Ministry of Health

The Kingdom of Eswatini

Eswatini National Medical Oxygen Operational Plan 2023 - 2025

November 2022

DOCUMENT TIMELINES

TABLE OF CONTENTS

Executive Summary 14
1 Introduction 16
1.1 Diagnosing and Monitoring Hypoxemia 17
1.2 Treatment of Hypoxemia 18
1.3 Medical Oxygen Delivery Devices 18
1.4 Medical Oxygen Generation and Supply Sources 19
2 Situational Analysis: Eswatini Current Medical Oxygen Ecosystem....................23
2.1 Medical Oxygen Sources 23
2.1.1 Oxygen Concentrators 23
2.1.2 Pressure Swing Adsorption (PSA) Oxygen Production Plants 24
2.1.3 Liquid Oxygen (LOX) Tank 26
2.1.4 Oxygen Cylinders 26
2.2 National Medical Oxygen Demand 27
2.3 Health Facility Infrastructure 28
2.4 Medical Devices 29
2.5 Guidelines and Worksheets 29
2.6 Standards and Regulations 30
3 Challenges in Eswatini's oxygen ecosystem 31
3.1 Policies, Protocols, and Regulatory Challenges 31
3.2 Financial Constraints 31
3.3 Supply Chain Challenges 32
3.4 Human Resource Challenges 32
3.5 Electricity Challenges 33
4 CURRENT GOVERNMENT AND PARTNER EFFORT 34
5 Eswatini Health facility Oxygen Topology 36
5.1 Primary Health Facilities 36
5.2 Secondary Health Facilities 37
5.3 Tertiary Health Facilities 38
5.4 Ambulances 39
6 National Medical Oxygen Supply Model 41
6.1 Regional Hub 42
6.2 Inter-Regional Supply 45
6.3 Intra-Facility Supply 45

7 ENMOOP implementation strategy 47
7.1 Objectives of the ENMOOP 47
7.2 Implementation Strategy 48
7.3 Roles and Responsibilities 56
7.3.1 Ministry of Health 56
7.3.2. Oxygen Taskforce 56
7.3.3. Implementing Partners 57
7.3.4. Private Health Facilities 57
7.3.5. Private Sector 57
8 Monitoring and Evaluation (M & E) 58
8.1 Review and Planning 58
8.2 Core Indicators 58
8.3 Output indicators 59
9 Budget Estimate 60
10. Conclusion 61
APPENDICES 62
Appendix I: Eswatini National Medical Oxygen Operation Plan Contributors 62
Appendix II: Oxygen Consumption for COVID Scenario 63
Appendix III: Oxygen Consumption for Non-COVID Scenario 66
Appendix IV: Funding Gap 69

LIST OF TABLES

Table 1: TWG Membership 12
Table 2: Comparative Description of Medical Oxygen Sources Adapted From 20
Table 3: Planned, Installed and Operational PSA Plants with Maximum Production Capacities as at September 2022 (NMOSAR,2022) 25
Table 4: Government and partners' support in the oxygen ecosystem 34
Table 5: Regional Hubs and cost per cylinder for facility served 43
Table 6: Strategic framework for implementation 48
Table 7: Estimated budget 60
Table 8: Major Contributors to the Development of the Document 62
Table 9: Oxygen consumption for COVID scenario 63
Table 10: Oxygen consumption for non-COVID scenario 66
Table 11: Unfunded Activities 69

LIST OF FIGURES

Figure 1: Diagnostics and monitoring devices for hypoxemia 18

Figure 2: Examples of oxygen delivery devices 19

Figure 3: Distribution of existing oxygen concentrators (NMOSAR, 2022) 24

Figure 4: Distribution of PSA Plants in Eswatini, 2022 (NMOSAR, 2022) 24

Figure 5: LOX tanks and their capacities (NMOSAR, 2022) 26

Figure 6: Distribution of Locally Owned Medical Oxygen Cylinders (NMOSAR 2022) 27

Figure 7: Eswatini's national medical oxygen generation capacity vs demand (NMOSAR, 2022)... 28

Figure 8: Regional distribution of beds for severe-critically ill patients 29

Figure 9: Oxygen supply system for primary health facilities 37

Figure 10: Oxygen supply system for secondary health facilities...................................... 38

Figure 11: Oxygen Supply System for Tertiary Health Facilities 39

Figure 12: Oxygen supply system for ambulances 39

Figure 13: Functionality status of oxygen storage and supply sources in Eswatini 41

Figure 14: Regional Oxygen Distribution Model.. 42

Figure 15: Regional Hub Oxygen Supply Components.. 43

Figure 16: Inter-Regional Distribution of Cylinders 45

Figure 17: Direct piping from PSA plant or LOX tank to host facility 46

Figure 18: Suggested core National Oxygen Operational Plan indicators.......................... 59

Figure 19: Output indicators 59

FOREWORD

Medical oxygen is a life-saving treatment for a wide range of medical issues which may quickly worsen if left untreated. With the installation of oxygen production plants in two regions (Manzini and Shiselweni) of the country, as well as plans put in place to install additional plants in two other regions (Hhohho and Lubombo), the Government of Eswatini and partners in the oxygen ecosystem, have made significant progress toward increasing access to medical oxygen by increasing in-country production capabilities. A coordinated framework within which continuous improvement in in-country oxygen production and related interventions can be carried out is required as the country works to improve its oxygen ecosystem.

A comprehensive strategy to increase both the demand for and supply of medical oxygen in Eswatini is outlined in the country's National Medical Oxygen Operational Plan (ENMOOP) 2023-2025. The plan's overall goal is to ensure access to Medical Oxygen for all people in Eswatini and ensure effective use to save lives by the year. This will be accomplished by leveraging multiple programs for which medical oxygen is a crucial therapeutic component.

The ENMOOP 2023-2025 outlines the key strategies for achieving an optimal oxygen ecosystem, including increasing in-country oxygen production capacity, developing training and supervision guidelines, developing a dedicated procurement and distribution system for oxygen equipment and accessories, a maintenance and repair system, coordination and financing arrangements, and a monitoring and evaluation framework.

To significantly enhance the country’s oxygen ecosystem, I encourage all stakeholders; public and private, to work together to promote all plan components at the national and subnational levels in order to achieve the plan's objectives and to also ensure that the necessary resources are mobilized through this plan.

Dr. Simon M. Zwane

Principal Secretary of Health – Eswatini

ACKNOWLEDGEMENTS

The Oxygen Technical Working Group (TWG), led by Mr. Themba Motsa (Assistant Director Central Medical Stores – Eswatini), commissioned the National Operational Plan 2023-2025 for improving Eswatini's oxygen ecosystem. The overall goal of the National Operational Plan is to ensure that all people in Eswatini have access to Medical Oxygen and that it is used effectively to save lives by the year 2025.

The Ministry of Health wishes to express its heartfelt appreciation to all stakeholders who participated in the development of the country's first National Medical Oxygen Operational Plan (ENMOOP) 2023-2025. Individuals who contributed to the development or review of the NMOP 2023-2025 on oxygen are also acknowledged.

The ENMOOP 2023-2025 for improving Eswatini’s oxygen ecosystem is hoped to guide safe delivery and rational use of medical oxygen across all levels of the health care delivery system, thereby contributing to a reduction in morbidity, disability, and mortality.

Dr. Velephi Okello

Director of Health Services – Eswatini

ABBREVIATIONS, ACRONYMS AND TERMINOLOGY

AFROX	African Oxygen
CHAI	Clinton Health Access Initiative
CM	Corrective Maintenance
CMS	Central Medical Store
COVID-19	Corona Virus Disease of 2019
CPD	Continuous Professional Development
EDB	Eswatini Dairy Board
EEC	Eswatini Electricity Company
FHI 360	Family Health International
GU	Georgetown University
HDU	High Dependency Unit
HFNC	High Flow Nasal Cannula
HMIS	Health Management Information System
ICU	Intensive Care Unit
IPs	Implementing Partners
LOX	Liquid Oxygen
LPM	Litres Per Minute
LRH	Lubombo Referral Hospital
M&E	Monitoring and Evaluation

MGH	Mbabane Government Hospital
MOH	Ministry of Health
NMOSAR	National Medical Oxygen Situational Analysis Report
ENMOOP	National Medical Oxygen Operational Plan
OSPT	Oxygen System Planning Tool
OXERA	Oxygen Efficient Respiratory Aid
PPM	Planned Preventive Maintenance
PSA	Pressure Swing Adsorption
RFM	Raleigh Fitkin Memorial
SpO_2	Saturation of Peripheral Oxygen
SOP	Standard Operating Protocol
TLC	The Luke Commission Hospital
TWG	Technical Working Group
UNICEF	United Nations International Children’s Emergency Fund
WHO	World Health Organization

GLOSSARY

Flow rate	The speed at which medical oxygen is administered to a patient in litres per minute (LPM).
Hypoxemia	A lower-than-average concentration of oxygen in the blood.
Hypoxia	A condition in which tissue-level oxygen levels are insufficient to maintain homeostasis.
Medical Oxygen	Oxygen administered to patients as part of their treatment, and which satisfies certain purity requirements in addition to other criteria for clinical use.
Morbidity	A diseased state, a disability, or poor health that is generally assumed to reduce one's quality of life.
Mortality Rate	The number of deaths that occurred in a population during a given period, normalized to the population's size.
Oxygen Ecosystem	The human resources, activities, devices, and logistics that are required for producing, distributing, storing, and delivering oxygen from the point of production to a medical patient or point of use.
Size J Cylinder	A medical oxygen cylinder with nominal content of 7650L and water capacity of 46.6L.
Size F Cylinder	A medical oxygen cylinder with nominal content of 1360L and water capacity of 9.4L.
Size E Cylinder	A medical oxygen cylinder with nominal content of 680L and water capacity of 4.7L.

MEMBERSHIP OF TWG ON OXYGEN

Table 1: TWG Membership

Name	Position	Organisation
Mr. Themba Motsa	Dept. Director CMS	MOH
Dr. Debrah Vambe	PMDT - Technical Advisor	MOH
Mr. Vusumuzi Dlamini	Biomedical Engineer	MOH
Miss Nomcebo Magagula	Biomed Technician	MOH
Dr. Lukhele Nomthandazo	NCD/TB/HIV National Program Officer	WHO
Chiara Pierotti	Chief Child Survival & Development	UNICEF
Makhosini A. Mamba	Health Specialist	UNICEF
Sifiso David Sabelo Dlamini	Cold Chain Specialist	UNICEF
Elvis Oheneba Manu	Biomedical Engineer - Consultant	UNICEF
Theo Ligthelm	Manager	Right to Care
Khumbulani Moyo	Manager	Right to Care
Peter Schilder	Consultant Professional Mechanical Engineer	Right to Care
Cliffs Wagbafor	Biomedical Engineer	Right to Care
Nyasatu Ntshalintshali	Country Director	CHAI

Qhubekani Mpala	Oxygen Program Manager	CHAI
Mpumelelo Ndlela	Oxygen Program Officer	CHAI
Sam Riggleman	Engineer	TLC
Mpumelelo Ncube	Engineer	TLC
Ncamsile Dlamini	Manager	FHI 360
Philisiwe Dlamini	Cap. Development	FHI 360
Normusa Musarapasi	Georgetown University	Associate Technical Director

EXECUTIVE SUMMARY

Hypoxemia is a leading cause of morbidity and mortality on a global scale; therefore, the ability to detect and treat Hypoxemia is crucial to patient care. It is therefore vital to create medical oxygen, a competent medicine to treat Hypoxemia, and ensure that it is accessible in all levels of Eswatini's healthcare system. However, medical oxygen access in Eswatini remains limited, particularly during emergencies such as COVID-19, due to production capacity, procurement, distribution, and the inability to use, operate, and maintain oxygen delivery and therapy devices properly.

The medical oxygen generation and supply sources in Eswatini include oxygen cylinders, oxygen concentrators, PSA oxygen generation plants, and bulk Liquid Oxygen (LOX) tanks. Due to the undersized and limited number of central oxygen delivery systems (oxygen piping and manifold system) across the country, oxygen cylinders are used to deliver oxygen at the bedside, putting both the patient and the staff at risk should cylinders fall. Since nurses are usually the ones to transport cylinders within and/or to the wards, this distracts nurses from their primary responsibility of caring for patients. In addition, the limited availability and functionality of cylinders at all levels of the country's health care also present challenges in the country's oxygen ecosystem.

Concentrators are available in the country, but their use is restricted to high-level health facilities. In addition, their effective operation is hindered by unreliable power supply from the national grid. There are currently PSA oxygen generation installations in two of the country's regions, the Shiselweni and Manzini Regions, with plans to install PSA oxygen generation plants in the remaining two regions, the Hhohho and Lubombo Regions. Additionally, three LOX tanks are installed in three of the nation's high demanding oxygen facilities: Lubombo Referral Hospital (LRH), The Luke Commission Hospital (TLC) and Raleigh Fitkin Memorial Hospital (RFM).

In the public sector, the Biomedical Unit of the Ministry of Health (MOH) is responsible for the maintenance of oxygen devices. Due to a lack of parts, tools, and workshops, however, the capacity to maintain oxygen equipment is limited.

In addition to the above-mentioned challenges in the country's oxygen ecosystem, the lack of knowledge among health care professionals regarding the use, operation, care, handling,

and basic preventive maintenance of oxygen therapy equipment contributes to low levels of utilization and decreased equipment durability.

The overarching objective of this National Medical Oxygen Operational Plan (ENMOOP) 2023-2025 is to improve access to Medical Oxygen for all people in Eswatini and ensure effective use to save lives by the year 2025.

This would be accomplished by achieving the following strategic objectives:

Objective 1
Create an enabling environment for scaling up sustainable oxygen supply system.

Objective 2
Implement an optimal oxygen production and distribution model.

Objective 3
Improve oxygen supply chain and monitoring systems.

Objective 4
Improve the capacity for delivering oxygen therapy.

In accordance with the preceding, a sequence of initiatives will be implemented across all facility types and at all levels of the country's health system. Oxygen availability will be addressed systematically, and the supply model will be supported with adequate maintenance, training, funding, organization, and monitoring. Effective implementation will require competent leadership and coordination, extensive stakeholder participation, and committed resources.

Improving access to high-quality, appropriate, and functional oxygen supply systems in Eswatini has the potential to substantially reduce mortality from Hypoxemia.

The ENMOOP 2023-2025 for the improvement of the country's oxygen ecosystem provides the framework for conception, funding mobilization, and all activities pertaining to the improvement of the country's oxygen ecosystem

1 INTRODUCTION

Eswatini is a landlocked southern African country with a population of 1.17 million people and a per capita income of 4,214.9 USD.[1] Eswatini, like many of its neighbors, has several cases of Hypoxemia.[2]

Hypoxemia, a medical condition for inadequate oxygen in the blood, is a major fatal complication of pneumonia and other respiratory diseases. Very often this condition can lead to death. Chronic obstructive pulmonary disease, acute asthma and pneumonia are the most common causes of Hypoxemia.[3]

This condition is most commonly diagnosed with pulse oximeters. These are non-invasive monitoring devices which measure blood oxygen saturation (SpO_2) levels in patients.[4] Pulse oximetry has proven in a resource constrained environment to be a very effective diagnostic tool and can ensure the most efficient use of oxygen therapy while also monitoring treatment response.

Even though medical oxygen is an essential medicine used to treat Hypoxemia,[5] it is also vital in operating theatres for anesthesia procedures, recovery periods and in intensive care units. As a result, oxygen therapy is a critical component in the management of medical illnesses, safe surgery, and anesthesia.

In addition, the increased number of Hypoxemia cases caused by the novel Corona Virus Disease of 2019 (COVID-19) has highlighted the benefits of oxygen, as it is an effective treatment for COVID-19.[6]

---

[1] The World Bank. Eswatini Country Profile. 2022 [Available from: http://data.worldbank.org/country/swaziland]

[2] Dlamini et al. Predicting COVID-19 Infections in Eswatini Using the Maximum Likelihood Estimation Method. 2022 [DOI: 10.20944/preprints202205. 0417.v1]

[3] Beenish et al. Hypoxia. 2022

[4] Joseph F. Kelleher. Pulse oximetry. 1989 [DOI: https://doi.org/10.1007/BF01618369]

[5] World Health Organization (WHO). WHO Model Lists of Essential Medicines. 2021

[6] The Pan American Health Organization (PAHO). Good Practices in the Rational and Effective Use of Oxygen. 2022 [Available from: https://iris.paho.org/handle/10665.2/55735]

Since the inception of the Covid-19 virus, Eswatini has reported 73,410 confirmed COVID-19 cases with 1,422 associated deaths as of October 4, 2022.[7] The country's pandemic response efforts have been hampered by inadequate and unreliable oxygen systems, resulting in low availability of oxygen at the bedside.

To improve the country's detection and treatment of respiratory diseases, the Ministry of Health (MoH) considers improved access to adequate oxygen and related equipment at all levels of the country's healthcare system to be a top priority.

As a result, the MoH has instructed the development of an integrated approach to address the chronic limitations to adequate oxygen therapy delivery at all levels of the country's healthcare system. The development of this ENMOOP 2023-2025 will serve as the framework for addressing the challenges in the country’s oxygen ecosystem.

1.1 Diagnosing and Monitoring Hypoxemia

Hypoxemia can be caused by a multitude of health conditions. The capacity to diagnose and treat Hypoxemia quickly is crucial to patient care. Blood gas analysis is the gold standard for assessing oxygen saturation, but it is invasive and costly.[8] The detection of Hypoxemia based on clinical symptoms is problematic due to the practice's inconsistent sensitivity and specificity. In low resource settings, the World Health Organization (WHO) recommends pulse oximetry as the most cost-effective approach for diagnosing and monitoring Hypoxemia (e.g., saturation level 90%) in health facilities.[9]

Pulse oximeters and other multiparameter monitors (see Figure 1) are user-friendly noninvasive medical devices used for diagnosing and monitoring Hypoxemia. Patient monitors and pulse oximeters are utilized dependent on the monitoring level, either intermittent or continuous. While fingertip pulse oximeters are mostly employed for screening patients in outpatient wards, they can also be utilized in inpatient wards.

[7] World Health Organization. WHO Health Emergency Dashboard. 2022 [Available from: https://covid19.who.int/region/afro/country/sz]

[8] Plüddemann et al. Pulse oximetry in primary care: primary care diagnostic technology update. 2011 [DOI: https://doi.org/10.3399/bjgp11X572553]

[9] World Health Organization. WHO guidelines for safe surgery 2009. [Available from: http://whqlibdoc.who.int/publications/2009/9789241598552_eng.pdf]

Blood Gas Analyzer	Multiparameter Patient Monitor	Vital Signs Monitor	Pulse Oximeter

Figure 1: Diagnostics and monitoring devices for hypoxemia

1.2 Treatment of Hypoxemia

Hypoxemia has a high success rate when treated with oxygen treatment once it has been diagnosed. In cases of emergency, during surgery, and when treating Hypoxemia, oxygen therapy is highly recommended by the WHO. Oxygen and peripheral oxygen apparatus are viewed as essential in all tiers of Eswatini's healthcare system.[10]

Oxygen treatment is recommended for a variety of diseases, including severely-critically ill COVID-19 patients, pneumonia, other severe respiratory infections, new-born resuscitation, trauma, poisoning, and anaphylactic shock.[11] This necessitates the presence of oxygen and related supplies at all care settings.

1.3 Medical Oxygen Delivery Devices

Medical oxygen is an essential medicine. It must be prescribed prior to administration to patients. It must therefore be delivered to patients with care, as needs differ from patient to patient. In oxygen therapy, oxygen delivery devices are utilised based on their permitted pressures (low vs. high) and flow rates (low vs. high). Understanding oxygen delivery methods and their applications is beneficial when evaluating oxygen therapy options. [12]

---

[10] Ministry of Health Eswatini. Standard treatment guidelines and essential medicines list. 2012.

[11] Ministry of Health Eswatini. Eswatini national COVID-19 management guidelines. 2021.

[12] Hardavella et al. Oxygen devices and delivery systems. 2019 [Doi: 10.1183/20734735.0204-2019]

To provide patients requiring oxygen at low flow rates, devices such as simple face masks, non-rebreather masks, and nasal cannula are utilised. Devices such as venturi masks, high flow nasal cannulas (HFNC), and oxygen efficient respiratory aids (OXERA) are used to administer oxygen to patients requiring oxygen at high flow rates.

Figure 2 provides examples of delivery devices.

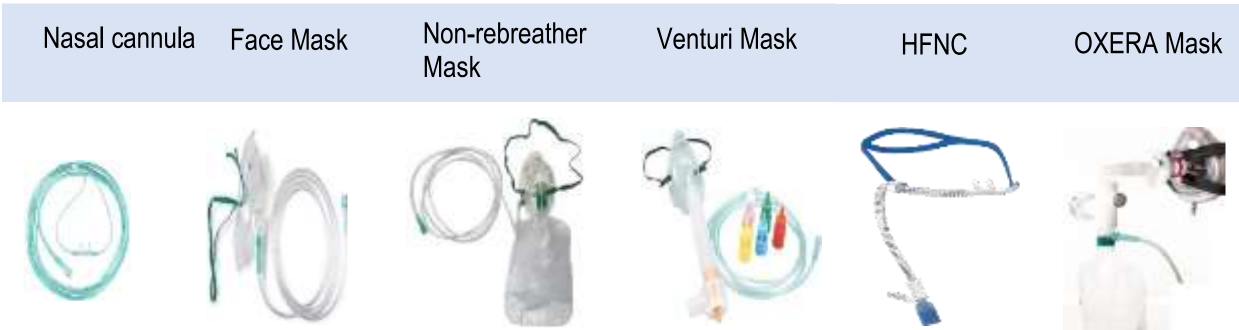


Figure 2: Examples of oxygen delivery devices

1.4 Medical Oxygen Generation and Supply Sources

There are variety of medical oxygen generation and supply sources however the most popular ones are concentrators, cylinders, pressure swing adsorption (PSA) plants and bulk stored liquid oxygen.

The appropriate choice of medical oxygen source depends on several factors, including the following:

1. Amount of medical oxygen required at the health facility.
2. Available infrastructure.
3. Capital and operation cost.
4. Generation and/or storage capacity.
5. Supply chain for local production (and delivery) of medical gases.
6. Availability and stability of electricity.
7. Availability of maintenance services and spare parts.

In addition to the above, the level of the health system at which these various sources may be utilised will rely on local legislation, training, and capability at the various levels of care. Various oxygen sources are compared in Table 1.

Table 2: Comparative Description of Medical Oxygen Sources Adapted From [13]

Aspect	Cylinders	Concentrators	PSA Plants	Liquid Oxygen
				
Description	A refillable container for storing and transporting oxygen in compressed gas form. Cylinders are filled at a gas generating plant, so transportation to and from the plant is required.	A self-contained electrically powered medical device that uses PSA technology to concentrate oxygen from ambient air.	On-site oxygen generating system using PSA technology that supplies high-pressure oxygen via a central pipeline or refilled cylinders.	Off-site produced liquid oxygen stored in a large tank and that supplies oxygen via a central pipeline. Tank needs oxygen refilling by suppliers.
Application	Can be utilised for all oxygen requirements, including high-pressure supply, patient transport, and as a backup system for other systems.	Can be used as a bedside oxygen delivery system and a single unit can also serve multiple beds using flow splitters.	Useful for all oxygen requirements, including high-pressure supply.	Can be used for all oxygen requirements, including high-pressure supply, and in facilities with intermittent or unreliable power supply.
Health System Level	All levels (any medical unit requiring oxygen).	All levels (any medical unit requiring oxygen).	Secondary and tertiary.	Secondary and tertiary

[13] WHO-UNICEF technical specifications and guidance for oxygen therapy devices. 2019

Aspect	Cylinders	Concentrators	PSA Plants	Liquid Oxygen
Distribution System	Oxygen supply via central / sub-central pipeline manifold or to patient with flowmeter and tubing	Direct supply to patient with tubing or through a flowmeter stand.	Central/sub-central pipeline distribution system, or to refill cylinders for facility manifolds.	Central pipeline distribution system.
Electricity Requirement	No electricity required.	Yes, electricity required.	Yes, electricity required.	No electricity is required.
Initial Costs	Moderate; cylinder, regulator, flowmeter, installation, and training.	Moderate; Concentrator, spares, installation, and training	High; plant and pipeline distribution system, installation, training, and plant housing.	Can be high; tank, pipeline distribution system, installation, and training.
Operating Expenses	High: cylinder deposit and leasing fees, refill costs, and transportation cost (from refilling station to health facility).	Low; electricity and maintenance (spare parts and labour).	Low/moderate; electricity and maintenance (spare parts and labour). If not managed by third party, additional staff may be required.	Moderate (can be high if tank is leased); refill costs, and maintenance.
Maintenance Requirement	Limited maintenance by skilled professionals.	Moderate maintenance by trained professional, can be in-house technicians	Significant maintenance by highly trained technicians and engineers, can be provided as part of contract.	Significant maintenance by highly trained technicians and engineers, can be provided as part of contract.

Aspect	Cylinders	Concentrators	PSA Plants	Liquid Oxygen
User Care	Moderate; regular checks of fittings, connections, regular and oxygen levels, and cleaning of exterior.	Moderate; cleaning of filters and device exterior	Minimal; at terminal unit only	Minimal; at terminal unit only
Merits	• Doesn’t use electricity.	• Continuous oxygen supply (if power available) at low running cost. • Delivery to multiple patients.	• Can be cost-effective for large facilities. • Continuous oxygen supply.	• High oxygen purity. • High oxygen output in a small footprint.
Demerits	• Requires transport/supply chain. • Exhaustible supply. • Risk of gas leakage. • Risk of unwanted relocation.	• Low pressure output, usually not suitable for CPAP or ventilators. • Requires uninterrupted power. • Requires backup cylinder supply. • Requires maintenance.	• High capital investments. • Requires uninterrupted power. • Needs adequate infrastructure. • High maintenance for piping. • Requires backup cylinder supply. • Risk of gas leakage from piping system.	• Requires transport/supply chain. • Exhaustible supply. • High maintenance for piping. • High total cost. • Needs adequate infrastructure. • Requires backup cylinder supply. • Risk of gas leakage from piping system.

2 SITUATIONAL ANALYSIS: ESWATINI CURRENT MEDICAL OXYGEN ECOSYSTEM

The Eswatini medical oxygen ecosystem includes the human resources, processes, equipment, and logistics required to deliver oxygen from a production source to patient. The MoH's recent National Medical Oxygen Situational Analysis Report (NMOSAR) 2022[14], contains a comprehensive situational report on the various areas of the country's oxygen ecosystem. The key findings are summarised below.

2.1 Medical Oxygen Sources

NMOSAR (2022) confirms that Eswatini has a mix of the following oxygen sources:

1. Oxygen Concentrators
2. PSA plants
3. LOX tanks
4. Oxygen cylinders

These various options are discussed further below.

2.1.1 Oxygen Concentrators

Currently, health facilities across Eswatini rely mostly on oxygen concentrators for on-site medical oxygen production and delivery to patient bedside. However, the prevalence and use of concentrators varies greatly across facilities. Concentrators with capacities of 5, 8, 10, and 15 litres per minute (LPM) are the most used. NMOSAR (2022) indicated that the country had 178 oxygen concentrators (Model: OLV-10) and parts for repairing 8 (Model: Jay-10) at the Central Medical Stores (CMS). NMOSAR (2022) highlighted the need for decentralising the availability and use of concentrators to lower levels of the country's healthcare system, i.e., to clinic level. Additional training for healthcare workers was also highlighted.

Figure 4 depicts a pictorial representation of operational and non-operational concentrators in the country, excluding the ones at CMS.

[14] Ministry of Health Eswatini. National medical oxygen situational analysis report. 2022.

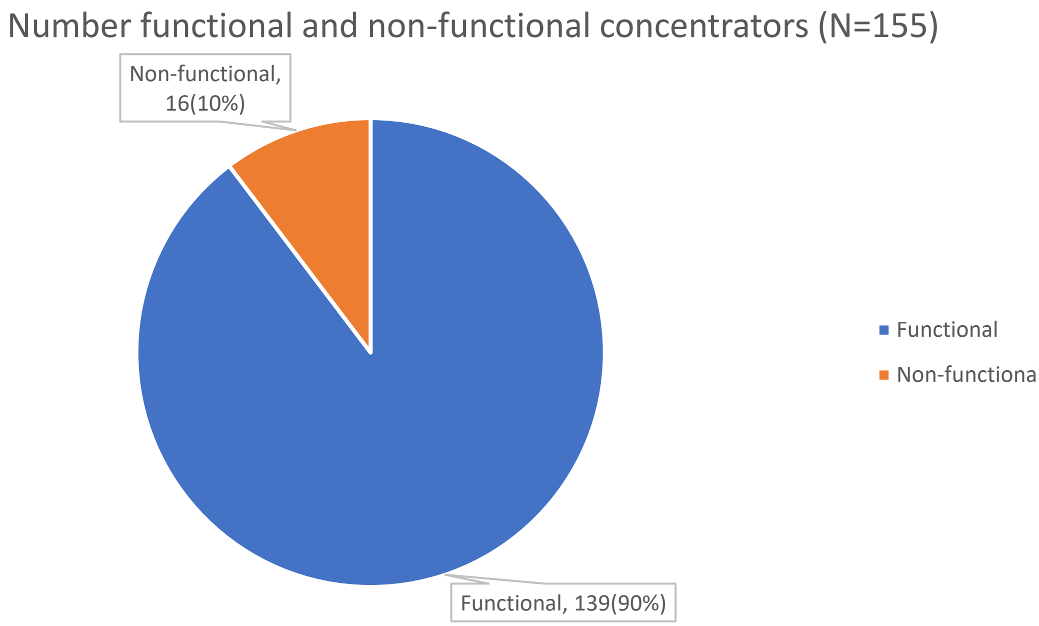


Figure 3: Distribution of existing oxygen concentrators (NMOSAR, 2022)

2.1.2 Pressure Swing Adsorption (PSA) Oxygen Production Plants

PSA plants are the primary source of large-scale oxygen production in Eswatini. PSA installations (operational and planned) are distributed regionally. Currently, the Shiselweni and Manzini Regions have PSA plant installations, with Lubombo Region's PSA plant

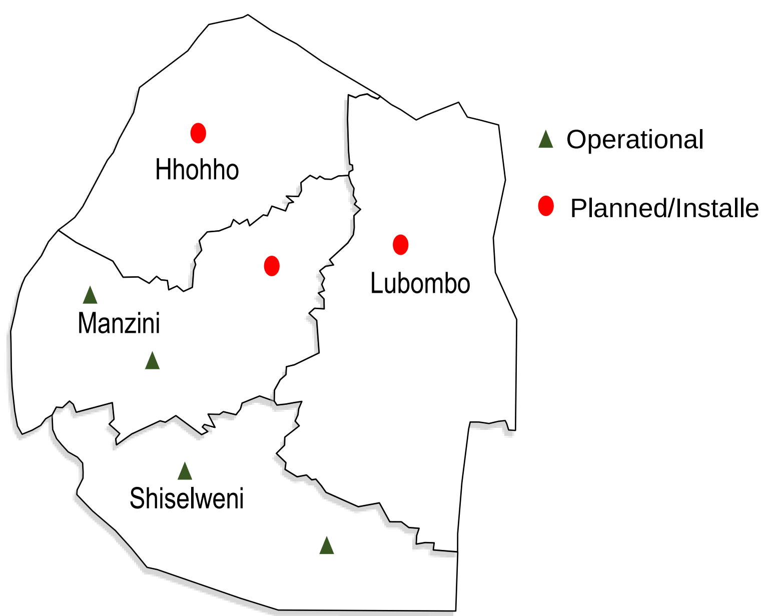


Figure 4: Distribution of PSA Plants in Eswatini, 2022 (NMOSAR, 2022)

being installed. The Hhohho Region is the only region without a PSA plant, but there are plans to procure and install PSA plant. Refer to figure 4.

Current installed PSA plants have the potential to produce 154,800,000 litres of oxygen per month, equivalent to 22 764 standard-sized cylinders (Size "J"; 10.2kg). Production capacity is likely to be significantly lower than the potential as PSA plants rarely run at full capacity.

Table 3: Planned, Installed and Operational PSA Plants with Maximum Production Capacities as at September 2022 (NMOSAR,2022)

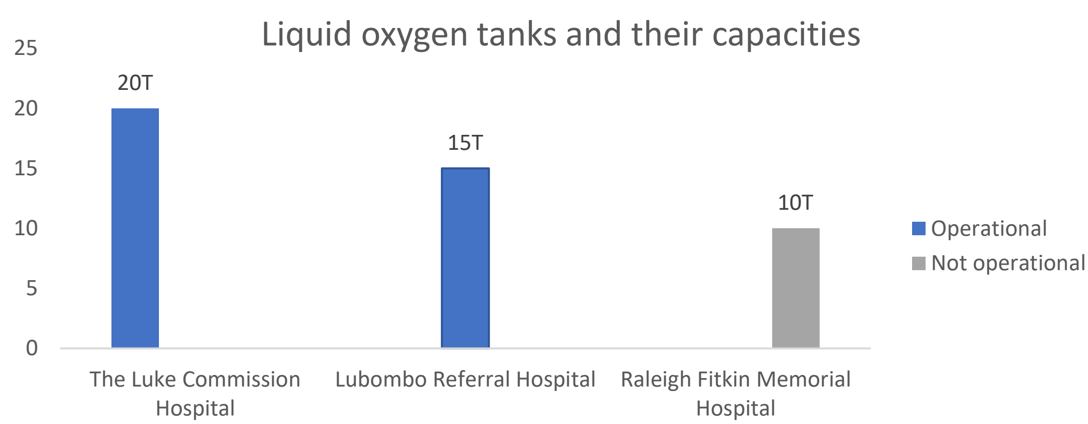
Location	Brand	Ownership	Capacity (Nm3/h)	Cyl./m (Type J)	Install. Year	Status
EDB	Mentis	Parastatal	11	1,165	2021	Operational
HGH	Intakatec	Public	30	3,176	2022	Operational
NHC	Intakatec	Public	30	3,176	2022	Operational
TLC	Mentis	Private	144	15,247	2021	Operational
CMS	N/A	Public	30	3,176	N/A	Planned
MGH	N/A	Public	30	3,176	N/A	Planned
LRH	Mentis	Public	108	11,435	N/A	Ongoing
TOTAL	Operation		215	22 764		
	Planned		168	17 787		

The existing PSA plants produce more oxygen than their facilities require, and thus have the ability to support facilities in their catchment area with their excess production. The establishment of an oxygen distribution network can be used to capitalise on current supply and distribution capacity, resulting in lower prices that can be used as an incentive for health-care facilities to purchase oxygen.

2.1.3 Liquid Oxygen (LOX) Tank

Eswatini currently has three LOX tanks. Two of the tanks, located at Lubombo Referral Hospital (LRH) and The Luke Commission (TLC), are operational, the third is still being installed at Raleigh Fitkin Memorial Hospital (RFM). LOX supply comes from South Africa by truck. Current LOX installations are in facilities with high oxygen requirements, and the nature of LOX tanks offers the facilities with the opportunity to increase refill times whenever demand increases. However, this is dependent on the availability of LOX from South African suppliers. Figure 5 illustrates the capacities of the operational and ongoing installations.

Figure 5: LOX tanks and their capacities (NMOSAR, 2022)



2.1.4 Oxygen Cylinders

Health facilities with PSA plants, parastatal organisations, and private vendors distribute oxygen in cylinders throughout the country. Hlathikhulu Health Centre, and TLC are involved in the oxygen distribution, while the Eswatini Dairy Board (EDB) was the only parastatal organisation involved. The cylinder vendors in the country are African Oxygen (AFROX) and Air Liquide, who distributes cylinders to facilities at a fee.

Though the country has the local capacity to fill and distribute more cylinders, distribution has been hampered by the limited number of locally owned cylinders in circulation. Most of the cylinders in circulation are owned by vendors. Figure 6 below depicts the distribution of local cylinder ownership based on cylinder size. Currently TLC owns more than half of the locally owned cylinders.

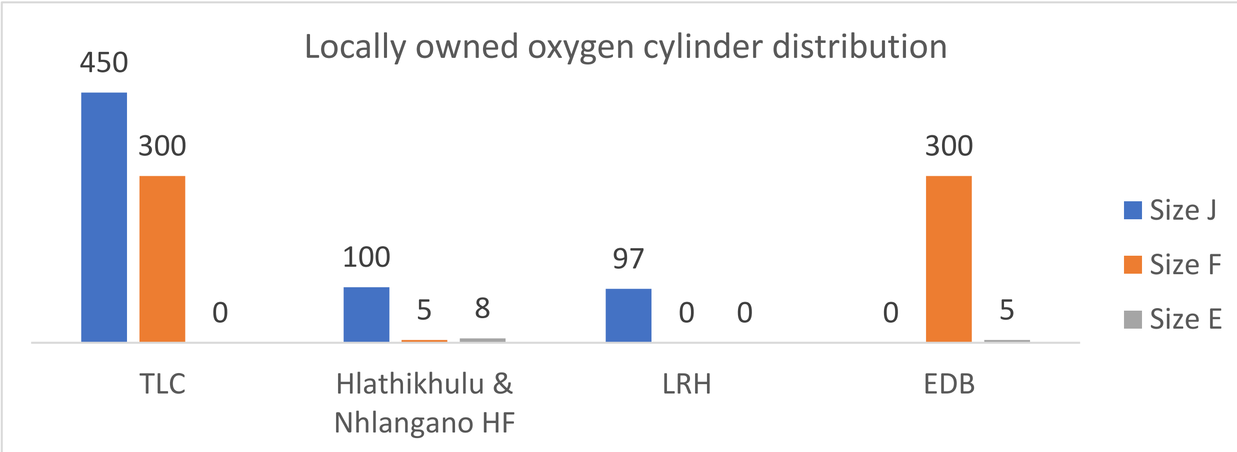


Figure 6: Distribution of Locally Owned Medical Oxygen Cylinders (NMOSAR 2022)

2.2 National Medical Oxygen Demand

A national quantification exercise was conducted in August 2022 as part of the country's situational analysis to understand the full extent of Eswatini's medical oxygen needs. Total oxygen requirement was calculated using the UNICEF Oxygen System Planning Tool (OSPT) version 2.1, which includes Hypoxemia prevalence assumptions for different bed and patient types, bed turnover rate, typical flow rate, and oxygen therapy duration for each bed type in its calculations.

Estimated oxygen demand outcomes were modelled using bed type occupancy rates and average bed type flow rates.

The current operational oxygen production and bulk storage installations, as shown in Figure 7, would be able to meet the country's oxygen needs during a demand surge as was experienced during COVID-19 waves. However, this would not be able to meet the country's oxygen needs during demand surge. The country's oxygen availability was estimated using a monthly LOX tank refill. It should be noted that a surge in oxygen demand could be met by increasing the frequency of LOX tank refills.

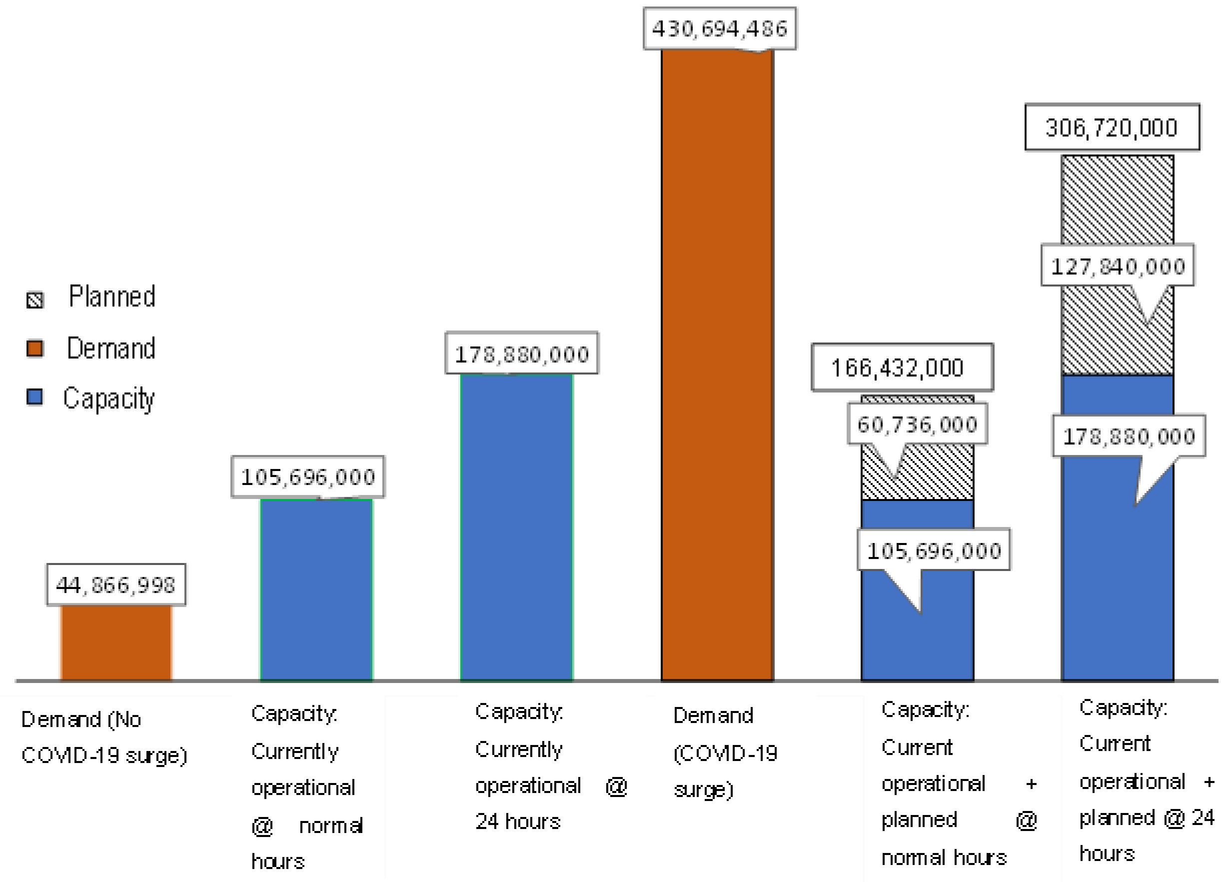


Figure 7: Eswatini's national medical oxygen generation capacity vs demand (NMOSAR, 2022)

2.3 Health Facility Infrastructure

Health facility infrastructure, such as oxygen piping and bed types, has an influence on clinical outcomes. The NMOSAR 2022 concluded that:

1. An uneven distribution of beds across the regions. This was attributed to misalignment between the population and hospital distribution.
2. An uneven distribution of critical care beds. Although Manzini and Hhohho regions had beds for COVID-19 and non-COVID-19 critical patients, the Lubombo region only had beds for critical COVID-19 patients. Shiselweni region on the other hand had no critical care beds at all. This situation negatively impacted clinical outcomes as patients requiring escalation of care did not have enough time to be transported over a long distance for such care. Regional distribution of advanced care beds is presented in Figure 8.
3. Most facilities did not have a central medical oxygen piping system. LRH, MGH, and TLC were the only facilities that had manifolds with the capacity to meet patient needs. The other facilities had no or undersized manifolds. This required moving cylinders to the bedside, putting both patient and staff at risk from cylinder falls. The situation also takes nurses away from their primary duty of caring for

patients, as they are the ones who usually move cylinders within and/to and from the wards.

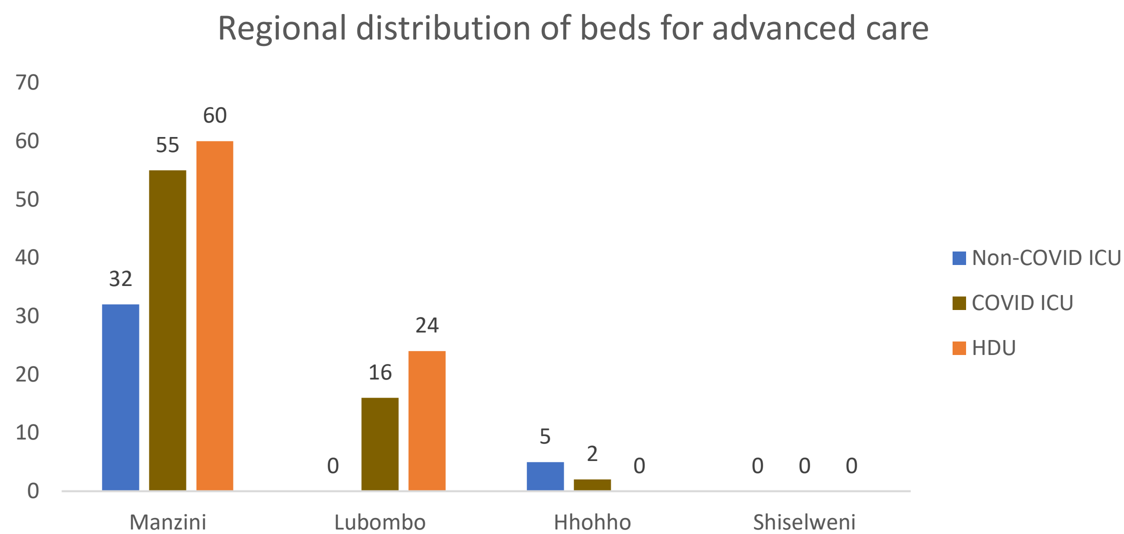


Figure 8: Regional distribution of beds for severe-critically ill patients

2.4 Medical Devices

Medical devices are used to diagnose, monitor and treatment of patients. However, keeping them in working order is crucial for availability. NMOSAR (2022), revealed that:

1. The requisite planned preventive maintenance (PPM) had not been performed on equipment in public facilities for over a year.
2. The biomedical unit of the MoH lacked the necessary parts to conduct corrective maintenance (CM).
3. Only MGH had a functional workshop for performing maintenance on medical equipment.

The above issues negatively affected medical device availability in public health facilities.

2.5 Guidelines and Worksheets

Clinical guidelines on oxygen therapy are required so that healthcare workers can provide the best possible care to their patients by performing tasks such as identifying Hypoxemia through screening tests and providing the appropriate amount of oxygen to those who require it. However, Eswatini's current medical oxygen therapy practise is guided by previously published clinical guidelines and non-standardized job aids with insufficient oxygen therapy-specific detail. In some cases, there is no specific guidelines and/or job aides to guide oxygen therapy practices.

2.6 Standards and Regulations

Regulation is needed for the production of medical oxygen and other medical gases. This guarantees consistent quality of oxygen at all stages. In order to guarantee oxygen quality and patient safety, there should also be compliance manuals for good manufacturing practises and standard operating procedures. NMOSAR 2022 indicated that at the facility level, there were very little resources for analysing oxygen device output to guarantee their proper operation.

There is also a lack of readily available, aggregated, or systematically analysed metrics concerning the detection and treatment of Hypoxemia.

3 CHALLENGES IN ESWATINI'S OXYGEN ECOSYSTEM

Five significant challenges have been identified in the oxygen ecosystem of the nation. These obstacles and their effect on overall healthcare outcomes highlight the importance of oxygen systems. The challenges are discussed in the sections below.

3.1 Policies, Protocols, and Regulatory Challenges

The WHO's classification of oxygen as an essential medicine highlights the need for a regulatory framework, clinical guidelines, protocols, and policies to govern oxygen production, distribution, storage, use, and devices.

Though the country has clinical oxygen guidelines, new and/or standardised job aids and clinical guidelines are needed to align international and local best practises and made available at all levels of the country's health system.

Additionally, the lack of regular reviews of clinical competencies in Hypoxemia diagnosis and oxygen therapy makes it impossible to enforce guidelines and job aides.

Furthermore, the logistical complexities associated with medical oxygen supply requires SOPs. The country currently does not have clear SOPs to manage oxygen supply.

There are no regulations nor a regulatory body to ensure that in-country oxygen production and imported oxygen supplies are to standard. Currently, health facilities use oxygen analysers and flowmeters to determine the functionality of oxygen concentrators without reference to any formal regulations or guidelines.

There is no certification system to guarantee the integrity of medical oxygen cylinders.

There is also a lack of guidelines regarding the types of data that should be monitored and how they should be used in managing fiscal, clinical, and technical output.

3.2 Financial Constraints

The low availability of oxygen and oxygen-related equipment in public health facilities is directly attributable to inadequate funding.

Inadequate financial provision (for PSA plant operating costs, LOX tank rental fees and refilling bulk storage tanks) directly affects oxygen availability.

3.3 Supply Chain Challenges

In public health facilities, numerous brands and models of pulse oximeters and other oxygen related devices are available. This lack of standardization leads to the further procurement of substandard equipment and consumables. A lack of standardisation impacts negatively on the logistics of spare parts.

Even though the country currently produces its own oxygen, a well-established oxygen distribution network and cylinder management system are lacking. This makes it impossible to leverage the installed oxygen production capacities.

Challenges such as supply stockouts occur as a result of administrative delays in releasing funds, supplier unreliability, and high transportation costs. Stock-outs can also occur when demand for oxygen exceeds available supply, which can be exacerbated by equipment downtime, inaccurate needs quantification, and delays and/or a lack of coordination in refilling cylinders.

3.4 Human Resource Challenges

A lack of knowledge among health care professionals regarding the clinical application of oxygen and user-level maintenance of oxygen supply equipment, contributes to low levels of oxygen utilisation and the shortened lifespan of oxygen equipment. As previously mentioned, pulse oximeters are vital to the accurate diagnosis of Hypoxemia; however, many healthcare workers are unfamiliar with the equipment or lack the skills to properly analyse and evaluate results. Despite the availability of supplies, there is a lack of adherence to best practise protocols and guidelines for the diagnosis and management of Hypoxemia.

Maintenance and asset management are essential for fully functional mechanical devices. Qualified biomedical engineers and technicians are not always available to provide dependable equipment maintenance and repair, because the Biomed unit at the MOH is chronically short staffed. Compliance with planned preventive maintenance programmes is low. These obstacles are largely attributable to knowledge gaps in oxygen plant management, the availability and accessibility of spare parts, and unmotivated maintenance staff.

3.5 Electricity Challenges

For efficient operation, oxygen production equipment such as oxygen concentrators and PSA plants rely on a high quality of power supply. Multiple power outages and undervoltage events that have been occurring daily in many health facilities across the country have had detrimental effect on equipment.

4 CURRENT GOVERNMENT AND PARTNER EFFORT

Efforts to improve the oxygen ecosystem in the country are already being supported by the Ministry of Health and several partners, including those listed below:

Table 4: Government and partners' support in the oxygen ecosystem

Partner	Initiative(s)
Ministry of Health (MOH)	• Provision and installation of 108Nm3/h PSA plant at the Lubombo Referral Hospital (LRH)
	• Provision of 98 cylinders (size “J” type) for Lubombo Referral Hospital
Médecins Sans Frontières (MSF)	• Provision and installation of 30Nm3/h PSA plant at Nhlangano Health Centre and Hlathikhulu Government Hospital.
	• PSA plant comes with 4 years comprehensive maintenance fully paid for by MSF.
	• Construction of PSA plant building at Nhlangano Health Centre.
	• Rehabilitation of plant building at Hlathikhulu Government Hospital.
	• Provision of 113 cylinders (100 cylinder with 50L capacity, 5 cylinders with 4.5L capacity and 8 cylinders with 10L capacity).
	• Piping of Nhlangano Health Centre.
	• Repairing leakages in the existing pipeline of Hlathikhulu Government Hospital.
	• Purchase and installation of 2x10 cylinder manifold at Nhlangano Health Centre.
Global Fund (GF)	• Provision and installation of 30m3/h oxygen plant at MGH and CMS.
	• Plant comes with 5 years comprehensive maintenance fully paid by Global Fund.
	• Purchase of oxygen delivery truck with fuel paid for 3 years.
	• Provision of 520 cylinders (400 cylinders with 50L capacity, 70 cylinders with 10L capacity and 50 cylinders with 4.7L capacity).
	• Supporting with the salaries of HR responsible for the PSA plants at CMS and MGH.

<table>
<tr><td></td><td>• Piping and installation of manifolds at Mankayane Government Hospital, Good Shepherd Mission Hospital, Matsanjeni Health Centre, Dvokolwako Health Centre, Mkhuzweni Health Centre and Sithobela Health Centre.</td></tr>
<tr><td rowspan="4">Clinton Health Access Initiative (CHAI)</td><td>• Development of asset management system for the biomedical unit of the MoH and CMS.</td></tr>
<tr><td>• Costing of operational plan</td></tr>
<tr><td>• Conducted baseline facility assessment</td></tr>
<tr><td>• Negotiating LOX prices</td></tr>
<tr><td rowspan="2">Right to Care (R2C)</td><td>• Training clinical staff and EPR on life support and the diagnosis of Hypoxemia</td></tr>
<tr><td>• Setting up HDUs at Pigg’s Peak District Hospital, Hlathikhulu Government Hospital, RFM and Good shepherd Mission Hospital</td></tr>
<tr><td>Georgetown University (GU)</td><td>• Provision and installation of oxygen pipes, manifold, and LOX tank at RFM</td></tr>
<tr><td rowspan="4">Family Health International (FHI 360)</td><td>• Upgrade of the oxygen manifold room (manifold and accessories) at MGH.</td></tr>
<tr><td>• Reticulation of medical gas piping at MGH.</td></tr>
<tr><td>• Piping and reticulation at Pigg’s Peak Government Hospital</td></tr>
<tr><td>• Training of Biomedical Engineers and Technicians.</td></tr>
<tr><td rowspan="4">United Nations International Children’s Emergency Fund (UNICEF)</td><td>• Training of Healthcare workers.</td></tr>
<tr><td>• Installation of solar source of energy at Nhlangano Health Centre and Hlathikhulu Government Hospital.</td></tr>
<tr><td>• Purchase of parts for the Biomedical unit of MOH; to repair oxygen related devices.</td></tr>
<tr><td>• Technical assistance</td></tr>
<tr><td rowspan="3">World Health Organization (WHO)</td><td>• Provision of critical care and biomedical experts.</td></tr>
<tr><td>• Train doctors, nurses, and biomedical officers.</td></tr>
<tr><td>• Procurement of biomedical test equipment.</td></tr>
</table>

5 ESWATINI HEALTH FACILITY OXYGEN TOPOLOGY

Oxygen delivery and monitoring requirements vary across healthcare levels. These requirements should be aligned with the population distribution, quality of infrastructure, clinical services offered and the demand for these services. This requires that oxygen systems for clinics will be different in design from those for regional or referral hospitals. According to WHO Health Care Facility Levels, healthcare facilities have been grouped into the following categories[15]:

1. Primary health facilities. This includes community healthcare services, clinics with maternity, clinics without maternity and public health units
2. Secondary health facilities. This includes health centers (which provide inpatient and outpatient care services).
3. Tertiary health facilities. This includes regional hospitals, referral hospitals and specialized hospitals
4. Ambulances.

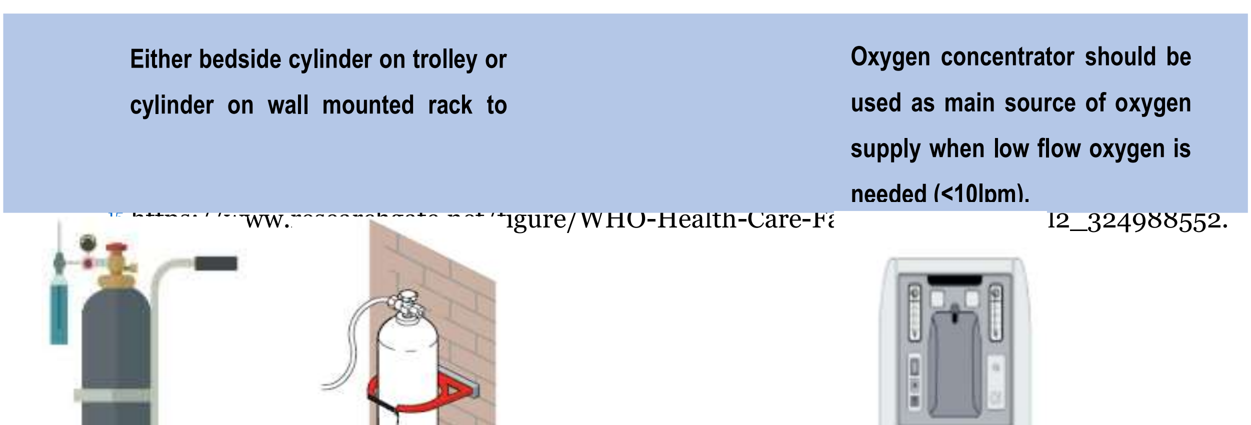
The oxygen systems necessary to deliver oxygen therapy for each of these levels, are outlined below.

5.1 Primary Health Facilities

Eswatini's primary health facilities (community healthcare services, clinics, and public health units), should have pulse oximetry and supplemental oxygen to support the following clinical functions where available:

1. Triage and Emergency
2. Maternity, labour, and delivery ward
3. General ward
4. Isolation ward

The primary source of oxygen would be oxygen concentrators. Two cylinders (size J) and two regulators should be available to cater for power interruptions or machine failure. This guidance for primary level health facilities' oxygen supply system is summarised in Figure



15 https://www.researchgate.net/figure/WHO-Health-Care-Fa... 12_324988552.

Figure 9: Oxygen supply system for primary health facilities

5.2 Secondary Health Facilities

Secondary health facilities (Health centres) should have pulse oximetry (for diagnosis) and oxygen from a cylinder bank to selected critical areas (for treatment) to support the following clinical functions, if applicable:

1 Triage and emergency
2 Maternity, labour, and delivery ward
3 Neonatal care
4 Pediatric ward
5 Adult ward
6 Operating theatre and recovery room
7 Critical care areas, typically high-dependency units (HDUs)
8 Infectious disease treatment center

The primary source of oxygen would be a cylinder bank. A single bank of cylinders will be kept on hand for emergencies A bank would typically consist of 6 cylinders will depend on the individual hospital requirement. A minimum of two oxygen concentrators should be available as a backup.

The guidance on oxygen supply system for secondary-level health facilities is summarised in Figure 4.

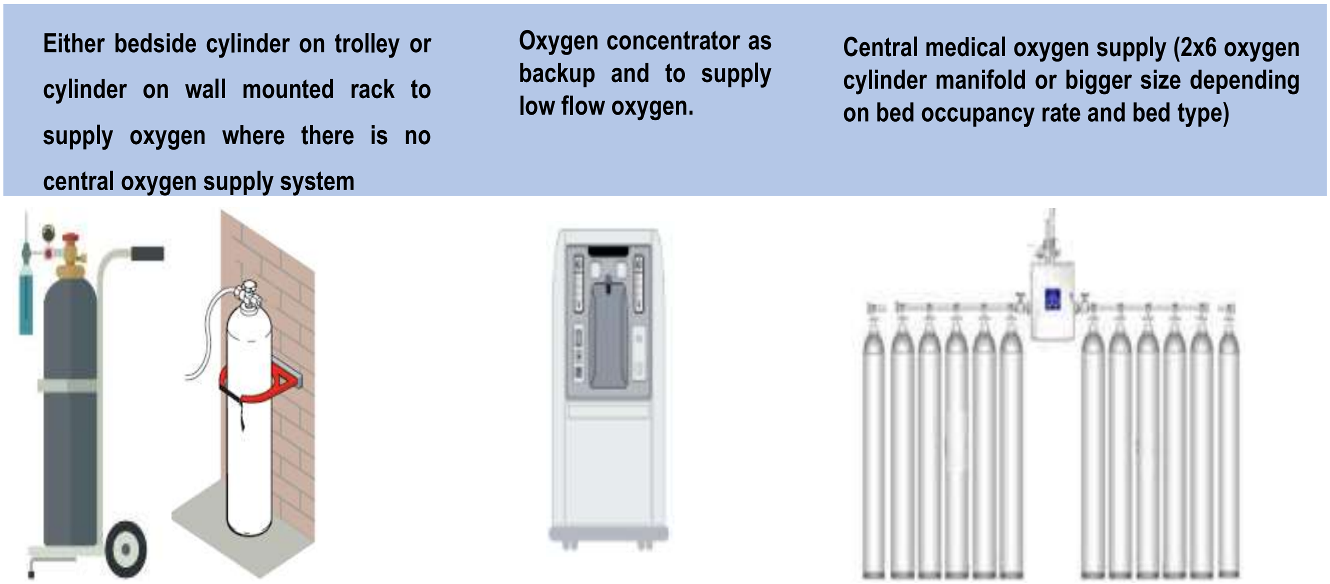


Figure 10: Oxygen supply system for secondary health facilities

5.3 Tertiary Health Facilities

The highest level of care in Eswatini's health care system includes regional hospitals, referral hospitals and specialised hospital. Wards found in this level of the country's health system includes:

1. All primary- and secondary-level care wards
2. Critical care wards (intensive care and high dependency units for adults, pediatrics and neonates)
3. Specialized wards and theatres

Due to the high demand for oxygen at this level, they must have a central oxygen supply system which is directly connected to an oxygen generating plant that can fill oxygen cylinders on a regional scale or have bulk LOX units. They also require large oxygen cylinder manifolds as backup. Additionally, mobile gas generating system can also be made available at this level of care, for use in the event of an oxygen shortage; due to plant breakdown or surge in demand. Bed side terminal units supplied with oxygen through central oxygen supply system should be made available in operating theatres and wards at these facilities, especially intensive care units and high dependency units. