The Government of The Kingdom of Lesotho

Technology Needs Assessment for Climate Change Mitigation in the Energy sector, and Agriculture, Forestry and Other Land Use sector

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Ministry of Defence, National Security and Environment


TNA TECHNOLOGY NEEDS ASSESSMENT

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University of Cape Town

Technology Needs Assessment for Climate Change Mitigation in Energy sector, and Agriculture, Forestry and Other Land Use sector

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Foreword

Climate variability and change have become major threats to sustainable development in Lesotho. Over the last few decades, the country has experienced an increase in magnitude of climate-induced hazards such as droughts, floods, heavy snowfall and extreme temperatures. These adversities tremendously impact sustainable livelihoods, security and well-being of society and contribute to increased incidences of poverty and undue pressures on social services. In order to tackle such climate change threats in a systematic manner, the National Climate Change Policy 2017 – 2027 (NCCP) was formulated. The policy guides the integration and mainstreaming of climate change management in development planning and implementation by all stakeholders at local, district and national levels. The policy further creates an enabling framework for a pragmatic, coordinated and harmonised approach to climate change management.

Although Lesotho is an insignificant contributor to global greenhouse gas (GHG) emissions, it is among the countries that are and will continue to be severely impacted by climate change. The country has thus committed itself to developing, adopting and implementing policies and measures that will assist it to reduce its carbon footprint and increase its resilience to the adverse impacts of climate change. Lesotho is highly committed to transitioning towards a low-carbon future in line with the 2nd Five-Year National Strategic Development Plan (NSDP II), 2018/19 – 2022/23, the nationally determined contribution (NDC) 2017 commitments under the 2015 Paris Agreement and the NCCP.

Urgent climate action is imperative for Lesotho to achieve its development aspirations. However, this is hindered by slow technological mobilisation coupled with inadequate knowledge transfer and limited financial capacity, all of which exacerbate systemic failures in addressing key drivers of climate vulnerability and inaction. This Technology Needs Assessment (TNA) process is therefore fundamental in helping to bridge this gap and ascertain the technological needs for transformative climate adaptation and mitigation initiatives at the national and sub-national levels.

In this regard, the Lesotho's TNA has been developed through extensive stakeholder engagements with Government agencies, private sector, financial institutions, academia, project developers and local technology experts, ensuring gender inclusion at all stages.

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Acronyms and Abbreviations

AFOLU	Agriculture, Forestry, and Other Land Use
AR4	Fourth Assessment Report of the IPCC
BAU	Business as Usual
BoS	Bureau of Statistics
CH_4	Methane
CFLs	Compact Fluorescent Lamps
CO_2	Carbon dioxide
CO_2eq	CO_2-equivalent
DoAR	Department of Agricultural Research
DoC	Department of Crops
DoE	Department of Energy
DOE	Department of Environment
DOF	Department of Forestry
DoSWC	Department of Soil and Water Conservation
DWA	Department of Water Affairs
EF	Emission factor
EWG	Expert Working Group
FBUR	First Biennial Update Report
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Greenhouse Gas
GoL	Government of Lesotho
GWP	Global Warming Potential
H_2O	Water vapour
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
LASAP	Lesotho Adaptation of Small-Scale Agriculture Production
LDCs	Least Developed Countries
LED	Light-Emitting Diode
LEC	Lesotho Electricity Company
LHDA	Lesotho Highlands Development Authority
LMS	Lesotho Meteorological Services
LPG	Liquefied Petroleum Gas
LULUCF	Land-Use, Land-Use Change and Forestry
LVAC	Lesotho Vulnerability Assessment Committee
M	Maloti (local currency) pegged to the South African rand on a 1:1 basis
MACC	Marginal Abatement Cost Curve
MCA	Multi Criteria Analysis
MDGs	Millennium Development Goals
MFRSC	Ministry of Forestry, Range and Soil Conservation
MMS	Manure management system
MDNSE	Ministry of Defence, National Security and Environment
$MtCO_2eq$	Million tonnes of carbon dioxide equivalent
MWPT	Ministry of Works and Public Transport

N_2O	Nitrous oxide
NAMA	National Appropriate Mitigation Actions
NAPA	National Adaptation Programme of Action
NCCC	National Climate Change Committee
NCCP	National Climate Change Policy 2017 – 2027
NDC	Nationally Determined Contributions
NEP	National Energy Policy 2015 – 2025
NO_X	Nitrogen oxides (nitric oxide (NO) and nitrogen dioxide (NO_2))
NSDP	National Strategic Development Plan
PV	Photovoltaic
PPP	Public Private Partnership
RE	Renewable Energy
REU	Rural Electrification Unit
SDGs	Sustainable Development Goals
SEforALL	Sustainable Energy for All
SHS	Solar Home System
SNC	Second National Communication
TAs	Thematic Areas
TFS	Technology Factsheets
TNA	Technology Needs Assessment
TNC	Third National Communication
UNCBD	United Nations Convention on Bio-Diversity
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WASCO	Water and Sewerage Company
WG	Working Group

Glossary of Terms[1]

Greenhouse Gases	Gases within the Earth's atmosphere, principally water vapour, carbon dioxide, methane, nitrous oxide and ozone, the increasing concentrations of which are raising the Earth's average temperature and causing a range of other adverse climate and weather effects.
IPCC	Intergovernmental Panel on Climate Change, the principal international authority coordinating research and information dissemination on climate change.
Low Carbon	Technology, including transport, that emits minimal carbon dioxide into the atmosphere or, in the case of 'zero carbon', emits no carbon dioxide at all.
Mitigation	An anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks (IPCC, 2007a; glossary).
Multi Criteria Decision Analysis	A technique used to support decision making which enables evaluation of options on criteria, and makes trade-offs explicit. It is used for decisions with multiple stakeholders, multiple and conflicting objectives, and uncertainty.
REDD+	Reducing Emissions from Deforestation and Forest Degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries. REDD+ was officially defined at the 13th meeting of the UNFCCC Conference of Parties (COP 13) with the aim to reduce emissions from deforestation and forest degradation and increase removals (enhance forest carbon stocks) in developing countries.
Short-term Technologies	Technologies which have proven to be reliable and commercially available in a similar market environment.
Small-scale technologies	A technology which is applied at the household and/or community level (e.g., off-grid), which could be scaled up into a program.
Technologies for Mitigation and Adaptation	All technologies that can be applied in the process of minimizing greenhouse gas emissions and adapting to climatic variability and climate change, respectively.
Technology Needs and Needs Assessment	A set of country-driven activities that identify and determine the mitigation and adaptation technology priorities of Parties other than developed country Parties, and other developed Parties not included in Annex II, particularly developing country Parties. They involve different stakeholders in a consultative process, and identify the barriers to technology transfer and measures to address these barriers through sectoral analyses. These activities may address soft and hard technologies, such as mitigation and adaptation technologies, identify regulatory options and develop fiscal and financial incentives and capacity building.

[1] Adopted from the Technology Needs Assessment for Climate Change & Technologies for Climate Mitigation (Transport Sector) (UNEP, 2011).

Technology Transfer	The exchange of knowledge, hardware and associated software, money and goods among stakeholders, which leads to the spreading of technology for adaptation or mitigation. The term encompasses both diffusion of technologies and technological cooperation across and within countries.

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EXECUTIVE SUMMARY

This report presents the mitigation technology needs assessment and prioritisation processes along with the results for priority sectors for Lesotho.

A Technology Needs Assessment (TNA) is a set of activities that identify and analyse technology priorities for mitigation and adaptation to climate change of developing countries such as Lesotho. The TNA project has allowed Lesotho to identify climate technology pathways that assist in the implementation of the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC). The process is country-driven, requiring heavy stakeholder engagement and local capacity building. Thus, stakeholder engagement was the primary tool used during the project. The TNA activities involved stakeholders from key institutions (ministries, government agencies, local governments, academia, development partners, international organizations and projects, non-governmental organizations and private companies) in all stages of technology prioritization to ensure relevance of appraised technologies and to engage stakeholders that will be central to implementation of prioritized technologies.

The scope and depth of the Lesotho TNA is well aligned to national development objectives and allows national stakeholders to explore synergies with other national processes, striving towards the implementation of Nationally Determined Contributions (NDC). Lesotho is sensitive to climate change because of its geographic location, fragile ecosystems and because a large part of its economy and society are highly dependent on weather and the natural environment. In the last forty years, Lesotho's ecosystems have been noticeably altered by increased variability and changes in global climatic conditions. These changes have consequences that negatively affect the national economy and the livelihoods of Lesotho citizens.

The institutional setup for the TNA Project includes the TNA Coordinator, National TNA Team and National consultant/experts organized in workgroups. A National Steering Committee is envisaged as the top-most decision-making body of the TNA Project, comprising policy makers from relevant key ministries.

The first stage of the TNA process was to identify the sectors in Lesotho that would be the focus of the assessment. The sectors were selected according to both national development priorities and GHG mitigation potential. The top two sectors that contribute more than 93 % of the total emissions are Energy (with transportation subsumed under the sector) at 2 861 Gg CO_2e (50.5 %) closely followed by Agriculture, Forestry and Other Land Use (AFOLU) at 2 417 Gg CO_2e (42.7 %). These two sectors are in-line with the NDC priorities and were therefore the focus of the subsector selection process.

This TNA report identifies and prioritises mitigation technologies for the identified key sectors of Energy and AFOLU based on the country development needs and priorities. Sectors prioritized for GHG mitigation have high GHG emissions, large potential for implementing feasible mitigation options, high potential for applying low-carbon technologies and in compliance with national development goals.

With the above directions, stakeholder consultations were held to prioritize sectors for GHG mitigation based on the following criteria: economic, social and environmental benefits and GHG mitigation potential. After extended discussions, the criteria selected for prioritizing the Energy and AFOLU technology factsheets were based on three general properties, namely: (a) Anticipated Costs, (b)

Sustainable Development Benefits and (c) Local Context. For easing the process of calculating criteria weights, costs were broken down into Capital, Operation and Maintenance costs of the technology. Benefits were categorized into Economic incentives, Social implications and Environmental aspects of their deployment, as well as climatic attributes mirroring performance of the specific technologies. To keep this in line with the development priorities,

1. Economic Benefits were subcategorized into:
    a) Job Creation Opportunities,
    b) Ability to spur private investment,
    c) Balance of Payment (Foreign exchange Savings),
    d) Income generation, and
    e) Cost savings /efficiency to support other economic activities
2. Social Benefits were subcategorized into
    a) Health and Safety Improvement
    b) Increased Energy and Food Security, and
    c) Potential for gender equity,
3. Environmental Benefits were divided into:
    - CO_2 Reduction Potential, and
    - Positive Local Environmental Impact: Reduction in deforestation and other environmental pollution (water, air, hazardous waste), Protection of biodiversity and natural resources

In the Local Context, the key criteria were

- Market Potential, and
- Acceptability to Local Stakeholders.

Likert scales were used to evaluate Job Creation Opportunities, Economic Activities, Energy Security and Reduction in deforestation and other environmental pollution (water, air, hazardous waste).

The Multi Criteria Analysis (MCA) was used for assessing current technology needs for climate change mitigation. First, this method identifies and categorized technologies/options based on their mitigation potential. Next, technologies are given points and weighted. Finally, decisions are made on which technologies are of high priority.

The crucial element of MCA is the Technology Fact Sheet (TFS) that are filled out for each technology. TFS serves as the main source of information that is required for generating expert and stakeholder opinion on how to "vote" on specific standards for specific technologies. The MCA is an 8-step process involving: (1) providing decision context on the sectors; (2) identifying technologies; (3) identifying objectives and criteria; (4) scoring; (5) weighting of criteria; (6) combining scores and weights; (7) examination and validation of results; and (8) sensitivity analysis based on the social, economic and environmental aspects needed for the successful implementation of the technology. To validate the results, the outcomes of the MCA underwent a sensitivity analysis repeating steps 4 to 7 of the MCA. Based on the MCA method, high priority GHG mitigation technologies were identified in both the Energy and AFOLU sectors.

Energy Sector

The Energy technologies ranking indicate preference for marketing and subsidy of ***Clean and Efficient Cooking Technologies (Improved Cookstoves)***, followed closely by promotion of ***Energy-Efficient Lighting and Appliances*** and ***Energy Efficiency and Conservation in Buildings (Residential,***

Commercial, Institutional and Industries). While the ranking is countrywide, the actual technology selection would be location based since certain areas may provide greater advantages to particular technologies.

Beyond simple ranking and numbers, it is important to note that this set of technologies broadly aligns with Lesotho's development priorities and have the greatest potential to contribute to the primary challenges facing the Energy sector in the country. It is also interesting to note that solar PV technology is not rated among the top three, despite the technology being recommended in most of the strategic energy and climate change mitigation documents. The stakeholders agreed that although **Solar PV (On-grid and off-grid)** are in the highest priority in Lesotho, they are already the focus of Donor and Government initiatives.

Agriculture, Forestry, and Other Land Use (AFOLU) Sector

All the prioritized mitigation technologies reviewed in this report are in harmony with the medium and long-term strategy of the GoL to develop, adopt and implement policies and measures/actions to reduce national carbon footprint, transition of development pathway from a fossil-based economy to cleaner, renewable energy use, and increase the country's resilience to the adverse effects of climate change. At the same time, the implementation of these technologies will contribute to the over-arching goal of the 2nd National Strategic Development Plan (NSDP II), which integrates medium-term economic development, poverty reduction, and longer-term sustainable development.

The three technologies that are prioritized by the stakeholders are; ***(i) Small-scale biogas and homestead vegetable production in a mixed (crop and livestock) agricultural system, (ii) Carbon sequestration through agro-forestry systems and, (iii) Promotion of conservation agriculture (minimum tillage, mulching, retaining of crop residues)***. Other important benefits that are incorporated in these technologies include advancement of renewable energy initiatives, prevention of land degradation and improvement of food security as well as natural environment and biodiversity.

CHAPTER 1: INTRODUCTION

1.1 About the TNA project

Technology Needs Assessments (TNAs) are a set of country-driven activities grounded in national sustainable development plans that identify and determine the mitigation and adaptation technology priorities of countries to climate change (Haselip et al., 2019). The TNAs need to be particularly relevant to the needs of developing countries. TNAs are central to the work of Parties to the United Nations Framework Convention on Climate Change (UNFCCC, article 4.5). They present a unique opportunity for countries to track evolving needs for new equipment, techniques, services, capacities and skills necessary to mitigate greenhouse gases (GHGs) emissions, enhance adaptation and reduce the vulnerability of sectors and livelihoods to climate change. The enhancement of technology development and its transfer, deployment, and dissemination is a key pillar of the international response to climate change.

The UNFCCC defines climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. Climate change is not just an environmental problem, but it is also a developmental issue. It has both direct positive and negative impacts on the socio-economic well-being of society. To ensure sustainable development, appropriate actions should be undertaken to address impacts of climate change through the selection, development and deployment of environmentally sound technologies.

The Paris Agreement takes a good note of the importance of developments of TNAs in addressing climate change challenges. In the 24th Conference of the Parties to the UNFCCC, the Parties completed drawing up of a technology framework that placed increased emphasis on TNAs and their role in promoting and facilitating enhanced actions on technology development and transfer (Haselip et al., 2019). The framework also gave TNAs a central role in the implementation of climate mitigation and adaptation technologies.

This project presents a fourth round of TNAs that cover 17 countries, including Lesotho. The project is funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme Copenhagen Climate Centre (UNEP-CCC). The technical support is provided by The University of Cape Town (UCT) as a Regional Centre for Anglophone countries in Africa. The Lesotho Meteorological Services (LMS) is responsible for the execution of the project in the country.

The overall goal of the TNA Project is to enable countries to identify technologies and prioritise them to address their context-specific needs for climate change mitigation or adaptation. The scope and depth of this TNA are well aligned to national development objectives and allow national stakeholders to explore synergies with other national processes, striving towards the implementation of Lesotho's Nationally Determined Contributions (NDC) and National Adaptation Plan (NAP).

The main steps of the TNAs project, which are guiding TNA activities in Lesotho are:

- **Step 1**: To identify and prioritize through a country-driven participatory process, technologies that can contribute to mitigation and adaptation for selected sector/subsectors, while meeting national sustainable development goals and priorities.
- **Step 2**: To identify, analyse and address barriers hindering the acquisition, deployment, and diffusion of prioritised technologies including enabling the environment for the same; and
- **Step 3**: Based on the inputs obtained from the two previous steps, develop Technology Action Plans (TAP) specifying activities and enabling frameworks to overcome the barriers and facilitate the transfer, adoption and diffusion of selected technologies. This step will include the development of specific project ideas for each prioritized sector.

This report focuses on step 1.

The first step in this TNA process is technology prioritization and includes:

- Identification and selection of the sectors with high GHG relevance;
- Review of national GHG inventory to identify the GHG emitting (sub) sectors, and analyse their interrelationships. Also, identify data gaps, and collect information on new technologies;
- Assessing of sectorial and development plans so there is the certainty of the future trends;
- Identifying the shortlist of prioritized (sub) sectors according to their maximum mitigation benefits and;
- Stakeholder consultation and use of multiple criteria analysis (MCA) (GHG mitigation and development priorities) for prioritizing technologies.

The TNA Project has a mitigation and an adaptation component, and both are being implemented simultaneously. This report focusses on the mitigation component only.

1.2 Existing national policies related to technological innovation, Climate Change Mitigation and development priorities

This section will include the National Policy Framework on Climate Change Mitigation in Lesotho, Development Priorities for Lesotho and rationale for selection of the sectors for technology prioritization. Since climate change is a global problem, national policies and strategies on climate change management must be in tandem with regional and international policies.

With respect to climate change, Lesotho's policies are geared towards low-carbon and climate-resilient development. Lesotho's topography and location influence its temperate climate with alpine characteristics. This makes the country more vulnerable to climate variability and long-term climate change (LMS, 2017). Lesotho is already experiencing the negative effects of climate change, including increased frequency of extreme events, inter alia droughts, increased rates of soil erosion and desertification, and reduced soil fertility (UNDP, 2015). The country is likely to become generally hotter and drier across projected future climates. Likewise, Lesotho will also continue to experience extreme events like droughts and floods and other climate-related hazards, in addition to continued rainfall variability and increasing temperatures. This will likely result in adverse environmental impacts particularly soil erosion, deforestation, recurrent droughts, desertification, land degradation, and the loss of biodiversity including wildlife. Key sectors such as agriculture and livestock, health, water resources, and tourism are increasingly vulnerable.

In the last forty years, Lesotho's ecosystems have been noticeably altered by increased variability and changes in global climatic conditions. Changes that have been observed include more frequent droughts, harsh winters, increased scarcity of water resources and greater biodiversity loss. These changes have negative impacts on the national economy and the livelihoods of Lesotho's citizens.

The UNFCCC sets out the overarching guidance for member countries towards the stabilization of anthropogenic GHG concentrations. Lesotho, as a Party to the Convention, has demonstrated its commitment to addressing climate change through policy and strategy interventions. Principal among them has been the development of the National Climate Change Policy (NCCP) 2017 - 2027 and National Climate Change Policy Implementation Strategy (CCPIS) 2017 - 2027.

An overview of the specific national policies for key sectors related to climate change mitigation is outlined below.

1.2.1. Overarching Policies and Strategies

2nd National Strategic Development Plan (NSDP II), 2018/19 – 2022/23 (Government of Lesotho, 2018)**:**
The Lesotho National Strategic Development Plan II (NSDP II) aims to transform Lesotho from a consumer-based economy to a producer and export-driven economy. It serves as the blueprint for all development efforts over five years, and implements the sustainable development goals (SDGs), the African Union Agenda 2063 Goals, and the Southern Africa's Development Community (SADC) Regional Indicative Strategic Development Plan (RISDP). It emphasizes private sector development and gives priority to pursuing people-centred development.

The NSDP II sets employment creation and inclusive growth as the overriding goal for combating poverty and inequality. The four Key Priority Areas (KPA) embedded in the NSDP II are:

- KPA I: Enhancing inclusive and sustainable economic growth and private sector job creation (all 17 SDGs),
- KPA II: Strengthening human capital (SDG 3, 4, 5, 10),
- KPA III: Building enabling infrastructure (SDG 6, 7, 9, 11) and
- KPA IV: Strengthening national governance and accountability systems (SDG 5, 16,17).

The cross-cutting themes are environment and climate change, gender, vulnerability and marginalised groups.

The NSDP II calls for increased clean energy production to attain self-sufficiency and export potential, expanded electricity access, and better, more efficient use of domestic energy resources. It proposes to change course in terms of energy supply for economic growth and rural electrification with GoL promoting renewable energy by harnessing energy from wind, solar and water. When it comes to clean energy and green technologies NSDP II specifies how GoL is to "promote appropriate technologies to reduce biomass and fuel consumption to maintain low carbon emissions, reduce pollution while preventing loss of biodiversity and ecosystems" and how "opportunities exist for both local and international companies in supplying renewable energy products or developing renewable power generation in Lesotho".

National Climate Change Policy (NCCP) 2017-2027 (Government of Lesotho, 2017a)

National Climate Change Policy (2017) aims, with regards to climate change mitigation, to promote green economy by adopting the concept of low carbon emission development and mobilizing of national and international financial resources for climate change mitigation and adaptation in a just manner. Under agriculture and food security sector, the policy adopts measures to promote water efficient technologies and low carbon emission and energy efficient technologies for production, collection, processing and storage. For the energy and water resources sectors, the NCCP encourages production and use of energy efficient technologies. The use of energy efficient technologies and electrical energy are also encouraged for use in industry, transport and physical infrastructure. Under the same sector, the policy also encourages the use of electrical vehicles. The tourism, and natural and cultural heritage sector encourages the use of renewable energy and energy-efficient technologies in tourist spots to highlight the concept of zero emission. The policy strategizes to receive and mobilize finance from bi/multilateral international financial mechanisms like REDD+, Green Climate Fund, Global Environment Facility, Adaptation Fund, Climate Investment Fund, Carbon Trade, etc.

The overarching objective of the policy is to ensure that all stakeholders address climate change impacts and their causes through the identification, mainstreaming and implementation of appropriate adaptation and mitigation measures while promoting sustainable development. The NCCP affirms GoL's commitment of fully addressing climate change issues to reduce the vulnerability of its people, ecosystems and socio-economic development to the effects of climate change through adaptation and mitigation, technology transfer and capacity building.

Notwithstanding the fact that Lesotho’s contribution to global GHG emissions is very small, its role as a responsible member of the global community in combating climate change has been highlighted by giving due importance to mitigation efforts in sectors such as energy, forestry, agriculture and livestock.

National Climate Change Policy Implementation Strategy (CCPIS), 2017 (Government of Lesotho, 2017b)**.**

This document is premised on the NCCP as it presents a 5-year Implementation Strategy of the NCCP. The overall objective of the CCPIS is to effect the implementation of the NCCP. It identifies action guidelines to build a climate-resilient society and promote green development pathways by mainstreaming and integrating climate change into key national socio-economic and environmental sectors. The strategic objectives of the CCPIS are three:

1. increase the resilience of Lesotho to the impacts of climate change by reducing climate risks to people, ecosystems and built environment while restoring and ensuring the rational use and the protection of natural resources;
2. identify and make use of opportunities to reduce GHG emissions that simultaneously contribute to the sustainable and affordable use of natural resources and access to finance and technology and reduce pollution and environmental degradation; and
3. strengthen the governance, institutional and human capacity enabling access to technological and financial resources for the implementation of the NCCP with equal participation of women, men, youth, vulnerable groups, civil society and the private sector.

Nationally Determined Contribution (NDC) (LMS, 2017)

Lesotho submitted its Nationally Determined Contribution (NDC) in 2017. The NDC outlines the country’s efforts to realize its development goals and increase its adaptive capacity to climate change. Lesotho is focused on implementing adaption mechanisms to improve and diversify livelihoods in view of current and future climate risks. The country is particularly vulnerable to the negative impacts from climate variability and climate change on water and food security, as well as to adverse conditions to health, human settlements, and the energy sectors. Climate change strategies are integrated in the country's development strategies in support of plans to eliminate poverty and eradicate inequality. The NDC for Lesotho is consistent with the country's overall goals of achieving medium-term economic development, poverty reduction, and longer-term sustainable development. Key areas of focus include the sustainability of the environment, water resources, sustainable land management, agriculture, energy, and health sectors (LMS, 2017) .

Furthermore, the NDC has identified a 10 % unconditional and 25 % conditional target reduction in GHG emissions compared to business as usual (BAU) by 2030. Lesotho has also set an ambitious, fair and responsible contribution to global efforts towards meeting the objective of the UNFCCC and the goal of limiting global average temperature rise to below 2.0 °C (LMS, 2017) aligning with the set emission targets under the Paris Agreement.

The NDC outlines the potential mitigation actions including CO_2 abatement from agriculture, land use, electricity, industry, and transportation.

Summary of the mitigation options under the NDC for selected sectors are as follows:

Energy

1. Energy efficiency and conservation (commercial/residential appliances, street lighting)
2. Low carbon clean, renewable energy especially for power generation.

Transport

1. Improving vehicle efficiency including road maintenance
2. Adoption of fuel economy and emission standards
3. Promotion of mass transit (buses)
4. Traffic management including vehicle demand reduction and promotion of non-motorized transport/walking.

Agriculture, Forestry and Other Land Use

1. Conservation agriculture
2. Promotion of irrigated agricultural production
3. Improvement of animal production
4. Promotion of innovation and attraction of private sector into the agriculture business.

Waste

1. Solid waste management (composting, waste to energy generation)
2. Wastewater treatment (industrial and domestic).

National Communications and GHG Inventories (LMS, 2000)**,** (LMS, 2013) and (LMS, 2018)
Lesotho has submitted its initial(LMS, 2000), second and third national GHG inventories under the UNFCCC as part of the country's National Communications. Lesotho's 1st National GHG inventory was compiled in 2000 for the year 1994, while the 2nd National GHG inventory was undertaken for the year 2000 and was published in 2013. Both inventories were based on the revised 1996 and 2006 Intergovernmental Panel on Climate Change (IPCC) guidelines. Lesotho's 3rd National GHG inventory was published in 2018, covering the years 2005 to 2010. The third inventory was based on the 2006 IPCC guidelines. Mitigation report for the TNC 2021 identified three options for the sectors to focus on mitigation. These include the Energy sector (electricity, energy efficiency and transport), AFOLU and Waste sectors.

1.2.2. Sectoral Policies and Strategies

National Energy Policy 2015 – 2025 (DoE, 2015)

The GoL is committed to addressing the challenges facing the Energy sector while managing the environment and climate change. The Government published its National Energy Policy (NEP) in 2015 to enhance the holistic utilisation of diverse energy resources to meet various needs. The policy articulates a national vision for the energy sector and sets clear development goals for the short, medium and long term in the Energy sector. The primary objective of the NEP is to ensure that energy shall be universally accessible and affordable in a sustainable manner to the business and the society, with a minimal negative impact on the environment. The NEP is further aligned with the Sustainable Energy for All (SEforALL) rapid assessment and gap analysis initiative of the United Nations.

The NEP emphasizes the importance of private sector participation in the sector and provides an environment conducive to such participation, be it in the form of direct investment, Public-Private Partnerships (PPPs), Independent Power Producers (IPPs) and other participation vehicles. The policy emphasizes sustainable and clean energy which is accessible to all. Energy efficiency is another priority area of this Policy, which also recognizes the importance of the security of energy supply systems. Mitigating environmental, social, safety and health impacts of energy production. Furthermore, energy utilization is a key part of the policy.

The NEP further aims to encourage non-governmental stakeholders' involvement in rural electrification and also aims to improve the effectiveness and sustainability of management models for off-grid rural electrification including Renewable Energy Service Companies (RESCO) being used to provide electricity to rural communities and areas not served by the grid extensions. It also seeks to promote research on new renewable energy technologies and the potential and cost-effectiveness of energy efficiency and renewable energy solutions.

Scaling-Up Renewable Energy Programme (SREP) Investment Plan for Lesotho, 2017
(Government of Lesotho, 2017c)

The SREP Investment Plan, which was developed through intensive consultation with key stakeholders, identifies renewable energy technologies and projects that can best contribute to Lesotho’s energy, economic and environmental development goals and outline the activities that must be carried out to realize the projects. Most importantly, the Investment Plan identifies the financing modalities under which the renewable energy (RE) projects can be realized and the ways in which SREP can help to leverage concessional and private sector financing.

National Soil and Water Conservation Policy

The purpose of the National Soils and Water Conservation Policy 2021 is to “facilitate a robust and comprehensive integrated approach to conserving Lesotho’s natural resources by engaging approaches that will effectively reduce soil erosion, strengthen catchment management systems that allow for enhanced supply of water to sustain both natural and socio-economic requirements and to facilitate the restoration of and sustained productivity of the natural resource base”.

The objectives of the policy are to do the following:

i. Protect and improve sustainable use of the soil
ii. Improve the management of watersheds resources to ensure regular supply and use of water resources.

iii. Implement integrated watershed management approach in order to sustain catchment ecologic integrity and promote social and economic development
iv. Facilitate engagement of the public and relevant institutions in soil and water activities within and outside catchment areas
v. Climate proofing of soil and water conservation strategies and interventions

The policy identifies the following 8 priority areas:

Priority Policy Area 1: Integrated watershed management for conservation and rehabilitation of degraded land.

Priority Policy Area 2: Development of climate smart soil and water conservation strategies and practices

Priority Policy Area 3: Climate smart and sustainable land management practices

Priority Policy Area 4: Climate smart agricultural water management

Priority Policy Area 5: Protection of land and water resources from negative impacts of land-based developments

Priority Policy Area 6: Climate smart soil and water conservation research

Priority Policy Area 7: Institutional coordination: public, private and NGO agencies in land and water management

Priority Policy Area 8: Gender equality, participation of youth and vulnerable groups including people with disabilities

National Forestry Policy

Forested land in Lesotho is small. This deprives industries and communities of several services offered by the forests and trees. Low survival rates of planted trees remain a challenge in afforestation programmes in the country. The goal of the National Forestry Policy of 2008 is to achieve sustainable management of forests in the country through promoting of community participation and building their capacity. The policy objectives are:

i. Sustainable forest management
ii. Social and economic dimensions of forestry development
iii. Enhancing equitable access and participation of stakeholders in forestry development

Development Priorities

Lesotho is a small, mountainous, and landlocked country, surrounded by its much larger neighbour, South Africa. It has a population of about 2.2 million, and nominal gross domestic product (GDP) per capita of US$1 091 in 2021. The World Bank classifies Lesotho as a lower-middle-income country. It is mostly highlands, with its lowest point being 1 400 meters above sea level. In recent years, Lesotho's economic performance has remained weak, exacerbated by the COVID-19 pandemic. Real GDP contracted by an average 0.7 % annually between 2017 and 2019 before it declined by 8.4 % in 2020.

The country is vulnerable due to its high dependence on rain-fed agriculture and reliance on regional, imported energy supplies. Much of the population depends on rain-fed subsistence agriculture for their livelihood. About 90 % of the population use traditional biomass for energy which is unsustainably supplied, causing both climate and environmental consequences.

The other challenge that the country faces is the decrease of forest cover due to deforestation and forest degradation. Human activities are the major cause of deforestation and forest degradation, such as extensive biomass harvesting for household fuel consumption and browsing of the re-growth of harvested woody plants by its huge population of communally grazed domestic livestock. Deforestation and forest degradation are exacerbated by population pressure, poverty and limitations in alternative livelihoods methods. The consequences for deforestation are costly for Lesotho as they include loss of biodiversity and reduction in ecosystem services.

The ND-GAIN Index (Chen, C *et al.*, 2015) ranks 181 countries using a score which calculates a country's vulnerability to climate change and other global challenges as well as their readiness to improve resilience. This Index aims to help businesses and the public sector better identify vulnerability and readiness in order to better prioritize investment for more efficient responses to global challenges. Due to a combination of political, geographic, and social factors, Lesotho is recognized as highly vulnerable to climate change impacts, ranked 127 out of 181 countries in the 2020 ND-GAIN Index. The more vulnerable a country is, the lower is its score, while the more ready a country is to improve its resilience the higher it will be its score. Figure 1 is a time-series plot of the ND-GAIN Index showing Lesotho's decline through 2018.

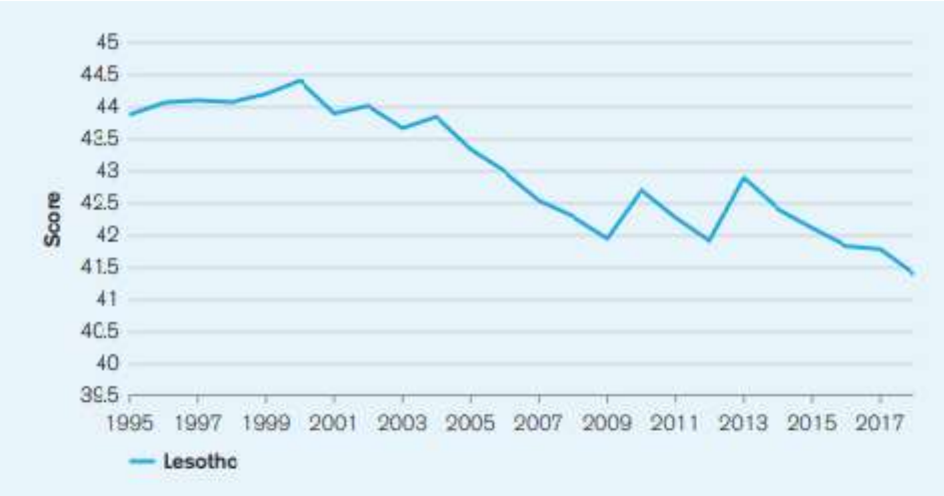


Figure 1: ND-GAIN Index for Lesotho

1.3 Sector selection

The baseline for the selection of the priority mitigation sectors was Lesotho's third national communications (TNC) to the UNFCCC, aligned with the NCCP, CCPIS, NSDP II, NDC, Lesotho's 4th national GHG inventory (2018) and SREP Investment Plan for Lesotho (2017). Lesotho has submitted its initial, second and third national GHG inventories under the UNFCCC as part of the country's national communications.

The preparation of the TNC was based on a participatory approach where relevant stakeholders were involved in data collection and validation of methodology, baseline and emission scenarios as well as proposed measures and action plans. The mitigation report for the TNC 2021 identified three options for sectors to focus on for mitigation. These include the Energy sector (electricity, energy efficiency and transport), AFOLU and Waste sectors. Attention to road transport remains an outstanding sector alongside the waste and agriculture sectors. The process for sector selection for the TNA project is described in section 1.3.2.

1.3.1. An Overview of the sectors, projected climate change and GHG emissions status and trends of the sectors

Figure 1 presents the results of the 4th GHG inventory, showing the GHG emissions for each year between 2011 and 2017. The Figure shows that Lesotho's emissions were at 5 617.26 Gg CO_2e in 2011, then declined slightly between 2011 and 2013 to 5 304.02 Gg CO_2e in 2013 before increasing again over the next four years to 5 660.44 Gg CO_2e in 2017.

The AFOLU sector was the largest contributor to the national GHG emissions in 2011 at 2 690.41 Gg CO_2e (47.9 %), trailed closely by the Energy sector at 2 583.61 Gg CO_2e (46 %). By 2017 the Energy sector, with transportation subsumed under the sector, had become the largest contributor to the inventory at 2 861.17 Gg CO_2e (50.5 %) followed by AFOLU at 2 416.97 Gg CO_2e (42.7 %). The Waste sector contributed between 6.02 % in 2011 and 6.54 % in 2017, while the Industrial Processes and Product Use (IPPU) sector was the least contributor throughout the period averaging 0.14 %.

	2011	2012	2013	2014	2015	2016	2017
Waste	338.06	343.78	349.08	354.38	359.70	365.01	370.39
AFOLU	2690.41	2515.92	2403.44	2350.74	2308.19	2294.52	2416.97
IPPU	5.18	6.03	6.03	7.23	8.76	10.24	11.91
Energy	2583.61	2513.68	2545.47	2713.05	2791.39	2869.92	2861.17

Figure 2: Lesotho's net GHG emissions for the period 2011 – 2017, by sector

Figure 3 shows the change in the percentage contribution of the sectors to the national GHG inventory over the period 2011 - 2017.

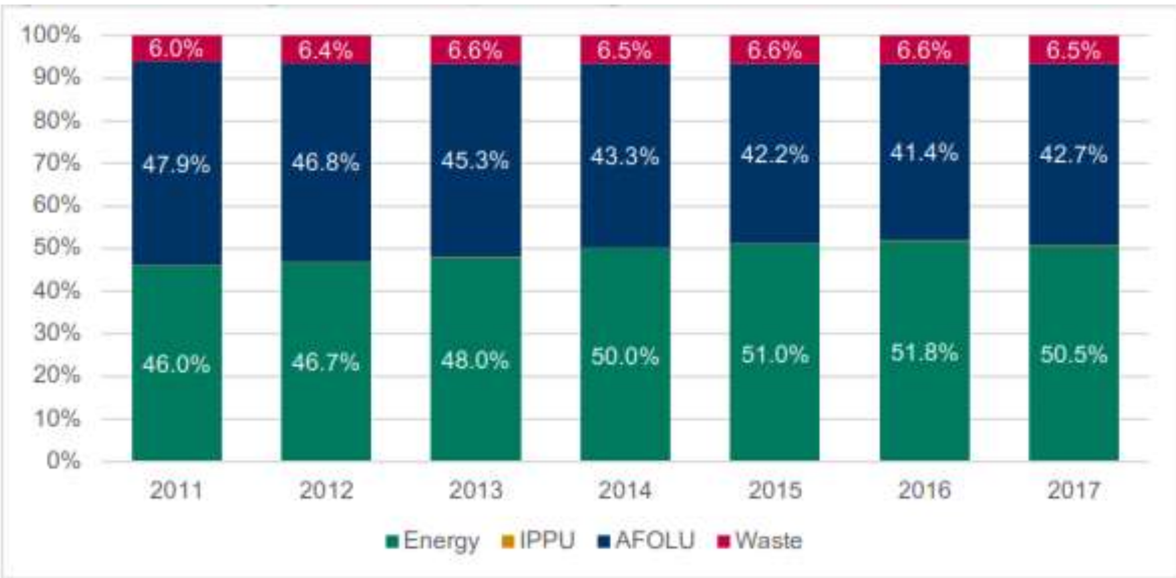


Figure 3: Changes in sector percentage contribution over time

In terms of GHG contribution, CO_2 has been the most prominent gas in Lesotho's GHG inventories, contributing between 60.6 % in 2011 and 62.4 % in 2017 (Figure 4). On average, methane (CH_4) and Nitrous oxide (N_2O) have contributed 24.2 % and 13.0 % respectively over the period 2011 – 2017.

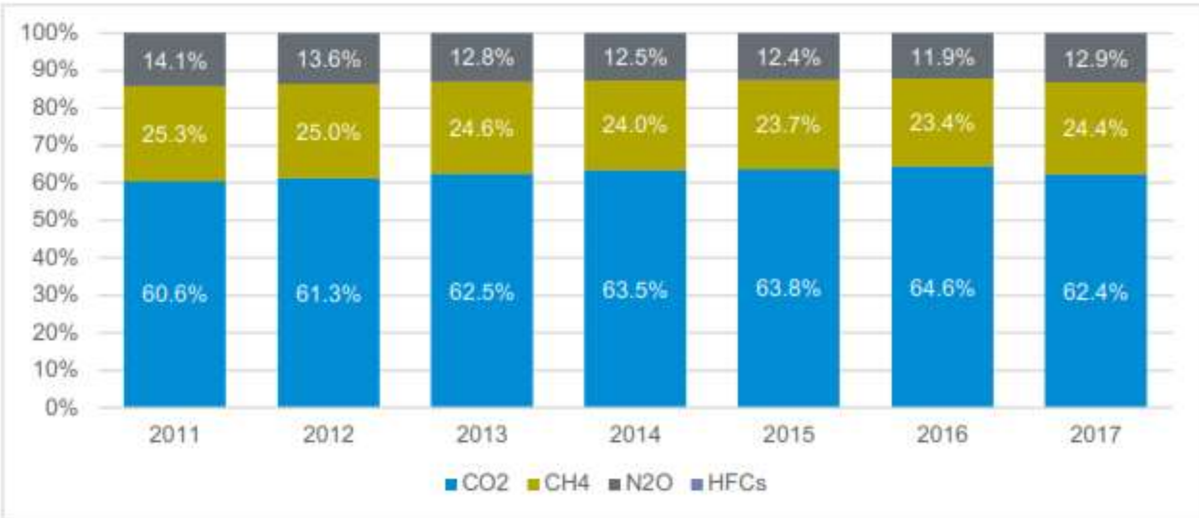


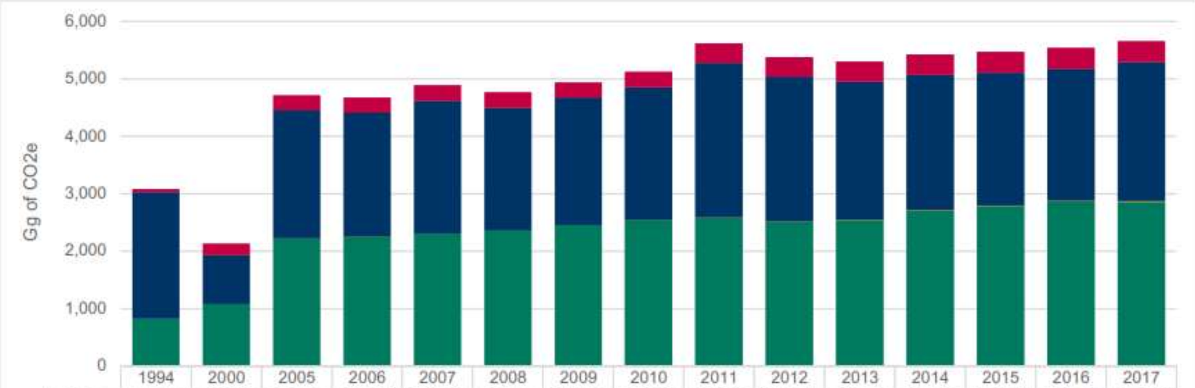
Figure 4: Changes in gas percentage contribution over time

Figures 5 presents the trends in Lesotho's GHG emissions from 1994 to 2017. According to the Figure, the country's GHG emissions have increased by 83.7 % from 3 080.7 Gg CO_2e in 1994 to 5 660.44 Gg CO_2e in 2017. This represents an average annual growth rate of 3.64 %. The Waste sector emissions have increased by 574.7 %, the Energy sector increased by 245.9 %, while the AFOLU sector increased by 9.9 %.

