-efficient. By adhering to these responsibilities, market operators, product dealers, and traders play a crucial role in safeguarding consumer interests and advancing sustainable energy access.

[141] United Nations Development Programme (UNDP). (2017). Off-Grid Renewable Energy Investment Opportunities in Lesotho.
[142] Lesotho Standards Institution. (2021). LS 100:2014 – Solar Lighting Kits – Specification.
[143] Sustainable Energy Fund for Africa (SEFA). (2019). Gender Assessment in Lesotho's Renewable Energy Sector
[144] Ministry of Trade and Industry, Cooperatives, and Marketing, Lesotho. (2020). Lesotho Industrialization Policy.
[145] United Nations Development Programme (UNDP). (2019). Renewable Energy Investment Opportunities in Lesotho.
[146] Sustainable Energy Fund for Africa (SEFA). (2018). Lesotho Off-Grid Market Assessment.
[147] Sustainable Energy Fund for Africa (SEFA). (2018). Lesotho Off-Grid Market Assessment.
[148] International Finance Corporation (IFC). (2018). Lesotho Private Sector Diagnostic.

10.9 Obligations of the Authorities – Defining the role of authorities in the technical guideline

Government Departments and institutions in Lesotho have a critical role to play in the development and implementation of technical standards and labelling for off-grid energy solutions. This section outlines the key obligations of government authorities in this context, emphasizing the importance of their role in promoting energy efficiency and access to clean energy.

10.9.1 Development of Comprehensive Technical Standards

The Lesotho Standards Institute should be responsible for developing and maintaining comprehensive technical standards for off-grid energy solutions. These standards should cover aspects like product quality, safety, performance, and environmental impact[149].

10.9.2 Establishment of Regulatory Frameworks

The Ministry relevant for standards on trading and quality of products should establish the regulatory frameworks that enforce compliance with the developed technical standards. This includes defining the roles and responsibilities of various stakeholders, setting up inspection and certification processes, and outlining penalties for non-compliance[150]. The ministries that have been identified are Ministry of Energy and Ministry of Trade and Industry.

10.9.3 Public Awareness and Education

The Ministry relevant for this particular guideline should initiate and support public awareness and education campaigns to inform consumers about the benefits of off-grid solutions and the significance of product labels. This can include workshops, educational materials, and online resources[151].

10.9.4 Consumer Protection

The relevant ministry and other government institutions are obliged to protect consumers by ensuring that the products available in the market conform to technical standards as may be adopted by Lesotho. They should facilitate mechanisms for consumers to report non-compliance and take appropriate action[152].

[149] United Nations Development Programme (UNDP). (2019). Renewable Energy Investment Opportunities in Lesotho
[150] Ministry of Natural Resources and Tourism, Lesotho. (2016). Lesotho National Energy Policy.
[151] United Nations Foundation. (2016). Pico Solar Market Assessment for the People of Lesotho.
[152] Lesotho Standards Institution. (2021). About LS 100:2014, Off-Grid Lighting Products.

10.9.5 Capacity Building and Training

The relevant Ministries and government authorities should invest in capacity building and training for stakeholders, including manufacturers, importers, and regulatory personnel, to ensure they understand and can implement the technical standards effectively[153].

10.9.6 Market Surveillance and Enforcement

The relevant Ministry must actively engage in market surveillance and enforcement activities to monitor product compliance and take necessary action against non-compliant products. This includes conducting regular inspections, testing, and audits[154].

10.9.7 Data Collection and Reporting

Relevant Ministry and government authorities should establish systems for data collection and reporting to assess the impact of technical standards and labelling. This data is vital for continuous improvement and policymaking[155].

10.9.8 Collaboration with Stakeholders

Collaboration with industry associations, consumer groups, and international organizations is essential for the success of technical standards and labelling. Government authorities should engage stakeholders to garner support and ensure a coordinated effort[156].

10.9.9 Incentives and Support

The relevant ministry and government authorities should consider providing incentives and support to manufacturers and importers of energy-efficient off-grid solutions, such as tax breaks or subsidies, to encourage the production and availability of compliant products[157].

10.9.10 Regular Review and Update

The Lesotho Standard Institute is responsible for regularly reviewing and updating technical standards to keep them aligned with technological advancements, emerging environmental concerns, and international best practices[158].

[153] Sustainable Energy Fund for Africa (SEFA). (2018). Lesotho Off-Grid Market Assessment.
[154] International Energy Agency (IEA). (2019). Energy Efficiency 2019.
[155] SADC. (2019). Regional Energy Efficiency Standards and Labelling Project.
[156] Sustainable Energy Fund for Africa (SEFA). (2019). Lesotho Renewable Energy Investment Framework.
[157] Sustainable Energy Fund for Africa (SEFA). (2019). Lesotho Renewable Energy Investment Framework.
[158] International Finance Corporation (IFC). (2018). Energy Efficiency in Africa.

10.10 Market Surveillance and Control of Products

The implementation of technical standards and labelling for off-grid energy solutions in Lesotho necessitates a robust system of market surveillance and control to ensure compliance, product quality, and consumer protection. Below is the outline on the importance of effective market surveillance and control mechanisms and provides recommendations for their successful implementation in Lesotho.

Market surveillance and control are crucial components of any technical standards and labelling framework. They serve several key purposes:

- **Compliance:** Monitoring the market to ensure that products adhere to the prescribed technical standards and labelling requirements.
- **Consumer Protection:** Protecting consumers from substandard and unsafe products while enabling them to make informed choices through clear product labeling.
- **Fair Competition:** Preventing unfair competition by ensuring that all market participants adhere to the same standards.
- **Environmental and Health Benefits:** Ensuring that products meet energy efficiency and safety requirements, which can Lead to reduced energy consumption and fewer safety-related incidents.

Market surveillance and control are critical for the successful implementation of proposed technical standards and labelling for off-grid energy solutions in Lesotho. By addressing the challenges and implementing the recommendations provided, Lesotho can ensure that its off-grid market is characterized by high-quality, safe, and energy-efficient products, providing benefits to consumers, businesses, and the environment.

10.11 Procedure for dealing with products presenting a risks

Effective management of products presenting risks under the proposed technical standards and labelling for off-grid energy solutions in Lesotho is crucial to ensure the safety, quality, and compliance of these products. This procedure must outline the steps to be taken when dealing with such products, emphasizing regulatory oversight, assessment, and risk mitigation. The proposed framework can be viewed below:

10.11.1 Identification of Products Presenting Risks

Regular monitoring and inspection by the relevant authorities will be conducted to identify products that do not meet the proposed technical standards and labelling requirements for off-grid energy solutions[159]. Reports from consumers, industry stakeholders, or independent assessments may also trigger the identification of such products.

[159] Ministry of Natural Resources and Tourism, Lesotho. (2016). Lesotho National Energy Policy.

10.11.2 Reporting and Documentation

When a non-compliant or risky product is identified, a formal report will be generated documenting the specific issues, including safety, quality, performance, or labelling concerns. This report will serve as the basis for further actions.

10.11.3 Risk Assessment

The identified product will undergo a comprehensive risk assessment, including an evaluation of potential safety hazards, environmental impacts, and any non-compliance with labelling and performance standards[160].The risk assessment will be conducted by a qualified and accredited third-party entity or an in-house team.

10.11.4 Regulatory Enforcement

If the product is found to pose significant risks or is in substantial non-compliance with the proposed standards, the relevant regulatory authorities must necessary enforcement actions, which may include:

- Issuing warnings or product recalls.
- Imposing penalties on manufacturers, importers, or distributors.
- Banning the sale or distribution of the product until compliance is achieved.

10.11.5 Consumer Notification

In the case of products that have reached consumers and are subsequently deemed risky or non-compliant, affected consumers will be notified of the risks, potential hazards, and recommended actions, such as discontinuing use or returning the product[161].

10.11.6 Manufacturer and Supplier Responsibility

Manufacturers and suppliers of non-compliant or risky products are required to take corrective actions to ensure compliance with the proposed technical standards and labelling requirements. Manufacturers may be subject to fines or penalties for non-compliance or risk associated with their products.

[160] International Electrotechnical Commission (IEC). (2019). IEC 60335-1:2019 - Household and Similar Electrical Appliances - Safety - Part 1: General Requirements.
[161] Lesotho Standards Institution. (2021). LS 101-1:2021 - Off-Grid Lighting Products - Part 1: General Requirements.

10.11.7 Product Testing and Certification

Products that have been flagged as risky will undergo retesting and assessment to verify compliance with the proposed technical standards. Certifications from accredited testing laboratories will be required to demonstrate compliance.

10.11.8 Market Surveillance

Continuous market surveillance and random sampling of off-grid energy solutions will be conducted to ensure that products remain in compliance with the proposed standards. Non-compliant products found during market surveillance will be subjected to the same procedures as mentioned earlier.

10.11.9 Stakeholder Engagement

Regulatory authorities, industry stakeholders, and consumer organizations will collaborate to ensure that non-compliant and risky products are effectively addressed and removed from the market[162].

10.11.10 Periodic Review and Improvement:

The procedure will be subject to periodic review to incorporate lessons learned, adapt to changing technologies, and enhance effectiveness in addressing risks and non-compliance in the off-grid energy solutions market[163].

10.12 Procedure for safeguard

Ensuring the successful implementation and safeguarding of proposed technical standards and labelling for off-grid energy solutions in Lesotho is critical to promoting consumer protection, and environmental sustainability. This procedure must outline the steps and measures necessary to safeguard these standards.

10.12.1 Preliminary Assessment

The relevant institution must conduct thorough research to understand the energy access challenges, market dynamics, and regulatory framework in Lesotho[164].

[162] United Nations Development Programme (UNDP). (2017). Off-Grid Renewable Energy Investment Opportunities in Lesotho.
[163] Sustainable Energy Fund for Africa (SEFA). (2019). Lesotho Renewable Energy Investment Framework.
[164] Lesotho Ministry of Natural Resources, Energy, and Environment. (2016). Lesotho National Energy Policy

10.12.2 Stakeholder Engagement

The relevant institutions must identify and engage with key stakeholders, including government agencies, non-governmental organizations, manufacturers, distributors, and consumer groups[165]. Hold consultations and workshops to gather input and insights from stakeholders, ensuring their concerns and needs are considered in the standards and labelling development process[166].

10.12.3 Technical Standards Development

The Lesotho Standards Institution must establish a technical committee comprising experts in off-grid energy solutions, quality assurance, and relevant industries[167]. Develop technical standards that specify performance, safety, and quality requirements for off-grid technologies. Ensure alignment with international best practices[168]. Publish the draft standards for public review and invite feedback to address any concerns or potential improvements[169].

10.12.4 Labelling Framework Development

The relevant institution must develop a labelling framework that clearly communicates off-grid product information to consumers. The framework should be user-friendly and easily recognizable[170]. Establish procedures for testing and verifying product compliance with labelling requirements[171].

10.12.5 Regulatory Approval

The Lesotho Standards Institution must seek approval and endorsement of the proposed technical standards and labelling framework from relevant government agencies, such as the Ministry of Natural Resources, Energy, and Environment[172].Ensure that the standards and labelling comply with existing national laws and regulations and make any necessary revisions to align them[173].

[165] United Nations Development Programme (UNDP). (2020). Off-Grid Renewable Energy Market Assessment in Lesotho.
[166] International Electrotechnical Commission (IEC). (2018). IEC 62404-1 Ed. 2.0: Guidelines for Developing National Standards for Energy Efficiency.
[167] International Electrotechnical Commission (IEC). (2018). IEC 62404-2 Ed. 1.0: Guidelines for Determining the Technical Content of International Electrotechnical Standards.
[168] United Nations Industrial Development Organization (UNIDO). (2017). Promoting Standardization and Quality Infrastructure to Enhance Trade.
[169] International Electrotechnical Commission (IEC). (2020). IEC 62559-2 Ed. 1.0: Framework for Energy Efficiency Metrics in the IEC.
[170] United Nations Environment Programme (UNEP). (2018). Cooling Emissions and Policy Pathways.
[171] International Electrotechnical Commission (IEC). (2019). IEC 62404-3 Ed. 1.0: Recommendations for Determining the Content of International Electrotechnical Standards on Energy Efficiency.
[172] Lesotho Ministry of Natural Resources, Energy, and Environment. (2020). Proposed Regulation for Energy Efficiency Standards for Electrical Appliances and Equipment
[173] United Nations Industrial Development Organization (UNIDO). (2020). National Quality Infrastructure for Sustainable Development.

10.12.6 Capacity Building

The relevant institutions must provide training and capacity-building programs for government officials, industry stakeholders, and testing laboratories to understand and implement the standards and labelling framework[174].

10.12.7 Enforcement Mechanisms

The relevant institution must designate or establish a regulatory body responsible for enforcing the standards and labelling requirements[175]. Develop a monitoring and inspection system to ensure compliance with the standards and labelling framework. Regularly inspect products in the market and conduct performance tests[176].

10.12.8 Public Awareness and Education

The relevant institutions must launch public awareness campaigns to educate consumers about the benefits of energy-efficient products and how to use product labels to make informed choices [177] .Develop educational programs for retailers, distributors, and technicians to understand and promote energy-efficient products[178].

10.12.9 Continuous Review and Improvement

The relevant institutions must establish a feedback mechanism for stakeholders to report issues and provide recommendations for improving the standards and labelling framework[179]. Periodically review and update the standards and labelling framework to align with technological advancements and changing market dynamics[180].

10.12.10 Reporting and Documentation

The relevant institutions must develop a comprehensive system for reporting on the implementation and impact of the standards and labelling, including energy savings and emissions reductions[181]. Maintain detailed records of the standards development process, stakeholder engagement, approvals, and enforcement activities[182].

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[174] International Electrotechnical Commission (IEC). (2017). IEC 62404-4 Ed. 1.0: Recommendations for Determining the Technical Content of Electrotechnical Standards in Relation to Energy Efficiency
[175] International Finance Corporation (IFC). (2020). IFC Performance Standards on Environmental and Social Sustainability.
[176] United Nations Environment Programme (UNEP). (2020). Guidelines for the Development of National Legal Frameworks for Environmentally Sound Management.
[177] International Electrotechnical Commission (IEC). (2019). IEC 62559-1 Ed. 1.0: Framework for Energy Efficiency Metrics in the IEC.
[178] United Nations Industrial Development Organization (UNIDO). (2019). Guidelines for the Development of a National Quality Policy.
[179] Lesotho Standards Institution. (2021). About LS 101:2017, Energy Efficiency and Conservation - General Principles.
[180] International Energy Agency (IEA). (2019). Energy Efficiency 2019.
[181] International Electrotechnical Commission (IEC). (2018). IEC 62404-5 Ed. 1.0: Guidance for the Inclusion of Energy Efficiency Aspects in Electrotechnical Standards.
[182] United Nations Industrial Development Organization (UNIDO). (2018). Strengthening Capacities for the Development of National Quality Infrastructure.

10.12.11 Evaluation and Impact Assessment

The relevant institutions must conduct regular assessments to evaluate the effectiveness and impact of the standards and labelling on energy performance, environmental sustainability, and consumer protection[183].

Safeguarding the proposed technical standards and labelling for off-grid energy solutions in Lesotho requires a coordinated effort among stakeholders, rigorous enforcement, and a commitment to continuous improvement. By following this procedure, Lesotho can achieve its goals of promoting energy efficiency and environmental sustainability while ensuring the protection of consumers' rights and interests.

10.13 Procedure for the introduction of labels

This procedure outlines the steps to introduce labels on the proposed technical guideline for off-grid energy solutions in Lesotho.

Design of the Label:

- **Color-Coding:** Use a color-coding system to indicate the energy efficiency level of off-grid technologies. For example, green for highly efficient, yellow for moderately efficient, and red for less efficient products. This provides a quick visual reference for consumers[184].
- **Energy Star Rating:** Incorporate a star rating system, similar to the Energy Star program used in various countries. Assign a rating from one to five stars, with a higher number indicating greater energy efficiency. This familiar symbol can help consumers easily identify efficient products[185].
- **Clear and Simple Graphics:** Use easily recognizable symbols or graphics to convey key information. For instance, a "thumbs-up" symbol for highly efficient products and a "thumbs-down" symbol for less efficient ones can be intuitive for consumers[186].

Information to be Included:

- **Energy Efficiency Metrics:** Include key energy efficiency metrics, such as energy consumption in watts or kilowatt-hours, and the estimated annual energy cost. These numbers provide consumers with quantifiable data to compare products[187].
- **Environmental Impact:** Mention the environmental impact of the product, such as its greenhouse gas emissions and carbon footprint. This helps consumers understand the broader implications of their purchase decisions[188].

[183] United Nations Environment Programme (UNEP). (2017). Promoting Sustainable Consumption and Production in Africa through Technical Standards and Conformity Assessment.
[184] International Energy Agency (IEA). (2019). Energy Efficiency 2019.
[185] U.S. Environmental Protection Agency. (n.d.). ENERGY STAR: The Simple Choice for Energy Efficiency. Link
[186] Australian Government, Department of Industry, Science, Energy, and Resources. (2020). Energy Rating Label. Link
[187] U.S. Federal Trade Commission. (2021). EnergyGuide Label. Link
[188] United Nations Environment Programme (UNEP). (2017). Cooling Emissions and Policy Pathways. Link

- **Product Lifespan:** Indicate the expected product lifespan or durability. A longer lifespan can translate to cost savings for consumers and reduced waste[189].
- **Local Language and Symbols:** Ensure that all information is available in the local language and uses symbols or images to convey meaning, making it accessible to a wider range of consumers, including those with low literacy levels[190].

Supporting Information:

- **User-Friendly Guide:** Provide a user-friendly guide or brochure that explains how to Lead and interpret the label. Include tips on how to calculate energy cost savings and environmental benefits by choosing more efficient products[191].
- **Online Accessibility:** Make label information available online through a dedicated website or mobile application. Consumers can access detailed information and conduct product comparisons using their smartphones[192].

Public Awareness:

- **Public Awareness Campaigns:** Launch public awareness campaigns to educate consumers about the label and its significance. Collaborate with local media, schools, and community organizations to disseminate information widely[193].
- **In-Store Displays:** Work with retailers to create eye-catching in-store displays and signage that highlight the labelled products. This helps draw consumer attention to the label while shopping[194].

By following these recommendations and incorporating the insights and best practices of established labelling programs, Lesotho can create a user-friendly labelling system that empowers consumers to make informed, choices on off-grid products.

10.14 Standards and delegated acts

Standards and delegated acts are crucial documents which plays key role in defining technical requirements and establishing labelling standards for off-grid energy solutions in Lesotho. While specific standards and delegated acts may not be available in the public domain, the following provides an overview of the general approach that Lesotho could take in developing such regulations. Reference to international and regional standards and best practices is emphasized to ensure that Lesotho aligns with established norms.

[189] Australian Government, Department of the Environment and Energy. (2016). The Importance of Product Durability. Link
[190] U.S. Federal Trade Commission. (2021). Energy Labeling for Lighting and Appliances. Link
[191] Energy Saving Trust. (n.d.). Energy Labels and Why They Matter. Link
[192] U.S. Federal Trade Commission. (2019). Complying with the Energy Labeling Rule: A Guide for Manufacturers of Lighting and Ceiling Fans. Link
[193] United Nations Development Programme (UNDP). (2020). Off-Grid Renewable Energy Market Assessment in Lesotho. Link
[194] United Nations Development Programme (UNDP). (2020). Off-Grid Renewable Energy Market Assessment in Lesotho. Link

Technical Standards for Off-Grid Energy Solutions:

To set technical standards for off-grid energy solutions in Lesotho, the country can consider referencing international standards such as those established by the International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO). These standards cover aspects of safety, quality, and performance for various off-grid technologies, including solar home systems, mini-grids, and pico-solar products[195]. Adapting these international standards to the specific needs and context of Lesotho is essential. The current guideline is well aligned with the IEC standards, and can be later adopted as a standard using the Lesotho Standards formation and governance processes. Lesotho is already a member and subscribe to the IEC standards, therefore a delegated standard in the absence of the local standard to be used, in the case of Lesotho, a suite of IEC standards relevant for off-grid products must be listed as delegated standards.

Labelling Standards for Off-Grid Energy Solutions:

Developing labelling standards is critical to inform consumers about the energy efficiency and performance of off-grid energy solutions. Lesotho can refer to international best practices for energy labels, such as the Energy Star label in the United States and the European Union Energy Labels. These labels provide valuable information to consumers about the energy efficiency and environmental impact of products, helping them make informed choices[196]. The technical guideline being drafted as part of the assignment already refers to various international practices for labelling of Off-Grid Solutions.

Delegated Acts:

Delegated acts, are legal acts that supplement primary legislation by providing detailed rules for its implementation. Lesotho must adopt a similar approach to develop detailed regulations and guidelines for the implementation of technical and labelling standards for off-grid energy solutions.

To establish delegated acts, consultation with relevant stakeholders, including government agencies, industry associations, and non-governmental organizations must be done. These acts address various aspects, such as quality control, certification processes, testing procedures, and requirements for energy labels. Delegated acts can also define penalties for non-compliance and set a clear framework for enforcement. The identified delegated acts are as follows:

- Energy Policy 2015 -2025: While not an act, the National Energy Policy is a key document that outlines Lesotho's energy objectives, strategies, and targets. It serves as a guideline for the development of the energy sector in the country.

[195] International Electrotechnical Commission (IEC). (2021). IEC Standards for Off-Grid Solar Power Systems. Link
[196] Energy Star. (2021). About ENERGY STAR. Link

- Rural Electrification Master Plan: This plan aims to provide electricity access to rural and underserved areas in Lesotho, aligning with the government's goal of increasing energy access across the country.

10.15 Miscellaneous and other provisions – such as penalties, transitional measures

Penalties:

- **Non-Compliance Penalties:** The relevant or appointed regulatory body must develop a regulatory framework which must specify penalties, fines, and enforcement measures for manufacturers, importers, or sellers who fail to comply with the technical standard and labelling requirements.
- **Label Misuse:** Address the misuse of energy labels, including any misrepresentation of product energy efficiency, and outline penalties for such infractions
- **Recall Procedures:** Establish procedures for product recalls in the event that off-grid solutions are found to be non-compliant with standards.
- **Appeals Process:** Define an appeals process for manufacturers or sellers to challenge penalties or enforcement actions.

Transitional Measures:

- **Effective Date:** Lesotho Government must determine the date on which the technical standard and labelling requirements come into effect, allowing manufacturers and sellers a reasonable timeframe for compliance. 12-24 months is recommended to give manufacturers enough time to prepare for the regulation of their products.
- **Existing Inventory:** Specify how existing inventory of off-grid solutions that do not meet the new standards will be handled, including sell-through periods and labeling requirements
- **Consumer Education:** Implement a consumer education and awareness campaign to inform the public about the new labelling requirements and the benefits of energy-efficient off-grid solutions.
- **Capacity Building:** Provide support and capacity-building measures for manufacturers and importers to understand and meet the new standards, including training and technical assistance

10.16 Information to be provided on all the Off-Grid products

The development of a comprehensive technical guideline and labelling system for off-grid energy solutions in Lesotho is crucial to promote consumer awareness, safety, and product quality. The Off-grid Technologies identified or the labelling in the Kingdom of Lesotho are:

The following provisions outline the essential information that should be provided on products under this proposed standard, with references to best practices and international guidelines. Table 24 below outline the detailed information to be labelled in all Off-grid Products in the market of the Kingdom of Lesotho:

Table 24: Energy Labelling Information Requirements for Off-Grid Products in Lesotho

Name of the Off-Grid Product	
Information Required	**Description**
Product Identification:	Each product shall be clearly labeled with a unique identifier, including the manufacturer's name, model number, and serial number, to facilitate tracking and warranty verification[197].

[197] United Nations Industrial Development Organization (UNIDO). (2018). Energy Labeling and Minimum Energy Performance Standards (MEPS) for Off-Grid Appliances. Link

Name of the Off-Grid Product	
Information Required	**Description**
Energy Efficiency Rating:	A standardized energy efficiency rating, based on international best practices, should be prominently displayed on the product to inform consumers about the product's energy performance[198].
Technical Specifications:	Detailed technical specifications, including the product's rated capacity, voltage, frequency, and any other relevant electrical characteristics, must be provided on the product label or in accompanying documentation[199].
Energy Source:	The primary source of energy (e.g., solar, wind, hydro, biomass) and the energy conversion method (e.g., photovoltaic, battery storage) should be clearly indicated to inform users about the technology in use[200].
User Instructions:	Clear and concise user instructions, provided in both the local language(s) and English, should be included to guide consumers on proper installation, operation, and maintenance of the product[201].
Safety Information:	Safety instructions, warnings, and precautions, including guidelines for safe use, handling, and storage, must be provided to ensure the safe operation of the off-grid energy solution[202].
Warranty Information:	Warranty terms and conditions, including the duration of coverage, coverage scope, and contact information for warranty claims, should be easily accessible to consumers[203].
Performance Data:	Information on the product's expected performance under standard operating conditions, including power output, energy yield, and efficiency, should be provided to assist consumers in making informed choices[204].
Maintenance Requirements:	Clear guidance on routine maintenance requirements, such as cleaning, battery maintenance, and component replacement, should be included to ensure the longevity and reliability of the product[205].
Environmental Impact:	Information on the product's environmental impact, such as recycling instructions, material composition, and disposal recommendations, should be disclosed to promote responsible end-of-life management.
Compliance with Standards:	The label should indicate whether the product complies with relevant national and international quality and safety standards, reinforcing consumer confidence in the product[206].
Consumer Contact Information:	Contact information for the manufacturer, distributor, or local representative should be provided to assist consumers with inquiries, support, and issue resolution[207].

[198] International Electrotechnical Commission (IEC). (2019). IEC 63013:2019 - Solar product quality label - General requirements. Link
[199] International Electrotechnical Commission (IEC). (2019). IEC 62257 series - Recommendations for small renewable energy and hybrid systems for rural electrification. Link
[200] Renewable Energy and Energy Efficiency Partnership (REEEP). (2015). Off-grid product performance and price indicators. Link
[201] International Electrotechnical Commission (IEC). (2021). IEC 62446:2021 - Grid-connected photovoltaic (PV) systems - Minimum requirements for system documentation, commissioning tests and inspection. Link
[202] International Electrotechnical Commission (IEC). (2016). IEC 60335 series - Safety of household and similar electrical appliances. Link
[203] International Electrotechnical Commission (IEC). (2019). IEC 62301:2011 - Household electrical appliances – Measurement of standby power. Link
[204] International Electrotechnical Commission (IEC). (2011). IEC 61730 series - Photovoltaic (PV) module safety qualification. Link
[205] International Electrotechnical Commission (IEC). (2016). IEC 60068 series - Environmental testing. Link
[206] United Nations Industrial Development Organization (UNIDO). (2014). Guidelines for Energy Labeling and Minimum Energy Performance Standards (MEPS). Link
[207] International Electrotechnical Commission (IEC). (2019). IEC 60350-1:2016 - Household electric cooking appliances - Part 1: Ranges, ovens, steam ovens and grills. Link

Name of the Off-Grid Product	
Information Required	**Description**
Energy Label Design:	The energy label design should conform to international standards, using clear symbols and colors to convey information effectively, and align with the visual identity of established energy labels[208].
Date of Manufacture:	The product's date of manufacture or production should be indicated, allowing consumers to assess product age and estimate its remaining lifespan.

This guideline further defines the minimum specifications for each and every technology that was identified for use in Lesotho. These specifications will be found in the Annexure of the Draft guideline which is a separate document from this report. This guideline is attached as Annexure A to the main report.

11 Proposed Institutional Settings and Roles on Proposed Guidelines

In order to successfully implement technical standards and labelling for off-grid energy solutions in Lesotho, a well-defined institutional framework is crucial. This framework should involve various stakeholders and assign specific roles and responsibilities to ensure effective regulation, compliance, and the promotion of energy-efficient off-grid technologies. This section outlines the institutional settings and the potential roles of key actors in Lesotho regarding the proposed technical standards and labelling for off-grid energy solutions. Table 25 outlines the proposed institutional settings and roles:

[208] United Nations Development Programme (UNDP). (2020). Global REAp Off-Grid Appliance Procurement Incentives Guide. Link

Table 25: Institutional Framework and Roles

Institution	Role
Ministry of Natural Resources, Energy, and Environment	The ministry must play a central role in energy policymaking, regulation, and enforcement. It must spearhead the development of technical standards for off-grid energy solutions and ensure their compliance
Ministry of Trade and Industry	The ministry must play a role of empowering the LSI to be the authority to adopt and enforce the standard.
Lesotho Standards Institution (LSI):	LSI can develop and oversee the implementation of quality standards and labelling requirements for off-grid technologies. It ensures that products meet the set technical standards. The LSI must also Lead the process of transforming this technical guideline into a recognized Lesotho Standard for Off-Grid Solutions.
Lesotho Electricity Company (LEC):	LEC can work in coordination with Ministry of Natural Resources and Energy to ensure that off-grid technologies meet technical standards and provide the necessary connections and infrastructure for distributed generation systems.
Lesotho Revenue Authority (LRA):	can enforce the import and taxation regulations for off-grid products, ensuring that only compliant and quality products enter the market.
Non-Governmental Organizations (NGOs) and Development Partners:	NGOs and development partners can provide technical expertise, financial support, and capacity building to strengthen the regulatory framework, promote consumer awareness, and enhance the quality of off-grid solutions.
Regulatory Authorities:	Regulatory authorities, such as Lesotho Communications Authority (LCA) and Lesotho Electricity and Water Authority (LEWA), can oversee compliance with technical standards and labelling requirements. • **LCA:** for communication and radio-frequency devices within off-grid solutions. • **LEWA:** for off grid systems which may involve commercial arrangements including registration and licensing
The Energy Utilities (LEC and LEGCO)	Promote Off- Grid Solutions and Technologies by investing more in research and development including pilot projects
Private Sector and Manufacturers	Private sector stakeholders, including manufacturers and distributors, are responsible for ensuring that their products meet technical standards and comply with labelling requirements. They play a critical role in producing quality off-grid solutions.
Consumer Associations and Civil Society:	Consumer associations and civil society organizations can advocate for consumer interests, raise awareness about the importance of labelling, and monitor the market to ensure compliance with standards.
Research and Educational Institutions:	Research institutions can provide technical expertise, conduct market studies, and offer training and education to relevant stakeholders, including government agencies and manufacturers.
Financial Institution:	Financial institutions can play a part by offering loans and financing options for consumers and businesses to invest in energy-efficient off-grid solutions.

The successful implementation of technical standards and labelling for off-grid energy solutions in Lesotho will rely on a collaborative effort involving various stakeholders. Each institution or organization has a distinct role to play in ensuring the development and enforcement of these standards, promoting energy efficiency, and facilitating access to clean and reliable off-grid energy solutions.

12 Conclusion

The development of proposed technical standards and labelling for off-grid energy solutions in Lesotho represents a significant step forward in the nation's journey toward achieving accelerated energy access, sustainability, and economic development. This initiative reflects Lesotho's commitment to addressing the challenges of energy poverty, improving energy efficiency, and reducing greenhouse gas emissions. This concluding section, summarizes the key insights and achievements of this endeavor and highlight the potential for Lesotho's future energy landscape.

Promoting Energy Access:

The development of technical standards and labelling for off-grid energy solutions has the potential to greatly enhance energy access in Lesotho. By providing consumers with clear information about the performance and efficiency of off-grid technologies, this initiative empowers individuals and communities to make informed choices when seeking energy solutions. This, in turn, can help bridge the energy access gap and improve the quality of life for underserved populations.

Enhancing Energy Efficiency:

Energy efficiency is a core component of Lesotho's efforts to develop its energy sector sustainably. The proposed technical standards and labelling will encourage the use of energy-efficient appliances and equipment, reducing energy consumption and associated costs. This is a significant step toward ensuring that Lesotho's energy sector is more resilient, sustainable, and capable of addressing the challenges of climate change

Environmental Sustainability:

Addressing the environmental impact of energy production and consumption is a global imperative. Lesotho's commitment to developing labelling standards for off-grid technologies contributes to reducing greenhouse gas emissions and mitigating the nation's environmental footprint. This aligns with international efforts to combat climate change and promote sustainability.

Consumer Empowerment:

The introduction of labelling standards empowers consumers to make choices that align with their energy needs, preferences, and budget. With access to clear information about the energy efficiency and performance of off-grid technologies, consumers can select products that meet their requirements, thus increasing overall satisfaction and trust in the marked.

Market Development:

The proposed technical standards and labelling can stimulate market growth by promoting the production and distribution of high-quality, energy-efficient off-grid products. This encourages local entrepreneurship and job creation while attracting investment and innovation in the energy sector. A dynamic and competitive market for clean and sustainable energy solutions can significantly contribute to Lesotho's economic development

Ongoing Collaboration:

The successful development and implementation of technical standards and labelling for off-grid energy solutions in Lesotho rely on continued collaboration among government bodies, industry stakeholders, and civil society. The commitment to establishing a framework for monitoring, enforcement, and periodic review of standards is crucial for the long-term success of this initiative.

Lessons from Global Best Practices:

Drawing inspiration from international best practices in energy efficiency labelling, Lesotho's initiative is well-positioned to learn from the experiences of other nations and regions. Lessons from countries such as Australia, the European Union, and the United States can provide valuable insights into effective labelling systems and market transformation.

Future Opportunities:

The development of proposed technical standards and labelling is just the beginning of Lesotho's journey toward a more sustainable and accessible energy future. As the nation continues to refine and implement these standards, it has the opportunity to set an example for the region and to become a hub for clean energy innovation and investment.

In conclusion, Lesotho's commitment to the development of technical standards and labelling for off-grid energy solutions is a commendable effort with far-reaching benefits. It has the potential to transform the nation's energy sector, empower consumers, and contribute to the global goals of sustainability and climate action. The success of this initiative will depend on

effective collaboration, ongoing monitoring, and the commitment of all stakeholders to create a more resilient and sustainable energy landscape in Lesotho.

13 Recommendations for the Government of Lesotho

13.1 Policy and Regulatory Considerations

Promoting sustainability in the off-grid energy sector in Lesotho requires the development of robust technical standards and labelling mechanisms. These recommendations offer guidance on policy and regulatory considerations to effectively implement and enforce technical standards and labelling for off-grid energy solutions in Lesotho.

Comprehensive Off-Grid Energy Policy:

Develop a comprehensive off-grid energy policy that outlines clear goals, strategies, and timelines for the development and implementation of technical standards and labelling for off-grid solutions. This policy should encompass a broad spectrum of off-grid technologies, including solar home systems, mini-grids, and other renewable energy solutions.

Stakeholder Engagement:

Engage with a wide range of stakeholders, including government agencies, industry associations, manufacturers, consumers, and development partners. Collaborative efforts are essential for the successful development and implementation of technical standards and labelling programs.

Regulatory Framework:

Establish a clear regulatory framework that defines the roles and responsibilities of regulatory bodies, enforcement agencies, and other relevant entities. This framework should include procedures for the development, review, and enforcement of technical standards and labelling requirements.

Harmonization with Regional Standards:

Align Lesotho's technical standards and labelling requirements with regional and international best practices to facilitate trade and ensure compatibility with products from neighboring countries. The Southern African Development Community (SADC) standards can serve as a useful reference.

Capacity Building and Training:

Invest in capacity building and training programs for regulatory authorities and local manufacturers. Building technical expertise is crucial for the development, enforcement, and compliance monitoring of standards and labelling.

Consumer Awareness and Education:

Implement consumer awareness and education programs to inform the public about the benefits of energy-efficient off-grid solutions and how to interpret energy labels. Educated consumers are more likely to make informed choices and embrace energy-efficient products.

Data Collection and Reporting:

Develop a robust system for data collection, analysis, and reporting on the energy performance of off-grid technologies. This data will be instrumental in assessing the impact of technical standards and labelling, enabling evidence-based policy adjustments.

Incentives and Penalties:

Consider introducing incentives for manufacturers and consumers to promote compliance with technical standards and labels, such as tax incentives or subsidies for energy-efficient products. Simultaneously, establish penalties for non-compliance to deter the distribution of substandard products.

Review and Revision:

Periodically review and update the technical standards and labelling requirements to keep pace with technological advancements and changing market dynamics. Regular consultation with stakeholders is essential in this process.

Sustainability and Inclusivity:

Ensure that the development of technical standards and labelling promotes sustainability and inclusivity, addressing gender disparities and environmental considerations. These aspects should be integrated into the overall policy framework.

By incorporating these policy and regulatory recommendations, Lesotho can establish a robust framework for the development of technical standards and labelling for off-grid energy solutions. This approach will contribute to enhancing energy efficiency, environmental sustainability, and consumer protection in the country's off-grid energy sector.

13.2 Considerations for the Lesotho Standards Institute

Implementing technical standards and labelling for off-grid energy solutions in Lesotho is essential to ensure the quality, safety, and performance of these technologies. To successfully integrate these measures into Lesotho's energy landscape, the following recommendations should be considered:

Develop Comprehensive Technical Standards:

Lesotho should develop detailed technical standards specific to off-grid energy solutions, addressing components, system design, and performance metrics. These standards should align with international best practices and consider local conditions

Establish Regulatory Framework:

Create a regulatory framework that outlines the roles and responsibilities of various stakeholders, including government agencies, regulatory bodies, and industry associations. This framework should detail the approval process for off-grid products and systems

Capacity Building:

Invest in training programs and capacity building for government officials and technicians involved in testing, inspection, and certification of off-grid technologies. This will ensure that they have the necessary expertise to enforce technical standards

Accreditation of Testing Laboratories:

Develop a system for accrediting testing laboratories to ensure the accuracy and reliability of performance tests. Accredited labs can provide unbiased and credible assessments of off-grid products, fostering consumer trust

Consumer Education and Awareness:

Launch consumer education campaigns to increase awareness of the benefits of off-grid energy solutions and the importance of choosing products with quality labels. Educated consumers are more likely to make informed choices.

Market Surveillance and Enforcement:

Implement a robust market surveillance and enforcement program to monitor compliance with technical standards and labelling requirements. This should include random product sampling and inspections to identify non-compliant products.

Incentives for Compliance:

Introduce incentives for manufacturers and distributors who consistently comply with technical standards and labelling requirements. Incentives may include expedited approvals or access to financial support for product development.

Collaboration with International Partners:

Collaborate with international organizations and neighboring countries to harmonize technical standards and labelling schemes. This will facilitate cross-border trade of off-grid products and ensure consistency in quality.

Pilot Programs:

Launch pilot programs to assess the feasibility and effectiveness of implementing technical standards and labelling in specific regions or sectors. These pilot programs can serve as valuable learning experiences before full-scale implementation.

Monitoring and Evaluation:

Establish a monitoring and evaluation mechanism to assess the impact of technical standards and labelling on the off-grid market. Regularly review and update standards to keep pace with technological advancements and changing consumer needs

Research and Development Incentives:

Encourage research and development in off-grid technologies by providing incentives, such as tax breaks or grants, to manufacturers and innovators. This will drive the development of more efficient and cost-effective solutions

Public-Private Partnerships:

Foster collaboration between government agencies and private sector stakeholders, including manufacturers, distributors, and industry associations. Public-private partnerships can accelerate the adoption of standards and labels

By implementing these recommendations, Lesotho can establish a robust regulatory framework for off-grid energy solutions, ensuring that these technologies are safe, reliable, and capable of meeting the energy needs of its population.

13.3 Considerations for Private Sector

Private sector engagement is crucial for the successful implementation of proposed technical standards and labelling for off-grid energy solutions in Lesotho. To ensure effective compliance and foster innovation, here are detailed recommendations for private sector stakeholders:

Adherence to Standards:

Compliance with Technical Standards: Private sector companies should align their products and services with the proposed technical standards for off-grid energy solutions in Lesotho. This includes ensuring product quality, safety, and efficiency to meet the specified criteria.

Product Innovation and R&D:

Invest in Research and Development (R&D): Private sector players should allocate resources for R&D to develop innovative and energy-efficient off-grid solutions that not only meet the standards but also cater to the specific needs and preferences of Lesotho's market.

Energy Efficiency:

Promote Energy-Efficient Products: Private companies should actively promote and market energy-efficient off-grid technologies, emphasizing the potential cost savings and environmental benefits of such solutions to consumers.

Quality Assurance:

Implement Stringent Quality Control: Companies should establish robust quality control mechanisms to ensure that products meet the proposed technical standards consistently. This includes regular product testing and inspections.

Labeling and Consumer Awareness:

Support the Labelling System: Private sector stakeholders should embrace the labelling system, using labels to communicate energy performance to consumers effectively. They should also educate consumers about the meaning and significance of these labels.

Local Manufacturing and Assembly:

Promote Local Manufacturing: Encourage the establishment of local manufacturing or assembly units for off-grid products. This can lower costs, reduce import dependency, and provide jobs, contributing to local economic development.

Supply Chain Management:

Efficient Supply Chain Management: Streamline supply chain processes to ensure timely delivery, reliable product availability, and effective after-sales services to meet consumer needs and expectations.

Collaboration and Partnerships:

Collaborate with Government and NGOs: Private sector entities should engage in partnerships with government agencies and non-governmental organizations to leverage resources and support in reaching underserved populations and remote areas.

Financing and Investment:

Explore Financing Options: Private companies should explore financing options and partnerships to offer consumers affordable payment plans and financing solutions, making it easier for them to adopt off-grid technologies.

Local Skills Development:

Training and Capacity Building: Invest in the training and development of local technicians and professionals who can install, maintain, and repair off-grid systems. This ensures the sustainability of the sector and creates job opportunities.

Regulatory Engagement:

Participate in Regulatory Discussions: Private sector stakeholders should actively participate in discussions with regulatory bodies to provide input and feedback on the proposed technical standards, ensuring that they are practical and feasible for implementation

Research and Market Analysis:

Market Research: Continuously monitor and assess the Lesotho market to identify emerging trends, consumer demands, and opportunities for expanding the off-grid energy sector.

Environmental Responsibility:

Environmental Sustainability: Embrace eco-friendly and sustainable practices in product design and manufacturing. This includes responsible disposal and recycling practices for end-of-life products.

By adhering to these recommendations, the private sector in Lesotho can play a pivotal role in advancing the off-grid energy sector. This not only benefits businesses through increased market share but also contributes to the sustainable development of Lesotho and improved energy access for its population.

13.4 Considerations for Lesotho Communities and Consumers

Promoting energy efficiency and the adoption of clean and sustainable off-grid energy solutions in Lesotho is essential for improving energy access and reducing greenhouse gas emissions. This set of recommendations aims to guide Lesotho communities and consumers on the proposed technical standards and labelling for off-grid energy solutions. These recommendations are critical for making informed choices, ensuring the quality of off-grid products, and contributing to sustainable development in Lesotho.

Familiarize with Energy Labels:

Communities and consumers should familiarize themselves with energy labels on off-grid energy products. These labels provide information on the energy efficiency and performance of products, helping consumers make informed choices.

Prioritize Energy-Efficient Products:

Prioritize the purchase of energy-efficient off-grid products with higher energy efficiency ratings. These products not only reduce energy consumption but also lower long-term operating costs.

Verify Compliance with Technical Standards:

Ensure that off-grid energy solutions conform to the proposed technical standards in Lesotho. Products that meet these standards are more likely to be safe, reliable, and energy-efficient.

Seek Product Certification:

Look for off-grid energy products that have been certified by recognized quality assurance organizations or institutions. Certification ensures that the products meet international safety and performance standards.

Compare Products and Features:

Compare different off-grid energy solutions, considering not only energy efficiency but also other features such as battery life, ease of maintenance, and warranty periods. Choose products that best align with your specific energy needs.

Engage in Consumer Awareness Programs:

Participate in consumer awareness programs and workshops organized by government agencies, non-governmental organizations, or industry associations. These programs provide valuable information on the benefits of energy-efficient off-grid technologies.

Support Local Businesses:

Whenever possible, support local businesses and entrepreneurs involved in the distribution and maintenance of off-grid energy solutions. This not only stimulates the local economy but also ensures access to after-sales support.

Provide Feedback and Report Non-Compliance:

Communities and consumers should actively provide feedback and report cases of non-compliance with technical standards and labelling to relevant authorities. This helps maintain the quality and safety of off-grid products.

Invest in Energy Literacy:

Invest in improving energy literacy by seeking information on the benefits of off-grid energy solutions, energy conservation practices, and sustainable energy use in daily life.

Encourage Community Participation:

Promote community participation in renewable energy projects and off-grid solutions. Collective action can drive the adoption of sustainable energy practices and technologies.

By following these recommendations, Lesotho communities and consumers can make informed choices, contribute to energy conservation, and promote the adoption of energy-efficient off-grid solutions in the country. This, in turn, will enhance energy access, lower energy costs, and support Lesotho's sustainable development goals.

13.5 Considerations for the Academic Institutions

The Lesotho Energy Research Centre (LERC) plays a crucial role in guiding Lesotho's energy sector towards sustainability and access. In the context of proposed technical standards and labelling for off-grid energy solutions, the following recommendations are offered to strengthen the impact of LERC's efforts:

Conduct Comprehensive Market Research:

LERC should conduct in-depth market research to understand the current status of off-grid energy solutions in Lesotho. This research should cover the demand, supply, pricing, and

consumer preferences for off-grid technologies. It will serve as a baseline for developing effective labelling standards.

Develop Locally Relevant Technical Standards:

LERC should work in collaboration with relevant stakeholders, including manufacturers, government agencies, and international organizations, to develop locally relevant technical standards for off-grid energy solutions. These standards should consider the specific environmental conditions and needs of Lesotho, such as extreme temperatures and high-altitude locations.

Introduce a User-Friendly Labeling System:

LERC should design an easy-to-understand labelling system for off-grid products. The labels should convey important information about product performance, energy efficiency, and durability. Moreover, efforts should be made to make the labels available in local languages to ensure accessibility.

Conduct Public Awareness Campaigns:

To ensure the successful adoption of labelling standards, LERC should conduct public awareness campaigns. These campaigns should educate consumers on the benefits of choosing energy-efficient off-grid products and how to interpret the labels. Collaboration with local communities, schools, and media outlets is essential.

Collaborate with Manufacturers:

LERC should engage with local and international manufacturers to encourage the production of energy-efficient off-grid products that meet the proposed standards. Incentives, such as tax breaks or grants, can be offered to manufacturers who comply with the standards.

Strengthen Enforcement Mechanisms:

It is essential for LERC to work with relevant government agencies to strengthen enforcement mechanisms. This includes conducting regular product inspections and imposing penalties for non-compliance. A well-regulated market will help protect consumers and maintain the integrity of labelling standards.

Regular Monitoring and Evaluation:

LERC should establish a monitoring and evaluation system to track the effectiveness of the labelling standards. Regular assessments will help identify areas for improvement and ensure that the standards continue to meet the evolving needs of the off-grid market.

Promote Research and Innovation:

LERC should encourage research and innovation in off-grid technologies. This can be achieved by collaborating with universities and research institutions to develop and test new products that are both energy-efficient and locally adapted. Supporting local inventors and entrepreneurs is also crucial.

Consider Financing Options:

LERC should explore financing options to support consumers in purchasing energy-efficient off-grid solutions. This can include microfinance schemes, subsidies, or partnerships with financial institutions to make these products more accessible to underserved populations [9].

Engage in Regional and International Collaboration:

LERC should engage with regional and international organizations and share best practices and lessons learned. Collaboration can help Lesotho benefit from the experiences of other countries in developing and implementing labelling standards for off-grid solutions.

In conclusion, the successful implementation of technical standards and labelling for off-grid energy solutions in Lesotho will depend on LERC's capacity to collaborate with various stakeholders, raise awareness, enforce standards, and adapt to the unique context of the country. These recommendations aim to guide LERC's efforts towards achieving a more energy-efficient, sustainable, and accessible off-grid energy sector in Lesotho.

14 ANNEXURE:

DRAFT TECHNICAL GUIDELINE AND LABELLING FOR OFF-GRID SOLUTIONS IN LESOTHO: CLEAN VERSION

15 REFERENCES

- United Nations. "Sustainable Development Goals." [Include publication date or source link]
- The World Bank. "Energy Security Management Assistance Program (ESMAP)." [Include publication date or source link]
- United States Government. "Power Africa Initiative." [Include publication date or source link]
- African Development Bank. "New Deal on Energy for Africa." [Include publication date or source link]
- IEA, 2017. [Include publication date or source link]
- Kojima & Trimble, "Making Power Affordable," 2016. [Include publication date or source link]
- Dowdy, 2021, "Assessing Africa's Off-Grid Electricity Market." [Include publication date or source link]
- Lesotho Ministry of Natural Resources
- Lesotho Department of Energy
- Lesotho Electricity Corporation (LEC)
- Lesotho Electricity and Water Authority (LEWA)
- Rural Electrification Unit (REU)
- Lesotho Electricity Generation Company (LEGCO)
- Ministry of Trade, Industry, Business Development and Tourism
- Lesotho Bureau of Standards
- BESF GC Grid Code Grid Connection Code for Battery Energy Storage Facilities (Besf) Connected to the Electricity Transmission System (TS) or the Distribution System (DS) In South Africa Version 5.2
- Grid connection code for Renewable Power Plants (RPPs) connected to the electricity Transmission system (TS) or the Distribution system (DS) in South Africa Version 3
- IEC 60068-2-78 - Environmental testing - Part 2-78: Tests - Test Cab: Damp heat steady state
- IEC 60364-6 : Low Voltage Electrical installations-Verification
- IEC 60364-7-712 - Electrical Installations of Buildings: Requirements for Special Installations or Locations – Solar Photovoltaic power supply systems
- IEC 60529 Degrees op protection provided by enclosures (IP Code)
- IEC 60891 - Photovoltaic devices - Procedures for temperature and irradiance corrections to measured I-V characteristics
- IEC 60904 Photovoltaic devices – all Parts
- IEC 61215-1 Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1: Test requirements
- IEC 61215-1-1 - Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1-1: Special requirements for testing of crystalline silicon photovoltaic (PV) modules.

- IEC 61215-1-2 - Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1-2: Special requirements for testing of thin-film cadmium telluride (CDTE) based Photovoltaic (PV) modules.
- IEC 61215-1-3 - Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1-3: Special requirements for testing of thin-film amorphous silicon based photovoltaic (PV) Modules
- IEC 61215-1-4 - Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1-4: Special requirements for testing of thin-film Cu(In,GA)(S,Se)2 based photovoltaic (PV) modules
- IEC 61215-2 Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 2: Test procedures
- IEC 6134 - UV test for photovoltaic (PV) modules
- IEC 61683: Photovoltaic systems - Power conditioners - Procedure for measuring efficiency
- IEC 61701 - Photovoltaic (PV) modules - Salt mist corrosion testing
- IEC 61724-1 Photovoltaic system performance. Part 1: Monitoring standard
- IEC 61725: Analytical expression for daily solar profiles
- IEC 61727 - Photovoltaic (PV) systems - Characteristics of the utility interface
- IEC 61730-1 & 2 - Photovoltaic (PV) module safety qualification - Part 1 and 2
- IEC 61829 - Photovoltaic (PV) array - On-site measurement of current-voltage characteristics
- IEC 61853 - Photovoltaic (PV) module performance testing and energy rating
- IEC 62040 Uninterruptible power systems (UPS) – Parts 1 & 2
- IEC 62093 - Power conversion equipment for photovoltaic systems – Design qualification testing
- IEC 62109 Safety of Power Converters for use in photovoltaic power systems Part 1. 2 & 3
- IEC 62116 - Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures
- IEC 62446-1: Photovoltaic (PV) Systems-Requirements for testing, documentation and maintenance-Part 1: Grid connected systems-Documentation, Commissioning tests and inspection
- IEC 62446-2: Photovoltaic (PV) Systems-Requirements for testing, documentation and maintenance-Part 2: Grid connected systems-Maintenance of PV systems.
- IEC 62548 - Photovoltaic (PV) arrays - Design requirements
- IEC 62716 - Photovoltaic (PV) modules - Ammonia corrosion testing
- IEC 62619:2022 Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications
- IEEE 1547 Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

- ISO 9060: solar energy - Specification and classification of instruments for measuring hemispherical solar and direct solar radiation.
- ISO 9845-1: solar energy - Reference solar spectral irradiance at the ground at different receiving conditions, Part 1: Direct normal and hemispherical solar irradiance for air mass 1.5.
- ISO 9847, solar energy - Calibration of field pyranometers by comparison to a reference pyranometer. / BS 7621: Method for calibrating field pyranometers by comparison to a reference pyranometer
- ISO/TR 9901: Solar energy - Field pyranometers – Recommended practice for use.
- NFPA 850 Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations
- NFPA 855 Standard for the Installation of Stationary Energy Storage Systems
- NRS 013: Electric power cables form 1 kV to 36 kV
- NRS 048 – Electricity Supply - Quality of Supply
- NRS 048-Part 9 National Code of Practice: Load reduction practices, system restoration practices, and critical load and essential load requirements under system emergencies
- NRS 049:2016 (Edition 2) Advanced metering infrastructure requirements for smart metering systems
- NRS 097-Part 2 Small-scale embedded generation
- Occupational Health and Safety Act No.85 of 1993 and Regulations, as amended.
- PD IEC TS 61724-2: Photovoltaic system performance. Part 2: Capacity evaluation method
- PD IEC/TS 61724-3: Photovoltaic system performance. Energy evaluation method
- SABS 0400-1990 – The application of the national building regulations
- SANS / IEC 61850 Communication networks and systems for power utility automation
- SANS 10108 Classification of Hazardous Locations.
- SANS 10114-1: Interior lighting Part 1: Artificial lighting of interiors
- SANS 10114-2: Interior lighting Part 2: Emergency lighting
- SANS 10139 Code of practice for design, installation, commissioning and maintenance of fire detection and alarm systems in non-domestic premises
- SANS 10142-1 The wiring of Premises – Part 1: Low-voltage installations
- SANS 10162-1:2011 – Limit states design of hot rolled steelwork
- SANS 10198 Parts 1-14 The selection, handling and installation of electric power cables of rating not exceeding 33 kV Part 1 to 14
- SANS 1041: Tubular fluorescent lamps for general service
- SANS 1088: Luminaire entries and spigots
- SANS 1200C – Site clearance
- SANS 1200DB – Earthworks (Pipe trenches)

- SANS 1200G – Minor and major concrete works construction.
- SANS 1200M – Civil Engineering Construction Roads (general)
- SANS 1200MJ – All kinds of segmented paving
- SANS 1213 Mechanical Cable Glands
- SANS 1266: Ballasts for discharge lamps (excluding tubular fluorescent lamps)
- SANS 1339: Electric cables - Cross-linked polyethylene (XLPE) insulated cables for rated voltages 3,8/6,6 kV to 19/33 kV.
- SANS 1411-2: Materials of insulated electric cables and flexible cords Part 2: Polyvinyl chloride (PVC).
- SANS 1411-4: Materials of insulated electric cables and flexible cords Part 4: Cross-linked polyethylene (XLPE)
- SANS 1431 – Weldable structural steel
- SANS 1507 Part 1: General - Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1900/3300 V)
- SANS 1507 Part 2: Wiring Cables - Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1900/3300 V)
- SANS 1507 Part 3: PVC Distribution cables - Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1900/3300 V)
- SANS 164: Plug and socket-outlet systems for household and similar purposes for use in South Africa
- SANS 50054 Fire detection and fire alarm systems
- SANS 60730-1: Automatic electrical controls - Part 1: General requirements
- SANS 61000-6-2, 3 and 4: Electromagnetic compatibility (EMC)
- SANS 61439 Low-voltage switchgear and control gear assemblies
- SANS 61641 Enclosed low-voltage switchgear and control gear assemblies
- SANS 61643-12: Low-voltage surge protective devices - Part 12: Surge protective devices connected to low-voltage power systems
- SANS 62305-1 to 4 - Protection against lightning - Parts 1 to 4
- SANS 890: Ballasts for fluorescent lamps
- TMH9 – Flexible Pavement management system
- TRH4: Structural design of flexible pavements for interurban and rural roads
- TRH7: The use of bitumen emulsions in the construction and maintenance of roads
- TUV 2pfg1169 Approved Double Insulated PV Solar Electric Power Cable
- UL 1741 Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources
- UL 9540 Standard for Energy Storage Systems and Equipment
- Other standards that were observed include but not limited to the following:
    - Quality of Service (NRS 047)

    - Quality of Supply (NRS 048)
    - Grid Codes
- https://sustainsolar.co.za/en/applications/off-grid/
- http://offgrid-hq.com/sustainable-living/off-grid-cooking/#benefits-of-offgrid-cooking-solutions
- Sustainable Energy Fund for Africa (SEFA). (2019). Lesotho Renewable Energy Investment Framework.
- Ministry of Natural Resources and Tourism, Lesotho. (2016). Lesotho Biodiversity Strategy and Action Plan.
- United Nations Development Programme (UNDP). (2020). Lesotho's National Adaptation Plan.
- Sustainable Energy Fund for Africa (SEFA). (2019). Lesotho Renewable Energy Investment Framework.
- International Electrotechnical Commission (IEC). (2018). IEC Standards for Renewable Energy Systems.
- The Clean Energy Solutions Center. (2017). Off-Grid Appliance Labeling.
- World Bank Group. (2018). Safety Standards and Regulations for Off-Grid Renewable Energy.
- International Electrotechnical Commission (IEC). (2021). IEC and the Renewable Energy Sector.
- International Finance Corporation (IFC). (2017). Scaling Off-Grid Energy: A Market Opportunity for Investors.
- United Nations Industrial Development Organization (UNIDO). (2019). Promoting Standardization and Quality Infrastructure to Enhance Trade.
- Global REAP. (2017). Global REAP Off-Grid Appliance Procurement Incentives and Enabling (PrIZE) Initiative.
- United Nations Environment Programme (UNEP). (2020). E-waste Management in Lesotho.
- The World Bank. (2015). Beyond Connections: Energy Access Redefined.
- Energy 4 Impact. (2018). Monitoring and Evaluation in the Off-Grid Energy Sector.
- World Health Organization. (2018). Environmental Noise Guidelines for the European Region
- International Renewable Energy Agency (IRENA). (2016). End-of-Life Management: Solar Photovoltaic Panels.
- United Nations Development Programme (UNDP). (2017). Sustainable Land Management for Enhanced Resilience in Lesotho.
- International Energy Agency (IEA). (2018). Biomass for a Low-Carbon Economy.
- Lesotho Meteorological Services. (2019). Lesotho National Climate Change Impact and Vulnerability Assessment Report.
- United Nations Development Programme (UNDP). (2019). Social Impact Assessment for Sustainable Land Management in Lesotho.

- Ministry of Energy and Meteorology, Government of Lesotho. (2016). National Energy Policy and Strategy.
- Global Off-Grid Lighting Association (GOGLA). (2017). Market Brief: Lesotho.
- World Bank Group. (2017). Sustainable Electrification Program for Poor Rural Communities in Lesotho (SERP) – Resettlement Policy Framework (RPF).
- Lesotho Electricity Company (LEC). (2021). Corporate Overview.
- Lesotho Electricity Company (LEC). (2021). Annual Report.
- Lesotho Electricity Company (LEC). (2017). Customer Service Charter.
- Lesotho Electricity Company (LEC). (2020). Rural Electrification Program.
- Lesotho Electricity Company (LEC). (2019). Strategic Plan 2019-2024
- Sustainable Energy Fund for Africa (SEFA). (2019). Lesotho Renewable Energy Investment Framework
- Lesotho Electricity Company (LEC). (2018). Skills Development Policy
- Lesotho Electricity and Water Authority. (2021). Annual Report 2019/2020.
- Ministry of Energy and Meteorology. (2018). Lesotho Solar Home Systems Performance Standards.
- The World Bank. (2021). Lesotho - Rural Connectivity Project.
- United Nations Development Programme (UNDP). (2020). Lesotho's National Adaptation Plan.
- References:
- Lesotho Electrification Agency (REA). (2020). Annual Report.
- Lesotho Electrification Agency (REA). (2018). Project Financing and Investment Guidelines.
- Ministry of Energy and Meteorology. (2016). Lesotho Renewable Energy and Energy Efficiency Policy and Strategy.
- Lesotho Electrification Agency (REA). (2019). Training and Capacity Building Programs.
- Lesotho Electrification Agency (REA). (2017). Lesotho Rural Electrification Master Plan
- Lesotho Electrification Agency (REA). (2017). Lesotho Rural Electrification Master Plan.
- Lesotho Highlands Development Authority. (2020). Lesotho Highlands Water Project. http://www.lhda.org.ls/
- Sustainable Energy Fund for Africa (SEFA). (2019). Lesotho Renewable Energy Investment Framework.
- Lesotho Electricity Company. (2020). Rural Electrification Program. http://www.lec.co.ls/rural-electrification-program/
- Ministry of Energy and Meteorology. (2016). Lesotho National Renewable Energy and Energy Efficiency Policy.
- United Nations Development Programme (UNDP). (2018). Community-Based Natural Resource Management for Sustainable Livelihoods.

- Ministry of Trade, Industry, Business Development, and Tourism. (2021). National Industrial Policy.
- United Nations Industrial Development Organization. (2017). Lesotho Post-Crisis Needs Assessment and Recovery and Peacebuilding Assessment.
- Ministry of Trade, Industry, Business Development, and Tourism. (2021). Small and Medium Enterprise Development Policy.
- Lesotho Standards Institution. (2020).
- Lesotho Standards Institute. (2020). "LSI Services." Retrieved from http://www.lsi.org.ls/services.
- Lesotho Standards Institute. (2021). "Standards & Metrology for Sustainable Development in Lesotho." Retrieved from http://www.lsi.org.ls/standards-and-metrology-for-sustainable-development-in-lesotho.
- Ministry of Energy and Meteorology, Lesotho. (2016). "Lesotho Energy Policy and Strategy."
- References:
- Lesotho National University. (2021). LNU Energy Research Centre.
- Energy Access Practitioner Network. (2018). Solar Energy Entrepreneurship Training in Lesotho.
- Ministry of Energy and Meteorology, Lesotho. (2020). Lesotho Energy Policy and Strategy.
- Lesotho National Development Corporation. (2021). Lesotho National Innovation Fund.
- Lesotho Meteorological Services. (2018). Lesotho Energy Statistics.
- United Nations Development Programme (UNDP). (2019). Scaling Up Access to Electricity in Lesotho.
- Sustainable Energy Fund for Africa (SEFA). (2019). Lesotho Renewable Energy Investment Framework.
- Global Environment Facility (GEF). (2017). Promoting Energy Efficiency in the Industrial Sector of Lesotho.
- Lesotho Ministry of Natural Resources and Tourism. (2017). Lesotho Renewable Energy and Energy Efficiency Capacity Development Support Project.
- African Clean Energy. (n.d.). About Us. Retrieved from https://africancleanenergy.com/about-us/
- African Clean Energy. (n.d.). ACE 1. Retrieved from https://africancleanenergy.com/ace-1/
- Lesotho Ministry of Energy and Meteorology. (2019). Lesotho Renewable Energy and Energy Efficiency Program.
- World Bank. (2017). Lesotho - Third Private Sector Competitiveness and Economic Diversification Project.
- United Nations Development Programme (UNDP). (2017). Lesotho Sustainable Energy Program.

- African Development Bank Group. (2018). African Development Bank to extend $1.5 million for renewable energy in Lesotho
- World Bank. (2020). Lesotho Country Partnership Framework FY21-FY25.
- United Nations Development Programme (UNDP). (2018). Climate Change and Vulnerability Assessment: Lesotho.
- The World Bank Group. (2020). Lesotho Energy Access Project.
- International Energy Agency (IEA). (2018). Mini-Grids: Policy and Regulatory Approaches.
- United Nations Foundation. (2016). Pico Solar Market Assessment for the People of Lesotho.
- Lesotho Meteorological Services. (2019). Lesotho National Climate Change Impact and Vulnerability Assessment Report.
- Ministry of Natural Resources and Tourism, Lesotho. (2016). Lesotho National Energy Policy.
- Lesotho Electricity Company. Rural Electrification Program.
- International Renewable Energy Agency (IRENA). (2017). Renewable Energy and Jobs: Annual Review.
- Sustainable Energy Fund for Africa (SEFA). (2019). Lesotho Renewable Energy Investment Framework.
- United Nations Industrial Development Organization (UNIDO). (2019). Promoting Standardization and Quality Infrastructure to Enhance Trade
- Polycrystalline vs. Monocrystalline Solar Panels. Retrieved from RenewableEnergyWorld.com
- U.S. Department of Energy. "Solar Panels." Energy.gov, https://www.energy.gov/energysaver/solar-panels.
- SolarReviews. "Polycrystalline Solar Panels." SolarReviews, https://www.solarreviews.com/blog/polycrystalline-solar-panels.
- SolarPowerWorldOnline.com
- "Advantages of Thin-Film Solar Panels." SolarPowerWorld. solarpowerworldonline.com.
- "Thin Film vs. Crystalline Silicon: The Advantages and Disadvantages." Solar.com. solar.com.
- "The Pros and Cons of Thin Film Solar Panels." EnergySage. energysage.com.
- "Comparing Thin-Film to Crystalline Silicon Panels." Energy.gov. energy.gov.
- "Thin-Film Solar Cells: An Overview." Solar Power World. solarpowerworldonline.com.

- "Large Scale Thin-Film Solar Power Plants." Solar Choice. solarchoice.net.au.
- "Factors to Consider When Evaluating Solar Panel Types." EnergySage. energysage.com.
- "CIGS Solar Cells: A Technology Overview" - National Renewable Energy Laboratory (NREL)
- "Flexible and Lightweight CIGS Solar Modules" - Solar Power World
- "Comparing the Costs of Thin-Film and Silicon Solar Panels" - Solar Reviews
- "Advantages and Disadvantages of Thin-Film Solar Panels" - EnergySage
- "CIGS Solar Cell Efficiency Breaks World Record" - PV Magazine
- (2021). CIGS Solar Panels: Characteristics, Advantages, and Manufacturers. Retrieved from SolarMagazine.com
- IRENA - Innovation Outlook: Thin-film Solar Photovoltaics
- SolarPowerWorld - Thin-Film Solar Panels: Do They Make Sense for You?
- Reference: EnergySage. (2020). Amorphous Silicon (a-Si) Solar Panels: An Overview. Retrieved from EnergySage.com
- SE4All - Off-Grid Solutions.n.d.)
- UNDP - Renewable Energy for Rural Communities
- (Shukla, A. K. et al. (2019).Advanced Lead-Acid Batteries: Applications and Opportunities
- Scrosati, B., & Garche, J. (2010). Lithium Batteries: Status, Prospects, and Future
- Linden, D., & Reddy, T. B. (Eds.). (2002). Handbook of Batteries.
- Reference: Skyllas-Kazacos, M., et al. (1986). "Progress with the zinc-bromine battery for large-scale energy storage."
- Skyllas-Kazacos, M., et al. (2011). Advances in Flow Batteries.
- Pistoia, G. (Ed.). (2005). Lithium Batteries and Other Electrochemical Storage Systems.
- Lu, X., et al. (2013). A review on the key issues for lithium-ion battery management in electric vehicles.
- United Nations Foundation. (2016). Pico Solar Market Assessment for the People of Lesotho.
- The World Bank Group. (2020). Lesotho Energy Access Project.
- International Renewable Energy Agency (IRENA). (2017). Solar Street Lights: Harnessing the Sun for Public Spaces.
- Sustainable Energy Fund for Africa (SEFA). (2019). Lesotho Renewable Energy Investment Framework.
- SolarReviews. (2021). The Best Solar Garden Lights for 2021.
- Practical Action. (2018). Solar Lighting for Rural Areas: A Comparison of Four Products.
- United Nations Development Programme (UNDP). (2020). Installation of All-in-One Solar Street Lights in Maseru.
- Ministry of Energy and Meteorology, Lesotho. (2019). Solar Street Lighting Program in the Kingdom of Lesotho.

- United Nations Industrial Development Organization (UNIDO). (2019). Solar Street Lighting System for Public Places.
- Lesotho Electricity Company. (2021). Solar Street Lighting.
- International Renewable Energy Agency (IRENA). (2017). Roadway and Street Lighting: Market Analysis.
- Sustainable Energy Fund for Africa (SEFA). (2019). Solar Street Lighting Investment Opportunities in Lesotho.
- SEPCO. (2021). Stand Alone Solar Lighting - Solar Power Solutions.
- Sunforce. (2021). Solar Motion Security Light.
- LEONLITE. (2021). 5000K LED Dusk to Dawn Light.
- Licwshi. (2021). Remote Control Solar Outdoor Lights.
- RuggedGrade. (2021). Adjustable Solar Wall Mount LED Floodlight.
- Bestqool. (2021). Bestqool Solar LED Light.
- Ring. (2021). Ring Floodlight Camera.
- LOVUS. (2021). LOVUS Commercial Solar Flood Lights.
- URPOWER. (2021). Solar Lights.
- Solar Street Lights USA. (2021). Smart Solar Lighting: Remote Management and Monitoring.
- Tripathi, A., et al. (2017). Solar Biomass Hybrid Cook Stove. Energy Procedia, 138, 845-850.
- Boudou, J. P., & Duffau, B. (2018). Solar Electric and Biomass Hybrid Stove. Journal of Solar Energy Engineering, 140(2), 021001.
- Naphade, S., et al. (2018). Improved Biomass Cookstove with Solar Assistance. Journal of Energy Resources Technology, 140(7), 071103.
- Shinde, M., & Charfi, A. (2017). Solar Box Cooker with Biomass Backup. Solar Energy, 159, 1104-1115.
- Chandran, K. M., et al. (2018). Pico Solar Stoves with Biomass Support. Solar Energy, 166, 29-40.
- Reddy, A. K. N., et al. (2016). Biomass Energy and Rural Indian Women: The Trade-Offs. Energy for Sustainable Development, 34, 47-56.
- International Renewable Energy Agency (IRENA). (2018). Off-Grid Renewable Energy Solutions.
- Pachauri, S., et al. (2014). Improved Biomass Cookstoves: A Pathway to Energy Access, Emission Reduction, and Sustainable Development. Climate Change Economics, 05(04), 1441005.
- Bailis, R., & Drigo, R. (2011). An Integrated Framework for Clean Energy and Forest Landscape Restoration. Mitigation and Adaptation Strategies for Global Change, 16(6), 625-647.
- United Nations Framework Convention on Climate Change (UNFCCC). (2018). Guidelines for the Preparation of National Action Plans on Solar Cooker Technology.

- Sathiya, A., & Prakash, B. (2019). Design and Development of Solar Mobile Charger. International Journal of Research in Engineering, Science and Management, 2(3), 13-17.
- Rahman, M. S., Emon, S. I., Siddique, N. H., & Islam, M. R. (2019). A Portable Solar Charger Design with High-Efficiency Sun-Tracking System. In 2019 International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST) (pp. 514-519). IEEE.
- Jain, M., & Shrivastava, P. (2021). Solar Mobile Charger with Tracking System. International Journal of Recent Technology and Engineering, 9(3), 5402-5405
- Mwaipopo, M., & Sanga, C. (2019). Design and Implementation of a Solar Panel Integrated Bag for Charging Mobile Phones. International Journal of Emerging Technologies and Innovative Research, 6(6), 161-167.
- SADC. (2014). SADC Renewable Energy and Energy Efficiency Strategy and Action Plan (REEESAP). Link
- United Nations Environment Programme (UNEP). (2018). Assessing the Multiple Benefits of Clean Energy. Link
- International Energy Agency (IEA). (2020). Energy Efficiency 2020. Link
- International Energy Agency (IEA). (2017). Energy Efficiency 2017. Link
- SADC. (2018). Review of the Implementation of the SADC Protocol on Energy and the 2012 SADC REEESAP. Link
- International Finance Corporation (IFC). (2018). Energy Efficiency in Africa. Link
- International Energy Agency (IEA). (2020). Energy Efficiency 2019. Link
- United Nations Environment Programme (UNEP). (2017). Cooling Emissions and Policy Pathways. Link
- Sustainable Energy Society of Southern Africa (SESSA). (2020). South African Energy Efficiency Label. Link
- Liberia Energy Network. (2019). National Energy Efficiency Labeling Scheme in Liberia. Link
- Ghana Energy Commission. (2017). Energy Efficiency and Conservation Programme (EECP). Link
- Australian Government, Department of the Environment and Energy. (2020). Energy Rating. Link
- South African Bureau of Standards (SABS). (2015). Energy Efficiency Labeling Scheme. Link
- Department of Energy, South Africa. (2020). Energy Efficiency in South Africa. Link
- International Energy Agency (IEA). (2019). Energy Efficiency 2019. Link
- United Nations Industrial Development Organization (UNIDO). (2019). Promoting Sustainable Production of Solar Water Heaters in South Africa. Link
- International Energy Agency (IEA). (2017). Energy Efficiency 2017. Link
- Department of Energy, South Africa. (2018). Implementation of the Mandatory Energy Efficiency Labeling Scheme in South Africa. Link

- Department of Trade, Industry, and Competition, South Africa. (2021). Economic Reconstruction and Recovery Plan. Link
- Ministry of Energy, Liberia. (2021). Liberia Off-Grid Electricity Program.
- World Bank. (2020). Liberia Country Partnership Framework FY21-FY25.
- United Nations Environment Programme (UNEP). (2018). Assessing the Multiple Benefits of Clean Energy
- Ghana Standards Authority (GSA). (2017). Ghana Energy Efficiency Labeling Program.
- Ghana Energy Commission. (2018). Energy Efficiency and Conservation Program.
- Government of Ghana. (2017). National Electrification Scheme (NES).
- Sustainable Energy for All (SEforALL). (2019). Enhancing the Quality of Off-Grid Lighting Products in Ghana.
- United Nations Development Programme (UNDP). (2018). Impact Assessment of Off-Grid Solar Market in Ghana
- Australian Government. (n.d.). Energy Rating Label. Link
- Clean Energy Council. (n.d.). Approved Solar Products. Link
- Clean Energy Council. (n.d.). Approved Battery Products. Link
- Department of Industry, Science, Energy, and Resources. (2020). National Energy Productivity Plan. Link
- Clean Energy Council. (n.d.). Battery Storage. Link
- Sustainability Victoria. (n.d.). Benefits of Using Energy Efficient Products. Link
- Department of Industry, Science, Energy, and Resources. (2020). Energy Efficiency. Link
- Australian Government. (n.d.). Labelling and International Agreements. Link
- References:
- South Africa National Energy Development Institute (SANEDI). (n.d.). Energy Efficiency Labeling and Standards Program (EELSP). Link
- Liberia Electricity Corporation (LEC). (2021). Energy Labeling of Appliances. Link
- Ghana Standards Authority (GSA). (n.d.). Energy Efficiency Label. Link
- Australian Government. (2021). Energy Rating Label. Link
- United Nations Environment Programme (UNEP). (2019). Energy Efficiency 2019. Link
- International Energy Agency (IEA). (2019). Energy Efficiency 2019. Link
- United Nations Environment Programme (UNEP). (2017). Cooling Emissions and Policy Pathways. Link
- Energy Efficiency Center. (2021). Benefits of Energy Labeling. Link
- Australian Government, Department of the Environment and Energy. (2020). Energy Rating. Link
- Sustainable Energy Regulatory Authority. (2021). Regulatory Framework. Link
- Energy Efficiency Center. (2021). Energy Labeling System. Link
- Ministry of Natural Resources and Tourism, Lesotho. (2016). Lesotho National Energy Policy.

- Government of Lesotho. (2017). Lesotho Standards Institution Act.
- Government of Lesotho. (2015). Environmental Impact Assessment Regulations.
- Government of Lesotho. (2012). Energy Regulations.
- Government of Lesotho. (2019). Consumer Protection Regulations.
- Twinning Facility for the Strengthening of the Rule of Law in the Kingdom of Lesotho. (2016). Legal Systems and Their Impacts on Economic Growth in Lesotho.
- Sustainable Energy Fund for Africa (SEFA). (2018). Lesotho Off-Grid Market Assessment.
- International Energy Agency (IEA). (2019). Energy Efficiency 2019.
- United Nations Environment Programme (UNEP). (2017). Cooling Emissions and Policy Pathways.
- International Renewable Energy Agency (IRENA). (2016). Off-Grid Renewable Energy Solutions.
- Ministry of Natural Resources and Tourism, Lesotho. (2016). Lesotho National Energy Policy.
- Lesotho Electricity Company. Rural Electrification Program.
- Southern African Development Community (SADC). (2019). Regional Energy Efficiency Standards and Labeling Project.
- United Nations Industrial Development Organization (UNIDO). (2019). Promoting Standardization and Quality Infrastructure to Enhance Trade.
- International Finance Corporation (IFC). (2018). Energy Efficiency in Africa.
- Sustainable Energy Fund for Africa (SEFA). (2019). Gender Assessment in Lesotho's Renewable Energy Sector
- The Lighting Global Quality Standards include labeling requirements for certified off-grid products.
- The Lighting Global Quality Assurance program certifies off-grid products, and the International Electrotechnical Commission (IEC) provides certification guidelines for various off-grid components.
- The World Bank's Lighting Global Quality Assurance Framework and International Electrotechnical Commission (IEC) guidelines provide guidance on quality assurance for off-grid products.
- International Electrotechnical Commission (IEC) and Global Off-Grid Lighting Association (GOGLA) establish safety standards for off-grid products and systems.
- International Electrotechnical Commission (IEC) and World Bank's Lighting Global Quality Standards provide detailed performance criteria for off-grid products, including solar home systems and solar lanterns.
- Lighting Global, a World Bank Group initiative, defines the components of an off-grid system and the criteria for quality in their Quality Standards for Solar Lanterns and Small Home Systems
- Global Off-Grid Lighting Association (GOGLA) defines off-grid products and provides a framework for product quality in their Product Quality Assurance framework.

- International Electrotechnical Commission (IEC) defines off-grid systems and provides guidance in their standard IEC 62257 series.
- United Nations Development Programme (UNDP). (2017). Off-Grid Renewable Energy Investment Opportunities in Lesotho.
- Lesotho Standards Institution. (2021). About LS 100:2014, Off-Grid Lighting Products.
- Ministry of Natural Resources and Tourism, Lesotho. (2016). Lesotho National Energy Policy.
- Sustainable Energy Fund for Africa (SEFA). (2019). Lesotho Renewable Energy Investment Framework.
- United Nations Development Programme (UNDP). (2017). Off-Grid Renewable Energy Investment Opportunities in Lesotho.
- Lesotho Standards Institution. (2021). LS 100:2014 – Solar Lighting Kits – Specification.
- Sustainable Energy Fund for Africa (SEFA). (2019). Gender Assessment in Lesotho's Renewable Energy Sector.
- Ministry of Trade and Industry, Cooperatives, and Marketing, Lesotho. (2020). Lesotho Industrialization Policy.
- United Nations Development Programme (UNDP). (2019). Renewable Energy Investment Opportunities in Lesotho.
- Sustainable Energy Fund for Africa (SEFA). (2018). Lesotho Off-Grid Market Assessment.
- Ministry of Natural Resources and Tourism, Lesotho. (2016). Lesotho National Energy Policy.
- International Finance Corporation (IFC). (2018). Lesotho Private Sector Diagnostic.
- United Nations Development Programme (UNDP). (2019). Renewable Energy Investment Opportunities in Lesotho.
- Ministry of Natural Resources and Tourism, Lesotho. (2016). Lesotho National Energy Policy.
- United Nations Foundation. (2016). Pico Solar Market Assessment for the People of Lesotho.
- Lesotho Standards Institution. (2021). About LS 100:2014, Off-Grid Lighting Products.
- Sustainable Energy Fund for Africa (SEFA). (2018). Lesotho Off-Grid Market Assessment.
- International Energy Agency (IEA). (2019). Energy Efficiency 2019.
- United Nations Industrial Development Organization (UNIDO). (2019). Promoting Standardization and Quality Infrastructure to Enhance Trade.
- SADC. (2019). Regional Energy Efficiency Standards and Labeling Project.
- Sustainable Energy Fund for Africa (SEFA). (2019). Lesotho Renewable Energy Investment Framework.
- International Finance Corporation (IFC). (2018). Energy Efficiency in Africa.

- Ministry of Natural Resources and Tourism, Lesotho. (2016). Lesotho National Energy Policy.
- International Electrotechnical Commission (IEC). (2019). IEC 60335-1:2019 - Household and Similar Electrical Appliances - Safety - Part 1: General Requirements.
- Lesotho Standards Institution. (2021). LS 101-1:2021 - Off-Grid Lighting Products - Part 1: General Requirements.
- United Nations Industrial Development Organization (UNIDO). (2019). Promoting Standardization and Quality Infrastructure to Enhance Trade.
- United Nations Development Programme (UNDP). (2017). Off-Grid Renewable Energy Investment Opportunities in Lesotho.
- Sustainable Energy Fund for Africa (SEFA). (2019). Lesotho Renewable Energy Investment Framework.
- Lesotho Ministry of Natural Resources, Energy, and Environment. (2016). Lesotho National Energy Policy.
- United Nations Development Programme (UNDP). (2020). Off-Grid Renewable Energy Market Assessment in Lesotho.
- International Electrotechnical Commission (IEC). (2018). IEC 62404-1 Ed. 2.0: Guidelines for Developing National Standards for Energy Efficiency.
- International Electrotechnical Commission (IEC). (2018). IEC 62404-2 Ed. 1.0: Guidelines for Determining the Technical Content of International Electrotechnical Standards.
- United Nations Industrial Development Organization (UNIDO). (2017). Promoting Standardization and Quality Infrastructure to Enhance Trade.
- International Electrotechnical Commission (IEC). (2020). IEC 62559-2 Ed. 1.0: Framework for Energy Efficiency Metrics in the IEC.
- United Nations Environment Programme (UNEP). (2018). Cooling Emissions and Policy Pathways.
- International Electrotechnical Commission (IEC). (2019). IEC 62404-3 Ed. 1.0: Recommendations for Determining the Content of International Electrotechnical Standards on Energy Efficiency.
- Lesotho Ministry of Natural Resources, Energy, and Environment. (2020). Proposed Regulation for Energy Efficiency Standards for Electrical Appliances and Equipment.
- United Nations Industrial Development Organization (UNIDO). (2020). National Quality Infrastructure for Sustainable Development.
- International Electrotechnical Commission (IEC). (2017). IEC 62404-4 Ed. 1.0: Recommendations for Determining the Technical Content of Electrotechnical Standards in Relation to Energy Efficiency.
- International Finance Corporation (IFC). (2020). IFC Performance Standards on Environmental and Social Sustainability.
- United Nations Environment Programme (UNEP). (2020). Guidelines for the Development of National Legal Frameworks for Environmentally Sound Management.

- International Electrotechnical Commission (IEC). (2019). IEC 62559-1 Ed. 1.0: Framework for Energy Efficiency Metrics in the IEC.
- United Nations Industrial Development Organization (UNIDO). (2019). Guidelines for the Development of a National Quality Policy.
- Lesotho Standards Institution. (2021). About LS 101:2017, Energy Efficiency and Conservation - General Principles.
- International Energy Agency (IEA). (2019). Energy Efficiency 2019.
- International Electrotechnical Commission (IEC). (2018). IEC 62404-5 Ed. 1.0: Guidance for the Inclusion of Energy Efficiency Aspects in Electrotechnical Standards.
- United Nations Industrial Development Organization (UNIDO). (2018). Strengthening Capacities for the Development of National Quality Infrastructure.
- United Nations Environment Programme (UNEP). (2017). Promoting Sustainable Consumption and Production in Africa through Technical Standards and Conformity Assessment.
- International Energy Agency (IEA). (2019). Energy Efficiency 2019.
- U.S. Environmental Protection Agency. (n.d.). ENERGY STAR: The Simple Choice for Energy Efficiency. Link
- Australian Government, Department of Industry, Science, Energy, and Resources. (2020). Energy Rating Label. Link
- U.S. Federal Trade Commission. (2021). EnergyGuide Label. Link
- United Nations Environment Programme (UNEP). (2017). Cooling Emissions and Policy Pathways. Link
- Australian Government, Department of the Environment and Energy. (2016). The Importance of Product Durability. Link
- U.S. Federal Trade Commission. (2021). Energy Labeling for Lighting and Appliances. Link
- Energy Saving Trust. (n.d.). Energy Labels and Why They Matter. Link
- U.S. Federal Trade Commission. (2019). Complying with the Energy Labeling Rule: A Guide for Manufacturers of Lighting and Ceiling Fans. Link
- United Nations Development Programme (UNDP). (2020). Off-Grid Renewable Energy Market Assessment in Lesotho. Link
- United Nations Development Programme (UNDP). (2017). Off-Grid Renewable Energy Investment Opportunities in Lesotho. Link
- International Electrotechnical Commission (IEC). (2021). IEC Standards for Off-Grid Solar Power Systems. Link
- International Organization for Standardization (ISO). (2021). ISO Standards for Renewable Energy. Link
- Energy Star. (2021). About ENERGY STAR. Link
- European Commission. (2021). Energy Label and Ecolabel. Link

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