

Monitoring, Verification and Enforcement of MEPS for Distribution Transformers



M, V & E for Distribution Transformers in Lesotho

18 September 2022



TABLE OF CONTENTS

1	5	
2	7	
3	11	
3.1	11	
3.2	12	
3.3	13	
4	15	
4.1	15	
4.2	16	
4.3	19	
0-3		21
5	22	
6	25	

LIST OF FIGURES

Figure 1. Transformer Imports since 2016 [1]	8
Figure 2. Increase in Total Usage due to Increased Electrification	9
Figure 3: Distribution Transformer Energy Label	14

LIST OF TABLES

Table 1: Electrification Numbers for 50kVA Transformers	9
Table 2: Electrification Numbers for 100 kVA Transformers	10
Table 3: Maximum load loss and maximum no load loss for liquid-immersed single-phase transformers with $U_m \leq 36\text{kV}$ and rated frequency equal to 50 Hz	12
Table 4: Maximum load loss and maximum no load loss for liquid-immersed three-phase transformers with $U_m \leq 36\text{kV}$ and rated frequency equal to 50 Hz	12
Table 5: Actions, Responsibility, Budget Requirements and Timelines for MV&E	21

ABBREVIATIONS

AFDB	African Development Bank
CTCN	UN Climate Technology Centre and Network
DoE	Department of Energy
GCF	Green Climate Fund
HEPS	Higher Energy Performance Standard
IMF	International Monetary Fund
IEC	International Electrotechnical Committee
kV	Kilo Volts
kVA	Kilo Volts Ampere
LEWA	Lesotho Electricity and Water Authority
LSI	Lesotho Standards Institute
LSL	Lesotho Loti
MEPS	Minimum Energy Performance Standard
MV&E	Monitoring, Verification and Enforcement
PWG	Policy Working Group
RSL	Revenue Services Lesotho
SADC	Southern African Development Community
SANS	South African National Standard
TCO	Total Cost of Ownership
U4E	United for Efficiency
UNEP	United Nations Environment Programme

1 INTRODUCTION

The ‘Leapfrogging to Energy Efficient Appliances and Equipment in Lesotho (Refrigerators and Distribution Transformers)’ project is funded by the Green Climate Fund (GCF) and being implemented under the guidance of the government of the Kingdom of Lesotho (Lesotho). The project is also being implemented simultaneously within 7 other countries of the Southern African Development Community (SADC) region, namely Botswana, Zimbabwe, Namibia, Malawi, eSwatini, Zambia and Tanzania. Lesotho is one of the few countries in the world that is completely encircled by another country and is completely contained within the borders of South Africa. Lesotho does not have access to the coast/sea and is therefore heavily reliant on trade with South Africa. The electrification rate in Lesotho is currently below 45% but it is on the increase as a result of the government of Lesotho’s electrification campaign, executed via the Lesotho Electricity Company (LEC). Electrification is also expected to drive economic growth in the country. At present, Lesotho imports over 60% of its electricity from South Africa which contributes to higher costs and emissions (South Africa’s generation capacity is heavily reliant on fossil fuels). For this reason, the average price of electricity (generation + import) in Lesotho is quite high and any losses are hence expensive. Once connected to the grid, distribution transformers are in constant operation, supplying power to all electrical devices on their designated network. The no-load losses of a transformer exist irrespective of electricity usage, whereas the load losses vary as the electricity usage changes. As they always consume energy, improvements in their efficiencies have a continuous impact on the electricity infrastructure in Lesotho.

The aim of the project is to focus on distribution transformers and household refrigeration appliances and attempt to establish a framework in order to improve the energy efficiency of these appliances. This is to be done through the establishment of national standards for both refrigerators and distribution transformers and development of Minimum Energy Performance Standards (MEPS) as well as an energy labelling scheme for both these appliances. The project also engages with the key stakeholders within the country to create a system through which the necessary legislation can be developed related to the implementation of the MEPS and to create a national implementation plan that will both enable the implementation of the MEPS but also create a framework within Lesotho for future development of related standards and legislation. Furthermore, the project investigates the possible financing mechanisms available to assist with implementation of the project and the respective training programmes to enable transition into a self-sustained and managed implementation of the project in the future. Pegasys was contracted by the UNEP through the UN Climate Technology Centre and Network (CTCN) to implement this initiative in Lesotho. The CTCN is overseeing the project together with United for Efficiency (U4E) as a technical partner.

This report focuses on distribution transformers. As part of the project a number of tasks have been completed and deliverables finalised. These include:

1. Development of the Lesotho National Standard on energy efficiency of distribution transformers [8] (including MEPS and HEPS)
2. Development of the Lesotho Energy Label (draft)
3. Development of the consumer awareness campaign
4. Development of the recommendations related to the financial supporting mechanisms
5. Development of the MV&E plan

This report outlines the plan for Monitoring, verification and enforcement, (MV&E) of the distribution transformer MEPS in Lesotho. The remaining sections outline the background to the project and the impact it can have on Lesotho. There are explanations of the national standard and the energy label and how it related to the regional standard. Furthermore, the implementational aspects are covered in more detail. These include the MV&E implementation and monitoring parts of the project, where recommendations of implementation are detailed.

2 Background

As indicated in the annual reports compiled by LEWA [2], Lesotho is reliant on energy imports from South Africa as there is insufficient generation capacity within the country at present. The legal, regulatory and standardisation frameworks are generally inexperienced and untried regarding energy efficiency. Additionally, the general population is largely unaware of the benefits of energy efficiency and much work will need to be undertaken on the public awareness campaigns related to this issue.

However, there are several opportunities for a successful implementation of MEPS in the refrigeration and distribution transformer environment. These are:

- Successful implementation of MEPS in the refrigeration and distribution transformer sectors could open a pathway to implement similar projects in other sectors and with other appliances (e.g., washing machines and dishwashers, stoves and ovens, air conditioners, etc.)
- Successful training of the customs officials of the Revenue Services Lesotho (RSL – previously known as the Lesotho Revenue Authority - LRA) in relation to energy efficiency compliance will make them more capable of enforcing other governmental initiatives related to energy efficiency and quality on a variety of products (e.g. air conditioners, power cables, etc.)
- Development of energy efficient appliances could lead to a green building revolution in Lesotho and align with the national energy policies
- Increasing public awareness related to energy efficiency would be beneficial to the general behaviour of the population towards energy use and could provide general energy saving benefits and an energy conscious behaviour beyond the confines of this project.

To successfully implement the newly developed Lesotho National Standard on energy efficiency of distribution transformers [8], the benefits of energy efficiency must be understood, appreciated, and supported by all stakeholders. It is therefore imperative that engagement, training and consumer awareness be championed throughout the process. Distribution transformers are used solely in electrical networks and unlike refrigerators, are not encountered by the general public. Instead, large industry, electrical utilities, tertiary engineering institutions and the various governmental departments concerned with energy are the targeted audience. It is also important to note that transformers are imported into Lesotho as there is no transformer manufacturing capability within the country.

The import numbers are shown in Figure 1 below.

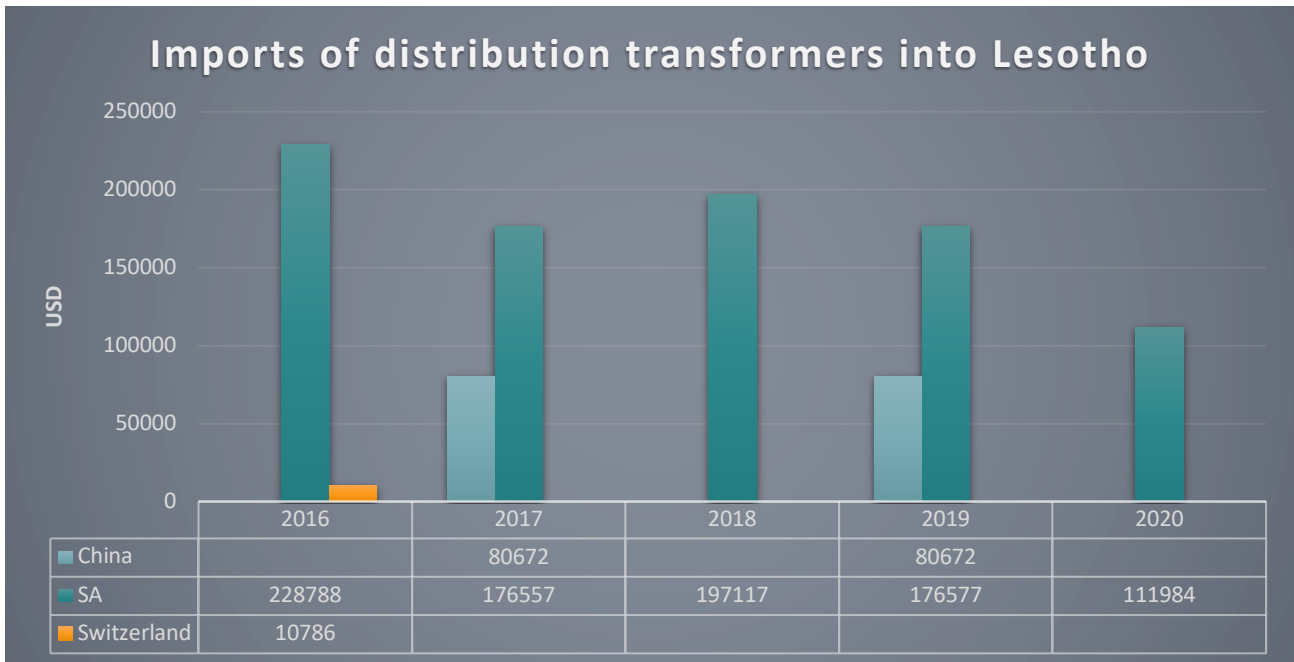


Figure 1. Transformer Imports since 2016 [1]

Information on the import of distribution transformers into Lesotho was obtained via the United Nations Global Trade Repository, Comtrade [1]. The trade data, seen in Figure 1 above, shows that in the period from 2016 – 2020, South Africa was the largest importer of transformers into Lesotho. China was the minority partner in 2017 and 2019, while a small number of transformers were imported from Switzerland in 2016. Lesotho has no local transformer manufacturing capabilities and hence does not export any transformers.

In order to analyse the energy efficiency of the distribution transformers installed on the Lesotho electricity network an accurate database of the transformers was required. This proved to be a challenge as the LEC had last updated their database in 2015. Since then, details of the transformers added to their network via the electrification programme were not captured. To overcome this hurdle the data published by the regulator regarding the growth in electricity usage attributed to increased access to electrification was used to project the number of transformers added to the grid since 2015 [2].

The increase in total consumption of power in mega volt ampere, (MVA) due to increased electrification is shown in Figure 2 below.