As can be seen in Figures 5, the fastest rate of growth occurred in the Waste sector followed by the Energy and industrial sectors. In general, the trend of increase in total GHG emissions closely follows the trend of emissions from the energy sector, which constituted 46 to 50.5 % of total emissions during this period. This significant growth in emissions reflects the growing energy demand, due in part to the changing socio-economic conditions and overall economic development of the country. As for the

AFOLU sector, GHG emissions have conserved a steady state throughout the 1994 – 2017 period, with an average annual growth rate of 0.43 %, mainly due to a decrease in the population of livestock and a decrease in forest fires from 1994 to 2017.

The inventory underscored the country's reliance on fossil fuel imports and the large contribution of the Energy sector to GHG emissions.



	1994	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Waste	54.57	199.63	259.53	267.18	266.88	265.75	265.10	266.20	338.06	343.78	349.08	354.38	359.70	365.01	370.39
AFOLU	2,199.0	855.85	2,227.7	2,154.0	2,311.4	2,137.2	2,215.9	2,300.3	2,690.4	2,515.9	2,403.4	2,350.7	2,308.1	2,294.5	2,416.9
IPPU	0.00	0.00	0.87	0.87	0.87	0.87	0.87	0.81	5.18	6.03	6.03	7.23	8.76	10.24	11.91
Energy	827.22	1,079.4	2,227.1	2,255.0	2,311.4	2,363.3	2,459.5	2,552.8	2,583.6	2,513.6	2,545.4	2,713.0	2,791.3	2,869.9	2,861.1

Figure 5: Totals per sector in Gg of CO_2e emissions from 1994 until 2017

1.3.2. Process and results of sector selection

Following an extensive review and analysis of policy and other documents pertaining to climate change and mitigation actions, combined with stakeholder consultations, the then Ministry of Natural Resources of the GoL presented the key priority areas in terms of emissions reductions, economic growth, policy direction, enabling framework, and poverty reduction and empowerment of the rural population. An inception workshop to discuss sector prioritisation was held on Friday 21st January 2022, with the representatives of various ministries, to introduce the project in its global and national context and to prioritise the sectors. The LMS played a significant role in sector prioritisations. As the arm of the Ministry responsible for mainstreaming climate change adaptation and mitigation into the economy, the technical team at the LMS acted as an Advisory team and informed the sector prioritisation process based on the mitigation, adaptation and development priorities of the country.

Deciding how the different sectors would be prioritised for mitigation was based mainly on the findings of the national GHG inventories that indicate that Energy and AFOLU are the two sectors that contribute the most to GHG emissions. The rationale for selection also considered the current capacity needs and strengths of the potential sector. This included the level of activity already underway in various sectors as well as the extent to which regulatory and institutional arrangements were in place to support the climate technology developments in each sector. The selection criteria were:

a) GHG mitigation potential
b) Availability of technologies
c) Market potential
d) Cost/benefit of mitigation
e) Poverty reduction

f) Economic growth

The discussions and deliberations led to a unanimous agreement that the energy (Energy Demand and Efficiency) and AFOLU sectors need to be prioritised for the TNA process since they are the largest contributors to GHG emissions and are priority areas for the development of the country, as reflected in all national development plans. The energy sector is also the sector with the highest potential for the application of technologies for mitigation against climate change.

Further subsector discussions led to the consensus that clean and energy-efficient cooking technologies could assist in the development of rural regions, reduce resource pressure on urban centres, assist in the decentralisation of industries/businesses and increase economic activities in these areas but were lagging and needed more technological support and advancements. Most rural communities are caught in a vicious cycle whereby they have very few income-generating activities at a commercial level, leading to relatively low cash flow and lower development rates. In order to break this cycle, the government is vying to channel some economic developments in these regions that could empower the people and allow them to venture into income-generating opportunities.

Mitigation is also seen as an important outcome or by-product of decreasing the country's dependence on imported fossil fuels (i.e. increase in energy security), and enhancing its balance of trade profile (through a reduction in its energy bill).

Table 1: Sector selection rationale

Summary of Sector Selection Rationale	
GHG Emissions	Level of GHG emissions by sector
Policy direction	Mandate and direction provided by CCM related policies and plans
Enabling Framework	Regulatory and institutional arrangements in place
Capacity	Sector capacity needs and strengths
CCM/SD implementation	Progress made to date on implementing CCM related actions

CHAPTER 2: INSTITUTIONAL ARRANGEMENT FOR THE TNA AND THE STAKEHOLDER INVOLVEMENT

2.1 National TNA team

The country-driven nature of the TNA requires an inclusive and participatory process that ensures that the prioritised technologies are a true reflection of the national needs. The institutional arrangement is important, to ensure that there is provision for project oversight, to ensure delivery of the project outcomes and achievement of the project objectives and goals that have been set up in Lesotho. The relevant institutional structure for implementing the TNA in Lesotho is shown in Figure 6;

The institutional set-up is guided by the following:

- The guidance notes on the institutional arrangement, presented in the UNEP DTU Partnership Guidebook for conducting the TNA project (Haselip *et al.*, 2019), and
- The existing institutional structures already in place in Lesotho for managing and coordinating climate change activities.

In line with the guidance from the UNEP DTU Partnership Guidebook for conducting TNA Project, the national institutional arrangement considered the critical components of a TNA institutional structure including National Steering Committee, National TNA Committee, TNA Coordinator, National Consultants and Sector working groups.

Figure 6 also shows linkages between different elements of the TNA institutional arrangement in Lesotho. The roles and responsibilities of each element are presented in the following sections:

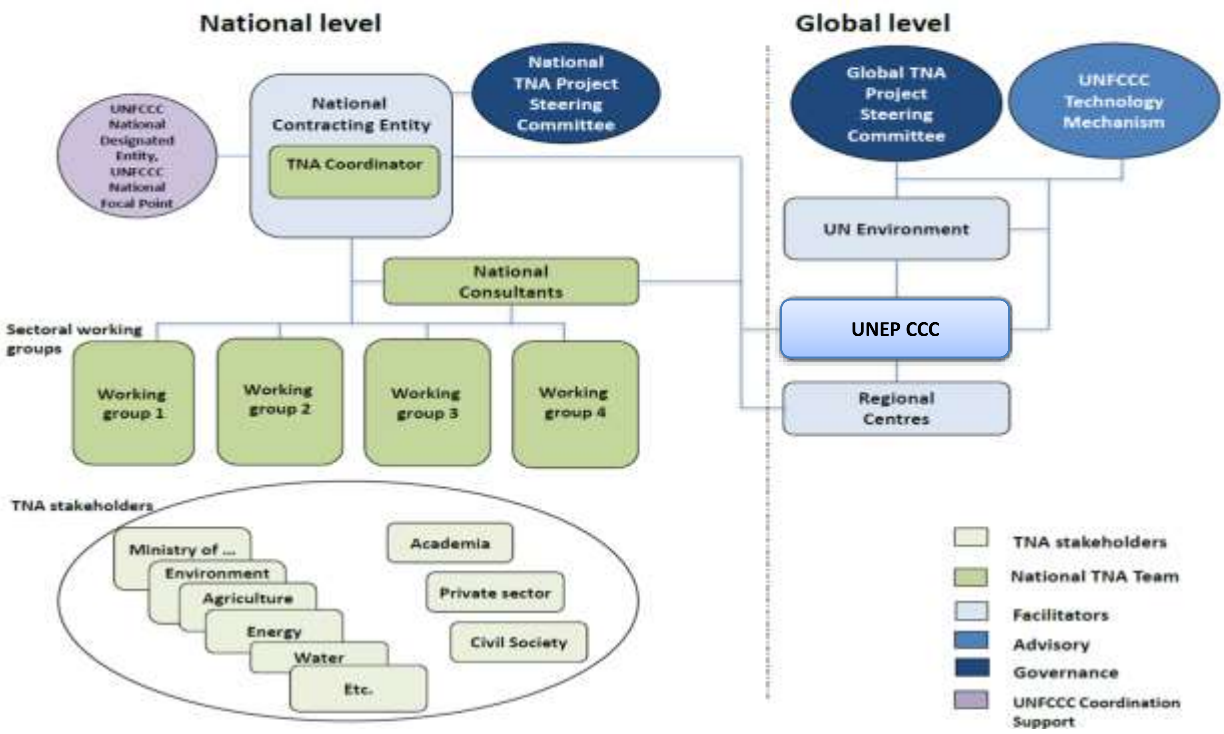


Figure 6: Implementation structure

TNA Project Coordinator

The TNA Coordinator is responsible for leading the TNA process within the LMS. Moreover, the TNA Project Coordinator facilitates both technical and administrative tasks and collaborates with the National Consultants, UNEP CCC, UCT and other stakeholders to facilitate the smooth implementation of the project.

Two technical working groups have been constituted under the guidance of the National TNA Committee. These are the Mitigation Working Group which is responsible for assisting the mitigation consultant and providing input to the TNA process and the Adaptation Working Group which is responsible for assisting and evaluate the work of the adaptation consultant.

National TNA Consultants

The TNA in Lesotho was performed with the involvement of local mitigation and adaptation experts. The lead national consultants were selected by the National TNA coordinator in close consultation with UNEP CCC, following national tendering processes, and an open and transparent selection process.

National expert consultants are responsible for finalising the TNA Report after thoroughly identifying and prioritising technologies for the two sectors identified under climate change adaptation and mitigation after exhaustive consultation with the relevant stakeholders and experts. The National Consultants lead the process of multiple-criteria analysis, along with the national stakeholder groups, and facilitate the process of technology prioritisation, addressing the barriers and developing an enabling framework.

2.2 Stakeholder Engagement Process followed in the TNA – Overall assessment

Stakeholder engagement is critical for inclusive decision making and for bringing in more ideas as each stakeholder is different and brings unique value to the process. Each stakeholder represents a different interest group from public sector, private sector, civil society and academia. In this case, the stakeholders have different roles along the various steps of the implementation of the TNA project, hence it was important to identify them at an early stage of the TNA process and make the decision as to which stage of the TNA process such stakeholders would be more crucial. A step-by-step approach was followed when deciding on the selection of stakeholders.

Stakeholder mapping and sectoral representation: The team of consultants and TNA coordinator had brainstorming meetings on identifying the relevant stakeholders. First, a broad list of relevant stakeholders was drawn up by the team. This was not a difficult task as the selection process benefited from using existing structures from projects implemented by the LMS. The stakeholders were carefully selected, targeting those that would bring the most value to the exercise. See Annex II for the list of stakeholders consulted.

At the outset, all major stakeholder institutions/organizations were invited to an inception workshop on the (21st January 2023), where they were introduced and briefed on the TNA project, its processes, outputs and timelines. The stakeholders were invited again for technology prioritization on the 22nd March 2023 and 4th April 2023. Prioritizations were based on 12 and 10 technologies from the Energy sector and AFOLU sector respectively. Stakeholder engagement in general had two broad objectives:

1) to seek views and opinions of stakeholders on matters, and 2) to make transparent decisions of national interest jointly.

The TNA report was prepared after an extensive stakeholder process. The stakeholder engagement methods included:

- Email correspondence and exchanges on the Technology Factsheets (TFS);
- National stakeholder consultation of key stakeholders for technology prioritisation;
- Direct Consultations (teleconferences, meetings, interviews, emails) were held with high-level Government representatives, sectoral specialists and experts to solicit information and perspectives to aid the preparation factsheets. This was necessary to ensure all key persons were involved in the TNA process.

Overall there has been a high level of interest and participation (as evident from attendance at National stakeholder consultation meetings) in the TNA thus far. This could be attributed to a heightened level of awareness of climate change and also the positive national momentum that has been built through proactive national policies and strategies as well as a discerning interest by many of the stakeholders to be part of a process that can harness new and improved technologies for climate change mitigation and stimulate a green economy.

2.3 Consideration of Gender Aspects in the TNA process

The Constitution of Lesotho (1993) provides for **gender equality through the Bill of Rights and non-discrimination in Sections 18, 26 and 30**. These provisions guarantee equality between women and men before the law.

There is an existing framework that guarantees that issues of gender are mainstreamed in all climate change mitigation and adaptation efforts across the country as a means of promoting inclusiveness, equity and adequate participation of all. This framework is set out in the NCCP Policy Statement 3.16.

The Key objectives of this policy statement are to:

- Promote equitable participation in climate change programmes;
- Encourage information and experience sharing with other climate-smart partners;
- Promote the development of gender-responsive policies and plans; and
- Increase climate change advocacy at all levels of society.

To ensure gender consideration in the TNA process, the consultants and Expert Working Groups (EWGs) were guided by the UNEP DTU Guidance document (De Groot, 2018) on gender responsiveness when conducting TNAs. Women play a unique role in natural resource management. Women are vulnerable to climate change, however; women are also the agents of change in societies. Improving and enhancing the incorporation of women's knowledge, skills, participation, and leadership into planning processes at the local and national levels creates opportunities to maximise both women's and men's contributions to environmental sustainability. Given women's traditional roles as caregivers, they are mainly the ones in charge of household energy management and food provisions. Women play a key role in household energy use by making and influencing decisions about 1) use of appliances (i.e., for lighting, cooking, heating, air conditioning, and hot water), including the choice of time of use, and, therefore, peak use; 2) household purchases of goods and services, which may be more or less energy-intensive or wasteful, e.g., packaging; and 3) the education and shape of children's future energy consumption habits. As people responsible for preparations of food in the family, women are active in food production systems in the country.

The TNA work on Lesotho builds up with the guidance of the NCCP and SDG 5. Women's civil society representatives have been included in the technical working groups and the stakeholder consultations. Equal opportunities have been provided to both men and women to voice their opinions and standpoints. However, energy, AFOLU and waste sectors are generally male-dominated and thus, continued mainstreaming of gender inclusiveness policies and strategies at the ministry and department levels should be encouraged and supported.

CHAPTER 3: TECHNOLOGY PRIORITISATION FOR ENERGY SECTOR

3.1 Overview of the Energy sector

This chapter of the report provides an overview of the existing technologies for climate change mitigation in Lesotho's Energy Sector by considering government priorities regarding power supply diversification, household energy, energy conservation and energy efficiency, and efficient use of electricity. It also outlines stakeholders' identification of applicable technologies for implementation in the country.

The energy sector is one of the sectors that has potential for climate change mitigation in the country. There are various national programmes and projects aimed at promoting and facilitating clean energy options and also creating the necessary policy framework for the implementation of such programmes. For the purpose of this exercise, the sector technologies have been categorized into the following subsectors/categories;

- Power generation
- Household energy
- Energy conservation and energy efficiency
- Road Transport Sector

Lesotho is highly dependent on imported energy (electricity, oil and petroleum products). The cost of imported electricity, fossil fuels and increasing threats from climate change necessitates a diversified energy mix and transition to alternative sources of energy. In this regard, several national plans, initiatives and policies are being implemented to transform and diversify the sector and reduce the dependence on imported fossil fuels to meet the country's energy demands.

The key challenges facing Lesotho's energy sector are the low rate of household access to electricity and modern, cleaner sources of energy for lighting, heating, and cooking, energy security, and declining biomass stocks. As per the 2009-2011 Energy Balance Report issued by the Bureau of Statistics in 2013, the country imported the equivalent of 2 000 barrels (317 975 litres) of oil/day (Bureau of Statistics, 2015). Demand for imported petroleum products (primarily petrol, diesel and illuminating paraffin) has been on the rise, increasing from 217.7 million litres in 2010 to 285.6 million litres in 2020. However, based on trends in the last ten years of imported petroleum-based products, the transport subsector has grown as the country's largest user of total petroleum-based products. From a consumption perspective, the transportation subsector currently consumes the largest share of fossil fuels compared with the other sectors. Moreover, the GHG inventory found emissions from the consumption of fuel in the transport sector, mainly road transport, to range from 390.50 Gg CO_2e in 2011 to 465.90 Gg CO_2e in 2017. Consequently, the energy sector, based on trends, is likely to grow significantly and concurrent with this would be an increase in the total GHG emissions (LMS, 2019).

In 2012, fuel imports accounted for 13 % of total trade with South Africa, and 7 % of Lesotho's GDP (UN Comtrade, 2012). Electricity peak demand in Lesotho totals more than 160 MW; however, about two-thirds of the demand is supplied from imports of electricity from South African Public Utility (ESKOM) and Electricity of Mozambique (EDM) – mostly coal-fired power generation (LEWA, 2019b). This heavy reliance on imported fossil fuels and electricity places heavy pressure on the country's foreign exchange reserves, exacerbates state budget deficits, and poses major energy security concerns, both in terms of access to supplies and pricing. Thus, there are abundant opportunities for renewable energy generation, energy conservation and energy efficiency.

In 2019/20, electricity imports for Lesotho were 529.4 GWh increasing from 262.8 GWh in 2010/11 growing at an average annual rate of 8.08 %.

3.2 GHG emissions and potential for GHG reduction in the Energy sector

3.2.1. Greenhouse gas emissions in the Energy sector

Figure 7 and Figure 8 present the breakdown of national GHG emissions in Lesotho and the Energy sector emissions between 2011 and 2017, disaggregated by category.

	2011	2012	2013	2014	2015	2016	2017
1A4c Agriculture, Forestry & fishing	9.85	8.94	9.04	11.62	12.46	12.95	9.99
1A4b Residential	1741.71	1741.85	1766.65	1806.58	1831.71	1866.01	1900.86
1A4a Commercial / Institutional	384.67	390.92	397.23	403.54	409.84	416.15	422.46
1A3b Road Transport	390.50	319.31	318.33	422.40	463.18	497.40	465.89
1A3a Civil Aviation	0.15	0.43	0.81	0.61	0.67	0.58	0.95
1A2 Manufacturing Industries and Construction	56.73	52.23	53.41	68.30	73.52	76.83	61.01

Figure 7: Breakdown of GHG emissions in Lesotho: 2011 - 2017

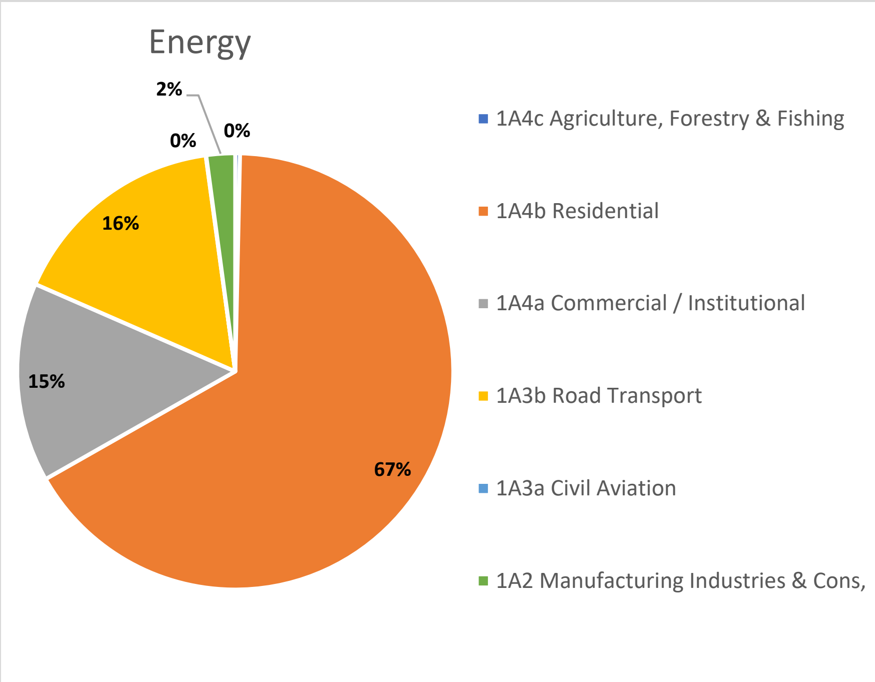


Figure 8: Energy Sector GHG emissions: 2011 - 2017

Lesotho's GHG emissions from the energy sector amounted to 2 583.6 Gg CO_2e in 2011, and increased steadily to 2 861.2 Gg CO_2e by 2017, with the residential sub-sector (specifically the burning of biomass (wood, shrubs, dung and crop residues)) accounting for the largest share in the sector's emissions at 66.44 % in 2017. Reduced consumption of diesel and petrol in 2012 and 2013 led to a reduction in GHG emissions to 2 513.7 Gg CO_2e and 2 545.5 Gg CO_2e respectively. Overall, the emissions from the energy sector increased by 10.74 % from 2011 to 2017.

Transport sector emissions were 390.65 Gg CO_2e in 2011, increasing to 466.85 Gg CO_2e in 2017. Road Transport accounted for over 99 % of all the transport emissions throughout that period. GHG emissions from commercial/institutional sectors amounted to 384.67 Gg CO_2e in 2011 and 422.46 Gg CO_2e in 2017.

Based on trends in the last ten (10) years of imported petroleum-based products, the transport subsector has grown as the country's largest user of total petroleum-based products. Consumption of petroleum products increased by 14 % from 227 125 kilolitres in 2016/17 to 258 972 kilolitres in 2019/20. Most vehicles in the country are often poorly maintained. It is therefore highly probable that emissions of CO_2 from the transport sector will increase in future due to the increased consumption of petroleum-based products in the sector. Consequently, the Energy sector, based on trends and expert opinions, is likely to grow significantly and concurrent with this would be an increase in the total GHG emissions (BoS, 2022).

National planning for GHG mitigation should take into account more recent macro-economic data and trends. Real GDP contracted by 3.2 % and 1.2 % in 2017 and 2018, respectively, before rebounding and expanding by 2.6 % in 2019. It then contracted sharply by 6.5 % in 2020 largely due to the COVID-19 related restrictions and several country lockdowns. The downturn continued into 2021, with the economy contracting by 11.1 % in the first quarter, after which it recovered and expanded by 10.5 % and 2.2 % in the second and third quarter of 2021, respectively. Real GDP growth is projected to average

2.1 % between 2022–2024. The expected recovery in the medium-term is set to be led by a rebound in the mining, manufacturing (including textiles) and construction activities on the back of supportive external demand conditions and improved business and consumer confidence. These sectors consume a considerable amount of energy on a continual basis for their operations. In 2017/18 and 2018/19 years, these sectors combined, consumed 309 007.48 MWh and 319 235.54 MWh respectively both equivalent to around 60 % of the national consumption (Bureau of Statistics, 2020).

In the medium-term, economic growth is expected to be boosted by construction-related projects including the second phase of the Lesotho Highlands Water Project (LHWP II), the Lesotho Lowlands Water Development Projects (LLWDP -I and-II), government roads construction projects and the Maseru district hospital construction. In the light of these economic trends, it appears likely that future efforts to mitigate GHG emissions in Lesotho will increasingly need to focus on energy consumption (demand-side management such as energy efficiency and saving), renewable energy development, and production activities.

Over the years, Lesotho has been implementing several mitigation technologies in the energy sector, both renewable technologies and energy efficiency measures, although at varying scales of application. In this regard, several national plans, initiatives and policy documents such as the NSDP II are being followed to transform and diversify the energy sector. Lesotho's Energy Policy 2015-2025 vision is: "Energy shall be universally accessible and affordable in a sustainable manner, with a minimal negative impact on the environment".

The main existing technologies in use in the sector are biomass, hydropower and solar.

3.2.2. Existing technologies in the Energy sector

Solar PV Off-Grid and On-Grid

An off-grid system is a decentralized renewable energy system adopted by homes and small businesses to produce reliable and cost-effective power. In isolated locations, off-grid systems tend to be cheaper than establishing transmission lines in the area.

On-Grid solar PV systems or Grid-connected systems are solar powered systems that are connected to the national power grid. Grid-connected PV systems do not require energy storage but instead use an inverter to convert electricity from direct current (DC) to alternating current (AC), and the generated electricity is then supplied through the distribution network to consumers. Grid connected PV systems are further classified into two types of applications – distributed and centralized. Grid-connected distributed PV systems are installed on residential, commercial or public buildings and generate electricity which is consumed by the customer and the excess is sent/sold to the grid to be consumed by other users. Most distributed systems range between 1-5 kW in power generation. The centralized systems are usually larger and not necessarily on building rooftops but can be designed as solar 'farms', ranging from 10 kW up to a few MW in generating capacity.

Lesotho experiences high levels of solar radiation, with average daily solar radiation of between 3.2 kWh and 7.0 kWh per square meter. This resource is relatively predictable and well distributed throughout the country. However, RETs are not widely disseminated in Lesotho. Lying between latitudes 28 and 31 in the south, it has the advantage of long hours of sunshine and more than 300 days of sunshine. Average sunshine hours range from 10.2 to 13.8 hours per day with more than 80 % of solar radiation coming as direct radiation because of limited cloud coverage and clear skies with no air pollution. The country's estimated solar energy potential is 1 857 790 042 MWh/year, which is enough to satisfy its energy demands many times over. However, effectively harnessing this free source of energy still remains a challenge mainly due to little government support, under appreciation of its potential and limited financial resources required to provide capital. Even with such vibrancy, the installed PV capacity is still way below the nation's potential. PV powered communal grids have hardly taken off in Lesotho due to lack of knowledge on the socio-economic benefits of such arrangements, lack of government support and regulation, and most importantly, lack of organizational structures necessary to establish and run such ventures.

The generation of electricity using photovoltaic (PV) systems is not new to Lesotho and it accounts for approximately 1.5 % of the electrical energy-generating mix. A limited number of PV standalone systems have been installed in Lesotho as part of private initiatives, or internationally funded projects to boost access to energy and stimulate socio-economic development. However, this technology is still in its early phases, and the off-grid renewable energy market in Lesotho is nascent. Solar home system PV technologies are sold by various retailers in Lesotho, and some are imported into the country by returning residents from abroad (for example Republic of South Africa).

UNDP-GEF funded pre-feasibility studies for RE-based mini-grids in 20 village communities spanning five of Lesotho’s 10 districts. The studies focussed on electricity generation using RE technologies for household use and small income-generating activities and provided a long-term plan for electrifying the identified remote areas. UNDP-funded studies and pilots were conducted early 2022, building on recommendation of the EMP 2018 - 2028.

The GoL has had some experience in implementing distributed RE technologies through distribution of solar home systems (SHS). The Rural Electrification Unit (REU), through a GEF-financed pilot project, distributed SHS to 300 households in the Linakaneng region in the Eastern highlands in 2014. Also, since 2007, UNDP and the GEF have supported a program to promote the use of RE technologies for basic household needs such as lighting, radios, and cell phone charging; this project installed 1 537 SHS in the districts of Mokhotlong, Thaba-Tseka, and Qacha’s Nek. Each SHS installation had a 70 or 75 W PV system with a 300 W DC/AC inverter (GoL, 2013). However, more than half of the systems installed are no longer functioning or are providing low quality service due to lack of adequate product standards and maintenance mechanisms. [2]

AfDB is funding Lesotho – Renewable Energy Grid Integration Study. The objective of the study is to assess the impacts on the transmission and distribution networks of the Lesotho Electricity Company (LEC) of variable renewable energy generation (VREG) and to establish the level of absorption, both quantitatively and in relative terms of such intermittent renewable energy generation in the LEC power system in the medium to long-term. The study will provide results under scenarios of integration in the transmission grid by LEC and Independent Power Producers (IPPs), and in the distribution system by households and other consumers. The study will address the technical barriers so that the greater adoption of renewable energy will progress quickly in Lesotho, assisting in the “take-off phase” by (i) mastering how to control grid with renewable energy; and (ii) lowering the cost of renewable energy integration by saving the investment on regulation reserve considering that the Lesotho power system is a fully integrated operating member of the Southern Africa Power Pool (SAPP)

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[2] There is no regulation governing the importation of solar products. Because of this, a range of noncertified products from China, India, and South Africa have entered Lesotho.

Local developer, OnePower, has embarked on an ambitious plan to roll out ten solar PV mini-grids in Lesotho's rural areas, including Thaba-Tseka, Mohale's Hoek, Qacha's Nek, Mokhotlong and Quthing. Utility-scale solar currently makes up a small proportion of Lesotho's generation capacity. Lesotho is gaining experience in medium scale solar PV systems. These include a 281 kWp PV micro-grid located at the Moshoeshoe I International Airport that is used primarily to serve the airport's electricity demand during the day. The system does not have storage capability and excess power generated flows back to the national grid. During periods of low radiation and no sunlight, the airport obtains electricity from the grid. There is a 50 kW small mini-grid pilot project constructed by the firm OnePower in Makebe village.

There has been substantial interest from the private sector and the GoL in developing larger scale solar parks in recent years. Two larger solar park projects are under construction by the GoL and a local private developer, OnePower, with a total installed capacity of 90 MW. Table 2 below summarizes the existing and proposed utility-scale solar PV projects in Lesotho.

Table 2: Existing and Proposed Utility-Scale Solar PV Projects (Reducing Eskom imports and biomass burning)

Project Name	**District**	**Ownership**	**Project Status**	**Capacity (MW)**
Ramarothole Solar Power project-1	Mafeteng	Government of Lesotho	Under construction	70
In theory the project could replace 102.2 million kWh of imported coal-based energy for the nation.				
Neo 1	Mafeteng	Private Sector	Under construction	20
This plant will replace electricity currently purchased from coal generation sources at Eskom in South Africa. In theory the project could replace 36.5 million kWh of currently imported, coal-based energy for the nation.				
Total				**90**

The two Solar PV sites will reduce the reliance of the country on imported energy that is primarily produced from coal. New transmission lines will connect multiple villages, now burning wood, to electricity sources that are far cleaner, produced with a generation mix that is sourced from clean renewables. Technological advances and falling capital costs for PV systems have considerably improved the competitiveness of solar power.

Hydropower

Hydropower has the potential to significantly contribute towards Lesotho's energy needs, diversify its energy mix and increase its energy security. Additionally, the installation of hydropower facilities can deliver co-benefits beyond the energy sector since its application does not only provide energy management but water management services (flood & drought control) and supports tourism.

The main source of power in Lesotho is the Muela Hydro Power Plant (Lifwenborg and Tohlang, 2011). It has a nominal installed capacity of 72 MW. The effective capacity depends on the reservoir level. The current peak requirement of Lesotho is 160 MW, so there is a shortfall in the amount of power that can be produced domestically. Imports from South Africa and Mozambique cover the deficiencies in the power production at Muela. Lesotho has a long experience with hydropower and several sites have been identified to expand hydro power. The total hydroelectric potential in the country has not been fully investigated, but conservatively estimated to be 361 MW.

A small mini-hydropower plant backed by a diesel generator during the dry season supplies a small island grid in Semonkong. This 180 kVA run-of-river micro-hydro site is currently operated by LEC. Due to increasing demand and the seasonality of the water flow, the mini-grid is now being supplied by a 350 kVA diesel genset. The quality of service has been limited to 14 hours per day, and the system consumes approximately 14 000 litres of diesel fuel per month, which is transported to the site by road. Domestic customers pay the normal LEC tariff of M 1.47 per kWh but the high cost of service provision is a burden to LEC (LEWA, 2019b) . A backup diesel generator produced most of the electricity at the Semonkong plant during the periods of drought (LEWA, 2019a). The government has decided to revitalize the Semonkong mini-grid. It is planned to establish a 1.5MWp solar PV off-grid to support the Semonkong hydroelectric power plant's functioning capacity. A 500 kWh storage system will support the solar power plant.

The Lesotho Highlands Development Authority (LHDA) owns one micro-hydropower plant (HPP), the 540 kW at Katse. Another mini-hydro plant of 2 MW is connected to the grid at Mantšonyane. This hydropower plant assists with the boosting of the voltage at 33 kV during the periods when it is operational. Low inflow of water brings the hydro plant off-line for some time during the year.

Table 3: Generation Assets in Lesotho

Asset	**Connection**	**Technology**	**Installed Capacity (MW)**	**Available Hydro Capacity**
Muela	Grid	Hydro	72	72
Mantšonyane	Grid	Hydro	2	2
Katse	Grid	Hydro/diesel	0.54 (0.8*)	0.54
Semonkong	Off-grid	Hydro/diesel	0.18 (0.4*)	0.18
		Total capacity	**74.72 (hydropower only)**	**74.72**

Technical assessments for small hydro were conducted as part of the Power Generation Master Plan in 2009. The Master Plan proposes 11 small hydropower plants (SHPP) with a total combined capacity of nearly 88 MW (Government of Lesotho, 2009). Table 3 provides a summary of the proposed hydropower sites.

Table 4: Potential Small Hydropower Plant Sites Proposed in the Hydrogenation Master Plan

Site	**Name of the River**	**Installed Capacity (MW)**	**Annual Generation (GWh)**
Hlotse HPP	Hlotse	6.5	39.7
Phuthiatsana HPP	Phuthiatsana	5.4	18.87
Khubelu HPP	Khubelu	14.6	64.26
Polihali HPP	Mokhotlong	19.3	83.89
Tsoelike HPP	Tsoelike	17.7	69.86
Makhaleng 1 HPP	Makhaleng	2	15
Makhaleng 2 HPP	Makhaleng	1.4	6.15
Makhaleng 3 HPP	Makhaleng	8.9	39.4
Makhaleng 4 HPP	Makhaleng	9.1	58.3
Quthing 1 HPP	Quthing	0.63	2.31
Quthing 2 HPP	Quthing	2.4	9.61
Total		**87.93**	**407.35**

Hydropower resources are the most researched and analysed of the known renewable energy sources in Lesotho. Lesotho is well endowed with enormous economically exploitable and viable hydro potential estimated at 450 MW for conventional hydropower systems and more than 3 000 MW of pumped storage schemes. However, only 75.25 MW of the hydroelectric potential has been harnessed so far. The unexploited potential is 374.75 MW for conventional hydroelectricity. Lesotho lacks both financial and technical capacity to develop its own conventional hydroelectricity potential. (*LHWP Phase II hydropower component underway*, 2022) This generally requires relatively large plants (capacity >10 MW), constructed at huge capital investments in the order of tens of millions of US Dollars**.** Small hydropower systems are usually useful because they can be developed exclusively off the national grid. The GoL intends to pursue the development of mini and micro hydro dams on its numerous rivers and streams. Hydropower which is acquired from various rivers and streams depends on rainfall that is susceptible to variation in climate. Consequently, the country suffers from reduced hydropower energy generation during periods of drought or low rainfall and therefore returns to the use of thermal plants to generate energy and therefore leads to increased emissions of carbon dioxide (CO_2).

Other renewable energy technologies such as wind turbines are not very common in Lesotho. However, these technologies are being piloted by Hirundo Energy (‘Global Wind Power Tracker’, 2022).

3.2.3. Energy Efficiency and Thermal Energy Technologies

Improved clean cookstove

A good improved clean cooking stove is one that meets technical, scientific and safety standards, and has high combustion quality, technical efficiency, minimal smoke emission, ergonomics and structural stability (Barnes and Weltbank, 1994). An improved clean cookstove is more comfortable and safe so that it can reduce a number of accidents. It also burns wood fuels more effectively, so the amount of dangerous particles that might be released is reduced (*ClimateTechWiki | Climate Technology Centre & Network | 1167979*, 2006).

Historically, in the residential sector, biomass has been playing a vital role in end-use energy consumption, since most households use inefficient cook-stoves including the traditional cookstove and 3 stone for cooking activities. Final energy consumption in rural area is dominated by fuelwood followed by dung.

Improved energy efficiency in households is a significant potential source of GHG emission reductions. The household sector is, by far, the largest energy user in Lesotho, accounting for more than 80 % of the country’s total primary energy consumption. The predominant source of energy in households is firewood, used for cooking in 56 % of households and for heating in 67 % of households (LMS, 2019). Most fuelwood is burned in inefficient, traditional three-stone cooking fires. Efficient solid biomass cookstoves have been promoted over the years but the uptake is relatively slow.

Thus, assuming that 25% of households, or about 100 000, are to introduce energy efficient stoves, a conservative estimate of the reduction potential is about 200 000 Certified Emission Reductions (CERs) annually (based on 2 tCO_2e per stove per year). In addition, about 67 % of all households in Lesotho use biomass fuels as main sources of energy for space heating (while approximately 27% use paraffin), which means that reduction potentials might be higher if the stoves are used not only for cooking, but also for heating.

Cookstoves that use biomass, such as fuel wood, are the primary source of thermal energy used throughout Lesotho. Current cookstove technology consumes almost 90 percent of biomass fuels, including shrubs, firewood, crop residue, and animal waste. Improved cookstoves are up to 50 % more efficient compared to traditional stoves and provide health benefits by reducing the amount of emissions in the home. Approximately 4 560 African Clean Energy (ACE) and 10 000 Solar Lights cookstoves have been sold in Lesotho; the estimated total available market is about 353 000 households (DOE, 2017) . The Government of Lesotho through its research and development centre, Appropriate Technologies Services (ATS), is also developing affordable efficient cookstoves that have a dual function for space heating.

Solar clean cookstoves have also been tested in Lesotho. A study conducted by the Program for Biomass Energy Conservation asked households to test various types of solar cookers to determine the acceptance level of these technologies, including large parabolic solar cookers, small parabolic solar cookers, and solar box cookers. The study found that most users wanted to own a solar parabolic cooker because of the time and energy saved from not having to gather firewood for cooking.[3] It is estimated that over 900 000 metric tons of common biomass could be saved annually in Lesotho with full conversion to clean cookstoves.

Efficient Institutional Cookstoves can be used where larger amounts of food than can be accommodated on a standard kitchen stove can be cooked. Typical examples are schools, hospitals, prisons and other institutions. Typically, these groups can use institutional stoves with a cooking capacity of 50 litres to 200 litres (Medina, 2007). Lesotho has more than 2 000 educational institutions and these mostly depend on firewood for cooking. Schools are open for a minimum of nine (9) months annually.

The longer school periods translate into higher demand for firewood. These high demands translate into increased destruction of forests and environmental damage. The growing institutions' needs for firewood justify the selection of efficient institutional cookstoves as a viable technology option to reduce the adverse impacts of climate change since they require less firewood to do more cooking.

Expansion of liquified petroleum gas (LPG) Stoves

Liquified petroleum gas is a relatively cleaner fuel from the emission point of view than paraffin (107 900 kg CO_2eq/TJ for LPG versus 157 400 kg CO_2eq/TJ for paraffin, 112 000 kg CO_2eq/TJ for wood). Hence expansion programmes have always been encouraged. A majority of grid-connected households in Lesotho use electrical power for nearly all of their domestic energy requirements. The use of electricity for cooking and heating has a high power factor and tends to strain local power grids at peak periods (evenings). Recent grid-power shortages necessitate the application of the available electricity supply to sectors that will contribute the most to socioeconomic growth, such as powering industries and commercial ventures, or household lighting and media power. LPG is a feasible alternative for clean household cooking and heating that could reduce the dependence on electricity for these tasks.

Importance of Clean and Efficient Cooking Technologies in delivering the SDGs

Universal clean cooking is a key component of SDG 7- access to affordable, reliable, sustainable and modern energy for all by 2030. However, progress is currently not on track, with access to clean cooking fuels and technologies lagging furthest behind. Access to clean cooking not only contributes to access to modern and clean energy (SDG 7) and improved health (SDG 3), but its impacts can be felt keenly in 10 out of the 17 global goals including gender equality (SDG 5), climate action (SDG 13) and the elimination of poverty (SDG 1). In other words- without a shift towards universal clean cooking solutions, achievement of most SDGs will also be affected.

[3] ProBEC, Final Assessment of Cooker Testing in Lesotho

Climate Impacts of Traditional Stoves

Burning solid fuels for cooking emits GHGs and other pollutants and is a significant contributor to global climate change. Unsustainable wood harvesting contributes to deforestation, reducing carbon uptake by forests. Increased fuel efficiency and the introduction of alternative fuels, utilizing renewable fuel sources, can reduce climate emissions caused by cooking. To achieve a significant climate impact, uptake of clean and efficient stoves and fuels must be large, and stoves must perform well in homes.

Energy Efficiency and Conservation

Energy consumption in buildings and households accounts for a large share of the total end use of energy in Lesotho. However, there are no data available on their energy consumption and their levels of energy efficiency. Most buildings in Lesotho suffer from large energy losses. Inefficient lighting and household appliances are additional factors for the low levels of energy efficiency in Lesotho's buildings. Despite the push for energy-efficient lighting such as compact fluorescent lamps (CFLs) and light-emitting diodes (LEDs) over incandescent lamps to meet peak electricity demand, incidences of poor quality CFLs in the country hamper the efforts to popularise this technology. Furthermore, absence of monitoring, verification and enforcement measures against poor quality efficient lighting technology have contributed to proliferation of poor quality lighting bulbs in Lesotho markets.

Solar Water Heating (SWH)

Lesotho is endowed with good solar radiation receiving 2 500 hours of sunshine per year and an average solar-radiation of between 4.5 and 6.5 kWh/m^2 per day. SWH is a proven technology that has been widely applied across residential, commercial, institutional and industrial sectors around the world. Considering the high solar radiation and that water heating accounts for up to 45 % of domestic energy consumption, one would expect more widespread use of domestic SWH. If a solar water heating system can deliver this energy, then in theory it will reduce the energy usage of the household by 45 %. The biggest barrier to large scale roll-out has always been the capital cost and low electricity prices. *However, times are changing: electricity prices have been rising sharply, the price of SWH has been going down.* Unlike power sector decarbonisation, there has been little progress made on heat, which is currently the biggest energy consumer in Lesotho, accounting for more than 45 % of total energy consumption in 2019, and almost 40 % of Lesotho's GHG emissions.

3.3 Decision context

Energy poverty is a critical indicator directly related to the welfare, health, gender, poverty, and food security of households and nations (Rodriguez-Alvarez, Orea and Jamasb, 2019). Energy poverty (SDGs-7) and GHGs (SDGs-13) are two major challenges on the road to sustainable development goals. Reducing GHG emissions and tackling energy poverty through the transition from fossil fuels to clean and renewable sources is a global imperative that requires a multifaceted approach. The energy sector is the main contributor to GHG emissions in Lesotho as well as the largest consumer of imported petroleum-based fossil fuels. Fossil and biomass fuel combustion were identified as the two main sources of emissions of CO_2 in the sector. The significant increase in emissions is a reflection of the rising energy demand occasioned by the shifting socioeconomic landscape.

In the light of this, the baseline for the selection of the priority mitigation sectors was Lesotho's TNC, aligned with the NCCP 2017, NCCPIS 2017, NSDP II, NDC and 4th National GHG Inventory. NCCP provides a platform for coordination among sectors and direction on national positions and priorities regarding climate change mitigation as well as adaptation. NSDP II promotes the decentralization of renewable energy sources such as solar, mini-hydro and wind systems that will be used to electrify rural areas where feasible. TNC strengthens the National Energy Policy with long-term objectives and associated operations.

Over the years, Lesotho has been implementing some mitigation technologies in the energy sector to further limit its GHG emissions. LEC draws predominantly from hydropower and maintains a national grid emission factor of just 0.0038 tCO_2/GWh (the rest of the SAPP's operating grid emission factor is 0.9958 tCO_2/GWh). Still, the share of emission from the energy sector has grown steadily, reaching about 50.5 % of national emissions, and producing an annual total of 2 861.17 Gg CO_2eq in 2017. The dominant source of emissions come from residential fuel combustion (66.44 %), emanating from the use of firewood, coal, dung, paraffin. This is followed by emissions from road transport (16.28 %), and emissions from commercial / institutional subsectors at 14.75 %.

According to Lesotho's NDC, the main opportunities for mitigation are in energy efficiency and demand management, coupled with increasing investment in a renewable energy programme for the electricity, building construction, and waste sectors. Chapter seven (7) of the TNC report highlights the gaps, constraints, financial and technical needs of each sector in order to achieve the climate change goals set out in the NCCP. The following areas were identified as most relevant to climate change mitigation in the Energy Sector:

- **Reduce coal-dominated electricity imports from South Africa:** This objective can be met by adding low-emission, renewable generation plants to domestic electricity sources. The power sector plays a pivotal role in any scenario for substantially mitigation climate. The sector must substantially reduce its emissions even as demand for power rises. The main action is:
    - Develop Lesotho's human, technological and institutional capacity to accelerate the uptake of appropriate clean energy and clean production technologies.
- **Substitution** of lower-emission energy sources **and reduction of traditional household fuels, especially firewood, coal, dung and illuminating paraffin for the areas that cannot be effectively electrified:** This objective can be addressed through accelerating the delivery of cleaner sources of energy to remote villages and rural populations. According to the Blue-Sky Model, wood fuel emits 1.5 kg of CO_2eq/kWh consumed (*1 kilowatt-hour · BlueSkyModel*, 2013); by contrast Lesotho's national grid delivers energy at 0.22 kg of CO_2eq per kWh. This objective also serves other important goals of reducing deforestation and eliminating negative health effects of smoke inhalation and accidental household fires.
- **Improving Energy Efficiency** to dramatically lower energy intensities across key economic sectors such as Transport, Industry, Buildings (Residential, Commercial, Institutional and Industrial), Public lighting and Agriculture. Efficiency opportunities are widespread across the economy, ranging from newer lighting to appliance technologies.
- **Decarbonizing Transportation**: Reducing emissions from transport will be essential in the race against climate change. Potential decarbonisation pathways in the transportation sector include the use of improved vehicle efficiency, improved system-wide efficiency, and mode switching (e.g., from passenger vehicles to mass transit)

- Since 2011, transportation has been the biggest direct source of Lesotho's GHG emissions. Most of the sector's emissions come from road transport, which derives over 90 % of its energy from petroleum.
- Unlike the power sector that is experiencing some supply diversification using renewable energy sources, almost the entire transport system in Lesotho is dependent on imported fossil fuels. Amongst others, Lesotho's CCP, SNC and TNC have listed the following mitigation options for the transport sector: Mass transit options (Bus Rapid Transits); Transport demand management through promotion of non-motorized transport and car sharing practices, parking management and road pricing and congestion.

Based on these mitigation factors, it is clear that no single measure will provide the solution and that action is needed simultaneously through different mitigation strategies.

Lesotho's main source of power generation is the 72 MW Muela hydropower plant, which accounts for all domestic grid electricity generation capacity, from which the LEC procures more than half of the country's electricity requirement. Minor plants are located at Semonkong (hydro 0.18 MW, diesel 0.50 MW) and Mantšonyane (hydro 2.00 MW), whereas a 0.50 MW hydro plant is located at Katse dam and serves essentially for dam operations.

A particular challenge facing Lesotho is the increasing unpredictability of hydroelectric power in the face of changing weather patterns. Supply is very susceptible to both hydrological variability and plant reliability and availability. LEC therefore procures more than half of the country's electricity requirement for peak demand via imports of electricity from South African Public Utility (Eskom) and Mozambique's Electricidade de Moçambique (EDM). Peak demand in 2017 reached 155 MW – exceeding domestic generation capacity by more than 100 %. As a result, Lesotho imported roughly 270 GWh from Eskom (30 % of total demand) and 98 GWh from EDM (roughly 11 % of total demand) in 2018 at prices which range from M 0.77 to M 1.50 per kWh, substantially higher than purchases from the Muela hydropower plant at M 0.13 per kWh. As such, electricity imports amounted to 86 percent of LEC's supply costs. According to LEC's projections, peak power demand is expected to grow to 432 MW by 2030 (LEWA, 2019a).

Figure 8 displays Electricity purchased in GWh from Muela, Eskom and EDM by LEC for the period 2015/2016 to 2019/2020. Electricity purchased from Muela has been declining from 2017/2018 (518.28) to 2019/2020 (389.14) showing a percentage decline of 24.92 %. Purchases from Eskom has an increase of over 100 percent from 2015/2016 (203.01) to 2019/2020 (429.82).

Source: Lesotho Electricity Company

Figure 9: Electricity Purchased in GWh from Muela, Eskom and EDM by LEC- 2015/2016 to 2019/2020

The consumption of biomass fuel has surpassed its manageable supply, consequently, the population relies on supplementary energy sources that consist of agricultural residues and cattle dung. About 90 % of rural households in Lesotho use biomass for thermal energy and cooking. Biomass consumption (wood, agricultural residues and cow dung) is the main source of domestic energy and energy in small-scale commercial sectors. The consequences of this dominance are the environmental degradation and increase in GHG emissions through reduction of the forest cover (GHG sink).

The main decision context of prioritising technologies considers the economic, political, social and technological environment that informs the technology prioritisation decision and is based on the climate change vision and the targets set by the Lesotho's NDC. According to Lesotho's NDC, the target is to implement policies that will result in approximately 35 % reduction of national greenhouse gas emissions in 2030. For energy, Lesotho will focus on

- Increasing the efficiency in the use of biomass in the traditional energy sector: Replacing cooking stoves with low thermal efficiency (5-10 %) with the higher efficiency (40 %) stoves.
- Increasing the efficiency in the modern energy sector, mainly of electricity
- Climate proofing investments in electricity power sector.
- Continuing to develop and promote uptake of renewable sources of energy, particularly wind and solar.

Clean and Efficient Cooking Technologies: As a means to mitigate and reduce the significant use of wood fuel in the country, there is need to address clean and efficient cooking through cookstoves in a substantive way to achieve the emission reduction in the energy sector while contributing to sustainable development. Inefficient biomass cookstoves and over fire cooking contribute directly to GHG emissions in the energy sector through emissions of methane and nitrous oxide, as well as emissions of carbon dioxide originating from biomass that is unsustainably harvested. Additionally, inefficient cooking contributes to health complications among the vulnerable population especially women and children and exacerbate gender inequalities. (Warwick and Doig, 2004) The efficient cookstoves reduce the amount of wood used and protect women from toxic chemicals produced by open fires and traditional stoves. There is also a need to increase awareness of improved cooking practices, increasing access to soft loans, building capacity of stove producers, and improving access to testing facilities. It is expected that the use of efficient cookstoves will significantly reduce emissions in the household and commercial sectors.

In rural areas that are not connected to the electricity grid, paraffin is a common fuel for lighting and cooking. While paraffin is described as a clean cooking fuel on par with LPG in terms of its potential to replace biomass in the 2007 IPCC assessment, the health impacts of paraffin cookstoves may be more severe than LPG cookstoves. When used in traditional paraffin stoves (Primus and Panda), paraffin leads to high indoor air pollution as well as to an increased risk of burns, fires and poisonings. Lesotho –being a net fossil fuel importer – also experiences negative macro-economic effects, foreign exchange and balance of trade, related to the import of paraffin.

Energy Efficiency and Conservation in Buildings (Residential, Commercial, Industries and Institutional)

The stakeholders pointed out the importance of energy-efficient structures for Lesotho in light of warming climate. It was noted that construction of buildings is generally influenced by the surrounding terrain, with little consideration given to how to minimize the demand for heating and cooling during the winter and summer, respectively. Additionally, the building designs do not include the possibility of adding solar water heaters or solar PV systems either as part of the original construction or at a later stage. Stakeholders observed that although there was a low level of skill for designing and constructing such buildings, there was a high interest in energy-efficient buildings in the country. The stakeholders wanted this technology option to be prioritised.

Energy Efficient Lighting and Appliances

Improving energy efficiency is the cheapest, fastest and most environmentally benign option to meet a significant portion of the Lesotho's energy needs. Energy efficiency measures for buildings, appliances and equipment can reduce the need for investment in energy infrastructure, lower energy bills, boost competitiveness and enhance consumer welfare. Numerous energy efficiency measures are already cost-effective, and they will pay for themselves over their lifetime through reduced energy costs. Energy efficiency options are generally characterised as having technical and cost barriers that are secondary to other barriers, such as lack of public acceptance, financing, information, education or appropriate incentives.

The main energy efficiency options that will have a significant energy reduction usage and are relatively easy to implement are LED lights, automatic lights controls and energy efficient appliances. *Low-energy halogen lamps, fluorescent-tube lights in combination with electronically controlled systems for dimming, and automatic shut-off are also readily available.*

Given the impetus by the government to increase access to electricity it is foreseen that the use of appliances and equipment will continue to increase in Lesotho. The use of inefficient appliances would lead to higher electricity demand. This demand can be suppressed by an increase in the efficiency of the appliances and the equipment used in Lesotho. This would also lead to reduction in the GHG emissions and contribute towards achievement of the NDC targets. However, the main barriers to achieve this are the lack of institutional capacity and regulatory frameworks. In addition, a financial mechanism must be established to facilitate deployment of energy efficient appliances and equipment.

Renewable Energy

Development of renewable energy is being recommended in most of the strategic energy and climate change mitigation documents in order to reduce the nation's dependency on imported fossil-fuel generated electricity from South Africa and Mozambique while addressing the issue of universal access to modern energy services. The demand for electricity will increase in Lesotho, but a shift towards renewable and more efficient energy source will moderate the ever-growing demand. Electricity power shortfalls, recent price increases and increasing threats from climate change highlight the need to diversify the country's energy mix and to alleviate the load on the electricity grid. In this regard, a number of national plans, initiatives and policy documents such as the NEP 2015 are being implemented to transform and diversify the energy sector. Concerns were raised on the risk of duplicating existing work, hence stakeholders felt that although *Solar PV: On-grid and off-grid* are in the highest priority, they are already the focus of Government and donor initiatives.

3.4 Overview of possible mitigation technology options in the Energy Sector and their mitigation potential and other co-benefits.

The energy sector is one of the most important sectors when it comes to climate change mitigation since it comes with other key co-benefits other than emission reduction like health benefits, job creation, increased access to energy for income generation and increased energy access for social upliftment as outlined in the SEforALL. In the face of climate change, the country also realises the need for energy efficiency technologies and the development of alternative energy sources to polluting fossil fuels.

During the first stakeholder consultation, a brainstorming session was conducted with stakeholder participation to list all known possible technology options that have mitigation potential and other co-benefits. The outcome of this session resulted in twelve technologies shown in Table 6. Feasibility of some of these options has been examined through national reports and from similar studies conducted in other countries and reports published by international organizations. In addition, estimations based on expert judgment were used when needed data were unavailable.

Table 5: Definitions of technology applicability and potential

Small-scale	Household and/or community level
Large-scale	Larger than household and/or community level
Short-term	Mature technologies which are already diffused in current market of Lesotho or which have been developed in Lesotho
Medium-term	Technologies which are pre-commercial in the current market of Lesotho but it would be available in full market in the next 5 years;
Long-term	Technologies which are needed to do R&D or are still in a phase of R&D or is a prototype;

Each of these technologies were reviewed extensively with stakeholders not so much in terms of their cost (capital, operation & maintenance) but more so on their viability given Lesotho's limited resources. This section provides an outline of the specific mitigation technology options identified for the Energy sector during the TNA process and elaborated in the preparation of the factsheets.

Table 6: Overview of mitigation technology options in Energy Sector with their benefits on climate change mitigation, applicability and potential

No.	Technologies	Climate Change Mitigation Benefit	Other co-benefit (Social, Economic, Gender)s		Applicability and Potential
1	Solar PV Mini-Grids: Off-Grid and On-Grid (up to 500 kW[4]	Lower GHG emissions lifecycle in the order of 30 to 70 gCO_2eq/kWh, as against more than 900 gCO_2eq/kWh for coal and more than 400 gCO_2eq/kWh for gas[5].	Can eliminate the need for candles, paraffin and/or battery charging, and provide increased convenience and safety, improved indoor air quality, and a higher quality of light than paraffin lamps for reading.	Reduce the need for expensive transmission lines and accessories for national grid linkup of far flung communities, and the need to import more electricity and petroleum products, as demands in rural Lesotho increase in the near future. Increase income generating activities, improve agricultural production, increase energy security;	Large scale, short term
2	Standalone Solar PV Systems with energy storage systems that can cater for AC loads.	Off-grid PV systems that are roof- mounted do not require additional land usage to for its installation; Solar PV systems are considered closed systems and hence require no fuel or any inputs during operation and electricity production. It also does not contaminate water; Solar PV systems cause no noise or vibration and hence considered environmentally friendly;	Tertiary institutions can benefit from offering technical programs relating to Solar PV systems. Increased income due to investment in Solar PV systems, employment through installation, maintenance, evaluation and monitoring of systems, and even training programs. Capacity development of locals through training and capacity building in the use and maintenance of solar technologies	Job creation for local technicians for the installation and maintenance of PV systems - This would require technical and manual labour, which would increase the workforce of Lesotho; Improvement in health, education and general livelihood of populations not served by the national grid; National Cost savings. Due to reduced imports of total petroleum products Lesotho would retain an otherwise outflow of currency.	Small scale, short term
3	Small hydropower plants: *off-grid and on-grid capacity up to 1 MW*	Produce no carbon dioxide during operation, thus significantly contributing to GHG emission reduction efforts; Decrease the use of wood and fossil fuels; In contrast to large-scale hydropower plants, small-scale plants barely alter the river flow; hence have few effects on the environment.	Water management services (flood & drought control) and supports tourism. The market potential of the micro hydroelectric facility will indirectly stimulate the local tourism market, enhance sustainable forest management and research	Increase income generating activities, improve agricultural production, reduce fossil fuel cost for electricity generation, increase energy security	Small-scale, short term
4	Efficient and Clean Cooking Technologies	Environmentally, efficient cooking stove reduce demand for fuel wood hence one of means of halting forest degradation. The saved forest from use of efficient cook-stove translates to reduction of GHG emissions through enhancing carbon sink.	Reduce drudgery time; Improve health and prolonged life expectancy of woman in the rural remote areas; More comfortable and safe so that it can reduce a number of accidents[6]	Increase doing productive activities, Create entrepreneurial opportunities, Job creation and income generation, Socially, efficient stove reduce indoor air pollution and improve health.	Small scale, short term Technology is proven and available in Lesotho. Market is undeveloped and production is low scale. Market can be

[4] Aslam et al. (2022)
[5] Kazem et al. (2023)
[6] Climate Tech Wiki. (2006). Improved cookstoves. Retrieved from http://www.climatetechwiki.org /technology/imcookstoves.

					improved if enabling environment is in place (awareness, financial incentives, policy and regulation, etc.)
5.	*Waste-to-Energy Recovery - Methane Capture from Landfills*	LFG capture projects aim at preventing the emissions of methane and other pollutants from landfills[7]	Environmentally safe waste management and disposal, clean electric power generation, reduces the volume of trash	Reduce land fill usage and land fill expansion, job creation, Increase electricity access; Reduce air pollution and water pollution, reduce GHG emission	Large-scale, long term
6	Substitution of Fuelwood with LPG at Household and Institutional Levels for cooking	LPG is a relatively cleaner fuel from the emission point of view than paraffin (107 900 kg CO_2eq/TJ for LPG versus 157 400 kg CO_2eq/TJ for paraffin, 112 000 kg CO_2/TJ for wood).	Income generation, reduce drudgery time, improve health and safety	Convenient to store and transport, time saving for cooking avoid respiratory problems	Small-scale, short term
7	Energy Efficient Lighting and Appliances (*Replacing incandescent lamps and fluorescent lamps with LED*)	More efficient appliances and lights use less electricity, reducing CO_2 emissions (*from electricity generated by fossil fuel power plants from SAPP*) for a safer climate. As a guideline, one candle emits around 12.5 lumens and a replacement LED saves around 0.091kg CO_2 per year based on a daily usage scenario of several hours per day.	Improve living standard, convenient to do livelihood activities, Reduce electricity bills	Improves indoor comfort, reduce consumers spending	Small-scale, short term
8	**Improved Public Transportation; Introduction of Bus Rapid Transit; Transport Management System;**	One bus carries more than 60 passengers which would, otherwise have been done by many small vehicles. GHG emission is reduced significantly in comparison to small sized vehicles An efficient public transport system could decrease the number of cars in the road thus reducing emissions from road transport	Reduced travel time, more reliable product deliveries, increased economic productivity, increased employment better work conditions Cheap fares; as people can travel cheaper, more efficiently, and faster.	This technology intervention seeks to improve the public transportation system through introduction of newer, cleaner and more comfortable buses with reduced carbon dioxide emission rates (CO_2 per mile). An additional spin-off effect would be the increased use of the public transportation system by private vehicle owners on a daily basis, that will reduce vehicle usage and as a consequence further reduce carbon emissions.	
9	Introduction of a Mix of Hybrid and Electric Vehicles (EVs)	There aren't any GHG emissions at all from these vehicles, only electrical energy is needed to run an EV, particularly if the electricity is generated using renewable energies	Hybrid vehicles consume much less fuel than other existing vehicles.	Due to the high prices of petrol/diesel, owners will save money using Hybrid vehicles since they consume little amounts of fuel	Large-scale, long term

[7] Climate Tech Wiki. (2011). Methane Capture at Landfills for Electricity and Heat. Retrieved from: http://climatetechwiki.org/technology/lfg_cap

10	Solar Water Heating - Domestic, Institutional, Commercial	It is considered that the delivery of SWHs could potentially reduce the overall national energy demand and the load at critical peak times of the day.	Income generation, reduce drudgery time, improve health and safety	Increase income generating activities, improve agricultural production, reduce fossil fuel cost for electricity generation, increase energy security	Large-scale, long term
11	*Production of Performance Based (CO_2 emission) Import Duties on Motor Vehicles [Vehicle Emission Duty)* / Restrict Age of Vehicle Imports to 5 Years	Reduce air pollution, reduce GHG emission	Reduce fuel bill, increase energy security, Reduce health risk	This technology intervention aims to change the way in which duties are charged on motor vehicles being imported. The main result of this project will be to modernize the way in which duty is charged so that it encourages the country's citizens to import more fuel efficient and less carbon emitting motor vehicles.	Large-scale, long term
12	Promotion of Energy Efficiency and Conservation in Buildings (Commercial, Industries and Institutional)	Especially in industry where heavy carbon fuel like coal is used, saved fossil fuel due to application of energy efficiency and conservation measures directly contribute to GHG reduction.	The saved fossil fuel and forests contributes towards environmental management in the area of improvement in outdoor air quality	Energy efficiency and conservation contributes to having power at all times, and thus social activities like health, education and security are discharged without interruptions. This contributes towards social development of a country	The technology could be applied in a short term

Information on these technologies was organized and tabulated in twelve technology factsheets, which have been finalized based on the mitigation consultant's experience. These factsheets contained information on the technology characteristics, potential of resources, potential of applications, cost, maturity, economic benefits and social benefits (Annex I).

3.5 Criteria and process of technology prioritisation for the Energy sector

The assessment of various technologies for the energy sector is based on their contribution to sustainable development by minimizing GHG emissions from the sector, maximizing the resilience of the sector to climate change impacts, maximizing development priority benefits in terms of environmental, social, economic and minimizing any negative consequences of the technology.

The energy sector was subdivided into four categories:

1. Clean and Efficient Cooking Technologies
2. Renewable energy promotion and development
3. Energy efficiency and conservation
4. Efficient and Improved Public Transportation.

For each of the identified technology under each category, Technology Factsheets (TFS) were elaborated and disseminated to a wide spectrum of researchers and experts from national and international institutions for review (Annex 1). These factsheets contained detailed information on technology characteristics, institutional and organization requirements, adequacy of use, capital and operational cost, advantages as well as barriers and challenges.

Prioritization of technologies was performed using the Multi-Criteria Analysis (MCA) approach. Prior to the MCA prioritization exercise, TFS were presented to all stakeholders of the Mitigation Sectoral Working Group. They were allowed some time to critically review and discuss them. Once the members of the group had reviewed, discussed and were satisfied with the TFS, a PowerPoint presentation was presented by the National Consultant for the Energy sector on the MCA process – the selection of criteria, the assignment of weights and proposed approach to scoring based on the decision context.

After extended discussions in terms of the country's development priorities, the criteria selected for prioritizing the Energy technology factsheets were based on three general properties, namely:

1. Costs / Anticipated Financing Needs;
2. Sustainable Development Benefits (Economic incentives, Social implications and Environmental aspects), and
3. Local Context.

These criteria were then inputted into the MCA Excel template.

For easing the process of calculating criteria weights, Financing Needs were broken down into:

a) Capital Investment, and
b) Operation and Maintenance (O&M) costs of the technology.

The Sustainable Development Benefits were demarcated into Economic incentives, Social impacts, Environmental aspects and/or corresponding impacts of their deployment, as well as climatic attributes mirroring performance of the specific technologies. To keep this in line with the national development priorities without compromising economic and industrial development,

a) Economic Benefits were subcategorized into (a) Job Creation Opportunities, (b) Ability to spur private investment and (c) Balance of Payment (Foreign exchange Savings), (d) Income Generation and (e) Cost savings /Efficiency to support other economic activities
b) Social Benefits were subcategorized into (a) Health and Safety Improvement (b) Improved Energy Security and (c) Potential for Gender Equity,
c) Environmental Benefits were divided into (a) CO_2 Reduction Potential and (b) Positive Local Environmental Impacts (Reduction in deforestation, water and air pollution and hazardous waste, Protection of biodiversity and natural resources)

In the Local Context, the key criteria were:

a) Market Potential, Replicability and Leverage, and
b) Market Potential and Acceptability to Local Stakeholders (Fit for purpose, Relative scale for impact, Ease of Implementation.

Likert scales were used to evaluate Job Creation Opportunities, Economic Activities, Energy Security and Reduction in deforestation and other environmental pollution (water, air, hazardous waste).

A performance matrix was constructed and the scoring carried out. During the national consultation, all the stakeholders involved in the energy sectors referred to the Technology Fact Sheets (TFS) and used their experiences to deliberate each of the criteria. The next step was the assignment of weights for each criterion. Weights were assigned using a participatory method where stakeholders took into consideration the importance of the criteria in the decision context. Stakeholders first allocated weights to the criteria categories and then later apportioned these weights to each of the criteria under the category.

Hence, a total of 15 criteria spanning 3 broad categories eventuated. The assigned weights for each criterion are presented in Table 7. Figure 10 illustrates the weights with respect to each category, and clearly shows that the benefits category has a larger influence on the selection of respective technologies. The Performance Matrix and Scoring Matrix were constructed based on Table 5.

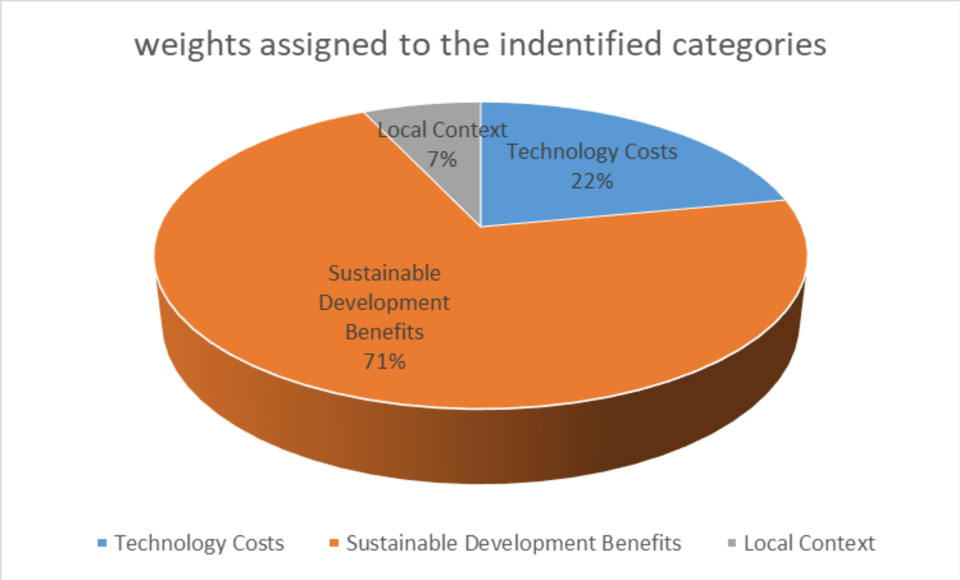


Figure 10: The weights assigned to the identified categories.

The scoring was the last step for deliberations. By consensus, members of the group agreed that the scoring matrix for each criterion's scores was from 1 to 5 where the most preferred option was assigned a score of 5, while the least preferred was given a score of 1 based on its importance as per local conditions, national priorities and mitigation potential. Hence, scores of 1 to 5 were given to each criterion during the evaluation of each technology using the MCA template.

Since the Performance Matrix consists of both quantitative and qualitative nominal data (from the Likert scales), these cannot be aggregated directly. Hence, a normalisation process was adopted whereby all nominal values were converted to scores in the range of 0 to 100. Particular attention was paid to preferred values together with benefits and costs, as the criteria that have higher preferred value need to have higher scores as well. Then the weights of each criterion were multiplied with the corresponding scores and aggregated across all criteria to ascertain the final scores. The technology options were ranked according to their total score, and the three best-scoring technologies were selected for further analysis. Finally, a sensitivity analysis was also carried out to confirm the results. During this process, the weights were varied to see if the ranking of the top three technologies would change. The purpose of sensitivity analysis is to remove any data uncertainties or differences in opinions that may have existed and thereby ensure that a small change in the weights does not bring about large changes in the technology rankings.

Table 7: Criteria category and the respective assigned weights

Level 1 Main Category	Category Weight (%)	Level 2 Criteria and description	Level 3 Sub-criteria and description	Unit	Data Source	Descriptions of Scores used in MCA process (%)	Individual Weight (%)
Costs This is the most important **criterion when** deciding which technology **to invest in** and how to **invest in it** to **achieve** the desired **outcome**[8]**.**	**22**	**Capital costs (infrastructure, etc.):** Fixed one-time cost for purchasing and setting up of the technology or equipment	**Capital Costs:** Technologies with less capital costs and positive return on investment (ROI) are the most preferable.	LSL / US$	Technology Providers, Operators	5 = Very Low; 4 = Low; 3 = Medium; 2 = High; 1 = Very High	10
		Operation and maintenance (O&M): Cost associated with the day-to-day operation and maintenance of the technology or equipment	**Operation and Maintenance Costs:** Technologies with less O&M costs are the most preferable.	LSL / US$	Technology Providers, Operators		12
Sustainable Development Benefits	**71**	**Economic benefits: Technology's** ability to improve **the** local **economy, promote** private sector **investment,** and create job opportunities / Technologies with proven private sector and donor interest, and a high number of potential investment Opportunities.	**Job Creation Opportunities and Sustainability:** Potential of technology to create job opportunities, thus reducing the rate of unemployment. - *Technologies that directly create jobs for the Basotho are ranked higher than those that result in temporary employment during construction*	High/Low	Expert Judgement (*based on international/ local case studies*), Research	5 = Very High; 4 = High; 3 = Medium; 2 = low; 1 = Very Low	10
			Balance of Payment: The potential of **technologies** to **help reduce** foreign **exchange expenditures, especially by** reducing material imports. **This** will **contribute** to stable and sustainable development and **reduce** imports.	High/Low	Expert Judgement (*based on international / local case studies*), Research		3
			Ability to Spur Private Investment: Technologies that directly support, **catalyze or encourage** private sector **engagement** in the energy sector are ranked **high / Technologies with proven private sector interest**	High/Low	Expert Judgement (*based on international / local case studies*), Research		5
			Income Generation: The potential of technology to be used to provide income for the user.				5
			Cost Savings/Efficiency to Support Other Economic Activities				5
		Social benefits – **Technology's** ability to reduce poverty and **inequality** between social **classes.** improve **people's health,** preserve cultural heritage.	**Increase Energy/Food Security**: Technologies that increase Lesotho's energy/food security (*reduces imports, increases reliability of energy supplies*) are ranked higher	High/Low	Expert Judgement (*based on international and local case studies*), Research	5 = Very High; 4 = High; 3 = Medium; 2 = low; 1 = Very Low	10
			Health and Safety Improvement: Potential to reduce health risks such as diseases or accidents - *Higher H&S improvement will result in higher score*.	High/Low	Expert Judgement (*based on international and local case studies*), Research		5
			Potential for Gender Equity: Technologies that directly promote gender inclusiveness, increase opportunities for women, and decrease the domestic burden on women are ranked higher	High/Low	Expert Judgement (*based on international and local case studies*), Research		5

[8] Capital and operational costing would ideally be done on the basis of respective projects and largely depends on the location, technology, suppliers, capacity factors, etc. Since specific data is not available, generic costs are used for the technology prioritisation process. The costs mentioned in the fact sheets are averages gathered from the suppliers, and it only includes generic product and installation. It does not cover the costs of feasibility studies, capacity building or training, etc.

		Environmental benefits – ability of the technology to protect the environment, biodiversity, reduce emissions, or emits less GHG compared to alternative	**GHG Emission Reduction Potential**: Very important and crucial criterion of technology assessment to mitigate the climate change and for future trends of GHG emission. Technology with higher GHG reduction potential will result the higher score.	High/Low	Expert Judgement (*based on international and local case studies*), Technology Providers, Research	5 = No Emission 4 = High Reduction 3 = Medium Reduction; 2 = Low Reduction; 1 = Low Reduction	10
			Adaptation Core Benefits	High/Low	Expert Judgement (*based on international and local case studies*), Technology Providers, Research	5 = Very High; 4 = High; 3 = Medium; 2 = low; 1 = Very Low	5
			Positive Local Environmental Impacts (Reduces deforestation, land degradation, water and air pollution, hazardous waste, Protects biodiversity and natural resources)	High/Low	Technology Specification, Research	5 = No or Very Limited Impact; 4 = Limited Impact; 3 = Medium Impact; 2 = High Impact; 1 -= Very High Impact	8
Local Context (*direct and indirect impacts that the technology may have in its value chain*).	7	Market Potential, Replicability and Leverage	Technologies that are marketable and can trigger additional projects	High/Low	Expert Judgement (*based on international and local case studies*), Research	5 = Very High; 4 = High; 3 = Medium; 2 = low; 1 = Very Low	4
		Acceptability to local stakeholders	Fit for purpose, Relative scale for impact, Ease of Implementation	High/Low	Expert Judgment, Research		3

The choice of the indicators is explained below to highlight the thought process of the stakeholders in the energy sector.

- **Job creation opportunities and sustainability:** The potential for the technology to create additional jobs; putting additional people to work. Technologies that directly create jobs for Basotho are ranked higher than those that result in temporary employment during construction ***- Due to national circumstances of high unemployment job creation was considered to be important.***
- **Foreign exchange** savings refers to the extent to which the technology can result in the country getting savings from reduced imports.
- **Increase security of supply:** Technologies that increase Lesotho's energy security (reduces imports, increases reliability of energy supplies) are ranked higher. ***On-grid technologies are ranked by the average resource capacity factor. Off-grid and distributed technologies that provide higher quality and more reliable energy to households are ranked higher*.**
- **Mitigation potential** refers to the total GHG emissions reduction potential of the particular technology option. Being the main objective of the TNA and TAP project, this criterion was considered to be the most important for this exercise. Proposed mitigation technologies would result in GHG reduction, though of different levels, as identified with each proposed technology.
- **Income generation** indicates the potential of that technology to be used to provide income for the user. This was included since some of the technologies could be used by low income groups for income generation purposes.
- **Gender Equity**: Promote gender inclusiveness, increase opportunities for women, and decrease the domestic burden on women are ranked higher - Stakeholders noted that some of these technologies are likely to be used mostly by women and therefore there must be something to address gender issues in these technologies.
- **Acceptability to local stakeholders**: The ease for that technology to be bought into or accepted by society. This criterion was considered important since there many technologies that have failed because they were not socially acceptable
- ***Ease of implementation (***(bearing in mind several factors like how complex it is, technical capacity of workers, institutional arrangements/governance, regulatory): *This includes aspects such as political, economic or cultural considerations that could either promote or present difficulties during the implementation of the technologies.*
- **Potential for local content**: Stakeholders also concluded that a strong social benefit of a technology would be its potential to integrate higher levels of local content. While increasing local content may imply increasing local jobs, it is a broader measure of the direct and indirect impacts that the technology may have in its value chain. Hence, a technology that has a stronger value chain in Lesotho would have a higher local content than a technology that is imported off the shelf from overseas (i.e. weak local value chain). It is measured on a relative scale based on the expert evaluation of stakeholders.

3.6 Results of technology prioritisation for sector the Energy Sector

Scoring was determined for each technology by stakeholders, facilitated by the energy consultant and national coordinator, and depicted in an Excel based worksheet designed using the Multi Criteria Analysis (MCA). The MCA was applied to score and rank the technologies.

Table 8 provides results for MCA performance matrix of each technology in the energy sector as scored by stakeholders. Table 7 shows results for MCA scoring matrix including assigned weights for all criteria. Table 8 provides results for MCA decision matrix of technology prioritization in the energy sector. Prior to being weighed, the scores were normalised on a MIN-MAX scale. Therefore, the final scores given in Table 8 are the product of the normalised scores and weights.

Table 8: Results of MCA Performance Matrix for Technologies in the Energy Sector

Mitigation Technology	Performance Matrix														
	Costs		Benefits											Local Context	
			Economic					Social			Positive Environmental Impacts	Climate Related			
	Capital (USD per MWh)	Operation & maintenance (USD per kW per year)	Job Creation Opportunities and Sustainability	Ability to spur private investment	Balance of Payment	income Generation	Cost Savings / Efficiency to Support Other Economic Activities	Potential for gender equity	Health and Safety Improvement	Increase Energy Security	Reduction of Deforestation and Environmental Pollution; Protection of Biodiversity and Natural Resources	GHG emission reduction potential	Adaptation Core Benefits	Market Potential	Acceptability to Local Stakeholders
Solar PV mini-grids: off-Grid and On-Grid up to 500 kW	4	2	3	5	4	5	4	4	4	3	4	5	4	5	2
Marketing and Subsidy of Clean and Efficient Cooking Technologies I: Improved Biomass Cookstoves	4	1	3	5	5	3	4	5	4	5	4	4	4	4	4
Energy Efficient Lighting and Appliances	3	1	1	5	4	3	4	5	5	4	4	4	4	5	4
Standalone Solar PV System with energy storage	3	2	1	5	4	3	4	4	4	4	4	4	4	4	4

that can cater for AC loads															
Marketing and Subsidy of Clean and Efficient Cooking Technologies II: Substitution of Fuelwood with LPG at Households and Institutions for Cooking.	3	3	1	5	1	4	1	4	3	4	3	2	4	5	4
Small-Scale Hydropower Plants up to 1 MW	5	3	2	4	4	3	3	4	4	4	3	3	3	3	3
Solar Water Heating - Domestic, Institutional, Commercial	3	1	2	5	4	1	4	5	4	4	4	4	4	4	4
Production of Performance Based (CO_2 emission) Import Duties on Motor Vehicles [Vehicle Emission Duty)	1	1	1	3	4	1	4	2	3	4	2	2	3	4	4
Improved Public Transportation, Introduction of BRT, Transport	4	3	1	4	4	1	4	4	4	3	3	3	4	3	3

Management System															
Waste-to-Energy Recovery - Methane Capture from Landfills	4	2	4	4	5	4	3	4	4	4	3	5	4	4	4
Marketing and Subsidy of Energy Efficiency and Conservation in Buildings - Commercial, Industries, Institutional, etc.	2	2	4	5	5	1	4	3	4	4	4	4	4	5	4
Introduction of a Mix of Hybrid and Electric Vehicles (EVs)	4	3	1	5	3	1	4	4	4	4	3	3	2	3	3

Table 9: Results of MCA Scoring Matrix for Technologies in the Energy Sector

Mitigation Technology	Scoring Matrix (For each criterion scores should vary from 0 to 100)															
	Costs		Benefits											Local Context		
	Costs		Economic					Social			Positive Environmental Impacts	Climate Related		Local Context		
	Capital (USD per MWh)	Operation and Maintenance (USD per kW per year)	Job Creation Opportunities and Sustainability	Ability to Spur Private Investment	Balance of Payment	income Generation	Cost Savings / Efficiency to Support Other Economic Activities	Potential for Gender Equity	Health and Safety Improvement	Increase Energy Security	Reduction of Deforestation and Environmental Pollution; Protection of Biodiversity and Natural Resources	GHG Emission Reduction Potential	Adaptation Core Benefits	Market Potential	Acceptability to Local Stakeholders	
Solar PV mini-grids: off-Grid and On-Grid up to 500 kW	25	50	67	100	75	100	100	67	50	0	100	100	100	100	0	
Marketing and Subsidy of Clean and Efficient Cooking Technologies I: Improved Biomass Cookstoves	25	100	67	100	100	50	100	100	50	100	100	67	100	50	100	
Energy Efficient Lighting and Appliances	50	100	0	100	75	50	100	100	100	50	100	67	100	100	100	
Standalone Solar PV System with	50	50	0	100	75	50	100	67	50	50	100	67	100	50	100	

energy storage that can cater for AC loads																
Marketing and Subsidy of Clean and Efficient Cooking Technologies II: Substitution of Fuelwood with LPG at Households and Institutions for Cooking.	50	0	0	100	0	75	0	67	0	50	50	0	100	100	100	
Small-Scale Hydropower Plants up to 1 MW	0	0	33	50	75	50	67	67	50	50	50	33	50	0	50	
Solar Water Heating - Domestic, Institutional, Commercial	50	100	33	100	75	0	100	100	50	50	100	67	100	50	100	
Production of Performance Based (CO_2 emission) Import Duties on Motor Vehicles [Vehicle Emission Duty)	100	100	0	0	75	0	100	0	0	50	0	0	50	50	100	
Improved Public Transportation, Introduction of	25	0	0	50	75	0	100	67	50	0	50	33	100	0	50	

BRT, Transport Management System																
Waste-to-Energy Recovery - Methane Capture from Landfills	25	50	100	50	100	75	67	67	50	50	50	100	100	50	100	
Marketing and Subsidy of Energy Efficiency and Conservation in Buildings - Commercial, Industries, Institutional, etc.	75	50	100	100	100	0	100	33	50	50	100	67	100	100	100	
Introduction of a Mix of Hybrid and Electric Vehicles (EVs)	25	0	0	100	50	0	100	67	50	50	50	33	0	0	50	
Criterion weight	**10**	**12**	**10**	**5**	**3**	**5**	**5**	**5**	**5**	**10**	**8**	**10**	**5**	**4**	**3**	**100**

Table 10: Results of MCA Decision Matrix for Technologies in the Energy Sector

Mitigation Technology	Decision Matrix: Weighted Scores															Total Score	Technology Rank
	Costs		**Benefits**											**Local Context**			
			Economic					**Social**			**Positive Environmental Impacts**	**Climate Related**					
	Capital (USD per MWh)	**Operation and maintenance (USD per kW per year)**	**Job Creation Opportunities and Sustainability**	**Ability to Spur Private Investment**	**Balance of Payment**	**Income Generation**	**Cost Savings / Efficiency to Support Other Economic Activities**	**Potential for gender equity**	**Health and Safety Improvement**	**Increase Energy Security**	**Reduction of Deforestation and Environmental Pollution; Protection of Biodiversity and Natural Resources**	**GHG Emission Reduction Potential**	**Adaptation Core Benefits**	**Market Potential**	**Acceptability to Local Stakeholders**		
Solar PV mini-grids: off-Grid and On-Grid up to 500 kW	250	600	667	500	225	500	500	333	250	0	800	1 000	500	400	0	**6 525**	**6**
Marketing and Subsidy of Clean and Efficient Cooking Technologies I: Improved Biomass Cookstoves	250	1 200	667	500	300	250	500	500	250	1 000	800	667	500	200	300	**7 883**	**1**
Energy Efficient Lighting and Appliances	500	1 200	0	500	225	250	500	500	500	500	800	667	500	400	300	**7 342**	**2**
Standalone Solar PV System with energy storage that can cater for AC loads	500	600	0	500	225	250	500	333	250	500	800	667	500	200	300	**6 125**	**7**
Marketing and Subsidy of Clean	500	0	0	500	0	375	0	333	0	500	400	0	500	400	300	**3 808**	**9**

and Efficient Cooking Technologies II: Substitution of Fuelwood with LPG at Households and Institutions for Cooking.																	
Small-Scale Hydropower Plants up to 1 MW	0	0	333	250	225	250	333	333	250	500	400	333	250	0	150	**3 608**	**10**
Solar Water Heating - Domestic, Institutional, Commercial	500	1 200	333	500	225	0	500	500	250	500	800	667	500	200	300	**6 975**	**4**
Production of Performance Based (CO_2 emission) Import Duties on Motor Vehicles [Vehicle Emission Duty)	1 000	1 200	0	0	225	0	500	0	0	500	0	0	250	200	300	**4 175**	**8**
Improved Public Transportation, Introduction of BRT, Transport Management System	250	0	0	250	225	0	500	333	250	0	400	333	500	0	150	**3 192**	**12**
Waste-to-Energy Recovery - Methane Capture from Landfills	250	600	1 000	250	300	375	333	333	250	500	400	1 000	500	200	300	**6 592**	**5**
Marketing and Subsidy of Energy Efficiency and Conservation in Buildings - Commercial, Industries, Institutional, etc.	750	600	1 000	500	300	0	500	167	250	500	800	667	500	400	300	**7 233**	**3**

Introduction of a Mix of Hybrid and Electric Vehicles (EVs)	250	0	0	500	150	0	500	333	250	500	400	333	0	0	150	**3 367**	**11**
Criterion weight	**10**	**12**	**10**	**5**	**3**	**5**	**5**	**5**	**5**	**10**	**8**	**10**	**5**	**4**	**3**	**100**	

Table 10 presents the top priority mitigation technologies in the energy sector with "Clean and Efficient Cooking Technologies (Improved Biomass Cookstove)" topping the list, followed by " *Energy Efficient Lighting and Appliances*". The third priority technology prioritized by the expert working group is "En*ergy Efficiency and Conservation in Buildings (Residential, Commercial, Industries and, Institutional).*

The three top prioritized technologies will be developed into technology action plans with further stakeholder engagement at a later stage in the TNA project. It is worth noting that the prioritized technologies do not deviate from the technologies identified by other climate change processes.

To test the robustness of the results relative to the weights and scores applied and other uncertainties, sensitivity analysis underpinned by selective and deliberative modifications / amendments of category and individual weight of costs, economic, social, environmental and climate related criteria was conducted. MCA results based on these modified criteria weights yield slight deviation in the total scores while maintaining the original technology ranking. These priority technologies will be taken to stage two of the TNA process which will involve analysing barriers to, and an enabling framework for their diffusion.

At first glance, some of the results that surfaced from the multi-criteria analytical exercises appear counter-intuitive, notably the strong performance of the Clean and Efficient Cooking Technologies vis-à-vis other technologies that stakeholders are more familiar with. Still, it is important to note that current rankings do not stop decision-makers from including those technologies in further technology assessments, or strategic deployment of specific technologies on different (management) scales.

In particular, it is also interesting to note that solar PV technology is not rated among the top three, despite the technology being recommended in most of the strategic energy and climate change mitigation documents. Although On-Grid and Off-Grid Solar PV Mini-Grid are in the highest priority in Lesotho, the stakeholders agreed that they are already the focus of donor and government initiatives.

Beyond mere ranking and numbers, it is important to note that this set of technologies broadly aligns Lesotho's development priorities, has the most potential to contribute to the primary challenges facing the energy sector. These results are also consistent with SREP Prioritisation which emphasized that the sector challenges cannot be overcome with a single resource or technology, but will require a mix of technologies.

Justification for Clean and Efficient Cooking Technologies

Energy efficient cooking and efficient lighting are the energy efficiency technologies with the highest scores. In addition to mitigation benefits, both have the potential for the largest social impacts and involvement of general population. In addition, efficient cooking technologies also have positive impact on forest resources of the country. As rural households overwhelmingly use biomass for cooking, the commercialization of Clean and Efficient Cooking Technologies contributes to preserving forest resources.

Development and implementation of clean cooking technology for households offer enormous promise to advance at least five Sustainable Development Goals (SDGs): 3. Good health and well-being; 5. Gender equality; 7. Affordable and clean energy; 13. Climate action; 15. Life on land.

These technologies have social benefits considering the effects of biomass on the majority of women and children. Clean and Efficient Cooking Technologies offer an immediate solution and have potential to reduce ailments related to indoor pollution resulting from use of paraffin and biomass for cooking while at the same time contributing to reduction of GHGs emissions.

Justification for Energy-Efficient Lighting and Appliances
Efficient electricity use promotes energy security, which lies at the heart of achieving Lesotho's economic and human development goals as well as many of the globally agreed SDGs. The use of efficient lamps often translates into significant savings in electricity costs. Analyzed across its entire lifecycle, an efficient lamp is a very cost-effective investment. However, the market price for CFLs and LED lamps is still higher than for traditional less efficient bulbs and motivating consumers to use efficient technologies may require diverse and creative ways of communicating the long-term benefits.

Justification for Energy Efficiency and Conservation in Buildings
This technology entails designing and constructing buildings to use the least amount of energy possible to keep occupants comfortable indoors. It also includes building structures that can house energy generation systems like solar PV and water heating. On a more complex level, it involves the installation of building energy management systems, which automatically regulate a building's energy usage. This technology was suggested by stakeholders who felt that there was need for the improvement of comfort inside buildings while saving energy and also mitigating climate change. The skills for design and construction of energy efficient buildings are very limited in Lesotho and stakeholders wanted Lesotho to be capacitated in this area.

During the MCA exercise, several technologies were judged by stakeholders as currently unsuitable for the Lesotho's conditions, in particular:

1. **Introduction of a Mix of Hybrid and Electric Vehicles (EVs):** Though electric mobility has proven itself as the future of transport, deployment of electrified vehicles that need to be plugged to the grid is difficult to achieve on the short and medium terms, as Lesotho is in deficit in terms of electricity generation. Currently the cost of EVs is high compared to comparable petrol and diesel versions, but the costs are reducing. Because there are no electrical charging stations, the electrical power in the country can't meet and satisfy the demand required by various sectors in Lesotho.

2. **Bus Rapid Transit (*within cities and between cities*)**: The stakeholders further deliberated on the priorities in the energy sector. It was noted that the efficient public transport option would be impossible to implement unless only between the two cities Maseru and Maputsoe, the reason being that there is no planning on how people are settled. People settle throughout the country randomly making it impossible for properly planned transportation services. The plans may also meet with resistance from incumbent transport operators who may feel the new system may threaten their businesses. The efficient public transport option although prioritised and the fact that it would be good if circumstances were different was removed by the stakeholders.

   There is no urban mass transport at this stage in Lesotho. Most people rely on cars to travel within cities. The rapid growth of vehicle ownership is mainly associated with the absence of mass transport. Thus, an energy efficient urban mass transport system would not only reduce GHG emissions, but also alleviate traffic congestion and improve local environment quality. Lesotho does not currently have vehicle emission standards, which results in highly polluting vehicles being operated on the roads. This has negative impacts not only on GHG emissions, but also on air quality standards in the cities.

3. **Waste-to-Energy Recovery - Methane Capture from Landfills:** The waste sector was also considered very important, in particular municipal waste. It was noted that current common method of handling waste was disposal in dumpsites. The organic waste in these dumpsites decompose and in the process releases methane into the atmosphere. Also, smaller towns still use open burning as a waste disposal method resulting in CO_2 emissions amongst other GHGs. It was also pointed out that municipalities are running out of landfill space and are finding it difficult and costly to get new landfill sites.

   Due to low collection rates and the inherent nature of the waste feedstock for WtE projects, securing sufficient waste feedstock for WtE projects is a highly problematic area for these types of projects. In particular, it is not as simple to secure long-term supplies of the feedstock as would typically be the case for coal, gas or oil. For this reason, a significant amount of up- front legal, regulatory and commercial due diligence needs to be carried out on the waste side of any WtE project in order to determine the viability and bankability of any such deal.

   Furthermore, solid waste incineration is the most inefficient and expensive way to produce electricity. Due to the low calorific value of waste, WtE plants convert less than 25 % of material energy in garbage into marketed electricity, even lower than other polluting systems – 35 % for coal and 45 % for natural-gas systems. Despite low energy production, incinerators are capital intensive. The general cost is twice the cost of coal-fired power plants. Operation and maintenance costs are also 10 times higher than coal. According to UNEP and International Solid Waste Association (ISWA), waste incineration is especially unfeasible for low and middle income countries due to its cost-prohibitive nature and unsuitable waste composition.[9] During the exercise, the Waste-to-Energy technology was by judged stakeholders as unsuitable for the Lesotho's conditions due to its high infrastructure requirements

4. The use of LPG will be constrained by the distribution system and collection of LPG cylinders.

[9] https://www.no-burn.org/wp-content/uploads/Ethiopia_factsheet_layout_SEP-7-2018.pdf

CHAPTER 4: TECHNOLOGY PRIORITIZATION FOR AGRICULTURE, FORESTRY AND OTHER LAND USE SECTOR

4.1. Overview of the AFOLU sector

Agriculture is a base of livelihoods as over 80 % of rural households in Lesotho depend on subsistence farming. Farming in the country is primarily rainfed and traditional with low inputs and output. As a result, Lesotho has not been able to produce enough for itself and relies on imports and food aid to supplement its food requirements. Although the share of agriculture to the GDP has declined from more than 15 % in the early 1980s to the current value of about 5 % (Oyaya, 1997; UNDP, 2021), the sector remains important in the country as it supports over 70 % of the rural population (UNDP, 2021). Animal farming is responsible for more than half of the agricultural share of the GDP. Nearly a third of the households in the country get their annual incomes from various activities related to subsistence production (BOS, 2019).

Lesotho's rugged landscape is only suitable for rangelands and livestock production as only 9 % of the national land area is arable. Grasslands, shrubs and agricultural land occupy 49.6 %, 19.1 % and 18.9 % of the land of Lesotho (LMS, 2020). Due to slopy landscape and shallow soils, soil erosion is a major challenge to national development and food security. Land degradation and poor land management make surface soil susceptible to both wind and water erosion. Arable land is not optimised as large areas of land remain fallow each season. There is also continuous conversion of productive rangelands and croplands to human settlements throughout the country. Nearly 70 000 hectares were cultivated with five major crops (maize, wheat, sorghum, beans and peas) during the 2018/19 agricultural season (BOS, 2020a). When managed efficiently and irrigation optimised, it is possible to produce adequate food for the country with the available land (Lesotho, 2018).

Agriculture is the main source of livelihoods in Lesotho as nearly a third of Lesotho's households get their income from subsistence farming (BOS, 2018). Livestock and their products are main agricultural inputs into the national GDP. According to the national Bureau of Statistics, there were over 360 thousand cattle in the country in 2018/2019 (Figure 11b; BOS, 2020b). The cattle during this season produced a total of 7.8 million litres of raw milk that were sold in the national local markets. Farmers sell about a third of their milk to the Lesotho Dairy Board and the other milk is sold informally from the farmers to the public. There were also 1.6 million sheep and 750 thousand goats in the country during this season. These small livestock export about 6.2 thousand tonnes of wool and 790 tonnes of mohair annually (Mokhethi et al., 2015).

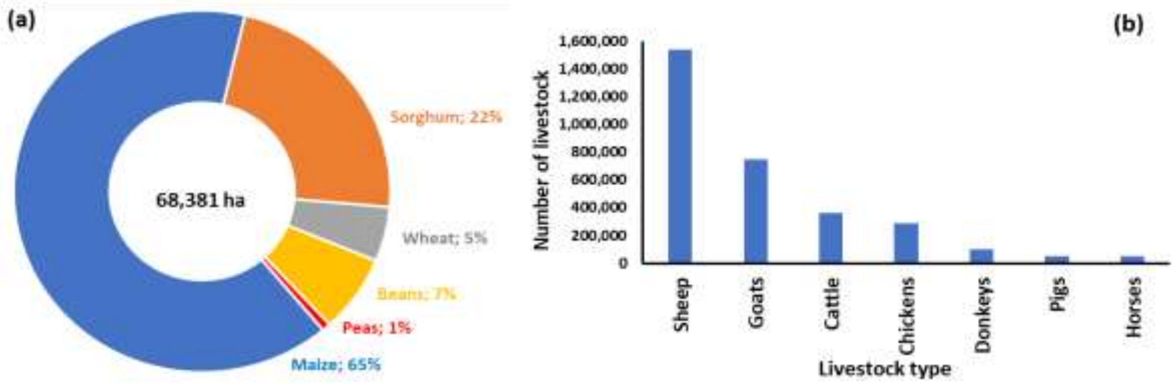


Figure 11: Agriculture production statistics during 2018/19 season in Lesotho (a) area planted to five major crops and (b) and livestock population

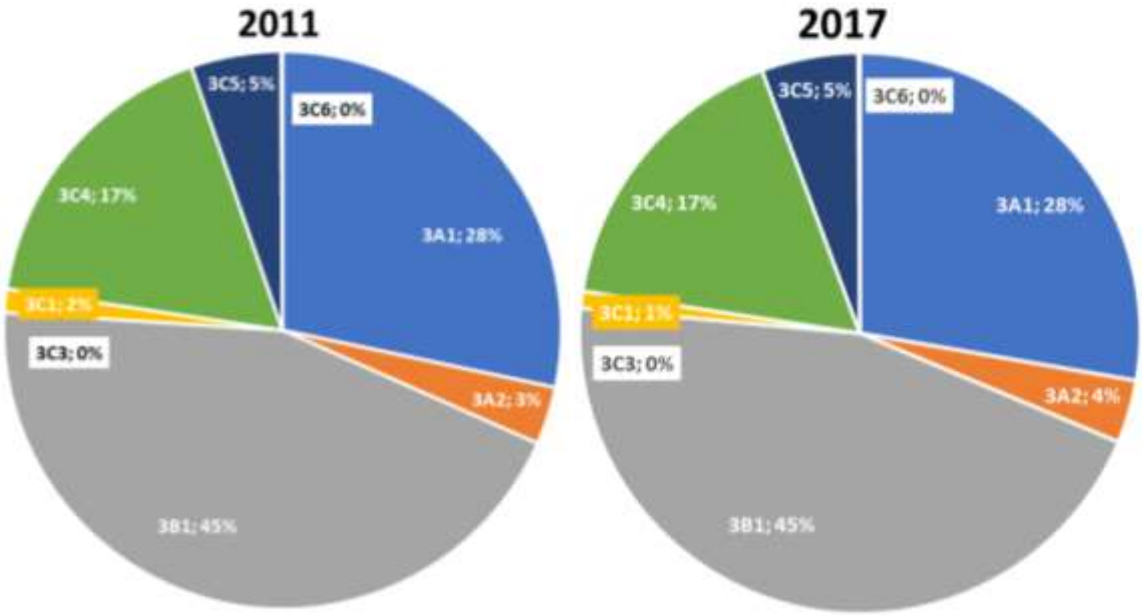
4.2. GHG emissions and potential for GHG reduction in the AFOLU sector

This section provides an overview of GHG emissions in the AFOLU sector and technologies that are being used to reduce the emissions.

4.2.1. Greenhouse gas emissions in the AFULU sector

Disaggregated profile of GHG emissions is crucial for mitigation planning. Emissions by source identify significant emitters that may need to be prioritized when planning for mitigation activities. In Lesotho, forest land and enteric fermentation are the main sources of emissions from AFOLU. Nearly half (45 %) of the emissions in the AFOLU sector are produced by forest land. They come from deforestation and degrading of shrub lands. Carbon loss due to high rates of soil erosion in the country remain a key challenge for the sustainability of the sector and livelihoods of Basotho. The second largest source of emissions is enteric fermentation (CH_4) from cattle, sheep and goats. Application of manure and lime during crop production contributes less than a quarter of the emissions.

Forest land is a major source of AFOLU emissions in Lesotho (Figure 12). These emissions are due to soil carbon loss because of forest degradation. Forest land in the country is dominated by shrubs. Emissions from forest land are followed by enteric fermentation from ruminant animals and managed soil. The breakdown of emissions has remained the same between 2011 and 2017.



3A1	Enteric fermentation
3A2	Manure management
3B1	Forest land
3C1	Biomass burning
3C3	Urea application
3C4	Direct N_2O emissions from managed soils
3C5	Indirect N_2O from managed soils
3C6	Indirect N_2O from manure management

Figure 12: Trends and GHG emissions by categories in the AFOLU in 2011 and 2017

Agricultural GHG emissions are increasing globally because of growing demand of food. Global livestock emissions have risen at a rate of more than 1 % per annum in the last two decades (Odhong et al., 2019). They are increasing despite gradual decline of emission intensities due to improving management systems and animal health. In southern Africa, the average intensity for dairy cattle is 102 g CH_4 per kg of milk produced, ranging from 25.5 g CH_4 per kg of milk in South Africa to 226 g CH_4 per kg milk in Madagascar (Balehegn et al 2021). National intensities are related to income levels that influence productivity with developed economies having better systems than those in emerging countries (Larborde et al., 2021). Identification and adoption of technologies that are suitable for production systems, socio-economic and ecological conditions in developing countries is therefore crucial (Balehegn et al 2021).

Being ruminants, cattle, sheep and goats are major sources of methane emissions in Lesotho and globally. Production and consumption of animal beef are highly carbon intensive. To produce a kilogram of beef results in between 23.4 and 27.2 kg of CO_2e emissions while the intensity of pork production is 4.6 kg CO_2e per kg produced (Gozalez et al., 2020). Consumption of protein from ruminant animals is nearly ten times more carbon intensive than alternative animal protein and more than 30 times more carbon intensive than vegetable protein (McKinsey, 2020). Consumption of beef products has highest intensity at 46 kg CO_2e per kg of protein when compared to 0.2 kg CO_2e per kg of wheat protein (McKinsey, 2020).

4.2.2. Existing technologies in the AFOLU sector

Lesotho being a landlocked country, engages in livestock and crop production. These farming activities are carried out on marginal soils in most parts of the country. There are technologies that are currently used in the sector.

Crop and forestry production in Lesotho

Traditional subsistence production systems are used for crop production in Lesotho. Farmers use tractors and oxen for ploughing. Population of the former is small and hardly meets demand during the beginning of the planting season. Sowing and weeding are predominantly done by oxen while application of pesticides and harvesting are done by hand. Transportation of items to and from the fields is achieved through the use of oxen and tractors. Irrigation is not common, despite the relatively good availability of water in the country.

Common crops grown in Lesotho are maize, sorghum, wheat, beans and peas. There are also small-scale forests and fruit trees that are grown throughout the country. Vegetables are produced in the homestead gardens, but use of greenhouse tunnels is increasingly becoming popular. Nearly two-thirds of crop land is used for maize production, followed by sorghum and wheat. Yields for all crops that are produced in the country are low. These crops are produced throughout the country under different agro-climatic conditions. Traditional mould ploughs, planters and weed removers that are all pulled by cattle and tractors are used during cultivation.

After every harvest there are crop residues that are either collected for firewood or left in the fields for animals to feed on especially in winter. This makes the land bare and without any above ground residues during the next planting season. Maize and sorghum produce most residues while wheat straws can also be used for roofing of traditional houses particularly in the highlands.

Lesotho is a least forested country. Patches of private forests are often planted along rivers and dongas to contain soil erosion and for provision of fuelwood. There are also communal woodlots under the management of local authorities in many locations. Although there were national campaigns to plant trees to increase forest cover over the past years, survival rates of the trees were very low. Eucalyptus, pines and poplars are common forest trees planted in the country. Although climate can be good for fruit production, there are no commercial orchards in the country, but fruit trees are found in the yards of the homesteads.

Livestock production in Lesotho

Traditional sheep, goats and cattle are main livestock types found in Lesotho. While nearly all cattle in the country are kept for meat and draught power, cows (58 % of total population) are also used to produce milk at very low yields. Sheep and goats are used for meat, wool and mohair production. Lesotho can produce and sell over 2.7 million kg of greasy wool per year (Cape Wools, 2020). Poultry farming and piggeries are small but growing industries in the country. They are commonly produced in homesteads for local markets.

Livestock depend on communal grazing lands, crop residues in winter and very little feed supplements. Feeding of animals is generally poor particularly in winter and during frequent drought periods. Cattle, sheep and goats are left to graze in the rangelands during the day and kraaled at night. This makes a split of animal manure into a fraction that remain in the pastures and that which accumulates in the kraals. The latter can be dried and used to make fire, spread in the fields and pastures as organic manure. Pasture production and supplementary feeding are not common practices in Lesotho.

Rangelands host many ecosystems that provide products and services that support livelihoods to many citizens. The highlands have wetlands that are rich with organic soils and sources of water and river systems. Rangelands also support growth of wild medicinal plants and eco-tourism activities. However, poor conservation and land degradation has resulted in a decline of services from the rangelands.

4.3. Decision context

The NSDP II has identified agriculture as one of the four sectors that have potential and therefore are prioritised to create employment to the masses that are jobless and to achieve inclusive economic recovery. These can be achieved through identification of appropriate technologies and attraction of the private sector to commercialise the sector.

The NCCP promotes climate-smart agriculture to achieve resilient crop and animal production systems and food security. Climate-smart agriculture will bring several many management practices that are not used currently in the country, and these include mulching and minimum tillage. The use of this technology is aimed to reduce vulnerability of the sector from climate variability and climate change, and to also prevent land degradation.

Both the NSDP II and the NCCP have promotion of irrigation technologies in their policy actions. Irrigation in Lesotho can be achieved through use of energy to pump up water from rivers and dams that may be in valleys down from the fields. Many locations in the country may have irrigation water available in river streams that need to be pumped up and brought to the fields. Water can also be harvested using dams and tanks. Many of irrigation systems have ceased to operate in the country due to lack of maintenance of the infrastructure and technical skills of the operators.

Land degradation continues to be a challenge which the GoL has battled with for many years. Land degradation happens in all forms of land use systems in the country particularly rangelands which is the largest land use type. The objective of the government through the NSDP II and the National Range Resources Management Policy is therefore to attain sustainable rangelands and biodiversity throughout the country. Rangelands are a host to wetlands that contain huge carbon stocks and play important role in water resource management in the country. Wetlands are often over exploited during droughts when water becomes scarce, resulting in their high levels of degradations.

The current policies encourage identification of new technologies that may improve productivity, food security and sustainable systems. Many of the current techniques are old, unsustainable and produce little returns. New technologies may be imported and adapted to conditions in Lesotho.

Main challenges in the sector include the following;

1. Land tenure system. The communal nature of the land use in the country and small pieces of land currently owned by the farmers are potential challenges that can limit the commercializing of the sector. For commercialization of the sector to be profitable and sustainable, large pieces of lands will be required and leased for long periods of time. However, current limitations in the land tenure system will risk viability of this objective.

2. Many of the farmers in the country are poor and may not afford buying equipment to improve their production methods.
3. Communal systems make management of rangelands and wetlands difficult especially during droughts when grazing areas are significantly reduced. Management policies are hardly adhered to.
4. Many of the technologies that are imported into Lesotho are often not fully adapted to local conditions. Training of practitioners and farmers is not adequate, repairs and maintenance are not usually planned for. This leads to technologies that do not reach their optimum potential. Many of these technologies end up being abandoned.

The main goals of the AFOLU TNA will be to identify the technologies that can achieve and advance national objectives. The identified TNA covers livestock, crops, land management and application of renewable energy resources in the sector. Although there are technologies that may need to be imported, many of the identified technologies are well known in the country but needs adequate promotion particularly for mitigation purposes. Many of these technologies bring with them, adaptation benefits and integrated approach that bring together several production aspects.

4.4. An overview of possible mitigation technology options in the AFOLU sector and their mitigation potential and other co-benefits

Greenhouse gas mitigation technologies in the AFOLU sector are identified from the interventions recommended in several national and sectoral plans. The selection of these technologies is based on their affordability, mitigation potential, adaptation co-benefits, scalability and adoptability to production systems in Lesotho. The table below links the policies, the SDGs and interventions that give rise to technologies that will be later recommended in this report.

Mitigation technologies are identified for both crop and livestock production systems. Ten (10) technologies are identified in the AFOLU sector. These technologies cover livestock and crop production systems as well as overall land management activities. These technologies are aligned to various national and sectoral policies and plans. This sub-section introduces these technologies.

Technology 1 - *Improvement of cattle production systems (breeds) in Lesotho*
Cattle are key sources of GHG emissions in the sector and the country. Cattle production in the country is under subsistence systems that are dominated by traditional breeds that are large in number and have low productivity levels. Improvement of breeds to the more productive animals will assist in decreasing the animal population, reduce pressure on rangelands and ultimately reduce the emissions. Improved breeds that are well fed can reduce GHG intensities while producing better yields. Improving management systems in modern agriculture have made GHG intensities to decline with time (Odhong et al., 2019).

Consumer dietary choices can provide the greatest GHG mitigation potential. Reduction of human consumption of beef products can influence a decrease in the number of beef cattle and reduce CH_4 (methane) emissions from enteric fermentation. The exchange of cattle protein for lesser carbon intensive animals and plant-based protein will, however, be difficult considering that it may be easier to produce cattle and sheep in the country than it is for other protein sources. Reduction of the numbers of cattle, sheep and goats is in general difficult considering the importance of these animals to the culture and livelihoods of the society in the country.

Technology 2 - ***Carbon sequestration through agro-forestry systems***

Agro-forestry systems involve combinations of crops, grasses, forests and trees. Crops and grasses for livestock are usually planted in the terraces between trees or forests. Successful agro-forests provide a carbon sequestration mechanism. Since Lesotho practices communal land tenure system, crop production per farmer is conducted on small pieces of land (average of 1 ha) farming. Crop production in the country is very vulnerable to climate change and climate variability. Probability of crop failure each year due to dry spells, droughts and floods is high. These climate hazards often result in poor harvests and poverty in the country. There is large land degradation throughout the country that is caused by poor land management systems on a hilly and mountainous landscape. Encroachment of settlement areas on agricultural land, bad ploughing techniques and overgrazing are main causes of land degradation.

Agro-forestry systems provide mutual benefits between the species that are inter-produced. They conserve soil moisture and reduce land degradation. They can provide increased crop productivity and are also used to support livestock production by planting of fodder in the systems. Trees can provide shade for plants beneath them.

Technology 3 - ***Small-scale biogas and homestead vegetable production in a mixed (crop and livestock) agricultural system***

Animal waste in the form of dung particularly that of cattle because it can easily be easily collected from homestead kraals to be used to produce biogas. Other animal wastes like that from poultry and piggery productions can also be used. These wastes are mixed with water and daily put into the biogas digesters that decomposes them to produce methane that can be collected or tubed to be used for cooking in the homes. The biogas slurry that comes out of the digesters can be used as manures in the gardens or fields. This technology converts methane that has higher warming potential to carbon dioxide when cooking.

Methane from animal manure can be harvested and used as biogas energy. Biogas digesters are an effective source of energy for remote farming households that may have few cattle that are kraaled at home in the evening. Small-scale dome digesters are more suitable in low-income regions, being relatively affordable for even midsize family farms (McKinsey, 2020). These domes can be built or prefabricated and bought to be installed on sites.

Technology 4 - ***Promotion of horticulture production through renewable energy irrigation scheduling and efficient fertilization (fertigation)***

Horticulture is a growing enterprise in Lesotho. This technology often requires high irrigation and fertiliser application. Due to the landscape of Lesotho, water resources are located in river streams and other water bodies that are down the valley and require energy to pump up the hill. Renewable anergy particularly solar can be used to pump this water for irrigation. The irrigation water can be mixed with fertiliser and channelled directly (fertigation) to the plant (i.e. drip irrigation) to maximize fertilizer placement and avoid waste. This technology has high productivity levels and reduces land degradation.

Technology 5 - ***Promotion of field irrigation system using renewable energy to improve productivity and reduce GHG emissions in Lesotho***

Field irrigation increases yields and improved productivity can reduce extensive agriculture that promotes encroachments to grasslands in search of croplands. The prevention of this land use change assists in reducing loss of soil carbon. Irrigation can be achieved by using renewable energy resources where required. Cropland in the country is very limited and further expansion exposes erodible soils in slopy terrains. Increasing of crop yields in current croplands can assist reduce land degradation and carbon loss.

Technology 6 - ***Improvement of livestock feed during dry seasons***
GHG emissions from livestock, especially ruminants, are highly influenced by poor feeding scheme. Poor feeds are commonly provided to animals particularly during dry seasons and major droughts. Depending on the choice of feeds, production of supplementary grasses and other form of feeds is important in that it can be healthy and more digestible. Improvement of feed digestibility is the key factor in reducing methane emissions from enteric fermentation.

Technology 7 - ***Production of biochar using crop straws, lablab, bamboos for crop fertilization***
Crop residues can be partially burned to produce biochar – a material that is similar to charcoal. Biochar is carbon-rich, highly porous and has increased surface area compared traditional crop residues. Application of biochar to cropping soils becomes a very effective carbon sequestration mechanism. Depending on the quantities produced or applied, biochar can be mixed with other inputs using available technologies or mass of it can be spread over the field.

Biochar can also be used to feed animals. Grinding crop residues into small pieces increases surface area, enhances microbial access to the substrate and make the small, crushed particles more digestible by animals. This reduces energy required for digestion, increases digestion efficiency and decreases methane production.

Technology 8 - ***Promotion of conservation agriculture (minimum tillage, mulching, retaining of crop residues)***
Conservation agriculture is a production system that promotes minimum soil disturbance, provision of mulch or soil cover, diversification of plant species and crop rotation. This technology improves soil carbon, assists in gradually reducing fertiliser application to the soil and conservation of soil moisture.

Soils have the second largest carbon pool after oceans (FAO, 2016). The land sector has a great potential to mitigate GHG emissions in Lesotho. The sector through application of conservation agriculture has a potential to sequester up to 35 $MtCO_2eq$ between 2010 and 2050 or approximately 1 $MtCO_2eq$/year (World Bank, 2019).

Retaining crop residues after harvest, and planting cover crops has co-benefits in that these practices improve soil organic carbon. Soil organic carbon improves water infiltration into the soil, water holding capacity of the soil and strengthens soil against droughts and floods. Conservation agriculture increases crop yields.

Technology 9 - ***Agro-Voltaic Farming***
This technology combines crop and solar energy productions. Through this technology, crops are produced underneath solar panels which has a benefit of reducing land use that would have been required when these activities were separated. This technology can benefit crops that prefer shaded environments for them to increase their yield. Beans have been shown to be one of such crops. This technology reduces land use change, land degradation and soil carbon loss. With increasing adoption of solar energy resources in the country, this technology can achieve multiple benefits.

Technology 10 - *Promotion of Biological and Organic farming*

Biological and organic farming involve improvement of natural soil chemical, physical and microbial activities. Through this technology, soil carbon, structure and overall fertility are improved. All these soil benefits assist in reducing fertiliser application while improving crop productivity. Reduction of artificial fertilization of crops results in reduced GHG emissions from crop production.

Table 11: Identified technologies, their mitigation potential and alignment to SDGs

No.	Technology	Mitigation potential	Ease of implementation	Timescale of implementation	Climate change adaptation co-benefits	Alignment to Sustainable Development Goals
1	Improvement of cattle production systems (breeds) in Lesotho	Medium Reduction. 5-15 %	Difficult	Long term	This technology can lead to reduced livestock population. This will improve conditions of rangelands, reduce land degradation, improve soil and water conservation.	**12.** Implement the framework of programmes on sustainable consumption and production, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries
2	Carbon sequestration through agro-forestry systems	Medium reduction. 5-15 %	Medium	Immediate	Improves soil fertility and soil moisture conservation. Mixed production systems can increase land productivity.	**15.** Ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development
3	Small-scale biogas and homestead vegetable production in a mixed (crop and livestock) agricultural system	Medium reduction. 10-13 %	Medium	Immediate	Biogas slurry can be used as manure in the gardens and fields. Provides renewable energy and improves food security.	**7.** Affordable and clean energy. **15.** Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
4	Promotion of horticulture production through renewable energy irrigation scheduling and efficient fertilization (fertigation)	Medium reduction. 5-15 %	Medium	Mid-term	Provides renewable energy to the farm. Improve productivity and availability of food resources.	**12.** Implement the framework of programmes on sustainable consumption and production, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries
5	Promotion of field irrigation system using renewable energizes to improve productivity and reduce GHG emissions in Lesotho	Medium reduction. 5-15 %	Medium	Mid-term	Provides renewable energy to the farm. Improve productivity and availability of food resources.	**12.** Implement the framework of programmes on sustainable consumption and production, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries
6	Improvement of livestock feed during dry seasons	Medium reduction. 5-15 %	Medium	Mid-term	Improved feeds increase productivity and animal health.	**12.** Implement framework of programmes on sustainable consumption and production, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries
7	Production of biochar using crop straws, lab-lab, bamboos for crop fertilization	High reduction. > 15 %	Difficult	Mid-term	Improved soil fertility increases yields and overall food security	**15.** Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
8	Promotion of conservation agriculture (minimum tillage, mulching, retaining of crop residues)	High reduction. > 15 %	Easy	Immediate	Improves mulching, soil carbon and soil moisture retention. Reduces impacts of droughts and floods.	**12.** Implement framework of programmes on sustainable consumption and production, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries
9	Land rehabilitation using agro-voltaic farming	Medium reduction. 5-15 %	Easy	Immediate	Reduces water demand of the crops. Increases yield and food security, renewable energy to the farming system and it can rehabilitate degraded land.	**7.** Affordable and clean energy. **9.** Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
10	Promotion of biological and organic farming	High reduction. > 15 %	Medium	Mid-term	Improves soil fertility. Improves soil water conservation. Improves crop yields.	**15.** Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

4.5. Criteria and process of technology prioritization for AFOLU sector

Stakeholders in the AFOLU sector were invited to a workshop to score and prioritize the ten identified technologies. Through engaging each other and discussing these technologies, the stakeholders assigned scores to each of the technologies. The scores were classified into three main categories (i) costs, (ii) benefits (economic, social, positive environmental impacts, climate benefits) and (iii) local context (market potential and acceptability to local stakeholders). These categories were further classified into criteria and sub-criteria. The stakeholders assigned weights which they applied to the scores so that the overall ranking of the technologies could be achieved. The categories and weights used in the AFOLU sector are the same to those used in the Energy sector.

Table 11: Technology scoring categories, criteria, and weights

Categories	Criteria	Sub-criteria	Weights (%)
Costs	Costs	Capital (USD per unit of measure)	**10**
		Operation and maintenance	**12**
Benefits	Economic	Job Creation Opportunities and Sustainability	**10**
		Ability to spur private investment	**5**
		Balance of Payment	**3**
		Income generation	**5**
		Cost savings/efficiency to support other economic activities	**5**
	Social	Potential for gender equity	**5**
		Health and Safety Improvement	**5**
		Increase Energy Security	**10**
	Positive Environmental Impacts	Reduction of deforestation, Environmental pollution, Protection of Biodiversity, Natural Resources	**10**
	Climate Related	GHG emission reduction potential	**5**
		Adaptation co-benefits	**8**
Local Context	Local Context	Market Potential	**4**
		Acceptability to local stakeholders	**3**
TOTAL			**100**

4.6. Results of technology prioritisation for AFOLU sector

The scoring of technologies resulted in overall low values for cattle production systems and the highest value for carbon sequestration through agro-forestry systems. The former generally obtained low scores in costs, economic and social benefits while the latter had high scores consistently. Three technologies that obtained highest overall ranking after applying weights are; (i) Small-scale biogas and homestead vegetable production in a mixed (crop and livestock) agricultural system, (ii) Carbon sequestration through agro-forestry systems and, (iii) Promotion of conservation agriculture (minimum tillage, mulching, retaining of crop residues) as shown in Table 14. These technologies present a mix of land management, renewable energy production as well as crop and livestock improvement systems. This suggests that if well conceptualised during project development and implementation, the three technologies have a potential to encompass many of the other technologies.

Prioritized technologies can be implemented in many environments in the country. This is because they are diverse in nature and cover several agricultural activities. They are also not completely new in the country. They have been promoted and implemented at different capacities in the country and their adoption and penetration into the local market can be high. It becomes important therefore, to identify barriers that have prevented these technologies to reach their true potential in the country in the past. These barriers will need to be addressed efficiently.

The identified technologies can be implemented immediately without major capital costs. Although benefits of conservation agriculture may be realized in the longer term, agroforestry and biogas digesters can achieve both their mitigation and adaptation co-benefits fairly quick. Reduction of methane by burning it in a biogas system can decrease GHG emissions in a short space of time while also producing renewable energy and manure for crop production. Agroforests can sequester emissions and produce food and land benefits including prevention of land degradation in the short term.

Table 12: Performance matrix for identified technologies in the AFOLU sector

Mitigation Technology	Performance Matrix														
	Costs		Benefits											Local Context	
			Economic					Social			Positive Environmental Impacts	Climate Related			
	Capital cost	Operation & maintenance	Job Creation Opportunities and Sustainability	Ability to spur private investment	Balance of Payment	Income generation	Cost savings / efficiency to support other economic activities	Potential for gender equity	Health and Safety Improvement	Increase Energy Security	Reduction of deforestation, Environmental pollution, Protection of Biodiversity, Natural Resources	GHG emission reduction potential	Adaptation co-benefits	Market Potential	Acceptability to local stakeholders
Improvement of cattle production systems (breeds) in Lesotho	4	4	1	2	1	4	3	1	2	2	4	5	4	5	3
Improvement of livestock feed during dry seasons	5	5	2	3	4	3	1	3	1	2	4	4	4	5	4
Carbon sequestration through agro-forestry systems	2	1	2	2	1	3	3	3	5	4	5	5	4	5	4
Promotion of conservation agriculture (minimum tillage, mulching, retaining of crop residues)	2	1	2	3	2	3	4	4	4	1	4	5	5	5	2
Small-scale biogas and homestead vegetable production in a mixed (crop and livestock) agricultural system	3	2	3	4	3	3	4	4	4	4	4	5	5	3	2
Promotion of horticulture production through renewable energy irrigation scheduling and efficient fertilization. (fertigation)	4	3	4	4	2	4	4	3	5	2	4	4	5	5	5
Promotion of field irrigation system using renewable energizes to improve productivity and reduce GHG emissions in Lesotho	5	5	2	3	3	4	4	4	4	4	3	5	5	5	5
Production of biochar using crop straws, lablab, bamboos for crop fertilization	5	2	4	4	1	3	3	3	3	4	4	5	4	3	2
Promotion of Biological and Organic farming	3	3	1	3	3	4	4	4	4	3	5	5	4	5	4
Land rehabilitation using agro-voltaic farming in Lesotho	5	3	4	5	3	5	4	5	4	5	3	4	4	4	3

Table 13: Scoring matrix for identified technologies in the AFOLU sector

Mitigation Technology	Score Matrix														
	Costs		Benefits											Local Context	
			Economic					Social			Positive Environmental Impacts	Climate Related			
	Capital cost	Operation & maintenance	Job Creation Opportunities and	Ability to spur private	Balance of Payment	Income generation	Cost savings / efficiency to support other economic activities	Potential for gender equity	Health and Safety	Increase Energy	Reduction of deforestation, Environmental pollution, Protection of Biodiversity, Natural	GHG emission reduction potential	Adaptation co-benefits	Market Potential	Acceptability to local stakeholders
Improvement of cattle production systems (breeds) in Lesotho	33	25	0	0	0	50	67	0	25	25	50	100	0	100	33
Improvement of livestock feed during dry seasons	0	0	33	33	10 0	0	0	50	0	25	50	0	0	100	67
Carbon sequestration through agro-forestry systems	100	100	33	0	0	0	67	50	100	75	100	100	0	100	67
Promotion of conservation agriculture (minimum tillage, mulching, retaining of crop residues)	100	100	33	33	33	0	100	75	75	0	50	100	100	100	0
Small-scale biogas and homestead vegetable production in a mixed (crop and livestock) agricultural system	67	75	67	67	67	0	100	75	75	75	50	100	100	0	0
Promotion of horticulture production through renewable energy irrigation scheduling and efficient fertilization. (fertigation)	33	50	100	67	33	50	100	50	100	25	50	0	100	100	100
Promotion of field irrigation system using renewable energizes to improve productivity and reduce GHG emissions in Lesotho	0	0	33	33	67	50	100	75	75	75	0	100	100	100	100
Production of biochar using crop straws, lablab, bamboos for crop fertilization	0	75	100	67	0	0	67	50	50	75	50	100	0	0	0
Promotion of Biological and Organic farming	67	50	0	33	67	50	100	75	75	50	100	100	0	100	67
Land rehabilitation using agro-voltaic farming in Lesotho	0	50	100	100	67	100	100	100	75	100	0	0	0	50	33
	0=very high cost. 100 = very low cost	0=very high cost. 100 = very low cost	0= Very low --> 100= Very high	0= Very low --> 100= Very high	0= Very low --> 100= Very high	0= Very low --> 100= Very high	0= Very low --> 100= Very high	0= Very low --> 100= Very high	0= Very low --> 100= Very high	0= Very low --> 100= Very high	0= Very low --> 100= Very high	0= Very low --> 100= Very high	0= Very low --> 100= Very high	0= Very low --> 100= Very high	0= Very low --> 100= Very high

Table 14: Decision matrix for identified technologies in the AFOLU sector

Mitigation Technology	Ranking Matrix															
	Costs		Benefits											Local Context		TOTAL SCORE	RANK
			Economic					Social			Positive Environmental Impacts	Climate Related					
	Capital cost	Operation and maintenance	Job Creation Opportunities and Sustainability	Ability to spur private investment	Balance of Payment	Income generation	Cost savings / efficiency to support other economic activities	Potential for gender equity	Health and Safety Improvement	Increase Energy Security	Reduction of deforestation, Environmental pollution, Protection of Biodiversity, Natural Resources	GHG emission reduction potential	Adaptation co-benefits	Market Potential	Acceptability to local stakeholders		
Criteria weights	**10**	**12**	**10**	**5**	**3**	**5**	**5**	**5**	**5**	**10**	**10**	**5**	**8**	**4**	**3**	**100**	
Improvement of cattle production systems (breeds) in Lesotho	333	300	0	0	0	250	333	0	125	250	500	500	0	400	100	**3 092**	**9**
Improvement of livestock feed during dry seasons	0	0	333	167	300	0	0	250	0	250	500	0	0	400	200	**2 400**	**10**
Carbon sequestration through agro-forestry systems	1 000	1 200	333	0	0	0	333	250	500	750	1 000	500	0	400	200	**6 467**	**2**
Promotion of conservation agriculture (minimum tillage, mulching, retaining of crop residues)	1 000	1 200	333	167	100	0	500	375	375	0	500	500	800	400	0	**6 250**	**3**
Small-scale biogas and homestead vegetable production in a mixed (crop and livestock) agricultural system	667	900	667	333	200	0	500	375	375	750	500	500	800	0	0	**6 567**	**1**
Promotion of horticulture production through renewable energy irrigation scheduling and efficient fertilization. (fertigation)	333	600	1 000	333	100	250	500	250	500	250	500	0	800	400	300	**6 117**	**4**
Promotion of field irrigation system using renewable energizes to improve productivity and reduce GHG emissions in Lesotho	0	0	333	167	200	250	500	375	375	750	0	500	800	400	300	**4 950**	**7**
Production of biochar using crop straws, lablab, bamboos for crop fertilization	0	900	1 000	333	0	0	333	250	250	750	500	500	0	0	0	**4 817**	**8**
Promotion of Biological and Organic farming	667	600	0	167	200	250	500	375	375	500	1 000	500	0	400	200	**5 733**	**5**
Land rehabilitation using agro-voltaic farming in Lesotho	0	600	1 000	500	200	500	500	500	375	1 000	0	0	0	200	100	**5 475**	**6**

Table 15: Sensitivity matrix for identified technologies in the AFOLU sector

Mitigation Technology	Ranking Matrix																
	Costs		**Benefits**											**Local Context**		**TOTAL SCORE**	**RANK**
			Economic					**Social**			**Positive Environmental Impacts**	**Climate Related**					
	Capital cost	**Operation and maintenance**	**Job Creation Opportunities and Sustainability**	**Ability to spur private investment**	**Balance of Payment**	**Income generation**	**Cost savings / efficiency to support other economic activities**	**Potential for gender equity**	**Health and Safety Improvement**	**Increase Energy Security**	**Reduction of deforestation, Environmental pollution, Protection of Biodiversity, Natural Resources**	**GHG emission reduction potential**	**Adaptation co-benefits**	**Market Potential**	**Acceptability to local stakeholders**		
Criteria weights	**12**	**10**	**5**	**10**	**5**	**3**	**5**	**10**	**10**	**5**	**5**	**8**	**5**	**3**	**4**	**100**	
Small-scale biogas and homestead vegetable production in a mixed (crop and livestock) agricultural system	800	750	333	667	333	0	500	750	750	375	250	800	500	0	0	**6 808**	**1**
Carbon sequestration through agro-forestry systems	1 200	1 000	167	0	0	0	333	500	1 000	375	500	800	0	300	267	**6 442**	**3**
Promotion of conservation agriculture (minimum tillage, mulching, retaining of crop residues)	1 200	1 000	167	333	167	0	500	750	750	0	250	800	500	300	0	**6 717**	**2**
Promotion of horticulture production through renewable energy irrigation scheduling and efficient fertilization. (fertigation)	400	500	500	667	167	150	500	500	1 000	125	250	0	500	300	400	**5 958**	**5**
Promotion of Biological and Organic farming	800	500	0	333	333	150	500	750	750	250	500	800	0	300	267	**6 233**	**4**
Land rehabilitation using agro-voltaic farming in Lesotho	0	500	500	1 000	333	300	500	1 000	750	500	0	0	0	150	133	**5 667**	**6**
Promotion of field irrigation system using renewable energizes to improve productivity and reduce GHG emissions in Lesotho	0	0	167	333	333	150	500	750	750	375	0	800	500	300	400	**5 358**	**7**
Production of biochar using crop straws, lablab, bamboos for crop fertilization	0	750	500	667	0	0	333	500	500	375	250	800	0	0	0	**4 675**	**8**
Improvement of cattle production systems (breeds) in Lesotho	400	250	0	0	0	150	333	0	250	125	250	800	0	300	133	**2 992**	**9**
Improvement of livestock feed during dry seasons	0	0	167	333	500	0	0	500	0	125	250	0	0	300	267	**2 442**	**10**

CHAPTER 5: SUMMARY AND CONCLUSIONS

5.1. Three prioritized technologies in the Energy and AFOLU sectors

A summary of all six (6) prioritized climate change mitigation technologies is provided in Table 16. Those technology fact sheets that are not prioritized will not be rejected, but stakeholders in each sector can use those technology fact sheets to develop project concept papers to apply for funding from various sources. Prioritized technologies will be further explored through the Barrier Analysis and Enabling Framework protocol of the TNA process, the results of which will be used to develop a Technology Action Plan or TAP, (a strategic roadmap or portfolio) of technology concept projects ready for funding.

All of the prioritized mitigation technologies examined in this report are consistent with the medium- and long-term strategy of the Government of Lesotho to develop, adopt, and implement policies and measures/initiatives to reduce its carbon footprint, transition its development pathway from a fossil-based economy to cleaner, renewable energy use, and increase the nation's resilience to the unfavourable effects of Climate Change. The adoption of these technologies will also contribute to the 2nd National Strategy Development Plan's (NSDP II's) overarching objective, which combines medium-term economic growth, poverty reduction, and long-term sustainable development. The NSDP II, the country's main development strategy, outlines four Key Priority Areas for national development and an improved standard of living for its citizens both now and in the future.

Table 16: List of prioritized climate change mitigation technologies

Technology Option	**Rank**
Energy Sector	
Marketing and Subsidy of Clean and Efficient Cooking Technologies (Improved Biomass Cookstoves)	1
Energy-Efficient Lighting and Appliances	2
Marking and Subsidy of Energy Efficiency and Conservation in Buildings (Residential, Commercial, Industries and Institutional)	3
Agriculture, Forestry, and Other Land Use (AFOLU)	
Small-scale biogas and homestead vegetable production in a mixed (crop and livestock) agricultural system	1
Carbon sequestration through agro-forestry systems	2
Promotion of conservation agriculture (minimum tillage, mulching, retaining of crop residues)	3

To implement the priority technologies in the sectors, Lesotho will need to put in place enabling policy and strengthen institutions frameworks, attract significant international climate finance and investments across sectors, receive support in terms of capacity development and awareness creation for various institutions and stakeholders to achieve the desired results at scale.

5.2. Recommendations

Energy Sector

Some recommendations for the Energy sector, as outlined in the TNC 2022 and the NCCP 2017 to support the sustainable development of Lesotho are:

- Improve energy efficiency to dramatically lower energy intensities across key economic sectors. Some actions may include:
    - Improve energy efficiency in buildings and appliances.
    - Promote transition to sustainable transportation.
    - Develop appropriate financial and market-based mechanisms that support energy efficiency and renewable energy.

- Develop renewable energy to shift the energy matrix away from fossil fuels (especially oil) to alternative renewable energy technologies. The main action is:
    - Develop Lesotho's human, technological and institutional capacity to accelerate the uptake of appropriate clean energy and clean production technologies.

In the Energy sector, for example, the principal strategic elements of Lesotho's Sustainable Energy Strategy 2017:

- Energy efficiency, which involves interventions in:
    a) appliances and buildings; and
    b) transport.
- Renewable energy policy actions aim at shifting the energy matrix away from fossil fuels to alternative renewable energy technologies.
- Modernizing the electricity infrastructure.
- Universal access to modern energy services is an essential pillar of Lesotho's energy strategy. Universal access to electricity is critical for the socio-economic development of the nation, and is fundamental to lifting the living standards of the people of Lesotho.

Some recommendation for the Transport sector with regards to the prioritized mitigation technologies under the TNA project are:

Upgrade the road maintenance system countrywide.

- Improve road safety ─ road infrastructure, bridges and stream-crossings, behaviour of drivers and road worthiness of motor vehicles, to name a few areas for improvement.
- Formulate and implement a Sustainable Transport policy to reduce economy-wide fuel intensity.
- Promote energy efficiency in the transport sector through appropriate policies and investments. These improvements should include:
    - Undertaking a traffic management study aimed at reducing traffic congestion in all urban areas
    - Improving public transportation

Agriculture, Forestry and Other Land Use (AFOLU)

The general objective in the ***Agriculture, Forestry and Other Land Use*** sector is a national land use strategy that promotes minimal impact of land use on the country's forest ecosystems and services, and the enhances Lesotho's forests carbon sequestration capacity in the medium and long-term. Some recommendations to this end include:

- Increase public budget allocation for reforestation and restoration of degraded forests.

- Upgrade the institutional capacity of the Forest and Agriculture Departments to promulgate agroforestry and forest management across Lesotho.
- Enhance the synergies between line ministries and the private sector to increase tree cover through agroforestry, urban forestry and tree planting in the rural landscape.

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ANNEX I: TECHNOLOGY FACTSHEETS FOR SELECTED TECHNOLOGIES

Energy sector

Technology 1: ***Solar PV mini-grids: Off-Grid and On-Grid up to 500 kW***

Sector	Energy: *Reducing emissions through increased low-emission energy access and power generation*
Sub-sector	Residential and Commercial
Technology name	Solar PV Mini-Grids: Grid-Connected and Off grid up to 100 kW (Community Based Electrification)
Sectoral GHG emission	• In 2017, Lesotho's total GHG emissions were approximately 5 660.44 Gg (5.66 million tonnes (Mt)) of CO_2 equivalent (CO_2eq), the energy sector being the main source of emissions, accounting for 2 861.17 Gg CO_2eq (50.5 %). • Residential sector was the largest contributor to Lesotho's energy sector emissions accounting for 1 900.86 Gg CO_2eq (66.3 %)[10]
Background/Notes, Short descriptions of the technology options	Solar photovoltaic, or simply photovoltaic (SPV or PV), refers to the technology of using solar cells to convert solar radiation (light) directly into electricity. Solar panels are limited to only produce electricity in periods of sunlight, direct, diffuse sunlight (on overcast days) and reflected. During the night they will not produce power. This means that solar cells, if used for remote/off-grid generation purposes, need to be implemented in conjunction with some kind of storage system such as a battery or as a hybrid system with some other type of generator. Where solar cells are grid-connected, this is less of a problem. They can be used during the day to reduce the local demand from the grid (or even to export back to the grid) and then at night, or during periods of the low incident light, the grid can supply the necessary power. The former kind of application, as a remote or off-grid generator, is most commonly observed in developing countries and in Lesotho, this could be easily implemented in remotely located communities where grid extension would not be feasible. The community-based electrification – Mini-Grids are deemed more stable and versatile for powering a small community's 24/7 electricity demands. The system generally includes tilted solar photovoltaic (PV) modules, inverter, storage systems, and outlets for AC appliances like television, radio, fans, laptops and charging of mobile devices. A SPV system of installed capacity in the range of 10 kW to 100 kW would likely be sufficient, depending on the respective community energy needs, however a full feasibility study is recommended. The device that converts the solar radiation into electricity is in the form of flat panels. The most efficient solar panels on the market today have efficiency[11] ratings as high as 22.8 %, whereas the majority of panels range from 16 % to 18 % efficiency rating. The average amount of electricity produced per m^2 of modern solar panels in Lesotho is around 1.1 kWh/ day, or 1.4 kWh/day for 20 % efficient panels. For example, the average daily power production that can be generated from a soccer field of size 105 m x 68 m = 7140 m^2 (*size of Setsoto National Stadium*) is 9 996 kWh/day of electricity,

[10] LMS, 2021. Lesotho's 4th GHG Inventory Report. Lesotho Meteorological Services. Maseru, Lesotho.
[11] Solar panel **efficiency** is a measure of the amount of sunlight (irradiation) that falls on the surface of a solar panel and is converted into electricity.

	assuming 20 % efficiency panels. Such an amount of electricity can power up to 41 650 households with 4 light bulbs (15 W/bulb Compact Fluorescent Light - CFL) for up to 4.5 hours. In spite of significant decreases in the cost of solar PV systems, the majority of PV deployment is still driven by donations and substantial subsidy schemes.
Implementation assumptions, *How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.*	The suitable unobstructed land area needs to be acquired within the vicinity to have the solar PV arrays installed. System sizing and proper feasibility will be carried out for the electricity need of the community prior to the implementation of the technology. Solar power generation has been limited to installation of rather small solar PV systems at homes and small establishments in rural and off-grid areas. The Government of Lesotho is aware that despite limitations, there may be scope for power generation based on solar energy. The plants may be put up by the private sector with either a license to distribute to off-grid customers or a contract to sell the electricity to Lesotho Electricity Company for grid-connected systems.
Country Specific Applicability and Potential	Lesotho experiences some of the highest levels of solar radiation in the world[12]. Average daily solar radiation varies between 3.2 and 7.0 kWh per square meter per day, with global horizontal irradiation in excess of 5.3 kWh/m^2/day in most parts of the country compared to about 3.6 kWh/m^2/day for most parts of the USA, and about 2.6 kWh/m^2/day for most parts of Europe[13]. Lying between latitudes 28 and 31 in the south, it has the advantage of long hours of sunshine and more than 300 days of sunshine. Average sunshine hours range from 10.2 to 13.8 hours per day with more than 80 % of solar radiation coming as direct radiation because of limited cloud coverage and clear sky (no pollution). Lesotho is thus a suitable country for the development of solar-based technology as a viable alternative to conventional energy sources, yet site-specific feasibility studies are important. Therefore, significant potential exists to develop and install solar farms using PV power systems for integration into the national grid.
Status of technology in country	Solar PV technology has been popular in Lesotho especially in rural areas where electrification rate is low compared to city areas. Based on lessons and experience for grid-connected solar PV in South Africa, application of large-scale PV is feasible in Lesotho. There is already one solar PV grid tie system in Lesotho: a 281 kW small solar installation at the Moshoeshoe I International Airport used primarily to serve the airport's electricity demand during the day. This system does not have storage capability and excess power generated flows back to the national grid. Two large-scale PV plants are being constructed at Ha Ramarothole village in Mafeteng district: a 20 MWp by local private developer (OnePower Lesotho (Pty) Ltd) and a 30 MW by Lesotho Government. The two plants are planned for commissioning in third quarter of 2022. There is also a privately financed 50 kW installation at Ha Makebe village, a 40 kW installation at Thaba-Bosiu village, 'Mamohato Children's Centre (Sentebale), 25 kWp installations at BBCDC in Bethel and seven remote rural health facilities (not served by LEC) - Ha Nkau, Bobete, Manamaneng, Tlhanyaku, Ketane, Methalaneng and Lebakeng.

[12] Huld T., Šúri M., Dunlop E., Albuisson M, Wald L (2005). Integration of HelioClim-1 database into PVGIS to estimate solar electricity potential in Africa. Proceedings from 20th European Photovoltaic Solar Energy Conference and Exhibition, 6-10 June 2005, Barcelona, Spain, http://re.jrc.ec.europa.eu/pvgis/

[13] Gaismaq, http://www.gaisma.com/en/location/maseru.html

Technology characteristics	Given the dispersed nature of rural populations and low densities, electricity access will have to be accomplished using a combination of grid extension, mini- and micro-grids, and stand-alone systems. The formulation of the Electrification Master Plan 2018-2028 has mapped the population distribution in relation to the MV grid network and characterized the distribution of population by density and identified the population best served by extending the LEC grid, served through mini-grids and those best served through solar PV micro-grids and stand-alone systems. The mini-grids may be powered by a range of energy sources, such as small hydro, solar, wind and hybrids. Solar PV Mini-grids are small-scale isolated distribution network with a centralized power generation source. The installed capacity typically comprises a range between 10 kW to 200 kW and can serve customers in communities from 50 to 1 000 households or more. In order to store the electricity, the mini-grid system shall include a battery, a power conditioning unit (PCU) consisting of junction boxes, charge controllers, inverters, distribution boards and necessary wiring/cabling. All located within a container or purposely constructed building, transmission system and distribution system according to the Lesotho Grid Code Standards to carry power to individual houses and other consumers. The main advantage of off-grid of solar PV mini-grids is that it can operate in isolation from national power grid and supply free-of-blackouts-energy to remote concentrated households and productive use customers at mains voltage levels (220 VAC/50 Hz).
Market potential	There are approximately 1 000 **schools**, 100 health facilities, 6 – 8 **Agricultural Resource Centers**, located in various Areas of each district, several small businesses, churches, and public buildings that lack electricity service. These community facilities can be anchor loads to enhance the commercial viability of rural electrification. Solar energy also presents great development opportunities in Lesotho. Opportunity for selling excess power to neighboring countries. In the last two decades the global solar PV market has experienced rapid expansion, with an average annual growth rate of 40 %. An annual growth rate of 17 % is forecast over the next decades[14]. There is a high potential for community-based micro/mini-grids and grid connected solar photovoltaic systems in Lesotho. Currently, there are two companies that are seriously considering installing on-grid solar PV plants. One aims at producing 20 MW and the other 70 MW. A private developer is rolling out energy infrastructure in 10 concessional service territories using solar PV hybrid mini-grids ranging in size from 12-200 kW that will provide prepaid cost reflective electricity service to rural customers. The developer is leveraging UNDP subsidy and debt and equity capital from UK and EU to introduce approximately 1.8 MW of solar capacity across these areas.
Financial requirements and costs	The levelized cost of grid connected PV electricity generation in the region is just below LSL 1 per kWh whereas for privately financed off-grid PV minigrids with storage and reticulation, a levelized cost of electricity inclusive of market capital cost for debt and equity is closer to 5 LSL per kWh. The national tariff retail rate is 1.6235 LSL/kWh. A recently financed minigrid portfolio in Lesotho will deploy 1.8 MW of solar PV for 7 300 connections at costs of 24 000 LSL per connection. An injection

14 Future of Solar Photovoltaic *Deployment, investment, technology, grid integration and socio-economic aspects. Available at: https://irena.org/-/media/Files/IRENA/Agency/Publication/2019/Nov/IRENA_Future_of_Solar_PV_2019.pdf*

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<td>of subsidy can be leveraged to buy down the asset owner’s capital cost of minigrids with benefits passed through to consumers via lower tariff, or alternately to stabilize demand and minigrid revenues via direct subsidy of consumption through transfers to rate payers (such as free basic electricity or lifeline tariff). The payback period for solar minigrids is typically over 8 years, while the lifetime of solar PV equipment is about 25 years, with an O&M cost, estimated at 2 % of capital cost per year.
<table>
<tr><th>Off-Grid System Type</th><th>Service Level</th><th>Estimated System Cost (Maloti)</th></tr>
<tr><td>Solar PV Mini-Grid (150 kWp solar PV array, battery storage, inverter bank, distribution network)</td><td>Lighting, standard AC appliances like fridge, TV, DVD, lap top, etc. and productive uses of electricity.</td><td>10 050 000</td></tr>
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A 1 000 kW (equivalent to 1 MW) solar panel system will cost at least US$1 million, typically around US$1.15 million.
With all the equipment and space between panel rows, a 1 MW solar farm typically needs 6–8 acres
Depending on the size of the solar project and the number of people working on it, construction on a solar farm can be completed in a matter of months.

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<tr>
<td>Implementation barriers</td>
<td>
High initial cost of development, installation, maintenance and repairs.
Competition from grid power which is highly prioritized and subsidized compared to off-grid
High cost reflective tariffs.
Locating solar farms and transmission lines requires negotiations, permits contracts and community approval which increase the cost and duration of the development of projects.
Tedious licensing procedures which were designed for large generation and distribution projects.
Difficult in securing financing for small-scale projects.
Lack of Standards and Quality Assurance:
Unpredictable extension of the grid.
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<td>Reduction in GHG emissions</td>
<td>Uptake of this technology replaces paraffin lamps and candles that are majorly used for lighting in rural off-grid communities and fossils fuels used in generators to power electric appliances such as milling machines, refrigerators, hair cutting machines, televisions, radios and telephone charging points.</td>
</tr>
<tr>
<td>Gender benefits</td>
<td>Potential benefits for women include the reduction of time dedicated to household tasks, income generation, as well as health and safety improvements.</td>
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<td>Country social development priorities</td>
<td>Health:

Improved health benefits owing to the reduction of indoor air pollution due to the decrease in the use of firewood and paraffin, which increases the incidence of general ailment and respiratory disease;
Solar PV Mini-Grids solutions can improve health services. Healthcare buildings such as clinics requires high-quality energy service for storage facilities such as refrigerators, to preserve medicines in good conditions. In
</td>
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	addition, by installing solar PV mini-grids, noise pollution caused by diesel generators can be reduced[15] **Education:** • Improved educational outcomes by enabling children to study for additional hours in the evening. • Better integration of rural households by facilitating communications using cell phones and access to information derived from radio and television use. **Job Creation:** • Increased employment opportunities derived from additional service hours, solar supplies, new appliances supply chains and service opportunities, with a special focus on women; **Community and safety benefits**. • With available public lighting, villagers will be able to carry out a whole range of activities that were previously limited. Shops and markets can be open in the evening for business; social ceremonies and events can be extended to the nighttime. In addition, public lighting could result in improved public safety.
Country economic development priorities	**Productive Use of Energy** • Past experiences in Lesotho (for example, Semonkong) have shown that the availability of energy services stimulates new income-generating activities. • Strengthened national private sector's capacity for mini-grid development and operations; • Increased economic opportunities by creating new income-generating activities and jobs in the RE subsector and involving the private sector;
Country climate and other environmental development priorities	Reduced GHG emissions since the mini-grids have a low carbon foot print The main environmental impacts of solar cells are related to their production and decommissioning. Solar PV has a very low lifecycle cost of pollution per kilowatt-hour compared to other technologies. Furthermore, they predict that upwards of 80 % of the bulk material in solar panels will be recyclable, and recycling of solar panels is already economically viable[16]. In terms of land use, the area required by PV is less than that of traditional fossil fuel cycles and does not involve any disturbance of the ground, fuel transport, or water contamination. Solar PV has energy payback periods ranging from 2 to 5 years for good to moderate locations and lifecycle GHG emissions in the order of 30 to 70 gCO_2eq/kWh depending on panel type, solar resource, manufacturing method and installation size[17]. This compares to emission factors for coal fired plants of more than 0.957t CO_2eq/MWh for South African grid power[18]. There is therefore a large potential for solar PV to contribute to reductions in carbon emissions from the power generation subsector. The carbon emission factor for solar PV is 46 gCO_2eq/kWh[19].
Gender aspects	Allow women to perform cooking chores and weaving activities.
Acceptability to local stakeholders	Very High Acceptability. May require community engagement for routine maintenance/checks.

[15] According to UNDP-GEF data, the clinics of Tlhanyaku, Lebakeng, Matebeng, Mashai, and Ha Mokoto use diesel generators as source of energy.
[16] ttp://www.solarwaste.eu/collection-and-recycling/
[17] http://www.climatetechwiki.org/technology/pv
[18] Randall Spalding-Fecher, Pöyry Management Consulting (Sweden) AB, what is the carbon emission factor for the South African electricity grid? Journal of Energy in Southern Africa Vol 22 No 4 • November 2011
[19] IPCC 2011 Agregated Results of the Available Literature

Other considerations and priorities	• Autonomous mini-grids can provide the lowest-cost electrification option in remote areas. • Well maintained mini-grids are more cost effective and robust in comparison to standalone systems. • Mini-grids can provide a much higher household energy consumption than solar home systems and enable income generation opportunities through the operation of appliances such as refrigerators as well as battery charging stations. • Having anchor clients connected to the mini-grid power system increases the revenue of the system since a stable cash flow stream is guaranteed, thus promoting system sustainability
Pros	• Reduces lighting costs compared to paraffin and candles and can be income generating with productive uses of electricity. • The price of grid electricity in the region is likely to continue increasing until the power supply in the Southern African Power pool meets demand. These price increases could make solar PV power more affordable in relative terms. • Has low lifetime carbon emissions • Could last up to 30 years. • Lesotho has comparatively high solar yield with its weather and irradiance characteristics
Cons	• Initial cost is still high: The main constraint to the deployment of solar PV minigrid systems in Lesotho is availability of construction or project finance for the high initial cost of set up and installation • Long term maintenance of power generation and distribution infrastructure in remote areas with poor road access is both challenging and critical to support the minigrid business case. • There are no tax or other incentives applied to solar minigrids. • Licensing and permitting procedures in Lesotho are not streamlined (e.g. no process or timeline for obtaining concessions) and can add undue cost and time penalties to project development • Previous experience with noncertified products from China, India, and South Africa, coupled with poorly designed and managed government off-grid access schemes has eroded public trust in renewable energy solutions[20].

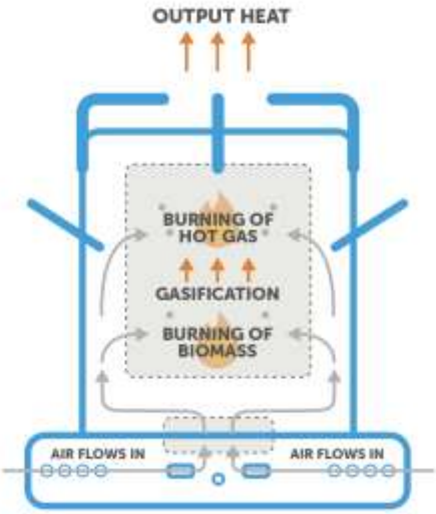
Technology 2: *Marketing and Subsidy of Clean and Efficient Cooking Technologies I (Improved Biomass Cookstoves)*

Sector	Energy Efficiency
Sub-sector	Residential and Commercial
Technology name	Energy Efficient/Improved Biomass Cookstoves (ICS)
Sectoral GHG emission	• By 2017, Lesotho's total GHG emissions were approximately 5 660.44 Gg CO_2eq of which at 2 861.17 Gg CO_2eq (50.5 %) were from the energy sector • Residential sector was the largest contributor to Lesotho's energy sector emissions accounting for 1 900.86 Gg CO_2eq (66.3 %)[21]
Background/Short description of the technology option	Most of households in the rural and semi urban areas use the traditional cast iron three-legged for cooking on open fire stoves to prepare their food. Some public institutions, especially, prisons and schools also use the same stoves to prepare meals. Another

[20] In a market with low supply, unchartered demand, and a burgeoning regulatory environment, multiple interventions will be required to increase supply, rebuild consumer trust, and carefully regulate the market.
[21] LMS, 2021. Lesotho's Fourth Greenhouse Gas Inventory Report. Lesotho Meteorological Services. Maseru, Lesotho.

	group of users are entrepreneurs who own cafés or restaurants, selling foods on the street, or grilling meat on open fire, or brewing local beers. In such cases, the open fire stove is likely to be used for several hours each day. It is recognized that the efficiency of the traditional stoves and open fire are very low (8 % - 10 %); hence a lot of fuel wood is burnt unnecessary, leading to loss of forest, tree and shrubs cover which is an important sink for GHGs. Biomass is an important contributor in satisfying Lesotho's growing energy demand, and already makes an important contribution in meeting current demand, see above. However, over-reliance on biomass for households' needs, especially using inefficient technologies such as open fire and traditional stoves, is leading to an excessive exploitation of biomass resources. In particular, the over harvesting of fuelwood is likely to activate deforestation, considering the limited extent of forest, tree and shrubs cover in Lesotho. On the other hand, the use of alternative biomass sources such as agricultural residues or cattle dung deprives the agricultural land of natural manure, with negatively impacts on soil quality and fertility. Moreover, using biomass for space heating and indoor cooking produces high levels of indoor air pollution. The key issue to cope with the above challenges is to promote the use of energy efficient improved cookstoves (ICSs). ICSs are widely recognized as mitigating the health, gender and environmental risks associated with rudimentary energy access in households. An ICS is efficient by reducing the loss of heat to the ambient, by designing the stove in such a way that the fire zone /combustion chamber is relatively insulated, self-fanned or induced air-fanned and the fire/heat is directed to/around the pot. The technology behind efficient biomass/firewood stoves, like any other efficient cookstoves, lies on having designed an efficient combustion process and heat transfer through the pot into the food. This is achieved through minimization of energy losses and having maximum efficiency of fuel combustion (up to 50 %).
Implementation assumptions. How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.	Information campaign is needed prior to implementation of efficient wood stoves dissemination to inform people of all benefits that the ICS can bring. Additionally, incentive campaigns are needed, such as loan schemes to help people to finance purchase of ICSs and to assist producers of stoves to increase capacity, assist market development through providing training, tax incentive schemes, grants, etc. In Lesotho, ICSs are being promoted on the market, and their utilization is support by many polices and strategies as one of the plausible solutions to deforestation and mitigation of respiratory health among the population • Lesotho Energy Policy 2015-2025 Policy Statement 3 (Bioenergy), Strategy (b) "Reduce pressure on biomass energy resources through fuel substitution and application of energy efficient cookstoves" Lesotho's households energy consumption is characterized by a reliance on biomass such as wood and dung (80 %) and imported coal and petroleum (16 %)
Status of technology in country	One such example of the stove is the Stainless Steel Save80 stove that has been developed and disseminated by a local company, Solar Lights (Pty) Ltd, which is reported to save up to 80 % of wood[22] for cooking compared to the traditional three-stone fire, leading to a sustainable level of wood consumption. It needs around 250 g of dry firewood to bring 6 liters of water to boil in about 25 minutes.

[22] Annually externally audited, since 2012 See UNFCCC CDM Website under Lesotho

	Another example is ACE One Stove, also developed and disseminated by local manufacturer, African Clean Energy Lesotho (Pty) Ltd. • The ACE One is a solar-biomass hybrid energy system which provides for the electrical and thermal energy needs of its users while emitting negligible levels of smoke, protecting their health. It uses a combination of thermal and electric generation to provide a clean, smokeless cooking experience for its users. The solar-powered electricity it generates can also be used for phone charging and lighting. • The electricity access provided by the ACE One allows users to charge their phone or plug in the LED light attachment which saves them money on electrical energy expenses, making the ACE One affordable. • The efficient burn of the ACE One plus its ability to burn any dry solid biomass fuel (animal waste, crop residue, small sticks) reduces the need for unsustainably harvested wood fuel and protects our environment. **How It Works** • The burning chamber of the ACE One is designed to reduce smoke emissions to a negligible level by creating clean biomass combustion. • Ventilator blows oxygen into the top and bottom of the burning chamber • Oxygen causes temperature of the fire within the chamber to increase to approximately 1 000 °C, at which point biomass will gasify • Hot gas floats to the top of the burning chamber where it meets more oxygen & combusts completely 
Implementation barriers	Lack of a comprehensive national energy policy Clean cookstoves may not reduce biomass dependency substantially during 3 winter months, since they cannot provide the same level of heating as traditional stoves.
Capital costs	1. The capital cost of the traditional cast iron 3-legged black (potjie) pot varies from LSL 250 (USD 20) – LSL 2000 (USD 130) depending on the size and capacity. 2. The cost of an efficient cookstove varies according to design features and materials used. • The cost of Save80 Stove is up to LSL 1 200 (USD 80) depending on the capacity. With the average lifetime of 20 years the annualized capital cost would be highly reduced.

	• The cost of ACE One Stove is up to LSL 1 750 (USD 117) depending on the capacity. With free service and maintenance (terms and conditions will apply) for every ACE One. The ACE One is also sold on a 12-15-month micro-loan. Customers use the energy savings achieved with the product to pay back the investment.
Operational costs over 10 years:	This measure saves the fuel costs to consumers compared to current usage of inefficient stoves. Thus the effect on operation costs is positive.
Other costs	Additional costs may be needed to provide awareness-raising activities among local population and commercial sector in order to promote application of the technology plus cost to increase production capacity for local manufacturers.
Gender benefits	Potential benefits for women include the reduction of time dedicated to household tasks, income generation, as well as health and safety improvements.
Social benefits	Attention to improved cookstoves focuses on the "**triple benefits**" they provide, in improved health and time savings for households, in preservation of forests and associated ecosystem services, and in reducing emissions that contribute to global climate change. • **Time savings:** ICSs allow women and children to spend less time collecting biomass. The burden of fuel collection and cooking tends to fall primarily on women and children, limiting the time they have available for income generation, education, and leisure activities. • **Morbidity & mortality reductions:** Reduced incidence of morbidity and mortality from disease (acute respiratory infections (esp. ALRI); COPD; etc.) • In addition, fuel collection exposes women and children to environmental hazards (animal attacks and dangerous terrain), physical pain from carrying heavy loads, and violence or sexual assaults when collecting fuel alone. • Although ICSs still require collection or purchase and preparation of biomass fuel, studies have found evidence of reported time savings with improved compared to traditional biomass stoves, ranging from 11.3 to 17.3 h per week. • ICSs are portable, allowing for shared use.
Economic benefits	Sustainable economic development, rural development. Implementation of efficient stoves can assist rural development through job creation, cost-saving for low-income rural residents, and prevent migration of people from villages.
Environmental benefits	The major benefit of energy efficient biomass stoves is reduction in consumption of biomass. In addition, use of such stoves lead to cost-savings for the consumer over the life-cycle of the appliance, and improve local air quality • Efficient cooking stove reduce demand for fuel wood hence one of means of halting forest degradation. • Reducing human reliance on wood fuel and other forms of fossil fuels creating positive knock-on effects on local natural resources • Reducing carbon emissions associated with unsustainable cooking and energy practice • Where residues can be used, two problems are solved at once – more fuel is available and the problem of waste management is resolved
GHG mitigation potential	The saved forest from use of ICS translates to reduction of GHG emissions through enhancing carbon sink and mitigation through reduced consumption • The Save80 set saves 80 % of wood compared with open fire and therefore reduces CO_2 emissions to the climate by 80 %. The average CO_2 saving per household (on daily use) for cooking and water boiling is about 2.8 tCO_2 annually. Over the lifespan of 20 years, a Save 80 Stove Cooking Set saves over 50 tCO_2.

	• The ACE One burns biomass fuels without smoke, reducing CO_2 and fine particulate matter (PM2.5) emissions by as much as 95 % compared to an open fire. • Each ACE One in Lesotho has the potential to offset around 3 to 5 tCO_2eq per annum.
Other consideration and priorities such as market potential	This technology is proven and available in Lesotho. The market is undeveloped and production is low scale. The market can be considerably improved if enabling environment is in place (awareness, financial incentive, policy and regulation, etc.).
Applicability of the technology in Lesotho (short, medium and long term)	Promotion of the efficient firewood cookstove could be applied in short time
Size (household and large-scale)	Promotion of the efficient firewood cookstove are applied at household and institutional level
Lifetime	If well taken care of, both stoves (ACE ONE and SAVE80) should be able to last 8-12 years.

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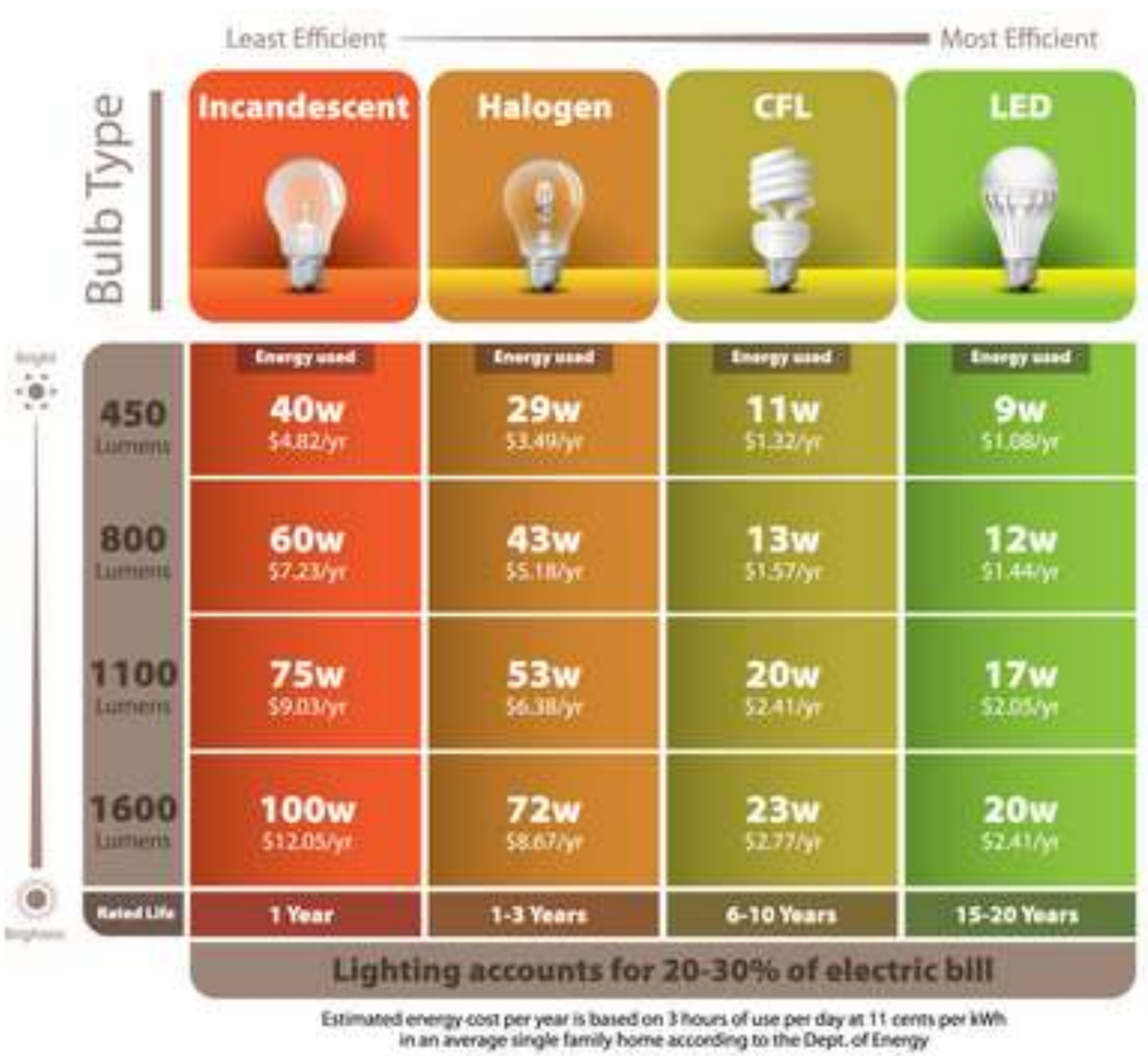
Technology 3: **Energy Efficient Lighting and Appliances**

Sector	Energy
Sub-sector	Residential, Commercial and Institutional Subsector
Technology name	**Energy Efficient Lighting and Appliances**: *Reducing energy consumption in Residential, Commercial and Institutional buildings through replacing incandescent lamps and fluorescent lamps with LED lamps and use of energy efficient appliances*
Background/Notes, Short description of the technology option	Incandescent lamps are "standard" electric light bulbs that were introduced for residential use more than 125 years. They have the lowest initial cost, and typically short life spans and use significantly more watts than Compact fluorescent lamps (CFLs) and Light-Emitting Diodes (LED) to produce the same lumens, or light output. Incandescent technology produces light by heating up a metal filament enclosed within the lamp's glass. More than ninety percent of the energy used by an incandescent light bulb escapes as heat, with less than 10 % emitting light. Incandescent are the most commonly found bulbs in Basotho homes. A 100-watt incandescent bulb switched on for two hours a day uses about 0.2 kWh a day, or 6 kWh per month. One can see these bulbs as small space heaters which also emit light. CFLs and LEDs have been available for residential use for about 30 years, with recent advances among LEDs, increasing their quality and popularity. They are the most energy-efficient choice readily available on the market for homes today. CFLs use gases, mercury and phosphor inside the lamp to create light.

	A 22-watt CFL has about the same light output as a 100 watt incandescent i.e., a CFL uses 75 % less power than an incandescent lamp to produce the same lumens. Lighting accounts for nearly 15 % of the average home's electricity use. Replacing incandescent bulbs with CFLs and LED lowers the electrical bill for lighting up to 75 %, or 11 % of the total energy bill. If 20 incandescent bulbs of 75-watt capacity are replaced by 22-watt CFLs, it would save about 1kilo watts for every hour that the lamps are used. At five hours per day, this means saving close to 2 000 kWh per year, or around M 3 000 per year, M 250 per month. LED is a two-lead semiconductor light source. There are various types of LEDs bulbs such as solid-state lighting (SSL), organic light-emitting diodes (OLEDs) and light –emitting polymers (LEPs). Light is emitted by LED in a narrow spectral band but white light can be produced. Therefore, these kinds of bulbs are applicable of daily life of offices and houses. Compared to other types of light bulbs, LED bulbs are more efficient, durable and longer lasting. LED consumes about 90 % less energy than incandescent bulb while CFL consumes around 75 % less energy than incandescent bulb (Alt, 2019). The narrow spectral band also reduces drastically the attraction of insects to the lights source, including mosquitos.
Country Specific Applicability and Potential	Lesotho in its NDC has prioritized the following actions, among others, in for its energy sector: • Development of renewable energy electricity • Promotion of distributed renewable lamps • ***Promotion of use of energy efficient light bulbs*** • Promote energy efficiency in electricity transmission Lesotho already has an enabling policy and legislative framework for the application and adoption of energy efficient LED lamps. A combination of use of renewable energy coupled with use of energy efficient bulbs will yield multiple benefits in energy savings, economic savings for users/return on investment, reduced greenhouse gas emissions and related benefits.
Status of technology in country	Energy efficient LED lamps are available for importation and distribution within Lesotho especially in the urban areas.
Implementation assumptions, How the technology will be implemented and diffused across the subsector?	Incandescent bulbs are commonly used in Lesotho. Incandescent bulbs produce 10 - 15 lumens/W and last for 1 000 – 2 000 hours. (CFLs) produce 50 - 60 lumens/W and last for 10 000 - 15 000 hours. Moreover, (LEDs) produce 100 - 130 lumens/W and last for 35 000 - 50 000 hours. A nationwide awareness raising campaign on the benefits of CFLs and LEDs is required prior to the commercial mass introduction of CFLs and LEDs Incentive schemes may also be necessary to promote the use of CFLs and LED among public (such as lower prices for CFLs and LED in case incandescent light bulbs are brought for exchange with CFLs or LED).
Reduction in GHG emissions	More efficient appliances and lights use less electricity, reducing CO_2 emissions (from electricity generated by fossil fuel power plants from SAPP) for a safer climate. As a guideline, one candle emits around 12.5 lumens and a replacement LED saves around 0.091 kg CO_2 per year based on a daily usage scenario of several hours per day.
Implementation barriers	• CFLs and LEDs are far costlier compared to incandescent lamps and this is a major barrier to its widespread use.

<table>
<tr><td></td><td>
The economies of scale are absent in such a small market to push implementation of projects that can make significant differences with reasonable returns on investment. Due to the smallness of the market, the cost competitiveness of certain new and emerging technologies may not attract investments, since the payback may be too long to fit in a commercial enterprise budget. The government needs to go a step further to remove all duties and taxes on energy efficiency and renewable energy products.
</td></tr>
<tr><td>Gender benefits</td><td>
Women are more important decision-makers when it comes to household products, they are often most affected by low-quality and inefficient products in households.
Better lighting can provide more comfortable life for the women and children such as women can finish their household tasks quickly and children can study conveniently under the bright and efficient light.
</td></tr>
<tr><td>Social benefits</td><td>
As efficient lights use less energy, electricity is freed up, enabling more people and businesses to access reliable power;
Using more energy-efficient lighting reduces household electricity bills due to lower electricity usage and subsequently less demand to the national grid.
With better lighting quality, study habits may change for the better leading to better education prospects as well as security.
</td></tr>
<tr><td>Economic benefits</td><td>
The cost of energy efficient light bulbs is more expensive than that of an incandescent light bulb, but this will be compensated by the longer lifetime of and the amount of energy saved.
Energy efficient light bulbs use 25 % - 80 % less energy and last 2 - 3 times longer than traditional incandescent bulbs
In times when electricity costs increase, using energy efficient light bulbs will save more money and thus the payback period is even shorter.
Using energy efficient light bulbs contribute greatly to reducing electric power consumption, resulting in more investments on increasing generating capacity.
With lower running costs for lights, businesses become more competitive.
They can create more jobs and increase income through distribution and retail system.
</td></tr>
<tr><td>Environmental benefits – GHG emission reduction benefits</td><td>
The major benefit lies in the improved energy efficiency, which has socio-economic benefits in terms of increased energy security and environmental benefits, i.e. lower GHG emissions, and lower environmental impact of electricity generation. All these are in line with the country’s environmental development priorities.
According to the International Energy Agency (IEA), an CFL can help to reduce 0.5 tCO_2 during its lifespan (2006) of several years.
LED lamps do not contain mercury. The aluminium heat sinks can be recycled therefore making them environmentally friendly
<table>
<tr><th>Lighting Technology (800 Lumens)</th><th>Daily kWh Consumed (@8hr)</th><th>Annual kWh Consumed (@8hr/day)</th><th>CO_2 Produced (Coal Based Power Generation)</th></tr>
<tr><td>Incandescent (60 Watts)</td><td>0.48</td><td>175.2</td><td>152.42 Kg</td></tr>
<tr><td>Halogen (42 Watts)</td><td>0.34</td><td>124.1</td><td>107.96 Kg</td></tr>
<tr><td>CFL (14 Watts)</td><td>0.11</td><td>40.15</td><td>34.93 Kg</td></tr>
</table>
</td></tr>
</table>

	LED (9 Watts)	0.07	25.55	22.23 Kg
Other consideration and priorities such as market potential	This technology is proven and available in Lesotho. Its market can be considerably increased if enabling environment is in place (awareness, financial incentive, policy and regulation, etc.).			
Capital costs over 10 years	The cost of LED and CFL varies with the design features, materials used, brands, etc. Average cost of a basic branded CFL and LED in Lesotho is less than US$2 for a 10 W bulb.			
Operational costs over 10 years	N/a			
Other costs	Additional costs may be need to increase awareness level of consumers to promote the application of high efficiency lighting system.			
Lifetime	Based on the color of LED, LED lamps have very long lifespan approximately between 40 000 and 100 000 operating hours			



Technology 4: Solar PV Systems with Energy Storage that Can Cater for AC Loads

Sector	Energy

Sub-sector	Residential and Commercial
Technology name	Solar Home Systems Type II with energy storage system-ESS that can cater for AC load as well.
Sectoral GHG emission	• In 2017, Lesotho's total GHG emissions were approximately 5 660.44 Gg CO_2eq of which at 2 861.17 Gg CO_2eq (50.5 %) were from the energy sector • Residential sector was the largest contributor to Lesotho's energy sector emissions accounting for 1 900.86 Gg CO_2eq (66.3 %), according to the Lesotho's 4th National Greenhouse Gas Inventory: 2011 - 2017[1] • Solar PV systems and other solar-based energy technology systems produce energy in a cleaner fashion when compared to fossil-based energy production, and can therefore contribute immensely in the reduction of greenhouse gas emissions due to energy generation in Lesotho.
Background/Notes, Short description of the technology option	A type II solar home system is a standalone solar photovoltaic (PV) system consisting of an array of solar PV modules, battery bank, charge controller, wiring, LED DC lights, inverter, and outlets for other AC appliances. A standard solar PV system is developed as per the solar irradiance of an area and the average load demand for the household. Solar PV has enormous energy potential in Lesotho. The average annual global radiation in Lesotho is 6750 MJ/m^2/year (1 875 kWh/m^2/year). The country experiences generally clear weather, with the capital Maseru, for example, having an average clearness index of 0.66. This is equivalent to about 5.14 peak sunshine hours per day on yearly average basis. The Lesotho Energy Policy 2015 - 2025[3] and many other strategic documents name solar PV technology as one of the viable options for clean energy supply and climate change mitigation. A key driver is the fact that, due to a steep learning curve and increased competition, worldwide, rapid cost reductions of Solar PV systems have been experienced over recent decades. Solar Home System (SHS) Solar Home Systems are stand-alone PV systems that offer a cost-effective mode of supplying amenity power for lighting and appliances to remote off-grid households. In rural areas that are not connected to the grid SHS can be used to meet a household's energy demand fulfilling basic electric needs. SHS can be an electrification option for households living in areas where a micro-grid is not viable. Globally SHS provide power to hundreds of thousands of households in remote locations where electrification by the grid is not feasible. SHS typically includes a photovoltaic (PV) solar panels/module (arranged in arrays), PV module mountings, a battery bank, a charge controller, wiring, fluorescent DC (direct current) lights, direct current to alternating current (DC-AC) converter, and outlets for other DC and AC appliances. A standard small SHS can operate several lights, a television, a radio or cassette player, and a small fan. Apart from investing in the solar PV system itself, it is necessary to invest in energy storage, such as a bank of deep cycle batteries. The power that is generated by the renewable energy source initially charges the batteries through the charge controller. The inverter converts the DC power to AC power, which is the normal requirement for home appliances. A SHS can eliminate or reduce the need for candles, paraffin and/or battery charging, and provide increased convenience and safety, improved indoor air quality, and a higher quality of light than paraffin lamps for reading. About one percent of rural households in Lesotho currently use SHS, with a total installed capacity of 61.6 kW.

	The fraction of the population in Lesotho with access to electricity in 47 % by 2018, World Bank[4]. About 73 % of the population lives in rural areas, of which only 22.9 percent have access to electricity. Most rural households rely on lower quality fuels for their energy needs such as biomass for heating and cooking, and paraffin for lighting. In addition, Lesotho's challenging topography means that grid extension is costly and often unfeasible. Off-grid RE solutions provide solutions to the rural population's energy needs. Lesotho's Energy Policy 2015 – 2025 recognizes that these resources can be transformational energy sources, especially in remote, hard-to-reach areas of the country such as the highlands located in the east and central parts of the country mainly in the districts of Thaba-Tseka, Mokhotlong, Qacha's Nek, and Quthing.
Implementation assumptions, How the *technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.*	While the Government of Lesotho is making significant efforts to add additional generation capacity and to extend the grid to various parts of the country, majority of the low-income households will still need alternative sources of energy due to the economic cost of grid power associated with the high costs incurred in extending the grid. The assumption for increased implementation of this technology is that ongoing Government grid power expansion plans especially for rural areas should be clearly communicated to the public. The purchasing power of rural households is highly affected by climate change since majority do farming for livelihood. Hence the purchasing power is higher during harvest season when they sell their farms produce. If the crops are affected by low rains, the yields are low hence low purchasing power. System sizing and proper feasibility will be carried out for the electricity need of the community prior to the implementation of the technology. Improved versions of strategies such as suggested in the report "Lesotho Energy Access Strategy"[4] can be used in an attempt to roll-out the implementation of SHS in rural Lesotho The strategies for SHS implementation in Lesotho can range from "stick" to "carrot approaches. For example, the government ministry responsible for the environment can introduce stricter legislation regarding the cutting down of forestry. and at the same time government can up with pro-poor financial mechanisms to prop up widespread uptake of SHS.
Technology characteristics	Given the dispersed nature of rural populations and low densities, electricity access will have to be accomplished using a combination of grid extension, mini- and micro-grids, and stand-alone systems. The formulation of the Electrification Master Plan 2018 - 2028 has mapped the population distribution in relation to the MV grid network and characterized the distribution of population by density and identified the population best served by extending the LEC grid, served through mini-grids and those best served through solar PV micro-grids and stand-alone systems. The mini-grids may be powered by a range of energy sources, such as small hydro, solar, wind and hybrids.
Reduction in GHG emissions	• Some greenhouse gases are emitted during the production of the SHS components but then no greenhouse gas (GHG) are emitted during the energy generating life of the SHS. The energy payback time (EPBT) is small (of the order of 1 year) compared to the energy-producing life of the SHS (about 25 years). There is therefore a large net GHG saving in using SHS.
Implementation Barriers	• The technology comes with high initial investments. • Low rural consumer ability to pay due to low disposable income. This is coupled with lack of affordable financing schemes most especially for end users. • Limited power supply, cannot power appliances with higher energy requirements e.g. electric kettle, unless the system is made very large. • Theft of solar panels scares off some potential customers

	• Sometimes deep-cycle batteries are stolen or used for other purposes • Vendors/technical providers are mainly based in urban areas, quite far from their clients thus making it difficult for clients to access prompt after-sales services; • Lack of business management skills; limited technical & institutional capacity; enforcement of standards and quality
Market potential	The market for SHS configuration is currently growing both in rural and urban areas. There are many local companies in Lesotho that offer these types of solar systems. Public institutions like schools are joining the market with the advent computer technology and the widespread need to extend learning hours beyond the evening.
Country social development priorities	• Gender considerations: Both men and women are engaged in the sale and use of SHS • Improved health due to the fact the systems do not emit and can also be used to provide light in the rural off-grid health facilities. Traditionally families in rural areas use paraffin candles and lamps as source of light. SHS can replace these candles and lamps that produce fumes which are harmful to human health • Better education as students can learn for longer hours in the evenings: For lighting, PV compact fluorescent light system is many times more efficient than paraffin, used in the rural areas to provide night lighting.[23] • Improved skills/capacity due to training opportunities especially for solar technicians • Improved quality of lives due to increased information flow and entertainment in the homes (televisions, radios, phones) • Increased home safety as it reduces fire hazards that would have resulted from using candles or paraffin lamps • Improves the security and reduces crime which occurs after nightfall. • Allow greater involvement of non-government providers in off-grid rural electrification, including community-based organizations, NGOs, and the private sector. • More night-time social activities
Country economic development priorities	• Job creation for distributors and retailers of SHS and those in the business value chain. The implementation of solar charging stations provides opportunities for new businesses that are environmentally friendly. Solar lighting extends the work day and allows merchants longer time periods to sell their goods. • Reduction of exodus from rural to urban areas • Increased income due to investment in Solar PV systems
Environmental and Climate Change benefits	• Off-grid PV systems that are roof- mounted and do not require additional land usage to for its installation. • Solar PV systems are considered closed systems and hence require no fuel or any inputs during operation and electricity production. It also does not contaminate the environment. • Solar PV systems cause no noise or vibration and hence considered environmentally friendly. • SHS can replace use fossil fuels for lighting and powering electrical appliances resulting in huge greenhouse gas emission savings.
Financial requirements and costs	• The cost of PV electricity generation in Lesotho is just below LSL 1 per kWh. • The payback period for solar system is up to 5 years, while the lifetime of solar PV systems is about 25 years, batteries have to be replaced at least every 5 years, and O&M cost are estimated at 1.5 % of capital cost per year.

[23] http://www.iaeel.org/IAEEL/NEWSL/1996/tva1996/LiRen_a_2_96.html.

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- Some indicative costs of SHS based on prices by a vendor[5] are shown below. The costs for acquiring the SHS in Lesotho are estimated.

<table>
<tr><td>System size</td><td>0.5 kW</td><td>1 kW</td><td>3 kW</td><td>5 kW</td></tr>
<tr><td>Application range</td><td>Off-grid solar home system with 5 hours back-up</td><td>Off-grid solar home system with 10 hours back-up</td><td>Off-grid solar home system for home</td><td>Off-grid solar home system for Homes, Small Office or Shops</td></tr>
<tr><td>Dealer Cost (USD)</td><td>650</td><td>960</td><td>2 850</td><td>4 850</td></tr>
<tr><td>Freight and Duty (USD)</td><td>130</td><td>192</td><td>570</td><td>970</td></tr>
<tr><td>Total (USD)</td><td>780</td><td>1 152</td><td>3 420</td><td>5 820</td></tr>
<tr><td>Total cost (Maloti)</td><td>11 700</td><td>17 280</td><td>51 300</td><td>87 500</td></tr>
</table>
</td></tr>
<tr><td>Pros</td><td>

- Reduces electricity costs and can be income generating if excess power is produced.
- The price of electricity in the region is likely to continue increasing until the power supply in the Southern African Power pool meets demand. These price increases could make solar PV power more affordable.
- Maintenance is minimal and mainly requires the cleaning of the solar panels to ensure efficiencies are maintained.
- Has low lifetime carbon emissions
- Could last up to 30 years.
</td></tr>
<tr><td>Cons</td><td>

- Typically, off grid systems require a larger up-front investment than grid tied systems due to additional charge controller and batteries that are employed in the former.
- Lack of local capacity in the rural areas for maintenance of the system.
- Power production is dependent on weather conditions.
- There is still no mechanism in Lesotho for low power solar PV grid connection
- There is no regulatory framework governing the importation of solar products: Because of this, a range of noncertified products from China, India, and South Africa exist in the market. This coupled with a poorly designed and managed off-grid access pilot in 2014 through the DoE's REU has ensured low demand for off-grid energy services[24].
</td></tr>
<tr><td>Other considerations and priorities</td><td>

Technology related

- Resource availability (sun is abundantly available in Lesotho) and ubiquitously distributed over the country
- Solar equipment is available on the market
- The SHS technology is reliable
- Most people in Lesotho are aware of the technology

Political benefits

- Alignment to national sector instruments such as NSDP II 2018/19 - 2022/23.
- Solar is one of the energy sources the country plans to develop to generate a considerable capacity of modern energy to drive the industry and services sectors.
</td></tr>
<tr><td>Lifetime</td><td>20-25 years, batteries have to be replaced at least every 5 years</td></tr>
</table>

[24] In a market with low supply, unchartered demand, and a burgeoning regulatory environment, multiple interventions will be required to increase supply, rebuild consumer trust, and carefully regulate the market.

References	**1.** Letete T, E. Matuszewska, L. Stevens, H. Mahlase and P. Ntshalintshali, Lesotho's 4th National Greenhouse Gas Inventory: 2011 – 2017, June 2019. **2.** K. K. Gopinathan, Solar energy utilization in Lesotho, RERIC International Energy Journal, Volume 11, Number 2, December 1989. **3.** IEA/IRENA, Lesotho Energy Policy 2015 - 2025, IEA/IRENA Renewables Policies Database, 2015. **4.** UNDP-UNCDF, Lesotho Energy and the Poor: Making Access Possible, 2020. https://www.undp.org/sites/g/files/zskgke326/files/publications/UNDP-UNCDF-Lesotho-Energy-and-the-Poor.pdf **5.** https://www.loomsolar.com/collections/off-grid-solar-system#:~:text=An%20initial%20cost%20of%20installing,buy%20it%20from%20Loom%20Solar.

Technology 5: Marketing and Subsidy of Clean and Efficient Cooking Technologies II: Substitution of Fuelwood with LPG at Households and Institutions for Cooking.

Technology	**Substitution of Fuelwood with LPG at Household, Institutional and Commercial Level for cooking**
Sector	**Energy**
Sub-sector	Commercial and Residential
Sectoral GHG emission	• In 2017, Lesotho's total GHG emissions were approximately 5 660.44 Gg CO_2eq of which at 2 861.17 Gg CO_2eq (50.5 %) were from the energy sector • Residential sector was the largest contributor to Lesotho's energy sector emissions accounting for 1 900.86 Gg CO_2eq (66.3 %)[25] • Residential/Institutional sector was the largest contributor to Lesotho's energy sector emissions accounting for 422.46 Gg CO_2eq (14.77 %)
Background/Notes, Short descriptions of the technology options	Liquefied petroleum gas (LPG) is a mixture of propane and butane, which are gases that become liquid under pressure and can then be stored in pressurized containers. LPG is manufactured during the refining of crude oil (40 %) or from natural gas during extraction (60 %). The proportion of each gas varies depending on the source. LPG has a high energy per unit volume and is convenient to use for thermal application. Its calorific value per unit volume is about 2.5 times larger than that of natural gas (methane). It is used for road transport, cooking, heating, refrigeration and air conditioning. It is a portable source of energy used for cooking and transport. The gas has low carbon content compared to coal and its use is thus connected to climate change mitigation. To reduce household air pollution, improve health outcomes, save nonrenewable biomass, and support local economic development, developing countries are seeking to increase the use of liquefied petroleum gas (LPG) as a clean cooking solution. In the absence of targeted subsidies, LPG will not be the solution for the world's poorest people. The typical composition of the LPG cooking system is made up of the stove itself, the gas cylinder, the piping system. The cylinder has a regulator that controls the flow of the gas. The gas flow to the stove can also be controlled by the stove itself. Generally, the LPG cooking technology is well mature, and it presents a viable alternative to use of charcoal for cooking, but to the wealthier households. The incentives are required so that LPG becomes a fuel of choice for all households.

[25] LMS, 2021. Lesotho's Fourth Greenhouse Gas Inventory Report. Lesotho Meteorological Services. Maseru, Lesotho.

	In comparison to biomass, use of LPG causes minimal household pollution and negative health impacts. Being an Energy Access 'Tier 4' solution, it has lower emissions than all cooking fuels and technologies other than solar and electricity, compares positively with biogas and alcohol fuels, and is several times better than Improved Cookstoves. Handled correctly and subjected to proper regulation and control, it is a very safe technology, but weak regulation and lack of control mechanisms has resulted in improper maintenance and handling in some markets and caused several serious accidents, giving LPG a reputation as unsafe..
Sustainable Development Goals (SDGs)	While Health, Energy Access, Climate Action and Gender equality may be the most evident, development of a sustainable LPG sector can also contribute to reducing poverty and inequalities, creating jobs, and making cities and communities more sustainable. Finally, a strong international partnership can support the efforts to scale up LPG and clean cooking in developing countries
Implementation barriers	Issues related to LPG safety, both real and perceived, inhibit the uptake of LPG by consumers, slowing potential market growth, and contributing to lack of confidence in return on investment for both investors and companies. It is therefore expected that the more the households perceive LPG as unsafe/dangerous, the more they are unlikely to increase the consumption of LPG or switch to LPG.
Implementation assumptions, How the technology will be implemented and diffused across the subsector? Explain if technology could have some improvements in the country environment.	The reliability of LPG cookstoves is generally considered high as the technology is mature and applied widely across the world. The same could be said about the supply chains for the LPG. IEA (2006) also points out that the gas supply infrastructure is becoming more complex and more investment is required, in particular to increase transport skills and reduce investment costs. For importers there needs to be local distribution infrastructure development both for the fuel and for new stoves and stove conversions. Although many developing countries already have access to LPG, the applicability of the technology to the rural poor is hampered by the required import facilities and distribution systems and complexities related to the poor quality of roads and relatively high per capita costs if the population density is low. The other main problem with LPG that they can be expensive relative to other fuels and thus less attractive for the poor. In addition, the prices of LPG could be more volatile than the price of other fuels and feedstock for cooking. These possible price impacts could negatively affect the affordability of the technology and LPG fuels, in particular to rural area households (IEA, 2006). However, LPG is not commonly found in rural areas where biomass use tends to be highest and where the health effects of smoke are also highest. Nonetheless, it is used amongst middle or high income groups in urban areas of developing countries. The high initial cost of purchasing appliances and cylinders, the relatively complex technology, irregularity of supply and risk of explosion mean that it is not widely used in the majority of poorer areas of developing countries (IEA, 2006). The LPG supply chain is not practical for the poor as cylinders are usually exchanged at filling

	stations. Since there are not many of these in rural areas and since transport is poor, access to LPG is very difficult.
Status of the technology and its future market potential	• As a cooking fuel, LPG is seen by the IEA as the main means for moving away from unsustainable use of biomass for cooking: the target expressed in IEA (2006) is to reduce the use of biomass in cookstoves by 50 % by stimulating 1.3 billion people to switch from biomass to LPG. Globally, the future market potential for LPG is thus huge, especially as a form of cooking energy. LPG price increases could make LPG-based cooking less accessible for the poor, particularly in the rural areas. • However, use of LGP for cooking is recommended in the National Energy Policy 2015 - 2025, and some of its "broad policy strategies to "Reserve local transportation of Petroleum and LPG to Basotho", Cap the prices of LPG and Illuminating paraffin at retail level"
Gender benefits	• Potential benefits for women include the reduction of time dedicated to household tasks, income generation, as well as health and safety improvements.
Economic benefits	• LPG is a private sector-driven industry with significant potential for job creation and entrepreneurship • If catering businesses (restaurants) switch from wood fuel to LPG, the saved time in cooking could result in increased sales. • LPG use could lead to economic and quality of life gains, through increased time for work, rest, and consumption of hot meals, and reduced arduous biomass fuel collection.
Social benefits	• In Lesotho, the main benefits of LPG cooking stove are in helping people to switch from unsustainable biomass use to a clean and safe cooking fuel. This provides enormous health benefits helping to avoid respiratory problems caused by smoke and other pollutants released by inefficient biomass burning in enclosed spaces. • It also releases women and children from the drudgery of collecting firewood and health problems associated with carrying heavy bundles long distances. There are also benefits for local ecology and biodiversity[26]. • Efforts to promote clean cooking through adoption of clean-burning fuels such as LPG are often based on the idea that near-exclusive use of LPG could lead to health improvements. However, benefits beyond health, such as time savings, could be more tangible and meaningful to LPG users. • Increased uptake of LPG could contribute to reduced poverty and in particular an improved situation for women and girls, who are mainly involved in cooking and fuel collection. • Avoid respiratory problems caused by smoke and other pollutants
Environment benefits	• The environmental footprint of LPG is negligible compared with biomass and other fuels[27], because of its very efficient and complete combustion and its sustained performance in field use over time[28]. • LPG emits negligible amounts of black carbon and other short-lived pollutants that contribute to global warming

[26] http://climatetechwiki.org/technology/lpg_lng_cooking
[27] Grieshop, Andrew P., Julian D. Marshall, and Milind Kandlika. 2011. "Health and Climate Benefits of Cookstove Replacement Options." Energy Policy 12 (12): 7530–42.
[28] Smith, K. R., J. Rogers, and S. C. Cowlin. 2005. Household Fuels and Ill-Health in Developing Countries: What Improvements Can Be Brought by LP Gas? Paris: World LP Gas Association.

	• Replacing biomass fuels by LPG will reduce pressure on forest reserves, which is a significant challenge in Lesotho where biomass is widely used as household energy • It actually takes just over 11 kg of wood to provide the same cooking heat as one kilogram of LPG due to higher energy content and greater efficiencies of gas stoves.
Cost	The cost initial cost of the equipment is relatively high, compared to other stoves. The cost of LPG is also quite high
GHG mitigation potential	• LPG is a relatively cleaner fuel from the emission point of view than paraffin (107 900 kg CO_2eq/TJ for LPG versus 157 400 kg CO_2eq/TJ for paraffin, 112 000 kg CO_2/TJ for wood). • LPG has a typical specific calorific value of 46.1 MJ/kg[29] or 12.8 kWh/kg. 1 kWh LPG consumption emits 0.24 kgCO_2[30] • LPG cooking stove provide a 'clean' burn with almost complete combustion of the fuel so that there are only low pollutant emissions from NOx and very low particulate or other hydrocarbon emissions.
Applicability of the technology in Lesotho	The technology could be applied in short term
Status of the technology and its future market potential	The reliability of LPG cookstoves is generally considered high as the technology is mature and applied widely across the world and even in Lesotho as well. LPG market has a huge potential for expansion and it provides a clean and cost-effective alternative fuel for cooking purpose, particularly in household levels. Demand for LPG has been growing. This growth is driven mainly by the population switching from traditional fuel to LPG as their preferred energy source for cooking.

Technology 6: ***Small-Scale*** **Hydropower** ***Plants up to 1 MW***

Sector	**Energy**
Sub-sector	Residential and Commercial
Technology Name	Micro Hydropower Plants: Off-Grid and Grid-Connected (up to 1 MW)
Sectoral GHG emission	• In 2017, Lesotho's total GHG emissions were approximately 5 660.44 Gg CO_2eq of which at 2 861.17 Gg CO_2eq (50.5 %) were from the energy sector • Residential sector was the largest contributor to Lesotho's energy sector emissions accounting for 1 900.86 Gg CO_2eq (66.3 %)[31]
Background/Notes, Short descriptions of the technology options	Hydropower systems exploit the energy of moving water. By falling water through a turbine and converts it into mechanical power which drives generators to produce electricity. The water strikes the blades of a turbine which rotates the generating unit resulting in the kinetic energy of the water converted to electricity. Modern hydro turbines can convert up to 90 % of the water energy into electricity. This is very efficient compared to fossil fuel power plants where the best ones have a performance of up to 60 %[32]. It is the second most used renewable energy source in the world after solid biomass. Hydropower is classified into small and large hydro[33]. Small hydropower here refers to hydroelectric power plants below 10 MW installed capacity. It is divided into further

[29] http://en.wikipedia.org/wiki/Liquefied_petroleum_gas
[30] http://www.engineeringtoolbox.com/co2-emission-fuels-d_1085.html
[31] LMS, 2021. Lesotho's 4th HGH Inventory Report. Lesotho Meteorological Services. Maseru, Lesotho.
[32] J Wisconsin Valley Improvement Company, "Facts About Hydropower," http://www.wvic.com/Content/Facts_About_Hydropower.cfm
[33] Climate Tech Wiki

	categories depending on its size, such as mini - (less than 1 000 kW), micro-hydro (less than 100 kW) and pico-hydro (less than 5 kW), and the definitions may vary according to manufacturers and countries, as there is no internationally accepted definition of small hydropower. For example, in China, small hydropower refers to capacities of up to 25 MW, in India of up to 15 MW and in Sweden 'small' refers to up to 1.5 MW. Large hydropower usually refers to more than 100 MW installed capacity. In Lesotho small means below 1 MW Mini-Hydro - Installations with a power output of 5 – 100 kW (usually provided power for a small community or rural industry in remote areas away from the grid). Proper site identification in terms of flow rate and head height needs to be determined prior to undertaking such a project. Usually, identifying, planning and managing take a higher proportion of the whole installation effort. Installation includes installing the turbine and grid installation to the appropriate point of need. Where applicable, it is one of the most cost-efficient solutions for supplying electrical energy. Source: https://energypedia.info/wiki/Pico_Hydro_Power.
Country Specific /Applicability	This is applicable to communities that are near rivers that have sufficient hydro potentials
Technology feasibility	Large scale hydropower stations require large dams or a series of dams to store large quantities of water. The dams can also be used for other purposes like irrigation. In recent years a lot of improvement in terms of efficiency, performance, operations, maintenance and advanced turbine development has occurred rendering this technology more feasible globally. There is therefore a larger potential for further deployment of this technology in Lesotho. Lesotho has put in place several policies that promote clean energy including hydropower. In 2002 the country undertook energy reforms which reduced the LEC's monopoly therefore establishing a regulatory body called the Lesotho Electricity and Water Authority (LEWA). Lesotho is also a party to regional integration agreements like the Southern African Power Pool (SAPP) which aims at ensuring access to cost effective electricity. Lesotho has been using hydropower technology and has experience with both small hydro stations. This means that the technology is economically and technically mature in the country. The current installed capacity of hydro power in the country totals to 74.72 MW in four sites, most of which comes from the 72 MW 'Muela Hydropower Plant (MHP). Other three sites are Mantśonyane (2 MW - grid-connected), Katse Dam (0.54 MW grid-connected), and Semonkong (0.18 MW off-grid).
Implementation assumptions, How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.	The first and foremost requirement would be to find a suitable site within the vicinity of the rural community that has a high level of hydro potential. The other requirement would be to acquire rights from traditional owners.
Implementation barriers	• The legal framework to allow for interconnection to the national grid through power purchase agreement since the local utility company LEC holds a monopoly on the transmission and supply of electricity.

<table>
<tr><td></td><td>Operating hydropower project in a river with large sediment load poses technical challenges – the increases sediment load induces wear on the hydraulic machinery and other structures of the plant..</td></tr>
<tr><td>Reduction in GHG emissions</td><td>Replacement of diesel engine power generators, wood and coal fuels will result in a significant decrease in GHG emissions
98.3 % Reduction in GHG emissions in comparison to equivalent Power generations from conventional Diesel usage per kW</td></tr>
<tr><td>Status of technology in country</td><td>Lesotho has experience in construction of hydropower plants with a capacity of up to 2 MW. Therefore, local expertise is already available. 4 mini-hydro power plants were established between 1983 and 1993:
Mantsonyane (2 MW hydro power plant with an estimated energy production of 6.60 GWh/year) connected to the national grid;
Semonkong (180 kW hydro generator and 120 kVA diesel generator); an estimated energy production of 1.30 GWh/year;
Tlokoeng (460 kW and 210 kW hydro generators and 200 kVA diesel generator) with 33 kV distribution to Mokhotlong; an estimated energy production of 3.30 GWh/year;
Tsoelike (275 kW and 125 kW hydro generators, and 200 kVA and 320 kVA diesel generators) with 33 kV distribution to Qacha’s Nek; an estimated energy production of 2.13 GWh/year.
Of the 4 mini-hydro power plants, the last 2 have been mothballed. The main reason for this has been the high operational costs for these units. Subsequently, the main grid was extended to the areas formerly supplied with electricity by the small hydro power units, rendering the plants redundant.

A number of studies, potential site assessments and feasibility studies were conducted over the years. It was found that Lesotho has significant potential to develop hydropower as a source of energy for electricity generation and a number of initiatives are being explored. These include (i) further site assessment to identify critical potential sites; (ii) construction of a large hydropower plant, 110 MW hydropower plant at Polihali in Thaba-Tseka district; (iii) expansion of a 500 kW hydropower plant at Katse dam to 1 MW</td></tr>
<tr><td>Market potential</td><td>Since hydropower is also dependent on the geographical conditions of the country or the terrain, the mountainous landscapes of the country provides for several areas for hydro power expansion.
The technology is commercially viable and is found to be the least costly technique of storing large quantities of energy. The technology also allows for adjustments in the quantity of electrical energy produced to that demanded by consumers.
Due to its lower cost and its high efficiency, the technology has a potential in the market. In Lesotho several sites have been identified for the installation of hydropower systems. These range from mini hydro to small hydro. These sites include the following:
<table>
<tr><th>District</th><th>River</th><th>Installed Capacity (MW)</th><th>Annual Generation (GWh)</th></tr>
<tr><td>Leribe</td><td>Hlotse</td><td>6.5</td><td>39.7</td></tr>
<tr><td>Maseru</td><td>Phuthiatsana</td><td>5.4</td><td>18.9</td></tr>
<tr><td>Maseru</td><td>Makhaleng</td><td>8.9</td><td>39.4</td></tr>
<tr><td>Maseru</td><td>Makhaleng</td><td>9.1</td><td>58.3</td></tr>
<tr><td>Thaba-Tseka</td><td>Malibamat'so</td><td>4.5</td><td>30.0</td></tr>
</table></td></tr>
</table>

	Qacha's Nek Senqu 0.40 3.61
Climate and other environmental benefits	• Hydropower can achieve significant GHG reductions as it reduces the fossil fuel based electricity imports from South Africa. The largest source of GHG for hydropower is the construction of the facilities and biomass decomposition from reservoir flooding[34]. However, on overall, the life cycle of GHG emissions per unit of electricity generated is lower for hydropower than for fossil fuels. Steinhurst et al, 2012 estimates that in the tropical regions, for an equal electric energy output, hydropower plants emit about 1/3 of the least emitting oil and coal power plants. For an example, for a dam which is anticipated to produce 2 700 GWh/year, the estimates show a lifecycle average emission rate ranging from 160 to 250 kg CO_2 eq/MWh. The average carbon intensity is 4 gCO_2eq/kWh. • A hydropower turbine is made mainly of metal parts, which means that its parts are almost 100 % recyclable. • In contrast to large-scale hydropower plants, small-scale plants barely alter the river flow, hence it has few effects on the environment. • It is climate friendly and does not produce air pollution or toxic by-products
Financial requirements and costs	• Hydro power produces electricity with low cost compared with other known ways of producing electricity, but the opportunities for investment are in fact limited by the high cost of the construction and possibilities for investment. The capital costs of hydropower projects are dominated by the civil works and equipment costs. Such infrastructure costs can account for up to half of total costs for a project in remote areas. Proper site selection can however reduce costs as hydropower is a highly site specific technology. The total installed cost for large scale hydropower stations typically ranges from as low as 1 000 US$ per kW to around US$ 3 500 per kW if the civil works is not in place. However, if existing dams built for other purposes like irrigation hydropower installations may cost as low as US$ 450 per kW[35] • According to the Intergovernmental Panel on Climate Change (IPCC) the average recent investment costs for storage (reservoir) hydropower projects is US$ 1 000 to 3 000/kW (Kumar et al, 2011). • According to IRENA (2015), the levelised cost of electricity (LCOE) for hydropower ranged from US$ 0.02/kWh to US$ 0.35kWh • Cost estimate compiled by the African Development Bank (AfDB) for a range of capital costs for small hydro projects in various African countries is US$ 5 060/kW – US$ 12 000/kW with an average of US$ 7 600/kW.
Operation and maintenance	• Hydropower typically have low operations and maintenance costs over their lifetime, but not as low as for solar PV. When a series of plants are installed along a river, centralized control, remote management and a dedicated operations team to manage the chain of stations can reduce O&M costs to very low levels. Annual O&M costs are often quoted as percentage of the investment cost per kW per year. Typical values range from 1 % to 4 % of investment capital. The IRENA assumes 3 % for smaller hydropower projects with larger plants having significantly lower Costs[36]. Installation and operation of these plants will also require training and capacity building to ensure expertise and skills are available locally for maintenance operations.

[34] Steinhurst et al, "Hydropower Greenhouse Gas Emissions", Synaps Energy Economics Inc., February 14 2012
[35] International Energy Agency: Hydropower Essentials 2013
[36] International Renewable Agency, "Hydropower Technology Brief", February 2015

<table>
<tr><td></td><td>The IPCC posits that operation and maintenance costs were found to be low and typically averaged around 2.5 % of investment cost (per kW) (Kumar et al, 2011). This cost excludes equipment replacement and/or refurbishment.</td></tr>
<tr><td colspan="2">Impact Statements – How this option impacts the country development priorities.</td></tr>
<tr><td>Socio-economic benefits</td><td>Increased energy security: Lack of own natural fossil fuel reserves is obliging the country to import more than 90 % of energy resources needed. More than 50 % of electricity demand is covered by imports. The direct impact will be on the reduction of the fuel import bill, hence improving the balance of payment and keeping more forex in the country. This will mean that there will be more government funds for capital project.

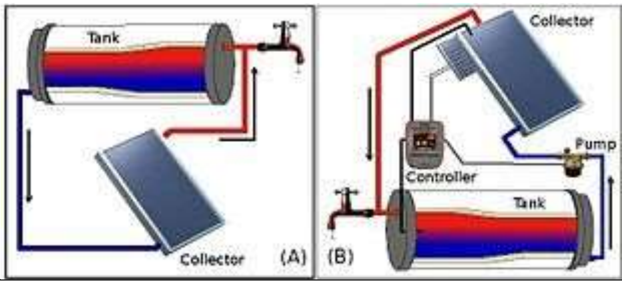
Electricity is a key factor for productive businesses. Developing small-scale hydropower in rural and remote areas where hydropower potential is high and electric dispatch from the national grid is not viable can produce social and economic benefits by:
Providing jobs through construction and operation of the hydropower plant to local population.
Promoting and creating new economic activities, providing job opportunities and enhancing income in areas that are supplied with electricity.
Facilitating irrigation, improving productivity and enhancing product quality.
Improving quality of health service, education and freshwater supply in the area.
Reducing fossil fuel and oil import expenditure.
Improving women’s access to energy and reducing their work on fuel wood collection
Encouraging productive energy use in rural areas
Better information communication technology penetration in rural areas
Enables EMP 2018 - 2028 in decentralizing renewable energy sources such as solar, mini-hydro, and wind systems to electrify rural areas where feasible
Supports the Government’s target to increase electricity access to rural population.</td></tr>
<tr><td>Environmental benefits</td><td>Small-scale hydropower produces no carbon dioxide during operation, thus significantly contributing to GHG emission reduction efforts.
In contrast to large-scale hydropower plants, small-scale plants barely alter the river flow, hence they have few effects on the environment.
Investments in the future climate-resilient electricity infrastructure project..</td></tr>
<tr><td>Gender benefits</td><td>Allow women to perform cooking chores and weaving activities.</td></tr>
<tr><td>Pros</td><td>In addition to providing access to energy, hydropower dams have other multiple benefits, including supplying water for irrigation, industrial production and residential use as well as flood prevention and habitat maintenance. With the demand for water increasing in the country and drought expected to worsen, competition for water resources is expected to increase and hydropower dams will provide dual use.
Hydro-electric technology is a proven technology that offers reliable and flexible operation and can respond within seconds to changes in load demand.
Dam can be used for leisure purposes such as fishing, boating, irrigation, etc.</td></tr>
<tr><td>Cons</td><td>The process of damming a river and creating a reservoir have several disadvantages and can pose its own environmental, economic, health and social problems. These disadvantages are:
May entail population displacement or relocation of communities living within or near the reservoir or construction sites.</td></tr>
</table>

	• The rotting organic matter in the reservoirs can lead to significant methane emissions • In addition to methane emissions from flooded biomass, the dam water is stagnant compared to free flowing water therefore can cause water-borne sediments and nutrients to be trapped, resulting in undesirable growth and spread of algae and aquatic weeds. • The construction and installation of hydroelectric power plants will have some impact on the ecosystem, biodiversity and surrounding communities as a result of modification of the natural and human environments for dam storage, transmission and distribution lines and plant operations.
Acceptability to local stakeholders	• May affect water resources and land-use. • Need for environmental impact assessment.
Lifetime	It has robust and long lasting technology with turbine having a lifetime of more 40 years which could be lengthened with proper management.

Technology 7: Solar Thermal (Commercial, Domestic and Institutional Water Heating)

Sector	Energy
Sub-sector	Commercial, Domestic and Institutional
Technology	*Solar Water Heater*
Sectoral GHG emission	• In 2017, Lesotho's total GHG emissions were approximately 5 660.44 Gg CO_2eq, the energy sector being the main source of emissions, accounting for 2 861.17 Gg CO_2eq (50.5 %). • Residential sector was the largest contributor to Lesotho's energy sector emissions accounting for 1 900.86 Gg CO_2eq (66.3 %)[37]
Introduction	Solar Water Heating (SWH) is a proven technology that has been widely applied across residential, commercial and industrial sectors around the world[38]. Solar water heating (SWH) takes advantage of the region's abundant solar resource to provide a simple, cost-effective, and sustainable means of heating water Solar water heating is not a known technology in Lesotho but the country currently has poor incentives, information and awareness promoting solar thermal technologies for heating water. Also, there is no direct financing scheme or low-interest loan facility for solar water heater purchase in Lesotho, and end-users must either pay up-front or access traditional commercial loans in order to meet the investment cost of SWH. This technology transfer initiative under the TNA project will seek to install SWH in commercial building across the country. The electricity bills for participants in this pilot project will be monitored over a 12-month period. Electricity consumption pre- and post-installation of the SWH will be compared to determine the real financial and environmental benefits and savings.

[37] LMS, 2021. Lesotho's 4th GHG Inventory Report. Lesotho Meteorological Services. Maseru, Lesotho.
[38] Renewables Global Status Report 2020 Update. www.ren21.net

Technology characteristics	Solar water heating (SWH) is the conversion of sunlight into renewable energy for water heating using a solar thermal collector. Solar water heating collectors capture and retain sensible heat from the sun and transfer this heat to a liquid. Solar thermal heat is trapped in a way similar to the "greenhouse effect"; but in this case, it is the ability of a reflective surface to transmit short wave radiation and reflect long wave radiation. Heat and infrared radiation (IR) are produced when short wave radiation light hits a collector's absorber, which is then trapped inside the collector. Fluid, usually water, in contact with the absorber collects the trapped, sensible heat and transfer it to storage[39].  Direct systems: (A) Passive CHS system with tank above collector. (B) Active system with pump and controller driven by a photovoltaic panel
	Heat transfer *Direct* *Direct* or *open loop* systems circulate potable water through the collectors. They are relatively cheap. *Indirect* *Indirect* or *closed loop* systems use a heat exchanger to transfer heat from the "heat-transfer fluid" (HTF) fluid to the potable water. **Propulsion** *Passive* *Passive* systems rely on heat-driven convection or heat pipes to circulate the working fluid. Passive systems cost less and require low or no maintenance, but are less efficient. Overheating and freezing are major concerns. *Active* *Active* systems use one or more pumps to circulate water and/or heating fluid. This permits a much wider range of system configurations. Pumped systems are more expensive to purchase and to operate. Active systems operate at higher efficiency that can be more easily controlled. Do it Yourself (DIY) SWH systems are usually cheaper than commercial ones, and they are used both in the developed and developing world.
Implementation assumptions (*how the technology will*	Solar technology needs to be promoted through a system of measures for market development. These measures shall include: market and technical information generation and outreach to inform customers about opportunities, costs and benefits. Creation of mechanisms for cheap financing for supply and purchase of solar systems. Development of

[39] https://en.wikipedia.org/wiki/Solar_water_heating

be implemented and diffused across the sub-sector)	independent technical and economic advice capacity, development of tax incentive schemes, etc. Dissemination of technology shall be supported through cooperation with building developers and condominium associations. New technical solutions for reducing the cost need to be developed and tested in pilot projects with strong monitoring and outreach components. The challenge is that the prices of solar water heaters especially for institutional sizes are still high unless if government or donors are paying.
Costs, including Cost to implement	Based on the three major SWH vendors in Lesotho, prices range from LSL 10 000 to LSL 40 000. The price varies depending on storage capacity and whether it is vacuum tubes or flat panel models being used.
Operational Cost	There are number of persons trained to install SWH in Lesotho, however most current installations are done by plumbers or even electricians. Installation costs about LSL 3 500, with a team of two persons, installation usually takes about half-a-day. Maintenance is minimal and mainly requires the cleaning of the glazed panel or tubes to ensure efficiencies are maintained. Maintenance also includes regular checks for leaks on the plumbing and occasional flushing of the system. Maintenance is also on renewing pipe insulations this is normally done once per year; and also fixing faulty electric element or thermostat if the geyser has electric back up. The other thing that needs maintenance for at most every 5 years is the replacement of Magnesium anode. Encapsulated tubes need to be replaced whenever they break or are damaged. According to one vendor's statistics, sales of vacuum tubes have been about 8 every year for every sale of 30 SWH unit, so a typical unit requires a single tube replacement every three years. Each tube costs about LSL 250.
Cost of not modifying the project	The cost of not implementing this project will see the gradual increase and reliance on non-renewable sources of energy for heating water.
Potential development impacts,	Most of Lesotho receives medium to high solar intensity (4.5 - 7.5 kWh/m^2/day) that can sustain a reasonably good solar water heating throughout most of the year.
Economic	Some of the economic benefits for Lesotho triggered by an increased uptake of SWH would include: • Direct job creation for locals: Installation and maintenance of SWH systems would require technical and manual labour, which would increase the workforce for Lesotho. • Replacing existing electric or LPG water heaters with SWH would reduce the energy intensity and hence save money. Both domestic and commercial sectors can benefit from this, but hotels, boarding schools, correctional services and resorts would be the biggest winners in SWH investments. • National Cost savings - due to reduced imports of total petroleum products Lesotho would retain currency. • Hotels and Resorts can benefit economically by promoting their regional or global green/environmental certifications.
Social	*Income, education, health, other* Electricity expenses make up a significant portion of operating expenses in the tourism industry, especially those providing accommodations, such as hotels and resorts. Solar water heaters can replace conventional thermal systems and drive down operating costs. Note that payback time on investments can be short term, as indicated by a recent study conducted by the International Renewable Energy Agency

	(IRENA) which states that the estimated payback period for SHW systems for hotels in the Africa can be as short as one year. The widespread adoption of renewable energy resources in the hotel sector of Lesotho can lead to increased demand for local trained personnel in installation, operation, and maintenance of SWH systems. An increase in investment in SWH can simultaneously benefit the environment and stimulate the local economy. It is a safe technology avoiding fire and other health risks. This option alleviates the suffering experienced by women and school children to fetch fuelwood for water heating
Environmental	*Local pollution, GHG emissions, other* Besides the reduction of GHG as mentioned earlier in the document, SWH is a clean technology and has the following additional environmental benefits: • Solar water heating systems require no fuel or any inputs during operation and electricity production and does not contaminate any water since there are no waste products. • SWH systems are noise and vibration free which can be considered environmentally friendly. • SWH systems have a service life of over 20 years with minimal maintenance, and most parts can be recycled
Status	Despite the favourable economic and climatic conditions, the SWH market in Lesotho is still emerging. Average per capita deployment is relatively low, compared to the market leader neighbouring countries. In Lesotho, SWH investment has the potential to reduce energy costs, stimulate local markets for clean energy technologies, mitigate GHG if the technology will replace electric and gas water heaters and hence improve the environmental performance of the tourism sector. Lesotho, in general, does not offer tax exemptions on solar water heater purchase. As is the case in many African countries, domestic hot water is not a priority in Lesotho households and focus on the application of renewable energy technologies have been largely centered on electricity-generation devices.
Barriers	Lesotho faces significant barriers to SHW technology and these are: - • **Financial Barriers** Despite the fact that a SWH investment has a short payback period of as little as 15 months and a generally high net present value, initial investments are very high, as much as LSL 15 000 for a 3 000-liters unit. High upfront costs than conventional technologies will discourage many homeowners from making this investment, although ongoing costs are lower. • **Organizational/regulatory Barriers** Many organizations including hospitals, public facilities and government departments still do not see energy efficiency and energy management as priority and in many cases, see energy expenses as a fixed cost. Motivation to invest in SWH may be triggered by occasional increases in fuel or electricity cost and then shortly after, this drive to save energy dies off. Other barriers identified that can restrict the mainstreaming of this technology are:

	• Weak Enabling policy environments for SWH to appeal to investors and users • Information Barriers • Technical Barriers
Acceptability to local stakeholders	This technology is proven and available in Lesotho. Market can be considerably strengthened with supportive enabling environment (awareness, financial incentive, policy and regulation, etc.). The realistic market potential is estimated at more than 60 thousand residential and commercial installations over the next 10 years. Lesotho has an enormous solar energy source. At the present, solar energy can be extracted to heat water in place of electric heaters in urban areas and providing electric power to areas without access to the national grid. Hot water has become a basic necessity. Many families want to include solar water heaters to their house's rooftop and hot water system designs. Moreover, hotels and guest houses in urban and rural areas also use electric water heaters to supply hot water to customers. All of these create a prosperous market future for solar water heaters.
Endorsement by experts	Solar thermal energy can cover a substantial part of the world's energy use in a cost effective and sustainable way. Any long-term vision for economic development must include solar thermal technologies to save finite energy sources. Key to solar' s growth is the willingness by governments, industry and all Basotho for the transition from fossil fuels to renewables.
Institutional capacity	For the pilot tests, the required institutional capacity can be met by the existing local solar companies. However, as the need for SWH grows, there will be need for more institutional capacity in the form of trained personnel to install and maintain.
Adequacy for current climate	It is possible to estimate that each m^2 of solar thermal collector surface in a properly sized residential solar water heating system would displace about 0.8 tCO_2 per year, as a rough approximation.

Technology 8: ***Production of Performance Based (CO_2 emission) Import Duties on Motor Vehicles [Vehicle Emission Duty)***

SECTOR	Energy
Sub-Sector	Transport: Public and Private
TECHNOLOGY	Production of performance based (CO_2 emission) import duties on motor vehicles. [VED – Vehicle Emission Duty]
Introduction	This technology intervention aims to change the way in which duties are charged on motor vehicles being imported into the country. The main result of this project will be to modernize the way vehicular import duties are charged, so that it encourages the country's citizens to import more fuel-efficient motor vehicles. The intervention will complement the objectives of the National Transport Master Plan, which is currently being drafted for adoption. Currently, the rate of duty applicable to Motor Vehicles is according to the engine capacity in Motor Cars/SUVs; according to the weight for Trucks, and according to the seating capacity in Vans and Busses for Public Transport. It is the intention of this technology intervention to formulate a system (Vehicle Emission Duty - VED) that charges duties on an imported vehicle not by the number of cylinders it has, but by the amount of Carbon Dioxide (CO_2) it emits per unit distance travelled (g CO_2/mile). The benefits will be a reduction in the transport sector carbon emissions, reduced air pollution and health risks, and a mode of assessing fuel quality.

Note that this technology factsheet does not propose a VED system, although an example is given in the following section. This factsheet will be used to initiate the consultative exercise in developing this VED system. The project will be carried out by a team of experts knowledgeable in the fields of customs and excise regulations, automotive systems and legislation.

The ultimate goal is to produce a document of this VED system to be presented to the relevant stakeholders (government and non-government) for approval, and later, implementation.

Technology characteristics

The proposed VED system will use the manufacture's data of emissions rates to calculate the percentage duty to be charge. It is envisioned that the system will comprise of categories designated by the vehicle emission rates – and duty percentage is assigned to each category.

Table below is a theoretical example of what the basic VED would look like.

Table: Proposed Vehicle Emission Duty

Category of Vehicle	**Vehicle Emission gCO_2/mile**	**Import Duty on Purchase Price Vehicles**
Electric / hybrid	0	10 %
A	1 – 100	20 %
B	101 – 200	30 %
C	201 – 300	40 %
D	300 +	50 %

Note that the table above is an example. The real system will need to be more complex and inclusive to ensure that all vehicle types are covered such as buses, trucks, tractors, etc. There will be the need for clauses that deal with vehicles in which the CO_2 emission rates are not available from the manufacturer.

Vehicle Emission Technology

Motor vehicle exhaust emissions are a significant source of pollution, including carbon monoxide, nitrogen oxides and hydrocarbons[40]. These pollutants can be harmful to human health and the environment and lead to the formation of ground level ozone (smog). Exhaust emissions from cars and trucks are one of the single greatest sources of air pollution and CO_2 emission.

Hydrocarbons, carbon monoxide and oxides of nitrogen are created during the combustion process and are emitted into the atmosphere through the tail pipe. Hydrocarbons are also emitted as a result of vaporization of gasoline from the tank and crankcase of the automobile.

Proposed Vehicle Emission Duty Concept

The main requirement for this technology transfer (i.e. VED Concept) will be the choice of a reliable and consistent vehicle emission testing protocol. Two systems that can be used are:

1) A laboratory emission testing facility;
2) Portable emissions measurement system.

A **Laboratory Emission Testing** facility is a major infrastructure and institutional investment that requires planning and institutional capacity. The cost – benefits has to be closely evaluated.

[40] Exhaust Gas. Retrieved January 10, 2020, from https://en.wikipedia.org/wiki/Exhaust_gas.

	A **portable emissions measurement system** (**PEMS**) is a lightweight 'laboratory' that is used to test and/or assess mobile source emissions (i.e. cars, trucks, buses, construction equipment, generators, etc.) for the purposes of compliance, regulation, or decision-making. The VED proposal will have to investigate these and other vehicle emissions measurement systems and protocols, and make recommendations to the government on the most appropriate systems that can be used to achieve the goals carbon emission reduction in the transport industry and reduce the health risks.
Cost of not modifying the project	Continuing with this archaic system that does not encourage the importation of more efficient vehicles such as hybrids and electrics.
Potential development impacts, benefits	
Economic	Country will spend less money on fuel. Hence it will have more for other areas of the economy.
Social	More money can go towards more essential functions such as health care and education.
Environmental	GHG emissions will be lowered
Barriers	• Cultural change. Urgent need of a cultural shift as a society to driving smaller, more fuel efficient vehicles; • lack of political will-power to implement this carbon emission based vehicle duty system if it results in lower revenues
Endorsement by experts	• The Department of Energy has expressed some interest in such a venture. • The National Determined Contribution (NDC) for Lesotho expresses the need for the development of a domestic transportation policy and a National Transportation Master Plan. Note that this Master Plan is currently being executed by a team of consultants. The main aim of the plan should be to achieve a 20 % reduction in conventional transportation fuel use by 2030 and promote energy efficiency in the transport sector through appropriate polices and investments.
Timeframe	Within a year to implement.
Institutional capacity	There is enough in-country capacity to conduct this exercise. Lawyers, Engineers etc.

Technology 9: ***Improved Public Transportation, Introduction of BRT, Transport Management System***

Sector	Energy
Sub-sector	Public Transport
Technology name	Improved Public Transportation, Introduction of Bus Rapid Transit and Transport Management System – Modal Shifts and Structural changes
Sectoral GHG emission	The transport sector is one of the major emission intensive sectors in Lesotho. According to Lesotho's 4th GHG Inventory Report[41], emissions from transport have grown consistently from 390.65 Gg CO_2eq in 2011 to 466.85 Gg CO_2eq in 2017, with road Transport accounting for over 99 % of all the transport emissions throughout that period. In terms of GHG accounting transport is counted within the energy sector and accounted for around 15.11% and 16.28 % of all energy-related activities countrywide, in the same reference years. The transport sector has shown the highest emission growth rate of all energy sectors since inventory year 1994. The on-road transportation, which includes passenger cars, light-duty trucks (e.g., vans and SUVs), medium- and heavy-duty trucks, buses, and motorcycles, in Lesotho

[41]LMS, 2021. Lesotho's 4th GHG Inventory Report. Lesotho Meteorological Services. Maseru, Lesotho

	accounts for a significant contribution to the GDP (6.9 %) of the economy of Lesotho, and accounts for nearly 10 % percent of the employment in the country. Petroleum supplies more than 99 % of the sector's energy, and essentially all of its GHG emissions come from the combustion of petrol and diesel. Thus managing emissions in this sector remains crucial for tackling climate change.
Introduction	Reviewing past and current mobility assessments for the Lesotho road transport sector, passengers' mobility demand has experienced a real explosion since 2000, particularly in Maseru and Maputsoe. There is an increasing number of private vehicles on the roads, in particular affordable second hand imports. This is the root cause for traffic congestion, high air pollution and GHG emissions.
Background/Notes, Short description of the technology option	BRT system is a high-capacity transport system with dedicated lanes for bus transit. It consists of a systematic combination of infrastructure (busways, stations, terminals) with organized operations and intelligent technologies to provide a higher quality experience than possible with traditional bus operation. Main services enhancements are increasing the average velocity and ensuring matching the scheduled timetables. BRT systems can make an important contribution to a sustainable urban transport system, particularly if combined to clean bus technologies. It is more energy efficient than passenger cars and conventional buses (per person-kilometer), due to the higher speeds and higher capacity buses. Thereby they contribute to the following aspects of sustainable development: • Reduction of air pollution • Reduction of GHG emissions • Congestion reduction • Increase in energy supply security, due to reduction of imported oil • Social equality and poverty reduction by providing affordable high-quality transport with lower operating costs than passenger cars per passenger-kilometer • Economic prosperity by reducing travel times and congestion However, BRT systems face significant challenges in terms of investment costs, though they vary widely. Depending on the required capacity, urban context and complexity of the project, BRT systems can be delivered for 1 - 15 million US$/km, with most existing BRTs in developing countries in the lower part of this range. These figures are substantially lower than those for rail-based systems, which cost approximately 50 million US$/km.[42] The number of vehicles imported and used in the country has seen a significant increase during the last few years. Road passenger transport sector dominates all modes of transport in Lesotho and consumes the most energy produced by petroleum products. Currently, the transport sector in Lesotho utilizes petroleum-based fossil fuels, leading to significant amounts of CO_2 and other GHG emissions (e.g. N_2O, CH_4) considered under the UNFCCC and Kyoto Protocol. The main type of buses being used have an average carrying capacity of 50 - 55 persons, and use large diesel engines with total displacements sometimes in excess of 8.0 litres. These buses average 5 – 8 miles per gallon [2.1 – 3.4 kilometres per litre].
Implementation assumptions, *How the technology will be implemented and diffused across the subsector? Explain*	Currently, the bus system is privately owned by numerous bus companies that are given licenses to run buses along designated routes. The Government's only role is to regulate. This proposal calls for a Public Private Partnership (PPP) between the Government and the private bus operators. As the regulatory body, the Government through the

[42] https://brtguide.itdp.org/branch/master/guide/why-brt/costs

if the technology could have some improvements in the country environment	Department of Transport would mandate that buses over a certain age should be phased out of the system over period (2 – 5 years) and replaced with new and more efficient buses. To assist operators with purchasing – the Government would then grant tax waivers for bus imports and also facilitate low interest loans. BRT is another mass transit system that provides a faster journey compared to regular buses, as BRT runs mostly on bus-only, exclusively right of way lanes. Modal integration at stations, rapid boarding and alighting, real-time information displays are also common features. The travel time is less in these sophisticated, low cost buses, and due to high fuel efficiency, the GHG emissions are reduced. Mass transit modes are in general 50 – 80 % more efficient compared to personal cars. This technology intervention seeks to improve the public transportation system through the revamping of the current bus fleet to allow for newer, cleaner and more comfortable buses with reduced carbon dioxide emission rates (CO_2 per mile). An additional spin-off effect would be the increased use of an upgraded, public transportation on a daily basis by private citizens who own vehicles, but choose to use the public transport system for one reason or another. This should contribute to the reduction in private vehicle usage, and consequently carbon emissions. The technology intervention will initially take the form of a pilot project. This pilot will see the purchasing and operational use of the desired buses on specific bus routes.
Implementation barriers	• Space requirement for developing infrastructure (bus lines, stations, and terminals), and at some places there might not be the possibility to expand the existing road space • Possible resistance by existing bus operators, with negative consequences on the initial implementation. • Lack of management and planning experience, making it difficult to define BRT routes during the planning phase.
Reduction in GHG emissions	Mass transit leads to reduced traffic congestion, which leads to GHG reductions for individual vehicles, as they can travel more efficiently. Also, if efficient, it can reduce private vehicle use at the same time leading to substantial GHG reductions.
Country Specific Applicability and Potential	Mass transit can prove to be a genuine solution for Lesotho to reduce the number of cars running on its roads and provide for a better, more consistent transportation system that can boast of reliability, safety as well as comfort. BRT systems are already operating in other developing countries in the region, and can be applied in Lesotho, as well, especially in city areas with heavy traffic and congestion due to too many low occupancy personal vehicles on the road. The possibility of using any existing road sectors, as well, needs to be considered in minimizing the costs associated with introducing this 'new' mass transport mode in the country This technology can encourage moving from private vehicles to public transport to reduce traffic congestion, air pollution. The growth in private vehicle is gaining momentum and with the increase average income of individuals, there is no end in sight for this growth. BRT is suitable to all people. As traffic congestion has become a serious issue in Maseru and Maputsoe, BRT is a feasible measure due to lower capital costs than subway and shorter construction time. Urban planners only have to study and rearrange the transport system in the city, reserve right-of-way passages for BRT in big streets, build bus stops for BRT.

Status of technology in country	At present Lesotho has a poor urban mass-transport system, with the public transport system being dominated by minibus taxis. The majority of Basotho are dependent on public transport, yet it is currently very inefficient and even unsafe. There are a number of options that could be considered for the improvement of urban mass-transport systems, such Bus Rapid Transit (BRT) System in Maseru and Maputsoe, and incentives to encourage people to use public transport instead of their own vehicles. Inefficient single occupant private car usage is a cause of growing congestion, especially in Maseru and other major towns. Public transport systems will require major improvements in road and communication infrastructure and developing this infrastructure will entail significant investment. Currently, privately owned buses and taxis are the principal mode of public transport. So far there is no BRT operating in the country. The technology is well known and there is enough know how about it. The country's national strategies are supporting the expansion in the mass transportation system.
Cost of not modifying the project	The status quo would remain as is with the use of unreliable, inefficient and uncomfortable buses. Carbon emissions from the Transport Sector will increase, as demands for public service transportation increases, and bus owners continue to import, inefficient and emission-control defective buses for their fleet.
Country social development priorities	• Provides safe, comfortable and timely mobility to female, children, old-aged and disabled passengers • Enhance mobility equality by providing means of transport for disabled, children, elderly etc. • Health benefits from reduced air pollution. Social equality and poverty reduction by providing affordable high-quality transport,
Country economic development priorities	• Create jobs at bus system e.g. drivers, collectors, conductors, etc. • Economic prosperity by reducing travel times and congestion • Low investment costs. Although the initial costs are relatively high, in the long term, benefits are much higher.
Country environmental development priorities	• Lower fuel consumption and higher energy efficiency lead to lower GHG emissions. • BRT systems help enhance the efficiency of public transportation and reduce air pollution • Reduced traffic congestion, travel times and need for land for the road network and parking spaces. • Increase in energy supply security, due to reduction of imported oil. • Reduced noise levels
Country development priorities	Energy efficient urban mass transport system would not only reduce GHG emissions, but also alleviate traffic congestion and improve local environment quality. Lesotho does not currently have vehicle emission standards, which results in highly polluting vehicles being operated on the roads. This has negative impacts not only on GHG emissions, but also on air quality standards in the cities.
Financial requirements and costs	Estimates for investment cost for BRT systems vary widely. Depending on the required capacity, urban context and complexity of the project, BRT systems can be delivered for US$ 1 - 15 million per km[43], with most existing BRTs in developing countries in

[43] IPCC, 2007. Transport and its infrastructure. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Metz, B. and Davidson, O.R. and Bosch, P.R. and Dave, R. and Meyer, L.A. (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, USA. Available at: https://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter5.pdf

	the lower part of this range[44]. These figures are substantially lower than those for rail-based systems, which cost approximately US$ 50 million per km. For China, the incremental cost of implementing BRTs have been estimated at 2.6 US$/t$CO_2$[45]. For Latin American cities, costs for BRTs were estimated to be 14 - 66 US$/t$CO_2$, depending on the policy package involved (IPCC, 2007). When assessing the benefits and costs of mass transit, many factors need to be taken into account. These factors include an assessment of travel time savings, reductions in fuel, pollution and accidents, and space saved. Transit systems can be financed and managed through public-private-partnerships, with private partners building the system, operating it, or both. Public funds may also be available through the World Bank, regional development banks or bilateral development cooperation arrangements. In addition, climate change funding mechanisms may fund transit projects. Transit operating costs can of course be at least partially covered by passenger fares.
Acceptability to local stakeholders	Acceptability by the major stakeholders (bus operators) will be a challenge.
Timeframe	**Short term implementation**: Public transport bus technologies implementation could start immediately. However, BRT system need an adequate planning and could be implemented on the short to medium-terms

Reference:
ClimateTechWiki | Climate Technology Centre & Network | 1167979 (ctc-n.org)

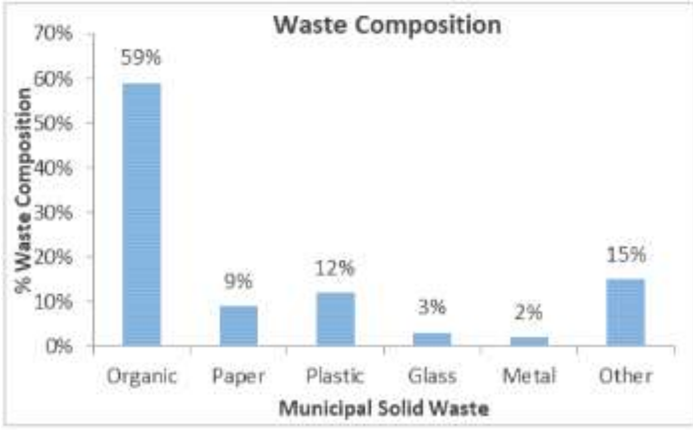
Technology 10: Waste-to-Energy Recovery - Methane Capture from Landfills

Sector	Energy
Sub-sector	Residential and Commercial
Technology name	Methane capture at landfills and waste dumps for energy production
Sectoral GHG emission	• In 2017, Lesotho's total GHG emissions were approximately 5 660.44 Gg CO_2eq of which at 370.39 Gg CO_2eq (6.54 %) were from the waster sector • By gas, the second largest contribution of GHG in Lesotho came from methane (CH4), which contributed 24.2 % over the period 2011 – 2017 of the total national GHG. • GHG emissions from the waste sector constituted 1.77 % in 1994 and up to 6.54 % of total emissions in 2017 • Since 1994, the waste sector emissions have increased by 574.7 % while the energy sector increased by 245.9 %. • The decomposition of organic waste generates methane, a GHG and a primary component of LFG. LFG energy projects reduce the amount of methane emitted from landfills as the LFG is captured and beneficially used in various types of technologies.
Background/Notes, Short description	Waste can take many forms – organic waste, municipal solid waste, light industrial waste, construction and demolition waste, electronic and electrical waste (e-waste) and mining

[44] ITDP, 2007. BRT planning guide. Available at BRT Planning Guide (English) - Institute for Transportation and Development Policy (itdp.org)
[45] ClimateTechWiki | Climate Technology Centre & Network | 1167979 (ctc-n.org)

of the technology option	waste. Returning waste fractions to some form of use and converting that which cannot be used into a more societally acceptable end-form recognizes that waste is an integral part of economic activity within the societal context. Waste management needs to evolve from consigning waste to ever-increasing landfills as a final resting place towards being a regular economic activity within a socio-economic framework. Waste disposal in unsanitary landfills have an adverse and everlasting effect on environment. Some problems such as water pollution through leachate, uncontrolled combustion and GHG emissions due to production of methane, unpleasant odor and causing asphyxiation. Although it is a simple and affordable method for waste disposal, it is the worst option and poses a threat to the environment. If this process is controlled under sanitary conditions, this can reduce the impact on environment by trapping the biogas and leachate management. Municipal Solid Waste (MSW) is waste generated by commercial and household sources that is collected and either recycled, incinerated, or disposed of in MSW landfills. The primary target of Municipal solid waste Management (MSWM) is to protect the health of the population, promote environmental quality, develop sustainability, and provide support to economic productivity. Landfill gas (LFG) is created as solid waste decomposes in a landfill. Methane capture from landfills entails the recovery and use of landfill gas (LFG) as an energy resource. Methane is a potent GHG 28 to 36 times more effective than CO_2 at trapping heat in the atmosphere over a 100-year period, per the latest IPCC assessment report (AR5). The waste disposal method practiced in Lesotho is open dumping. There is a complete absence of engineered landfills. Instead, there are many dumpsites available in proximity to major communities posing threat to human's health and water resources. There is potential for methane gas capture in municipal landfill in Maseru and other towns in the country. The captured methane gas can be used for electricity generation. The Largest municipal landfill in Maseru is located at Ha Tšosane. LFG capture is currently not occurring at the site. It is estimated that the landfill receives approximately 70 916 tons per year of municipal waste. With the rapid economic growth and urbanization, this value would increase rapidly. According to UNDP report, an unsustainable waste management system in Lesotho threatens the health of public through water contamination[46]. MCC collects solid waste produced by the industries, residential and commercial in Maseru to Ts'osane dumpsite, which is the only dumpsite in the capital city, positioned less than 5 kilometers away from the center of the city of Maseru. This dumpsite is situated within the Maqalika reservoir catchment, which provides drinking water to the entire Maseru region. The leachate leakage from the dumpsite is currently a treat to water supply in this region. MSW generation rate of Lesotho according to UNDP is 0.5 kg/capita/day cumulating into 115 000 tonnes per annum for the city of Maseru alone. It has been projected that by the year 2025, the generation rate would increase to 0.8 kg/capita/day cumulating into total MSW generation of about 279 000 tonnes per annum[47]. This current state of waste quantity and future projections of waste in Lesotho on one hand implicates a disaster for waste management system especially with the current poor waste management infrastructure in the country. On the other hand, the figures indicate a promising waste to energy potential

[46] UNEP, "Integrated Solid Waste Management (ISMP) for the City of Maseru/Lesotho (Final draft)," University of Cape Town and Enviro Tech Environmental Consultants, Lesotho2008.
[47] M. V. Scarlat N, Dallemand JF, Monforti-Ferrairo F, Mofor L., "Evaluation of energy potential of MSW from African urban areas," Renewable and Sustainable Energy Reviews, pp. 1269-86, 2015.

	for the country. Hence the need to balance the energy-environmental gap in the country. The waste composition of Lesotho is as depicted in the figure below[48].  Solid waste composition for Lesotho The figure reveals that the bulk of the waste in Lesotho are organic waste making up about 59 % of the total generated waste. This suggest that biological methods of waste conversion could be a potential waste to energy technology of choice.
What components make up landfill gas?	By volume, LFG is about 50 % methane and 50 % carbon dioxide and water vapor. It also contains small amounts of nitrogen, oxygen, and hydrogen, less than 1 percent non-methane organic compounds (NMOCs), and trace amounts of inorganic compounds. Some of these compounds have strong, pungent odors (for example, hydrogen sulfide). NMOCs consist of certain hazardous air pollutants (HAPs) and volatile organic compounds (VOCs), which can react with sunlight to form ground-level ozone (smog) if uncontrolled. Nearly 30 organic hazardous air pollutants have been identified in uncontrolled LFG, including benzene, toluene, ethyl benzene, and vinyl chloride. Exposure to these pollutants can lead to adverse health effects.
Implementation assumptions, How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment	LFG capture projects aim at preventing emissions of methane and other pollutants from landfills. The basic idea behind the technology is that the landfills are covered and that LFG is extracted from landfills using a series of wells and a blower/flare (or vacuum) system. This system directs the collected gas to a central point where it can be processed and treated depending upon the ultimate use for the gas. From this point, the gas can be flared, used to generate electricity, replace fossil fuels in industrial and manufacturing operations. Energy and clean environment are crucial to the development and living standards of any nation. Therefore, effective management, utilization and conversion of MSW to useful energy (*Waste-to-Energy*) could be a potential means of providing a sustainable and environmental friendly solution to bridging the gap between energy and the environment. Waste -to -energy involves thermal and biological processes that extract the usable energy stored in the organic portion of solid waste to produce heat (steam) or electricity or both (combine heat and power). This involves recovery of landfill gas, incineration, gasification, production of H_2, pyrolysis and anaerobic digestion of the organic fraction of the waste. Therefore, utilization of MSW as a renewable energy source could overcome waste disposal issues, generate electric power and mitigate GHG emissions.

[48] The World Bank, What a waste. vol. 15. Washington, DC, USA, 2012.

Implementation barriers	• Unfavorable financial performance: As shown by several CDM projects in the field of LFG capture and use[49] , the financial performance of such projects is generally insufficient to attract enough investment funding from financial institutes. • There could be a lack of social acceptability, for example, when landfills are a source of live for nearby communities. • The volume of waste in landfill must be greater than 1 million tons for cost effectiveness • The low standards of landfill operation form the high risk of feasible project implementation due to uncertain amount of recovered LFG.
Reduction in GHG emissions	The combustion of LFG for the production of energy contributes to the reduction of GHG emission in two ways. LFG capture prevents the release of methane into the atmosphere (as GHG methane is 25 times as powerful as CO_2) and the electricity subsequently produced by LFG combustion produces less CO_2 emission than conventional fossil fuel combustion.
Country-Specific Applicability and Potential	• There is potential for methane gas capture in a municipal landfill in Maseru. The captured methane gas will be used for electric generation • The rapid MSW generation rate, poor waste management system and inadequate electricity supply in Lesotho motivate the need for WtE technology implementation in Lesotho.
Status of technology in-country	• Currently, there is no deployment of landfill gas collection, recovery and/or utilisation technology in Lesotho • Feasibility studies, including resource assessment, have been suggested based on the waste profile of Lesotho for use of methane gas from MSW although there are no concrete plans for implementation. Cost-benefit analysis has also been carried out.
Country social development priorities	Methane capture from landfills improves the livelihood of people and as well as it provides a sustainable supply of energy and enhances population health by removing the hazards they face from the landfills both in the short and long runs
Country economic development priorities	The process of designing, constructing and operating LFG capture plants create jobs associated with the design, construction and the ration of energy recovery systems. LFG energy projects involve engineers, construction firms, equipment vendors, and utilities or end-users of the power produced. Much of this cost is spent locally for drilling, piping, construction, and operational personnel, providing additional economic benefits to the community through increased employment and local sales. Can be used to meet both baseload and peak electricity demand
Country environmental development priorities	• Using LFG helps to reduce odours and other hazards associated with LFG emissions and helps prevent methane from migrating into the atmosphere and contributing to local smog and global climate change • Converting LFG to energy offsets the need for non-renewable resources such as coal and oil, and reduces emissions of air pollutants. • LFG energy projects go hand-in-hand with community commitments to cleaner air and reductions in GHG that cause global climate change. • Decrease risk of explosion or fire hazard from landfill • Reduced health risk from infectious and respiratory diseases
Other considerations and priorities such as market potential	The market potential of LFG energy utilization is limited by percentage of landfills with one million tons of waste in place and percentage of waste in anaerobic condition

[49] cdm.unfccc.int

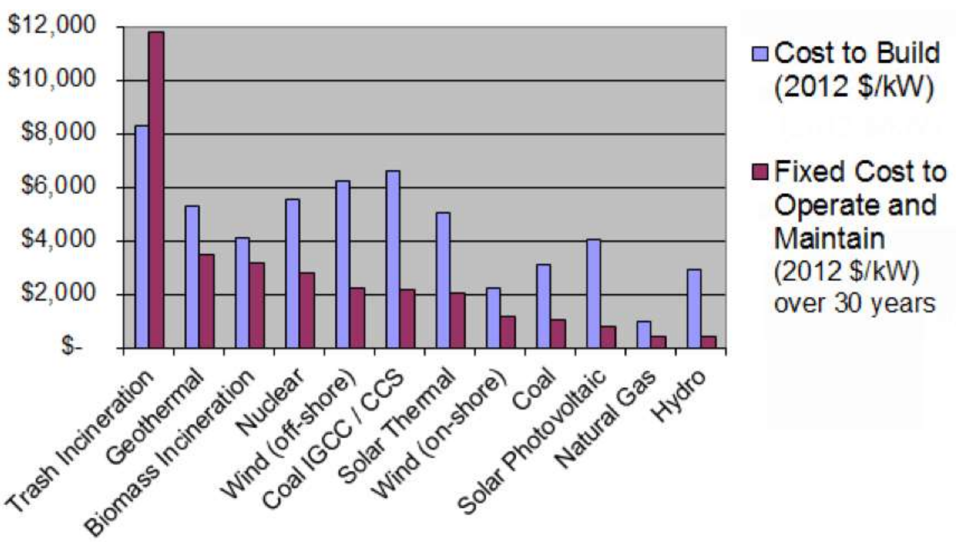
<table>
<tr><td>Financial requirements and costs</td><td>Initial costs for the installation of methane capture are quite high. Investment costs in obtaining the site, construction and equipment may tend to be relatively high. The cost of an LFG project depends on a number of factors, including the size, location, and layout of the landfill. Major capital outlays include designs, permits, and installation; major operation and maintenance costs include parts and materials, financing, and administration. Typically, one million tons of landfill waste emit approximately 12 232 878 liters of LFG per day, enough to produce either 0.78 MW of electricity

Approximately 70 % of LFG projects generate electricity, primarily via internal combustion engines, gas turbines, and micro-turbines. Costs vary, but internal combustion engines (ICEs) smaller than 1 MW typically cost US$ 2 300/kW to install, with annual operation and maintenance costs of US$ 210/kW, and ICEs larger than 800 kW typically cost US$ 1 700/kW, with annual operation and maintenance costs of US$ 180/kW.</td></tr>
<tr><td>Lifetime</td><td>The gas yield will depend on the nature of the landfill. For a large modern landfill, useable LFG may be generated for between 15 and 30 years after landfill closure</td></tr>
<tr><td>Disadvantages</td><td>

Incineration is the most expensive way to make energy

Waste incineration is the costliest form of power generation, in terms of both the cost to build and to operate, as shown in the figure below. This is linked to its inefficiency.

Cost per kW of installed capacity for electricity generation technologies (as at 2012)



- Incineration facilities are expensive to build and operate – this is the most expensive way to produce energy. The high upfront cost means they often require public sector support to underwrite private investments.
- Investment in incineration locks cities into high-carbon pathways by requiring them to continue producing lots of waste to feed the incinerator, undermining efforts to reduce waste generation or increase recycling rates.
- Producing energy from solid waste incineration is very inefficient unless source segregation of waste is good. This is because cities' waste streams contain high levels of food waste and organics, which have high water content.
- Waste incineration produces toxic pollutants, requiring strong environmental controls to prevent their release into the atmosphere – this is often the most expensive operational cost. When budgets are squeezed, facilities sometimes cut back on these environmental controls, with serious consequences for pollution.

</td></tr>
</table>

		• Energy produced from waste incineration is not clean or renewable, as it burns materials that are derived from fossil fuels, like plastics. It releases greenhouse gases.

Technology 11: ***Marketing and Subsidy of Energy Efficiency and Conservation in Buildings (Residential, Commercial, Industries and Institutional).***

Sector	Energy
Sub-Sector	Energy efficiency and conservation
Technology name	Promotion/Construction of Energy Efficiency and Conservation in Buildings: Commercial, industries and institutional, etc.
Introduction	Construction of energy efficient infrastructure means constructing buildings that are energy efficient and lead to energy savings in the construction sector. Building with steel and cement requires a lot of energy during production of those building material, while building with natural stone, clay/mud and wood requires very little energy
General information	The built environment can be designed to consume minimal energy and also increase the potential for the building to generate energy through the installation of energy generating technologies such as solar PV systems. Currently, most structures in Lesotho are constructed without consideration of minimising energy consumption. This ends up increasing heating, lighting and cooling costs for the built environment. Many people are aware that there are some interventions that can be done in the design and construction of structures that could reduce energy consumption throughout the life of the structure. Related to this is a system that intelligently manages the energy and other needs in buildings and which can have considerable benefits. Such a system is called building energy management system (BEMS). BEMS is a sophisticated method to monitor and control the building's energy needs. Next to energy management, the system can control and monitor a large variety of other aspects of the building regardless of whether it is residential or commercial. Examples of these functions are heating, ventilation and air conditioning (HVAC), lighting or security measures. BEMS technology can be applied in both residential and commercial buildings Buildings are some of the energy consuming units, especially in high-income households and institutions, to power energy consuming appliances such as water geysers, cooking utensils, lighting, cooling/heating, entertainment and security facets. Included in the building category are: commercial offices, retail, warehouses (excluding industrial), hotels and catering, transport and communication (building-related energy use only), sport and leisure including libraries and theatres, education (schools and universities), health centres, hospitals, government and other buildings including churches, mosques and community centres. Within buildings energy saving can take place through refurbishment of existing property or by building new buildings which replace old buildings and/or which energy performance is better than that of existing buildings.
Technology characteristics	Energy conservation in buildings can be achieved through a variety of technologies, some of which have been explained below • **The orientation and form** of the building to improve daylighting: Preferably, a building's longest side should face north since Lesotho is in the southern hemisphere. Lighting controls such as occupancy

	sensors have been shown to save significant electrical energy in commercial buildings. • **Warming and ventilation**: Buildings can be designed to be naturally ventilated with considerations such as inlet and outlet aperture sizes for the air flow being important. Air conditioning using electrical energy is second only to lighting in terms of energy demand in buildings. • **Double Glazed windows:** A double glazed window consists of two layers of glasses, which are separated by a spacer bar. The cavity between the two panes is filled with inert gas or air and sealed around the perimeter. As inert gas or air is poor conductor of heat, it reduces heat conduction between the two panes. This reduces the peak heating and cooling load of the building, resulting in reduced size of air-conditioner/heating unit. • **Energy Efficient HVAC Systems:** HVAC (heating, ventilation, and air conditioning) provides conditioning of space with respect to temperature, humidity also using fresh air from outdoors. Since heating or cooling a space contributes to maximum energy consumption of the building, using energy efficient systems help to conserve energy, without compromising with the quality and comfort of living. • Further, intelligent HVAC systems provide variable fan speeds, results in energy saving when the room is empty or has less occupancy as designed for. Temperature control mechanism allows setting the desired temperature of the room, avoiding excess cooling or heating in the room. Additionally, room heating is performed by recovery of the waste heat from present HVAC systems or any other systems available at site. • **Energy Efficient Lighting System**: Energy Efficient Lighting System such as Light Emitting Diode • give better light outputs, bringing in substantial energy savings. In case of LEDS, 80 % of the electricity gets converted to light energy as compared to incandescent bulbs that convert only 20 % of electrical energy into light energy. CFLs also use at least two thirds less electricity than the standard incandescent lamps they replace and last up to 4 times longer. • Double roofing • Ceiling insulation, • Floor insulation • Solid thermal north facing walls as heat storage in winter
Financial requirements and costs	The costs for building energy efficient buildings should not be much different from standard building methods. The extra costs involved could be offset by reduction in energy costs. There is a lot to learn with exposure to this technology option. The IPCC (2007)[50] concludes that the BEMS technology can reduce energy usage and but costs depending on a variety of conditions including weather conditions, energy used for heating and/or cooling, size of the establishment etc. Estimates provided on the technology energy savings differ considerably and therefore the technology requires more research and development to determine the financial

[50] IPCC (2007) BEMS

	requirements and costs. For example, Birtles and John (1984) estimate energy savings up to 27 % compared to no BEMS installed, while the IPCC notes estimates between 5 % and 40 % (IPCC, 2007). Additionally, Roth et al. (2005) estimate energy savings up to 20 % in space heating energy consumption and 10 % for lighting and ventilation, combining to a 5 % to 20 % overall energy savings range.
Technology feasibility	Lesotho has limited experience in this technology but the interest is very high. With BEMS, while the operation of the technology might be relatively straightforward due to a sophisticated interface, there is still a need for skilled operators of the technology. In addition, the installation of the technology requires training of the installation personnel.
Status of technology and Market potential	The government has recognized the need for energy efficiency in Lesotho's energy sector. There is interest in this technology. The problem is lack of demonstration and promotion. Some people who have already built their houses realize now that the orientation of their roofs does not enable them to fully benefit from sunlight, shading, and installation of solar PV and solar geyser. For example, a local company already implemented most available cost and energy saving technologies, such as design form (passive solar design), north orientation, double roofing, floor insulation, thermal storage walls, double glass windows, etc and the long-term experience proved that no air conditioning in summer is needed and very little heating needs are required in winter. The buildings are done by using only locally available materials.
Economic	• Reduction of energy cost for production of unit service and product. This would make contribute energy savings for households and reduction in unit market price of the service and product resulting into competitive advantage and growth of an industry • Energy efficiency and conservation are some of the peak-power management options, which minimises power interruptions during peak hours, contributing to smooth operations of economic activities at all times.
Social	• Energy efficiency and conservation contributes to having power at all times, and thus social activities like health, education and security are discharged without interruptions. This contributes towards social development of a country
Environment	• The saved fossil fuel and forests contributes towards environmental management in the area of improvement in outdoor air quality • Savings in energy consumption could lead to direct reduction in greenhouse gases, since a lot of energy production leads to these emissions.
GHG mitigation potential	Especially in industry where heavy carbon fuel like coal is used, saved fossil fuel due to application of energy efficiency and conservation measures directly contribute to GHG reduction.
Applicability of the technology in Lesotho (short, medium and long term)	The technology could be applied in a short term
Size (household and large-scale)	The application could be at household and large-scale

*On Applicability of the technology

Applicability of technology is defined as follows: short term is the technology that is proven to be liable and is commercially ready in similar market

Medium term refers to the technology that is in pre commercial in a similar market

Long term refers the technology that is still under research and Technology phase

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Western Cape Department of Environmental Affairs and Development Planning, 2008. A Guide to Energy Management in Public Buildings. Available online at http://www.cityenergy.org.za/uploads/resource_156.pdf.

Technology 12: Introduction of a Mix of Hybrid and Electric Vehicles (EVs)

Sector	Energy
Sub-Sector/Technology Option	Road Transport
Technology	Introduction of a Mix of Hybrid and Electric Vehicles (EVs): Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs), Battery Electric Vehicles (BEVs), Mild Hybrid-Electric Vehicles (MHEVs).
Introduction	Transportation is responsible for 24 % of the direct global CO_2 emissions due to fossil fuel combustion. The Paris agreement on climate change set the goal of limiting global warming to well below 2, preferably to 1.5 ^{o}C, compared to pre-industrial levels. Electric Vehicles (EVs) are widely considered a powerful mitigation option to reduce CO_2 emissions from buses, passenger cars and two and three-wheelers in the transport sector. The global push toward EVs is reflected in impressive growth rates of sales of electric vehicles (EVs) doubled in 2021 from the previous year. Nearly 10 % of global car sales were electric in 2021, four times the market share in 2019. This brought the total number of electric cars on the world's roads to about 16.5 million, triple the amount in 2018. However, this global push for EVs has not translated into similar numbers in the developing world. As Lesotho looks to curb its emissions and offset coal-intensive electricity imports, EVs offer the ability to decarbonize the country's domestic transportation sector. Unlike the power sector that has experienced some supply diversification using renewable energy sources, almost the entire transport system in Lesotho is dependent on imported fossil fuels. The use of electricity as an energy source for vehicles from renewable sources is one way to reduce fossil fuel use in the transport sector. There are two (2) main categories with a number of options to electrify vehicles. The first category is vehicles operating purely on electricity or 100 % electric propulsion for mobility. These are called electric vehicles (EVs) or battery electric vehicles (BEV) and can source electricity either from the grid or off-grid. This type of vehicle uses a rechargeable battery- pack to power an electric motor (s) for mobility and auxiliary power without the use of the internal combustion engine, fuel cell or tank. The second category is the use of hybrid electric vehicles, in series or parallel configuration, and there are a number of options for these kinds of vehicles ranging from mild hybrid, full hybrid, and plug-in hybrid to extended range hybrid. The batteries on these vehicles are smaller in comparison to the EVs, can be plugged into the grid to charge, using a downsized internal combustion engine to provide power when the battery is at minimum discharge level or under specific driving conditions, as needed.

	The concept of the PHEV option is well known in the transport sector but its diffusion and deployment have not been characterized by a high speed of penetration in the market
Status of technology in country	EVs are new to Lesotho. Currently there is no known application of EVs to the vehicle fleet in country and any introduction would require supporting polices for its transition and operation, in particular, to support the recharging infrastructure.
Technology Characteristics	The critical components of an EV are the electric battery and charger, electric motor and motor controller. The battery can be charged by direct connection to the grid or by regenerative[51] braking. Power is supplied to the electric motor via the motor controller and is then converted for use[52] . Lithium-ion (Li-Ion) battery chemistry is the technology of choice for EVs because of their specific energy and power density qualities. These are necessary performance requirements to allow for the mainstreaming EVs.
Capital Investment Cost	Conventionally, EVs were about 2 - 3 times more expensive than the internal combustion engine vehicles (ICEV) mainly due to high cost of the battery- pack. This cost is the capital investment that that could be recouped over time by the low running cost[53] and enhanced performance of the batteries. On average, annual cost of ownership varies significantly based on the type of vehicle and market/region of deployment[54]
Operating Cost	EVs have low operating costs in terms of energy use and maintenance. IRENA (2013) and Simpson (2011) stated that battery costs dominate the costs of EVs. IRENA (2013) projected that EVs are in the early stages of mass commercialization and this has a bearing on cost reduction over time. It is projected that cost reductions will be significant by 2030, that is, the overall cost of EVs, including that of the battery will become competitive with ICEVs markets providing that supporting policies are in place. It is also projected that improvements in battery technology will allow for enhanced battery performance thereby extending the overall battery life (IRENA, 2013).
Maturity	The technology platform for EVs has been in use for over a century and is available in many different forms across the spectrum. Significant advancements were made in recent years, especially to the battery performance and life of the EVs to make them comparable in terms of cost and performance to the ICEVs. Current development places EVs at the early stage of mass commercialization and close to being competitive with the intention to fully diffuse the technology across various markets and regions by 2020, providing that the supporting policies are in place.
Country Specific Applicability	
Market potential	EVs are at the early stage of mass commercialization to allow for rapid uptake. It is forecasted that EVs could account for at least 5 – 10 % of new vehicles sold by 2025 (Simpson, 2011) as a result of a number of factors including increases in performance and reduction in costs making EVs highly competitive with ICEVs.
Institutional and Organizational requirements	Regulations and standards will be required to ensure vehicle safety and fleet monitoring, as well as, deployment. Incentives should be considered to encourage diffusion in the long term.
Operation and maintenance	Special technical trainings are required to ensure that acceptable and appropriately safe maintenance and repair can be conducted. EVs will require battery

[51] Regenerative braking allows for the capturing the energy created by the momentum of the vehicle at the moment of braking to re-charge the battery, which would otherwise dissipate as heat, Simpson (2011).
[52] Helmers, E., Marx, P., (2012): Electric Cars: Technical characteristics and environmental impacts. Published in Environmental Science Europe.
[53] Simpson, A. (2011): Electric Vehicles. In Technologies for Climate Change Mitigation: Transport Sector. [Dhar, S., Newman, P., & Salter, R.(Eds.) and Reviewed by Hidalgo, D., Litman, T., & Rogat, J.]
[54] IRENA (2013): Road Transport: The Cost of Renewable Solutions – Preliminary Findings. www.irena.org/publications

	changes over the life of the vehicle since the battery performance degrades over time with the number of charge cycles (charge/discharge cycles).
Acceptability to local stakeholders	This technology may take some time to be accepted by the wider stakeholder groups in Lesotho providing the barriers, especially cost and understanding of the recharging infrastructure, can be addressed.
Mitigation Benefits	
Greenhouse gases abatement potential	Electric vehicles (EVs) help decarbonize transportation because they are more efficient and use a cleaner fuel than the internal combustion engines they replace on the road. At the same time EVs reduce carbon emissions, they also dramatically reduce harmful smog-causing pollutants and vehicle soot. EVs also help to decarbonize the electricity sector, because they can be managed to maximize the use of zero-carbon renewables like wind and solar. Thus, while electricity as a transportation fuel is getting cleaner every day, EVs can help speed the decarbonisation of electricity.
Potential Development Benefits: Economic, Social, Environmental	
Economic benefits	The introduction of EVs will improve energy security and reduce dependence on imported petroleum-based products. • EVs, based on projections by IRENA (2013), can be cost competitive with internal combustion engines and 2020 due to mass production and diffusion are readily available, with low running costs in terms of energy use and maintenance. • EVs can be recharged with electricity produced from local sources. • EVs can be supported through augmentation of existing electrical energy infrastructure in the short term. It is important to ensure that the electrical energy is from renewable sources.
Social benefits	Electric motors are cheaper and more efficient than internal combustion engines and reduce local pollutant emissions, providing indirect health benefits. EVs are economical to operate, thus, allowing for cost savings from the use of less energy and maintenance. It means more money is available for other purposes.
Environmental benefits	• As a result of producing zero tailpipe exhaust emissions such as soot or NOx, EVs contribute to improvements in local air quality, especially in urban areas. • EVs are characteristically more silent than conventional vehicles with internal combustion engines and therefore reduce the overall noise levels in urban areas.
Timeframe	**Medium term implementation** EVs' and PHEVs' implementation could not start immediately. A specific recharging infrastructure is requested. EV and PHEV concept are expected to become a mature expandable technology on the short to medium terms

Reference:
ClimateTechWiki | Climate Technology Centre & Network | 1167979 (ctc-n.org)

Agriculture, Forestry and Other Land Use sector

Technology 1: Improvement of cattle production systems (breeds) in Lesotho

Subsector GHG emissions	Methane from enteric fermentation
Background/Notes, Short description of the technology option	Cattle production is the main source of GHG emissions from livestock. It is also a major source of agricultural emissions in the country. Cattle are responsible for over 57 % of enteric fermentation emissions in the country. They are followed by sheep and goats. Methane emissions are influenced by number of animals and feeding schemes. Cattle production in Lesotho is traditional and employs old production methods. Production systems are subsistence in nature and lack technological inputs. Cattle produced in the country consists of animals of small size (body structure). The common breed in the country is Nguni, but there are also other breeds. They are used for draught power in the fields, milk production mainly at a household level, and they are key animals used for cultural festivals and other ceremonies. Traditional cattle have low outputs per animal unit. These outputs include main animal products obtained in the form of meat and milk. As a result, there are large cattle herds in the country. Large cattle numbers put pressure on rangelands, and which cause over-grazing and land degradation. On the other hand, improved cattle breeds have increased outputs per unit. Their increased adoption can reduce cattle population in the country. For animals with a higher annual milk yield, the overall farm GHG emissions are distributed over a larger amount of milk. In terms of feed energy utilization, the herd directs a higher percentage of feed energy intake to generate the products, rather than simply maintain body and reproduction functions.
Implementation assumptions. How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.	1. Improved breeds may be foreign to local climate and other environmental conditions – unlike local breeds that are resilient. Proper research is required before the technology is brought into the country. 2. Animals may require some changes in management practices. Adoption of new techniques may be necessary. 3. New animal breeds may be diffused with the national initiative of commercialization, improving livestock productivity and food security. 4. Improved breeds with higher productivity will require less livestock stocking. This can reduce pressure from rangelands and overall land degradation.
Implementation barriers	1. Availability of consistent quality feeds. The transition to remove traditional animals and introduce improved breeds can be difficult. Cross breeding is possible and that can reduce the wanted quality. 2. Animals may be prone to diseases. New environments and management systems can result in challenges to the new and improved breeds. 3. Limitation of improved breeds for draught power use. Improved breeds may not be suitable to provide draught power which may create resistance from the farmers to embrace the technology. 4. Animals may be expensive for local farmers.
Reduction in GHG emissions	Increasing milk production from 250 to 900 kg per cow can result in a reduction in emissions intensity from 45 kg CO_2eq/kg FPCM to 12 kg CO_2eq/kg FPCM, i.e. 73 % decrease in emission intensity compared to baseline.
Impact statements – How this option impacts the country development priorities	

Country social development priorities	The Government of Lesotho has agriculture as one of the key pillars identified for economic growth. Improved cattle breeds can increase productivity of the sector and national food security by deriving getting enhanced agricultural products.
Country economic development priorities – economic benefits	Improved cattle breeds can promote commercialization of agriculture in the country. Both quantities and qualities of animal products can be improved through the adoption of this technology and this can improve commercialization of the products.
Country environmental development priorities	Land degradation is a major environmental challenge facing Lesotho. This is exacerbated by poor management of environmental resources throughout the country.
Other considerations and priorities such as market potential	There is market for improved cattle breeds as they have several benefits over current traditional breeds. There is also market for cattle products that can reduce heavy reliance of imports from the neighbouring South Africa.
Costs	
Capital costs	Beef weaners cost around R 10 000 while bulls can reach up to R 70 000 in a market.
Operational and maintenance costs	Dairy heifer may cost average of R10 000 in 2 years Dry matter of fodder may cost between R 15 000 to R 20 000 per tonne
Costs of GHG reduction	Livestock sector has generally, a large potential to reduce emissions with cost saving benefits.
Lifetime	Improved breeds can propagate sustainable production of animals. Lifetime of the breeds can be long.
Other	

Technology 2: Carbon sequestration through agro-forestry systems

Subsector GHG emissions	- CO_2, Increases carbon sinks in the ecosystem - N_2O, Reduces application of artificial fertiliser to the soil
Background/Notes, Short description of the technology option	Agroclimatology of Lesotho is suitable for fruit trees production. Cold winter climates can provide chilly environment for Mediterranean fruits. Although supplementation with irrigation may be necessary in some occasions, cold temperatures and several snow occurrences in winter are favourable for cultivation of Mediterranean fruit trees including grapes, apricots and citrus. Plants remove carbon dioxide from the atmosphere through photosynthesis and keep it as both biomass above ground (leaves and stems) and below ground (roots). Improvement of agroforestry assists by storing carbon in the terrestrial systems and prevents carbon loss through land degradation. This technology can mitigate emissions by restoring degraded grazing lands by through a combination of intensive, extensive agroforestry (silvopastoral) livestock systems and planting of improved and nutritious forage trees. Agroforestry involves integration of forest (or tree) planting with other crops and grasses. Trees are planted at strategic points in the field to allow for production of crops together with them. Agroforestry enhances biomass production and therefore carbon sequestration. Trees in this system provide shading which reduces evapotranspiration, prevents soil erosion and increase nutrient cycling. They also protect crops from strong winds and storms. Crops grown can include fodder crops (pastures) for livestock. Since roots of trees extends to deeper soil levels, they avoid competition for resources with other crops they are integrated with.

	Agroforestry systems improves soil carbon content which improves overall soil fertility.
Implementation assumptions. How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.	1. It is assumed that trees and crops will be suitable to agroclimate of the country / location where they will be planted. They can be planted using current tree planting campaigns of the GoL and other stakeholders. 2. It is assumed that the farm management of the system will be adequate. There is a growing skill set of tree management within communities. Private orchards are increasing in number in the country. 3. The technology can prevent soil erosion and land degradation. The micro-environment created by agroforestry systems have been shown to reduce soil erosion in many parts of the world. 4. The technology can be diffused across the sector according to the existing plans of the government entities involved. Tree seedlings are easily accessible in the country. Growing of other crops with the trees can be achieved.
Implementation barriers	This is a slow process and can take years to achieve intended benefits. Shading can limit other crops access' to light and reduce yield
Reduction in GHG emissions	Agro-forestry reduces GHG emissions through carbon sequestration by both above- and below-ground biomass production. It also prevents land degradation. Afforestation, switching from annuals to orchards, rangeland improvement, forest rehabilitation, and improved crop production can sequester about 13.5 million tCO_2eq. Agro-forestry (silvopastoral) has a potential to reduce emissions by between 1 - 5 tCO_2eq ha^{-1} $year^{-1}$ depending on the climate, soil, pasture type and tree species (Khatri-Chhetri et al., 2021).
Impact statements – How this option impacts the country development priorities	
Country social development priorities	The Government of Lesotho has agriculture as one of the key pillars identified for economic growth.
Country economic development priorities – economic benefits	- Commercialization of agriculture. Agroforestry can produce cash crops and high yields than can result in surpluses for the market. - Improvement of ecosystems. Agroforests create microenvironments that are good for ecosystems. Ecosystems are major sources of rural livelihoods in the country in that they provide several services to the communities including raw materials used for different cultural items. - Reduces soil degradation, food security and improves socio-economic conditions.
Country environmental development priorities	Land degradation is a major environmental challenge facing Lesotho. This is exacerbated by poor management of environmental resources throughout the country.
Other considerations and priorities such as market potential	There is a good market for agroforestry products in the country. These include vegetables and fruit products. There is market for this technology in the country to (i) increase food security and (ii) to prevent land degradation.
Costs	
Capital costs	Tree seedlings, vegetable/crops seeds, basic implements
Operational and maintenance costs	Approx. US$ 55 ha^{-1} $year^{-1}$ based on a Colombia livestock NAMA
Costs of GHG reduction	
Lifetime	Agroforestry is a sustainable production system. Its benefit of improving soil conditions and productivity make it a good candidate for long lifetime.
Other	

Technology 3: Small-scale biogas and homestead vegetable production in a mixed (crop and livestock) agricultural systems

Subsector GHG emissions	Methane emissions from manure management systems
Background/Notes, Short description of the technology option	Cattle production is the main source of GHG emissions from livestock. They produce methane from enteric fermentation and manure management. There is also nitrous oxide from manure latter. Cattle dung and urine deposited on rangelands and kraals are also sources of the GHGs. Biogas technology utilizes human waste, food waste, municipal waste and other biodegradable substances. In Lesotho, cattle are taken to the communal rangelands in the mornings and return for a sleep in the small encloser of kraals. The dung they leave in the kraals and the rangelands is dried and used as fuel source in the form of *lisu* by many households. For biogas production, the dung can be collected in the morning, mixed with water and poured in the biogas plants. When the dung decomposes in the biogas digesters, it will produce methane which can be collected to be used in the homes for cooking. Methane produced from manure and agro-industrial waste management systems can be captured using anaerobic digestion technologies including small-scale digesters. Cattle dung can be used to produce biogas that can be used to supply clean energy at household levels. Cow dung contain CH_4 which has a greenhouse effect that is 25 times greater than that of CO_2. Biogas is produced under anaerobic conditions and contain CH_4. Biogas contains 50-70 % combustible CH_4, 20-40 % CO_2 and other trace gases. When it is burned, CH_4 is reduced to CO_2 and water, reducing the impact of the greenhouse impact. Collected biogas can provide basic household energy requirements like cooking. The biogas digestate downstream of the plant, can be used as organic manure for vegetable production in the garden. This also improves soil organic content and overall fertility. The digestate which is in liquid form reduces costs of manure for farmers and also assists with irrigation of the crops. This shows that the technology can have additional benefits by improving household food security. Biogas can also improve air quality in the homes compared to particulates matter that is produced when *lisu* are burnt. Biogas digesters are optimum at 35 ºC and CH_4 production drops significantly when temperatures drop below 20 ºC. Low temperatures which are a norm in Lesotho in winter may require biogas systems that are heated using external sources. This may therefore necessitate a provision of solar heating systems. Clear skies that are dominant in winter can provide abundant solar energy for warming the biogas digesters. In order to produce adequate volume of bigas for an average household (of < 5 members), a minimum of 5 cattle may be required to feed the digesters. The feeding is done by fresh dung collected in the kraals in the mornings and mixed with water at a ratio of 1:1 before pouring into the system. This technology can be more effective in the 'commercial' dairy systems.
Implementation assumptions. How the technology will be implemented and	At a small-scale farmer setting, anaerobic digesters require daily collection of animal and agro-processing waste to feed the systems. This requires animals that are kept in an enclosure at some point to enable for the collection of the dung. The digesters can be constructed where the animals reside (in the farm or in the homes

diffused across the subsector? Explain if the technology could have some improvements in the country environment.	where the animals sleep). The digesters can also be constructed in the agro-processing industries like abattoirs. Assumptions: 1. The assumption will be that the agro-waste from these industries can be easily collected and channelled into the plants. 2. Plant heating systems using renewable energy resources (solar) can be used to warm the plants in winter when temperatures are low. Improvement of environment 1. Household air quality improvement by avoiding burning of *lisu* for cooking 2. Removal of waste from the environment (agro-processing) 3. Prevention of odour/smell from the air from rotting agro-waste
Implementation barriers	Biogas systems may lose yields in the highlands particularly in winter due to cold temperatures. A lot of manual labour involved with feeding biodigesters may be a cause for discouragement. Biogas plants can reduce their productivity in winter when it is cold. Where possible, a heating/warming technique may be incorporated in the technology especially for winter.
Reduction in GHG emissions	0.98 $MtCO_2eq$ over 10 years for 20 000 households can be achieved.
Impact statements – How this option impacts the country development priorities	
Country social development priorities	The Government of Lesotho has agriculture as one of the key pillars identified for economic growth. Biogas can improve energy and food security in the country. Constructions of biogas plants can be through pre-fabricated equipment or building of systems using bricks and mortar which has a benefit to create employment to the society. Maintenance of the plants can be another form of job creation.
Country economic development priorities – economic benefits	Biogas can be used to advance production of renewable energy in the country. It can provide energy security especially to the rural communities that are far from the national grid. Digestates can be used as manure in the gardens and fields.
Country environmental development priorities	Land degradation is a major environmental challenge facing Lesotho. This is exacerbated by poor management of environmental resources throughout the country.
Other considerations and priorities such as market potential	Many households in Lesotho can have a minimum number of cattle in their kraals to feed the plants. The technology can also be fed with other forms of biodegradable wastes which can be used for mass production of biogas.
Costs	
Capital costs	Initial costs are high. Includes tanks and piping. Approximately R 2 000/m^3 unit
Operational and maintenance costs	Wear and tear. Several parts in the connection lines may need to be replaced from time to time. These items can be obtained in local hardware stores at the affordable costs.
Costs of GHG reduction	US$ 20/ha
Lifetime	
Other	

Technology 4: Promotion of horticulture production in Lesotho

Subsector GHG emissions	N_2O emissions from managed soils
Background/Notes, Short description of the technology option	To ensure optimum productivity, the vegetable production in a dry land production system in Lesotho can be supported with water harvesting technologies and solar-powered irrigation system. Photovoltaic solar panels can be used to pump water

	into prefabricated or build tanks in the farms or gardens. Standard plastic piping and connecting materials can be used to transport water from the tank to the crops. Filters at different points will be necessary to prevent clogging of the system especially at the sprinklers. Scheduled irrigation can facilitate correct applications of fertilizer to reduce nutrient loss by leaching. Fertilizer can be mixed with water in the tank and be applied with irrigation (fertigation). Vegetables can be produced under climate-smart agriculture system where crop residues and other mulching materials are used to conserve moisture and increase soil carbon when they decompose. Horticulture provides both climate change adaptation and mitigation benefits. Vegetable production improve nutrition levels and overall national food security.
Implementation assumptions. How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.	1. Systems and horticulture productions will be conducted near water sources to avoid lengthy connections and large pumping energy. 2. Horticulture production is being promoted by the government and civil societies to improve food security 3. Vegetables can be produced together with fruit trees to increase production diversity 4. Climate-smart agriculture that has mulching and retain crop residues reduce soil erosion, land degradation and evaporation.
Implementation barriers	Farmers being reluctant to produce vegetables, instead favouring grains. Post-harvest losses due to lack of storage facilities.
Reduction in GHG emissions	GHG emissions can be reduced by applying inorganic fertilizer in a regulated manner that will minimize leaching. Crop residues and mulch increase soil fertility provide that will make on the other hand, reduce use of inorganic fertilizer. Fertigation has potential to reduce emissions by 170 - 5000 kg CO_2eq/ha
Impact statements – How this option impacts the country development priorities	
Country social development priorities	The Government of Lesotho has agriculture as one of the key pillars identified for economic growth.
Country economic development priorities – economic benefits	Commercialization of agriculture.
Country environmental development priorities	Land degradation is a major environmental challenge facing Lesotho. This is exacerbated by poor management of environmental resources throughout the country.
Other considerations and priorities such as market potential	There is market potential for horticulture products in the country as Lesotho is currently dependent on imports. There is a growing number of units that produce horticulture products in the country and this progress can be assisted with proper technologies.
Costs	
Capital costs	Include tanker, PVC piping and connectors, PV solar panels
Operational and maintenance costs	Wear and tear of irrigation technology may need periodic replacements. Irrigation may require increased fertilization depending on the technology used. Irrigation may cause leaching of nutrients if not managed properly.
Costs of GHG reduction	US$ 240/ha – nitrogen use efficiency through fertigation
Lifetime	
Other	

Technology 5: Promotion of field irrigation system to improve productivity and reduce GHG emissions in Lesotho

Subsector GHG emissions	- N_2O from managed soils - CO_2 from land use
Background/Notes, Short description of the technology option	Although available water per capita in Lesotho is high, water resources in the country are spatially skewed in favour of the highlands where agricultural production is low. It is also difficult to develop and implement irrigation systems around river systems due to complex terrain that has slopy landscape throughout the country. Fields in Lesotho are often up a hill and distant from water sources. In many cases, irrigation systems in the country require energy to pump water and diesel generators are commonly used. Lesotho needs irrigation systems to improve food security. Irrigation improves yields and overall crop biomass. This leads to enhanced crop residues and carbon sequestration which becomes a great mitigation activity. In the era of climate change where air temperatures are projected to increase with time, water efficient irrigation technologies are highly encouraged. Engine-powered irrigation systems may be used to overcome slopes and gravity. Where necessary, these irrigation systems can be powered by low carbon energy sources including renewable resources. The use of renewable energy in the irrigation systems assists by mitigating the greenhouse gas emissions. Water efficient technologies especially drip irrigation can also reduce fertiliser application rate through incorporation of fertigation. Micro-irrigation (sprinklers/drip) are water efficient and reduce operational water losses to less than 10 % (Mohan et al., 2022). Of several micro-irrigation technologies, canal-lining has highest cost and mitigation benefits (Zhou et al., 2013). Canal irrigation consists of furrows lined with concrete to reduce seepage losses.
Implementation assumptions. How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.	1. Desire of the farmers to adopt the technology. Irrigation technologies have failed in the past due to several factors including lack of maintenance and skills to manage the systems. As a result, reintroduction of this technology may be resisted. 2. Implementation to be near reliable water resources to avoid long piping. Long connections from water bodies to the fields may be a challenge in Lesotho due to marginal soils that may not cover them properly. The technology can be diffused across the subsector throughout the country. The technology can improve water resources management in the areas it is implemented.
Implementation barriers	1. Affordability of the technology to farmers. Capital costs may be high and affordable by the farmers. 2. Maintenance of the technology may be costly and not affordable to the farmers. Skills to maintain the technology may not be adequate in the country. 3. Land tenure and farming systems in Lesotho affords farmers with small pieces of land that may not be bring good returns of investments. Acquiring of additional production land may also be a challenge.
Reduction in GHG emissions	Irrigation increases crop productivity and reduces levels of extensive agriculture which mainly produces emissions through land use change.

	Overall 163 - 1200 kg CO_2eq/ha
Impact statements – How this option impacts the country development priorities	
Country social development priorities	The Government of Lesotho has agriculture as one of the key pillars identified for economic growth. This is because the sector irrigated field production has potential to increase productivity in the country.
Country economic development priorities – economic benefits	This technology may attract private sector to invest in the sector as it improves investments returns. It is the priority of the GoL to commercialize the sector. It can also improve productivity and income of the farmers especially when cash crops are produced.
Country environmental development priorities	Land degradation is a major environmental challenge facing Lesotho. This is exacerbated by poor management of environmental resources throughout the country.
Other considerations and priorities such as market potential	Considerations for field irrigation should include whether gravity irrigation is applicable, or pumping will be required. The latter may require paying for energy, which may increase all costs.
Costs	
Capital costs	Approximately R 10 000/ha
Operational and maintenance costs	Expenses for wear and tear higher for equipment that is moved manually. Replacement kit every 60 months.
Costs of GHG reduction	US$ 100/ha
Lifetime	
Other	

Technology 6: Improvement of livestock feed in Lesotho

Subsector GHG emissions	CH_4 from enteric fermentation
Background/Notes, Short description of the technology option	Livestock production in Lesotho is primarily concentrated on three animal types in cattle, sheep and goats. These are ruminant animals that are major sources of methane from enteric fermentation. They are all produced under extensive subsistence systems on communal rangelands and fields. Mitigation measures for livestock include improved feeding. It is usually difficult to feed animals during dry seasons (i.e., winter) and periods of below normal rainfall (i.e., drought periods) in Lesotho. Feeding in winter is primarily based on crop residues that are either left in the fields after harvests or cut and collected to homes. These residues are maize, sorghum and wheat stalks. Grasses are rare in the country in winter and can also be very poor during droughts. Feeding in winter or during droughts becomes very poor in both quantity and quality. Poor feeds result in high rates of methane emissions from enteric fermentation. To avoid these emissions, it becomes important that technologies that improve feed quality be considered and used. Straw ammonisation is a technology that improves feed quality. Addition of urea, ammonia or ammonium bicarbonate to low-forage straws (i.e., crop residues of maize, sorghum or wheat etc) reduces lignin concentration in the straws but increases the feedstock nutrients. This addition increases digestibility of the feedstock. Improved feed digestibility reduces methane emissions by making the animal energy uptake more efficient and thereby reducing energy loss as methane emissions. Using urea-treated crop residues in ruminant diets reduces emissions

	compared with traditional diets (untreated straw). This technology increases feed digestibility and uptake by the digestive system of the animal by up to 20 %. To further improve feed roughage and balance, straw ammonisation can be combined with leguminous fodder, hay, silage and crop by-products. This mixture can reduce reliance of the farmers from a comparatively higher carbon footprint concentrates feed.
Implementation assumptions. How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.	1. Farmers will be able to collect straws from the fields to their farms or homes where they keep animals for some periods 2. Implementation can start with farmers that can easily have straws from their fields and use them as nucleus to grow from. 3. Improving feed quality help by reducing amount of feedstock given to animals. The remaining straws can be made available for other environmental benefits like mulching and they can also improve soil organic matter.
Implementation barriers	Benefits of this technology are high for farmers with large enterprises that will have good amount of straws and animals. Subsistence farmers in some countries with less resources are reluctant to use this technology. Some farmers may find it difficult to comprehend technical issues related to the technology.
Reduction in GHG emissions	Improvement of feed digestibility is a key factor required to reduce methane emissions from enteric fermentation. Improved feed with hay and fodder achieved 1.57 $MtCO_2eq$ $year^{-1}$ in Kenya
Impact statements – How this option impacts the country development priorities	
Country social development priorities	The Government of Lesotho has agriculture as one of the key pillars identified for economic growth. This technology can improve national food security as animals will be more productive – have higher yields.
Country economic development priorities – economic benefits	Commercialization of agriculture particularly livestock production can benefit by using this technology. Improved accessibility of feeds can also reduce animal mortality during droughts when animals can starve to their deaths.
Country environmental development priorities	Land degradation is a major environmental challenge facing Lesotho. This is exacerbated by poor management of environmental resources throughout the country.
Other considerations and priorities such as market potential	There is a good market potential for this technology as it is easier to use. Improved feeds may not require high capital costs and it can be done in most parts of the country. It can also be used to address the challenge of land degradation – which may increase its market potential in the country.
Costs	
Capital costs	Mainly cover construction of storages, buying of equipment and covers.
Operational and maintenance costs	Will depend on the costs of straw material and replacement covers Reduces feeding costs
Costs of GHG reduction	Improved feed can achieve US$ 63/tCO_2 emission abatement in Kenya
Lifetime	Equipment and storages can have long lifespan.
Other	

Technology 7: Production of biochar using crop straws

Subsector GHG emissions	- N_2O emissions from managed soils - CH_4 from enteric fermentation Non-dairy cattle; 21.213 Gg (CH_4)

	Dairy cattle; 0.501 Gg (CH_4)
Background/Notes, Short description of the technology option	Crop residues can be partially burned to produce biochar – a material similar to charcoal. Biochar is carbon-rich, highly porous and has increased surface area compared traditional crop residues. Biomasses of maize, sorghum, legumes etc are exposed to moderate temperatures in the kiln under partial or complete exclusion of oxygen. This process produces biochar which is a carbon-rich, fine-grained, porous substance and solid a by-product. Application of biochar to cropping soils becomes a very effective carbon sequestration mechanism. Depending on the quantities produced or applied, biochar can be mixed with other inputs using available technologies or mass of it can be spread over the field. Biochar can also be fed to animals and assist reduce methane emissions from enteric fermentation. This technology has a disadvantage in that it can produce particulate matter during its manufacturing process.
Implementation assumptions. How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.	1. It is assumed that the technology of kilns can be easily used and (culturally) acceptable in the country. 2. There are technologies that can be used by small-scale farmers in the market and this makes diffusion of this technology much easier. 3. Use of biochar improves the following; microbial activities of the soil, soil water holding capacity, nutrient efficiency of the soil 4. Gases and heat that are produced during production of biochar can be harvested to provide energy that can be used for other purposes in the household or farming enterprise. 5. Biochar improves soil fertility and its powdery form increases absorption of minerals by the crops. 6. Biochar can be used as a replacement of lime with good economic returns
Implementation barriers	1. Crop residues are often used for animal feed in the country. Provision of residues for biochar may be limited. 2. Biochar production is generally expensive especially the capital costs and operational costs.
Reduction in GHG emissions	Depending on the straw material, up to 50 % of biomass carbon can be returned to the soil as biochar.
Impact statements – How this option impacts the country development priorities	
Country social development priorities	The priorities of the country include increasing food security and environment.
Country economic development priorities – economic benefits	The country is seeking for several ways of crop fertilization and this can be a potential technology to achieve that.
Country environmental development priorities	Improvement of fertility and yields
Other considerations and priorities such as market potential	Production of biochar in its entirety is not a common technology in Lesotho. Generally, unavailability of straws in many parts of the country make cause the adoption of this technology may therefore not be easy. This will reduce its market potential.
Costs	
Capital costs	Capital costs may be high. The burning kilns may not be available in markets in the country and the region.

Operational and maintenance costs	Operational and maintenance costs may be high due to unavailability of parts in the local markets.
Costs of GHG reduction	
Lifetime	
Other	

Technology 8: Promotion of conservation tillage in Lesotho

Subsector GHG emissions	N_2O from managed soils.
Background/Notes, Short description of the technology option	Conventional tillage where a plough is used to completely turn the soil is the primary cultivation method in Lesotho. This method increases aeration of the soil and moisture loss. Conservation tillage on the other hand minimizes turning of the soil, but conserves soil moisture. For conservation tillage, crop residues are left in the field and used for mulching and reduction of soil erosion. Keeping of crop residues in the field increases soil carbon sequestration. Conservation tillage has different forms that include zero-tillage and minimum tillage. While there is no tillage at all for the former, the latter involves little disturbance of the soil to primarily place inputs into the soil. It encourages organic practices and crop rotation. Zero tillage may require heavy machinery which may not be afforded by small-scale farmers. However, conservation tillage reduces use of fossil fuels and with time, reliance of agrochemicals including artificial fertilisers. This reduces GHG emissions and improves crop productivity as the soil becomes fertile and retains moisture.
Implementation assumptions. How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.	1. There are some farmers that are already using this technology, making diffusion much easier. 2. Retention of crop residues increases mulching, reduces evaporation, improves soil carbon content and overall soil fertility. 3. Conservation tillage reduces use of synthetic fertilizer and thus decreases emissions of nitrous oxide. 4. The technology decreases soil erosion and prevents land degradation.
Implementation barriers	1. Capital costs may be high. Depending on the scale of use, conservation technology tools may be difficult to manufacture and get in the local markets. 2. High manual labour for farmers without machinery. Lack of proper machinery and use of manual labour may discourage farmers. Manual labour takes long to operate and may result in damaged crops in some cases. 3. This technology can take time to bear benefits (in terms of carbon sequestration). Decomposition of mulch, roots and crop residues takes time and cause delays in the fertilization and improvement of the soil.
Reduction in GHG emissions	Zero-tillage: 3 - 522 kg CO_2eq/ha/year mitigation potential
Impact statements – How this option impacts the country development priorities	
Country social development priorities	The Government of Lesotho has agriculture as one of the key pillars identified for economic growth.
Country economic development priorities – economic benefits	Commercialization of agriculture. Conserves moisture and reduces irrigation requirements & costs.

Country environmental development priorities	Land degradation is a major environmental challenge facing Lesotho. This is exacerbated by poor management of environmental resources throughout the country.
Other considerations and priorities such as market potential	Low-cost technologies have potential to replace conventional tools that are dominantly still been used in the country.
Costs	
Capital costs	< US$ 100/acre inclusive all no-till equipment
Operational and maintenance costs	Costs (for fuel, time, etc) less than those of conventional practices
Costs of GHG reduction	-11 to -3 US$/ha gross cost of mitigation
Lifetime	Implements are durable and can be used for several years
Other	

Technology 9: Rehabilitation of land using agro-voltaic farming in Lesotho

Subsector GHG emissions	Energy related emissions in agriculture
Background/Notes, Short description of the technology option	Agro-voltaic farming is a technology that co-locate installation of solar panels and crop production below them. Installation of the solar panels allows for movement of farming personnel and machinery in the isles between panel's rows and the heights of the panels allows for crop production below them. Solar panels can be designed to provide energy requirements of the farm. This can include provision of energy for irrigation purposes for crops or water heating in dairy farming among others. Agriculture is a significant consumer of energy and the sector is responsible for a third of global energy emissions. Energy consumption in the sector include in drying processes, provision of light and heat. It is therefore important that co-production of renewable energy within farming processes is considered so that carbon footprint of the sector can be reduced. This technology is suitable for crops that prefer shaded environments. The solar panels create a microclimate of reduced wind speed, humid atmosphere, reduced direct radiation and reduced air temperature. Combined, these conditions reduce evaporation below the panels. These microclimates can be used to rehabilitate degraded lands (including deserts). In addition to protecting crops from hailstorms, yields obtained from application of this technology have been shown to increase. It can increase income if cash crops are produced.
Implementation assumptions. How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.	1. Use of solar technology in other industries in the country is on the rise. It has been used for water pumping in some rural villages. Therefore, its adoption in farming can be achieved. 2. Irrigation is being promoted to increase yields in the country. Landscape of Lesotho will probably require energy consumption to pump water up the slope where renewable resources can be applied. 3. The technology can reduce fossil energy consumption in the sector. It achieves the greening of the sector.
Implementation barriers	Capital costs of solar panels may be high
Reduction in GHG emissions	The technology can reduce consumption of fossil energy in farming.
Impact statements – How this option impacts the country development priorities	

Country social development priorities	The Government of Lesotho considers renewable energy generation and its use in various sectors including in agriculture as important.
Country economic development priorities – economic benefits	Agro-voltaic technology can promote commercialization of agriculture, especially for cash crops. It can reduce irrigation requirements & costs in the sector.
Country environmental development priorities	The technology can reduce pollution caused by fossil fuels. Use of fossil fuels cause GHG emissions and machinery can result in noise and dust pollution.
Other considerations and priorities such as market potential	The technology can have high market potential especially considering that production and use of renewable energy resources are promoted in the country.
Costs	
Capital costs	Costs of solar technologies remain high.
Operational and maintenance costs	These costs are low
Costs of GHG reduction	
Lifetime	Implements are durable and can be used for several years
Other	

Technology 10: Promotion of biological and organic farming in Lesotho

Subsector GHG emissions	N_2O emissions from artificial fertiliser and CO_2 from agricultural fossil energy use.
Background/Notes, Short description of the technology option	Biological and organic farming is primarily based on exclusion of agrochemicals including artificial fertiliser and increasing activities that can enhance microbial activities in the soil. This involves rotating crops to break chains of pesticides and increasing soil fertility. Microbial activities increase decomposition in the soil and soil carbon. Organic farming integrates cropping systems with livestock management practices. It also removes or reduces use of fossil fuel in the farming processes. It has been shown that overall, organic farming reduces consumption of fossil fuel by half compared to traditional production systems. This technology improves soil fertility and soil moisture retention which enhance productivity. Increasing soil organic content and overall fertility have benefit of reducing application of artificial fertiliser and increasing crop yields. This reduces emissions and farming costs that would have resulted from this agrochemical. Organic farming uses less energy per unit of land. This reduces GHG emissions from fossil fuels. Improvement and optimum management of soil organic content is very important in carbon sequestration in the agriculture sector. The use of green manure, composts, animal manure and crop rotation improves soil organic content, soil fertility, soil sequestration and reduces soil carbon loss through erosion.
Implementation assumptions. How the technology will be implemented and diffused across the subsector? Explain if the technology could have	5. Use of this technology is increasing globally. Organic agricultural wastes can be used as inputs into the technology. These can include wastes from abattoirs (slaughter places) and untainted food wastes. 6. These wastes can be put in the fields and managed there under biological and organic principles. 7. The technology can improve the environment in the country by converting waste into a usable manure (or soil improvement practices).

some improvements in the country environment.	8. Improved soil fertility caused by this technology can increase yields.
Implementation barriers	4. Collection or obtaining of biological wastes (substances) in required quantities maybe a challenge in the country.
Reduction in GHG emissions	1. The technology can reduce reliance on artificial fertiliser during production. This can reduce GHG emissions. 2. Reduction of use of fossil fuel in this farming system reduces GHG emissions.
Impact statements – How this option impacts the country development priorities	
Country social development priorities	By obtaining fertile soil and not using agrochemicals, the technology can save farmers money they would have used to buy fertilisers and other implements.
Country economic development priorities – economic benefits	The technology can stimulate economic activities by harnessing and use of waste material to enhance agricultural activities and food production. Improvement of soil conditions has important economic benefits that include protection of biodiversity and prevention of loss of soil.
Country environmental development priorities	The focus in the country is on reducing soil loss, improving soil fertility and reducing agricultural production costs.
Other considerations and priorities such as market potential	There can be market potential for the adoption of this technology – but limited to availability of biological and organic materials.
Costs	
Capital costs	This technology can incur low to moderate capital costs. They relate to costs of biological and organic materials if unavailable from the farm or site.
Operational and maintenance costs	These costs are low
Costs of GHG reduction	
Lifetime	Implements are durable and can be used for several years
Other	

ANNEX II: LIST OF STAKEHOLDERS INVOLVED AND THEIR CONTACTS

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