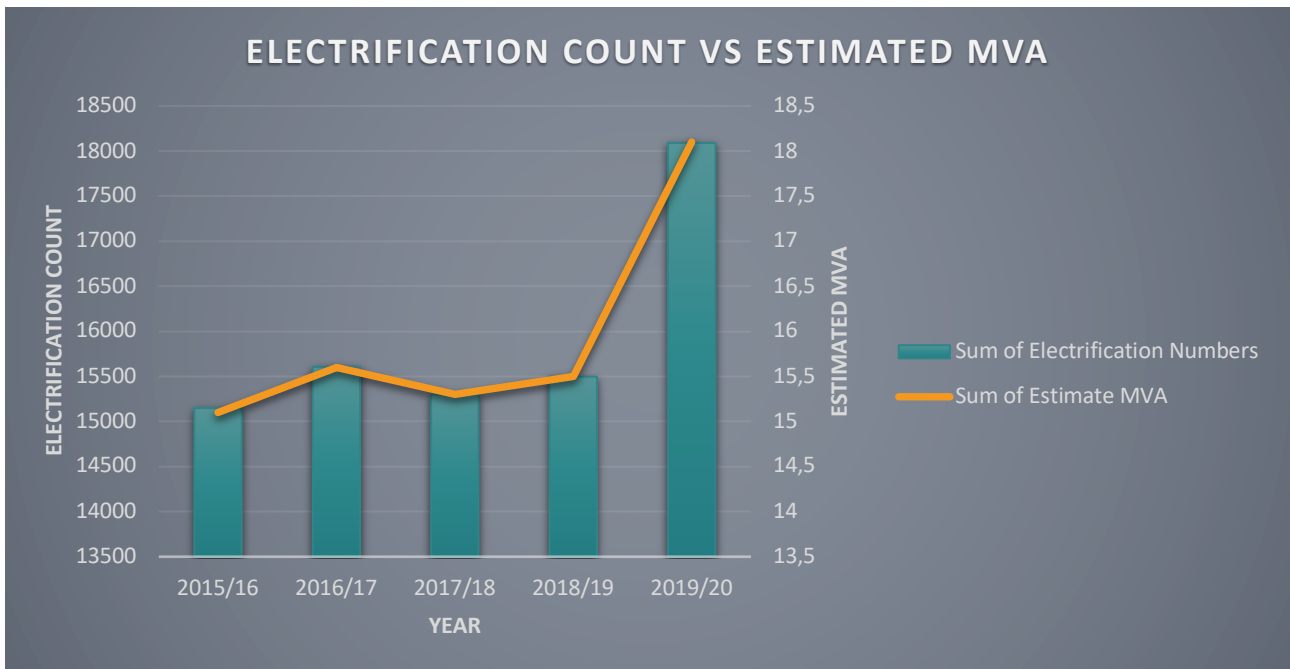


Figure 2. Increase in Total Usage due to Increased Electrification

A further complication arose regarding the proportion of transformers added to the grid from increased electrification as the number of new connections added to existing installations were unknown. If new transformers are installed for every new connection, then the LEC asset base will increase, whereas utilising existing transformers will maintain LECs asset base. Since 50 kVA and 100 kVA are the most used transformers within LEC’s infrastructure it is assumed that a large portion of electrified customers are supplied by these units.

Tables 1 and 2 illustrate potential increases (in 20% increments) to LEC’s asset base for both transformer ratings. For example, in 2015/16, LEC electrified 15 149 customers. Assuming 1 kVA per customer connection yields an annual estimate of 15.1 MVA. If 80% of these customers are connected using existing transformers in the field and 20% are new 50 kVA transformers, LEC will increase their asset base by 61 transformers. If only 20% of 100 kVA transformers are utilised for the same scenario, then the LEC will increase its asset base by 31 transformers.

Table 1: Electrification Numbers for 50kVA Transformers

Year	Electrification Numbers	Estimated MVA	20% New Trfrs	40% New Trfrs	60% New Trfrs	80% New Trfrs	100% New Trfrs
2015/16	15149	15.1	61	121	182	242	303
2016/17	15606	15.6	62	125	187	250	312
2017/18	15299	15.3	61	122	184	245	306
2018/19	15498	15.5	62	124	186	248	310
2019/20	18090	18.1	72	145	217	289	362

Table 2: Electrification Numbers for 100 kVA Transformers

Year	Electrification Numbers	Estimated MVA	20% New Trfrs	40% New Trfrs	60% New Trfrs	80% New Trfrs	100% New Trfrs
2015/16	15149	15.1	30	61	91	121	151
2016/17	15606	15.6	31	62	94	125	156
2017/18	15299	15.3	31	61	92	122	153
2018/19	15498	15.5	31	62	93	124	155
2019/20	18090	18.1	36	72	109	145	181

While not ideal, these exercises allowed for a more accurate representation of the number of transformers on the LEC grid.

Throughout its tenure, the LEC purchased transformers according to the requirements stipulated by the South African Standard SANS 780 [3]. The transformer losses stipulated in SANS 780 remained unchanged until 2019 [4]. We were therefore able to ascertain the efficiencies of the transformers in the LEC grid and determine the impact of their losses on their impact on the electricity network. This information also allowed for the calculation of savings that the LEC would have seen should they have employed a TCO approach to procurement [6] and transformer standards that promoted higher efficiencies.

The results of the comparison exercise are shown in detail in the Market Assessment Report [7]. The Market Assessment Report shows that there are significant advantages to be gained by promoting the procurement of higher efficiency transformers and by developing and implementing MEPS in Lesotho. It is important that the development of MEPS is underpinned by a thorough implementation plan, which will allow the national stakeholders to sustain the implementation and develop the required legislation. It is also key that a financial backing for the implementation is planned and that there is a thorough skills transfer process in place as part of the implementation.

To affect reap the benefits of the transformer efficiency project, it is important for Lesotho to:

- Develop a national standard
- Develop an energy label
- Develop an implementation plan
- Develop supporting structures such as verification programs and consumer awareness campaigns
- Obtain financial backing for the implementation of the project

The sections below cover each of these aspects in more detail.

3 National Standard for Efficiency of Distribution Transformers in Lesotho

3.1 CONTEXT

In parallel with this project, plans to introduce MEPS are being implemented in 7 other SADC countries, namely, Botswana, Eswatini, Malawi, Namibia, Tanzania, Zambia and Zimbabwe.

The scope of the National Standard for Efficiency of Distribution Transformers in Lesotho [8] relates to liquid-immersed distribution transformers that are manufactured in, or imported into Lesotho, and are either sold, installed or put into service as standalone equipment or as a component of a system, and which meet the following criteria:

Distribution transformers within scope have:

- 2 windings per phase.
- a rated capacity equal to or between 5 kVA and 3150 kVA.
- a primary voltage greater than 1,1 kV, but not exceeding 36 kV; and
- are designed for use in electricity networks or industrial applications.

Distribution transformers regardless of when they were first placed on the market or put into service, shall be reassessed for conformity, and comply with this standard if they are subject to replacement operations both of the core (or part thereof) and one (or more) of the complete windings.

This standard does not apply to:

- instrument transformers, specifically designed to transmit an information signal to measuring instruments, meters, relays and other similar apparatus.
- dry type transformers.
- transformers with low-voltage windings specifically designed for use with rectifiers to provide a DC supply.
- transformers specifically designed to be directly connected to a furnace.
- transformers specifically designed for offshore applications and floating offshore applications.
- transformers specially designed for emergency installations.
- transformers and auto-transformers specifically designed for railway feeding systems.
- earthing or grounding transformers, this is, three-phase transformers intended to provide a neutral point for system grounding purposes.
- traction transformers mounted on rolling stock, this is, transformers connected to an AC or DC contact line, directly or through a converter, used in fixed installations of railway applications.
- starting transformers, specifically designed for starting three-phase induction motors so as to eliminate supply voltage dips.
- testing transformers, specifically designed to be used in a circuit to produce a specific voltage or current for the purpose of testing electrical equipment.

- welding transformers, specifically designed for use in arc welding equipment or resistance welding equipment.
- transformers specifically designed for explosion-proof and underground mining applications.
- transformers specifically designed for deep water (submerged) applications; and
- Medium Voltage (MV) to Medium Voltage (MV) interface transformers up to 5 MVA.

3.2 NATIONAL STANDARD

Transformers in the scope of the National Standard for Efficiency of Distribution Transformers in Lesotho [8] must comply with the maximum allowed load and no-load losses values set out in the following tables. If not otherwise specified, three phase or single-phase power transformers shall be evaluated against the rated power of the individual unit. Maximum allowable losses rated powers that fall in between the given values shall be obtained by linear interpolation.

Table 3: Maximum load loss and maximum no load loss for liquid-immersed single-phase transformers with $U_m \leq 36kV$ and rated frequency equal to 50 Hz

Rated power (kVA)	Tier 1			Tier 2			Tier 3		
	Maximum load losses (in W)	Maximum no-load losses (in W)	El _{A50} %	Maximum load losses (in W)	Maximum no-load losses (in W)	El _{A50} %	Maximum load losses (in W)	Maximum no-load losses (in W)	El _{A50} %
5	133	37	97.17%	123	28	97.68%	112	18	98.18%
10	243	44	97.90%	224	33	98.23%	205	21	98.56%
15	331	58	98.13%	305	43	98.42%	278	27	98.71%
16	346	60	98.16%	319	44	98.45%	292	28	98.73%
25	486	83	98.36%	448	61	98.61%	410	39	98.87%
32	599	93	98.48%	552	69	98.71%	505	44	98.94%
50	889	119	98.63%	819	88	98.83%	749	56	99.03%
64	1070	145	98.71%	986	106	98.90%	901	68	99.08%
100	1535	211	98.81%	1414	155	98.98%	1293	99	99.16%

Table 4: Maximum load loss and maximum no load loss for liquid-immersed three-phase transformers with $U_m \leq 36kV$ and rated frequency equal to 50 Hz

Rated power (kVA)	Tier 1			Tier 2			Tier 3		
	Maximum load losses (in W)	Maximum no-load losses (in W)	El _{A50} %	Maximum load losses (in W)	Maximum no-load losses (in W)	El _{A50} %	Maximum load losses (in W)	Maximum no-load losses (in W)	El _{A50} %
25	520	70	98.40%	460	56	98.63%	400	42	98.86%
50	880	110	98.68%	782.5	92	98.85%	685	74	99.02%
100	1500	190	98.87%	1340	156	99.02%	1180	122	99.17%
160	2200	270	98.98%	1930	225	99.12%	1660	180	99.26%
250	3100	380	99.08%	2715	320	99.20%	2330	260	99.33%
315	3600	450	99.14%	3200	387	99.25%	2800	324	99.35%
400	4400	540	99.18%	3825	463.5	99.29%	3250	387	99.40%
500	5200	630	99.23%	4550	544.5	99.33%	3900	459	99.43%
630	6200	750	99.27%	5400	645	99.37%	4600	540	99.46%
800	7500	900	99.31%	6750	742.5	99.39%	6000	585	99.48%
1000	8900	1070	99.34%	8200	855	99.42%	7500	640	99.50%

1250	10500	1260	99.38%	9650	1025	99.45%	8800	790	99.52%
1600	12800	1520	99.41%	11800	1247.5	99.48%	10800	975	99.54%
2000	15100	1790	99.44%	14050	1460	99.50%	13000	1130	99.56%
2500	18000	2120	99.47%	16750	1720	99.53%	15500	1320	99.58%
3150	21500	2520	99.50%	20250	2075	99.55%	19000	1630	99.59%

The standard also caters for distribution transformers having dual voltage and have kVA ratings different from the standard transformer ratings.

The energy performance requirements set out in the standard also stipulates the dates that the different MEPS shall take effect. These are stipulated as follows:

Tier 1 - one (1) year after adoption of MEPS or 1 July 2023, whichever is sooner.

Tier 2 - four (4) years after adoption of MEPS or 1 July 2026, whichever is sooner.

Tier 3 – seven (7) years after adoption of MEPS or 1 July 2029, whichever is sooner.

3.3 ENERGY LABEL

The technical data pertaining to transformer losses and efficiency is listed on the rating plate of all transformers and is a requirement stipulated by functional specifications such as SANS 780 and IEC 60076 [3][4][5]. Some of the SADC countries have therefore decided not to make a separate energy label a mandatory requirement. There was also concern raised over the durability of the label in the harsh southern African environment given that distribution transformers are exposed to the elements, unlike other equipment like refrigerators that are almost exclusively used indoors.

Lesotho, however, decided in favour of having a dedicated energy efficiency label for transformers as it will be of benefit to non-technical staff such as those at the ports of entry, who may find it difficult to decipher a transformer rating plate.

All distribution transformers manufactured for use in Lesotho should be clearly labelled to indicate the tier of losses that the transformer complies to, in accordance with the requirements of the National Standard for Efficiency of Distribution Transformers in Lesotho [8]. The labels will assist port authorities in preventing non-compliant transformers from entering Lesotho.

The Ports Authority will correlate the losses stipulated on the transformer's rating plate and energy label to the tiers of losses stipulated in accordance with the requirements of the National Standard for Efficiency of Distribution Transformers in Lesotho [8]. Non-compliant transformers will not be allowed entry into Lesotho.

The label is in line with the MEPS and timelines set out the National Standard for Efficiency of Distribution Transformers in Lesotho [8] and is shown in Figure 3 below.

4 MV&E

4.1 CONTEXT

At this point of the project the National Standard for Efficiency of Distribution Transformers in Lesotho [8] has been accepted by the policy working group (PWG) and technical committee for distribution transformers (TC-DT). The National Standard for Efficiency of Distribution Transformers in Lesotho [8] has been out for public consultation since September 2022 and is due to conclude in October 2022. At present, we are waiting on feedback on the finalisation of the standard from the LSI as no comments or objections were received on the standard to date. The National Standard for Efficiency of Distribution Transformers in Lesotho [8] also caters on a proposed energy label that has been drafted as part of the project and is a mandatory requirement of the standard [8]. These aspects are therefore ready to be put into practice. For this to be done effectively a well-planned, supported, systematic Monitoring, Verification and Enforcement (MV&E) framework is required.

For the MEPS and the energy label to be successfully implemented, a well-defined, planned and actioned MV&E plan is crucial. Through the MV&E plan the manner of implementation of the standard and the associated label is outlined. Effectively an action plan is developed. The proposed MV&E plan in Lesotho is one that will focus on implementation of the National Standard for Efficiency of Distribution Transformers in Lesotho [8]. This will create a framework for compliance and ensure that all players in the market are subjected to the same requirements. It will also provide a mechanism for market surveillance and for handling non-compliances. By implementing these structures, it is likely that there will be substantial levels of compliance in the market. Having such a system is often beneficial for those market players that are looking to comply and that aim to sell energy efficient products. It is therefore beneficial to such companies and if the MV&E structures are implemented it is primarily a negative to the non-compliant companies and those that are looking to bring in inefficient, cheap alternatives. For such a reason the market becomes partly self-governing in such a setup as it is suited to compliance. Once such a system is established it also lends itself to continuous improvement. The MEPS in Lesotho is set to increase in 2026, as set out by the National Standard for Efficiency of Distribution Transformers in Lesotho [8] in conjunction with the Regional Standard for Efficiency of Distribution Transformers in 7 SADC countries [9]. Furthermore, through public awareness (the implementation of which is part of the MV&E plan) the average consumer will demand higher efficiencies and market forces dictate that these will come as a result of manufacturer's improvements and will eventually lead to increased efficiencies and quality of distribution transformers in Lesotho.

To successfully implement the MEPS, a well-defined, planned and actioned MV&E plan is crucial. Through the MV&E plan, the manner of implementation of the standard and the associated label is outlined. The proposed MV&E plan in Lesotho is one that will focus on implementation utilising the structures that are already existing as part of the distribution transformer procurement process. This will create a framework for compliance and ensure that all players in the market are subjected to the same requirements. It will also provide a mechanism for market surveillance and for handling non-compliances. These structures will ensure that transformer

manufacturers comply with the requirements of National Standard for Efficiency of Distribution Transformers in Lesotho [8] as they risk being excluded from transformer tenders if they don't.

There are 3 aspects to the MV&E plan:

- *Monitoring* –Monitoring is the process of checking the energy efficiency of distribution transformers by taking note of the no-load and load losses of transformers designed and manufactured for use in Lesotho. The second, critical role of monitoring is to perform checks on project implementation at various intervals. These checks are performed not just on the overall project but also at predetermined inspection points such as from the transformer schedules (supplier offer), the final electrical design of the transformer (after order/tender award), the transformer test report (issued for every transformer as per international and local specifications and, via inspections of the transformer and its energy label at ports of entry.
- *Verification* – this is the process of checking whether the product performs as it is required by the standard and the regulation. This includes the witnessing the electrical testing of random transformers at the manufacturers facility, testing at accredited third-party laboratories to compare to the transformer manufacturers test results and random testing of delivered transformers at the property of the customer.
- *Enforcement* – this is the process of ensuring that there is compliance with the requirements of the National Standard for Efficiency of Distribution Transformers in Lesotho [8], and thus the contractual terms for purchase of transformers. The actions to be taken against those that are non-compliant are stipulated in the plan. Effectively, it is important to set up the rules of operations and to set up structures for these rules to be implemented but it is equally critical for the rules to be enforced and for the consequences of not complying with those rules to also be enforced.

The upcoming sections of this report outline the final recommendations for the MV&E plan and describe the action plan has been developed to aid implementation. The responsibilities assigned to various stakeholders within the project are highlighted. Additionally, a preliminary budget for implementation for the next 3-year period has been developed and can be found in the final section of this chapter.

4.2 GOALS AND OBJECTIVES

The main aim of developing the National Standard for Efficiency of Distribution Transformers in Lesotho [8] was to ensure that any transformers imported into the country meet the minimum requirements for energy efficiency. This will ensure that Lesotho does not incur additional costs from the purchase or generation of more energy than necessary due to transformer losses greater than those stipulated by the MEPS. The environmental impact of importing or generating energy is also reduced.

Monitoring of Transformer Efficiency in Lesotho

Whether as part of a large tender (contract) or for isolated purchase, the process for monitoring of transformer parameters already exists within the procurement process.

- **The first opportunity to monitor transformer efficiency** is at the bid stage. When a transformer is required, the customer requests a quote for the transformer based on the specification that is being used to stipulate the functional requirements of the transformer. Going forward, entities purchasing transformers for use in Lesotho will stipulate that the requirements of the National Standard for Efficiency of Distribution Transformers in Lesotho [8] take precedence over any other functional specification. Suppliers are required to declare the no-load and load losses in their bid. The customer will evaluate the offer and determine suitability of the transformer based on among other aspects, the compliance to the MEPS. The no-load and load losses declared at this stage of the process will also be used for the calculation of the total cost of ownership.
- Once a bidder is successful with an offer, a detailed transformer design is produced. The customer must insist on being informed of the no-load and load losses of the transformer after the detailed design is completed. **This is the second opportunity for monitoring transformer efficiency during the procurement process.** The no-load and load losses as calculated from detailed design should not exceed that of the initial bid as it would compromise the procurement process that was based on the total cost of ownership of the transformer. Should the losses exceed that declared during the bid stage but remain with the MEPS, penalties in line with the capitalised cost of losses should be applied. Should the losses exceed that declared during the bid stage, and exceed the MEPS, then the order should be cancelled.
- The **third opportunity for monitoring transformer efficiency is during the completion of factory tests after the transformer is manufactured.** It is a requirement of the IEC and SANS [3][4][5] specifications for every transformer to be tested upon manufacture and a test report produced and filed for every transformer. This test report is readily available to the customer and declares the no-load and load losses as per the test results. Should the losses exceed that declared during the bid stage but remain with the MEPS, penalties in line with the capitalised cost of losses should be applied. Should the losses exceed that declared during the bid stage, and exceed the MEPS, then the order should be cancelled.
- The **fourth opportunity for monitoring transformer efficiency is during the inspection of the transformer at the port of entry.** Officials representing the Ports Authority must inspect transformers entering the borders of Lesotho and determine whether the losses declared on the energy label comply with the requirements of the National Standard for Efficiency of Distribution Transformers in Lesotho [8]. Transformers that do not comply must be quarantined. Contracts for the purchasing of Transformers must clearly state that the complete responsibility (and costs) for non-compliant transformers lie with the supplier, and that the onus is on the supplier to collect the non-compliant transformer from the quarantine.

Verification of Transformer Losses

Verification of the no-load and load losses of transformers can only be executed via electrical testing of the transformer. There are opportunities to conduct verification exercises during the manufacture of the transformer and even after the customer has taken delivery.

- The **first opportunity for verification of the transformer losses is during the factory acceptance testing of the transformer after manufacturing**. It is common for the customer to witness the testing of the first transformer of a particular design. In this process, a suitably qualified representative of the customer observes the no-load and load loss tests, conducted at the supplier's premises, on the transformer to determine whether there is a correlation with the bid offer and the National Standard for Efficiency of Distribution Transformers in Lesotho [8]. Should the losses exceed that declared during the bid stage but remain within the MEPS, penalties in line with the capitalised cost of losses should be applied. Should the losses exceed that declared during the bid stage, and exceed the MEPS, then the order should be cancelled.
- After taking delivery of the transformer, the customer may also conduct electrical tests on the transformer to verify the no-load and load losses of the transformer. This is the **second opportunity for verification of the transformer losses**. The customer may then decide on the penalties to be applied for non-compliant transformers. Should the losses exceed that declared during the bid stage but remain within the MEPS, penalties in line with the capitalised cost of losses should be applied. Should the losses exceed that declared during the bid stage, and exceed the MEPS, then the transformer must be quarantined. Contracts for the purchasing of Transformers must clearly state that the complete responsibility (and costs) for non-compliant transformers lie with the supplier, and that the onus is on the supplier to collect the non-compliant transformer from quarantine.
- The **third opportunity for verification of the transformer losses is available via the testing of the transformer at a neutral third-party, accredited laboratory. The customer may choose to have a random transformer transported and tested at an accredited test facility. The customer and supplier can be present to witness the tests**. Should the losses exceed that declared during the bid stage but remain within the MEPS, penalties in line with the capitalised cost of losses should be applied. Should the losses exceed that declared during the bid stage, and exceed the MEPS, then the transformer must be quarantined. Contracts for the purchasing of Transformers must clearly state that the complete responsibility (and costs) for non-compliant transformers lie with the supplier, and that the onus is on the supplier to collect the non-compliant transformer from quarantine.

Enforcement of the MEPS

The Monitoring and Verification processes will highlight any non-compliance with respect to the requirements of the National Standard for Efficiency of Distribution Transformers in Lesotho [8]. It is imperative that the recourse for non-compliance is clearly stated at the bid stage and during the contracting phase of the procurement of transformers, as provided for in national engineering contracts. To enforce the MEPS, the customer may:

- Impose penalties in cases where the losses exceed those declared at bid stage but remain within the requirements of the MEPS. The penalties should be in line with the capitalised cost of losses.
- Cancel the order in cases where the calculated losses at design stage, or the tested losses post manufacturing, exceed the losses declared during the bid stage as well as exceed the MEPS. The supplier should be issued with a non-conformance and may be blacklisted should the deviation be deemed to be intentional.
- Quarantine the transformer in cases where the transformer delivered to the customer is tested and found to be non-compliant. The responsibility for the replacement of the transformer lies with the supplier. The engineering contract placed with the supplier must clearly state that the onus and costs for the collection and replacement of the transformer lies with the supplier.

Note: It is advisable that the customer catalogue non-conformances per supplier, whether for non-compliance with the MEPS or other issues. This will assist in the analysis of suppliers and will aid future contracting. (Penalties and recourses for future contracts may be amended based on the lessons learned).

4.3 MEASURES AND ACTIONS

For the MV & E process to function, it is important that engineering contracts state clearly:

- The requirement for compliance with the National Standard for Efficiency of Distribution Transformers in Lesotho [8] (MEPS and Labelling).
- The points at which the no-load and load losses are to be declared for monitoring.
- The points at which verification of the no-load and load losses may be executed.
- The implications for non-compliance of the MEPS as set out by the enforcement guidelines described in 5.2 above.
- The responsibility for collection and replacement of non-compliant transformers.

It is important to include these requirements in the engineering contracts, as losses are regarded at a technical parameter. Having these requirements included in engineering contracts provides a framework that allows the customer to enforce the MEPS and penalties for non-compliance.

The responsibilities within the Lesotho state owed entities lie with the following stakeholders:

- RSL – Inspection of transformers at ports. The inspectors will record information provided on the energy label to determine whether the losses declared by the supplier are in line with the MEPS stipulated by the National Standard for Efficiency of Distribution Transformers in Lesotho [8].
- LEC – Monitoring and Verification of transformer losses during the procurement process of the transformers. The LEC will be responsible for monitoring the transformer losses at the bid stage, after the final detailed electrical design and after the transformer is manufactured via the analysis of the test certificates issued post factory acceptance tests. The LEC are responsible for verification of the losses. Verification can be performed by witnessing the factory acceptance tests, having the transformers tested by the LEC on-site and comparing the results to the manufacturer’s test reports, or by having a third party test random transformers.
- In order to successfully implement the project a number of actions require implementation. An action plan has been developed as part of the project. Based on that action plan an estimated cost has been extracted, which can be seen in Table 5 below.
- LSI – Development and maintenance of the National Standard for Efficiency of Distribution Transformers in Lesotho [8]. With the advance in technology, it is possible that transformer efficiency can be improved upon in the future. As the custodian of the National Standard for Efficiency of Distribution Transformers in Lesotho [8], the LSI will be responsible for improving on the MEPS when the need arises.

Note: It is advisable that the customer catalogue non-conformances per supplier. This will assist in the analysis of suppliers and will aid future contracting. (Penalties and recourses for future contracts may be amended based on the lessons learned).

Activity	Responsibility	Budget LSL	Timelines (Months)
Standard Distribution	LSI	20,000.00	● 0 - 3
Internal training	LSI, LEC, DoE, RSL, LNDC	1,100,000.00	0 - 3
RSL inspectors at borders	RSL	3,000,000.00	3 - 6
Surveillance inspectors	RSL	3,000,000.00	3 - 6
Dealing with non-compliance - legal	DoE, LEC	1,000,000.00	6 - 12
Warehousing	LEC	500,000.00	0 - 3
Laboratory testing of samples	LEC	3,500,000.00	6 - 12
Monitoring	DoE	1,200,000.00	12 - 18
	Total (LSL)	13,320,000.00	
	Total USD (Rate \$1 = LSL 18)	740,000.00	

Table 5: Actions, Responsibility, Budget Requirements and Timelines for MV&E

5 Conclusion

In the past, losses and hence the efficiency of distribution transformers purchased for application on Lesotho's electricity network have not been a priority. The database of transformers provided by the LEC indicate that the transformers procured have been according to older versions of the South African SANS 780 [3][4] specification which allowed for transformers of higher losses to be supplied when compared to minimum efficiency requirements of other specifications such as those mandatory in the IEC 60078-20 specification [5]. The 2019 revision of the South African SANS 780 specification [4] has addressed the weaknesses with regards to the specifications MEPS and in some cases demands higher efficiencies than the IEC 60078-20 specification [5], especially with regards to transformers with lower capacities than 25kVA.

The calculations performed in the market assessment [7] indicate that Lesotho would benefit greatly with respect to environmental impact and the costs of electrification, from procuring transformers with higher efficiencies due to the high cost of generation and importation of electricity to meet the demand of the country now, and even more so over the next two decades when the access to electricity in the country is expected to rapidly increase.

It is evident that there is a great willingness from the country to migrate to a more stringent energy efficiency requirement for transformers. This has been borne out by the unanimous support for the MEPS and proposed labeling scheme for distribution transformers from the 7 SADC countries in which the project is being implemented . This is reflected in the requirements of the National Standard for Efficiency of Distribution Transformers in Lesotho [8] which aligns with the Regional Standard for Efficiency of Distribution Transformers in 7 SADC countries [9] and outlines the requirements for MEPS and a labeling scheme for all distribution transformers procured for use in Lesotho.

To ensure a successful migration to the use of higher efficiency transformers in Lesotho a detailed monitoring, verification and enforcement plan was developed. The plan aligns with the mechanisms for transformer procurement that currently exist in the LEC are described in detail in Chapter 5 and are summarized below.

Monitoring of Transformer Efficiency in Lesotho

Whether as part of a large tender (contract) or for isolated purchase, the process for monitoring of transformer parameters already exists within the procurement process

- ***The first opportunity to monitor transformer efficiency*** is at the bid stage. Suppliers are required to declare the no-load and load losses in their bid. The customer will evaluate the offer and determine suitability of the transformer based on among other aspects, the compliance to the MEPS. The no-load and load losses declared at this stage of the process will also be used for the calculation of the total cost of ownership.
- Once a bidder is successful with an offer, a detailed transformer design is produced, where the no-load and load losses are calculated ***This is the second opportunity for monitoring transformer efficiency during the procurement process.***

- The **third opportunity for monitoring transformer efficiency is during the completion of factory tests after the transformer is manufactured.** On completion of the tests, a report is issued where the transformer losses are declared. The customer has the opportunity to compare the results of the tests to the MEPS.
- The **fourth opportunity for monitoring transformer efficiency is during the inspection of the transformer at the port of entry.** Officials representing the Ports Authority must inspect transformers entering the borders of Lesotho and determine whether the losses declared on the energy label comply with the requirements of the MEPS.

Verification of Transformer Losses

Verification of the no-load and load losses of transformers can only be executed via electrical testing of the transformer. There are opportunities to conduct verification exercises during the manufacture of the transformer and even after the customer has taken delivery.

- The **first opportunity for verification of the transformer losses is during the factory acceptance testing of the transformer after manufacturing.** The customer has the opportunity to witness the completion of the tests, and verify the results in the manufacturer's
- After taking delivery of the transformer, the customer may also conduct electrical tests on the transformer to verify the no-load and load losses of the transformer. This is the **second opportunity for verification of the transformer losses.**
- The **third opportunity for verification of the transformer losses is available via the testing of the transformer at a neutral third-party, accredited laboratory. The customer may choose to have a random transformer transported and tested at an accredited test facility. The customer and supplier can be present to witness the tests.**

Enforcement of the MEPS

The Monitoring and Verification processes will highlight any non-compliance with respect to the requirements of the National Standard for Efficiency of Distribution Transformers in Lesotho [8]. It is imperative that the recourse for non-compliance is clearly stated at the bid stage and during the contracting phase of the procurement of transformers, as provided for in national engineering contracts. To enforce the MEPS, the customer may:

- Impose penalties in cases where the losses exceed those declared at bid stage but remain within the requirements of the MEPS. The penalties should be in line with the capitalised cost of losses.
- Cancel the order in cases where the calculated losses at design stage, or the tested losses post manufacturing, exceed the losses declared during the bid stage as well as exceed the MEPS. The supplier should be issued with a non-conformance and may be blacklisted should the deviation be deemed to be intentional.

- Quarantine the transformer in cases where the transformer delivered to the customer is tested and found to be non-compliant. The responsibility for the replacement of the transformer lies with the supplier. The engineering contract placed with the supplier must clearly state that the onus and costs for the collection and replacement of the transformer lies with the supplier.

In summary, this report outlines the key points related to the implementation of the project. These include the consumer awareness campaign that has been developed in order to reach the various consumers and stakeholders of the project, the key financial mechanisms that can be exploited in Lesotho that would enable project implementation, and the requirements for monitoring, verification and enforcement of the transition to using more efficient distribution transformers as normal practice. Furthermore, the budget for the implementation of the project over the next 3 years has been developed.

The National Resource Plan summarises the development of the National Standard for Efficiency of Distribution Transformers in Lesotho [8], it's alignment with the Regional Standard for Efficiency of Distribution Transformers in 7 SADC Countries [9] and maps out plans for the implementation of the National Standard for Efficiency of Distribution Transformers in Lesotho [8] within the country.

6 References

- [1] Comtrade, A United Nations Global Trade Repository.
- [2] Lesotho Electricity and Water Authority (LEWA) annual report for 2020.
- [3] SANS 780, 2009 South African National Standard, Transformers.
- [4] SANS 780, 2019 South African National Standard, Transformers.
- [5] IEC, 2017. Power Transformers – Part 20: Energy efficiency. Technical Specification, IEC TS 60076-20. Edition 1.0 2017-01
- [6] U4E, 2022. A Guide to Using Total Cost of Ownership When Purchasing Distribution Transformers.
- [7] The Market Assessment Report for Distribution Transformers in Lesotho.
- [8] National Standard for Efficiency of Distribution Transformers in Lesotho.
- [9] Regional Standard for Efficiency of Distribution Transformers in 7 SADC Countries.
- [10] Fatih Karanfil, Luc-Désiré Omgba. Do the IMF's structural adjustment programs help reduce energy consumption and carbon intensity? Evidence from developing countries. Structural Change and Economic Dynamics, Elsevier, 2018. fahal-01946565.
- [11] African Development Bank Article, <https://www.afdb.org/en/news-and-events/lesotho-us-16-million-for-electricity-supply-project-4294>
- [12] 240-45395762 – Eskom Specification for Pole and Ground Mounted Transformers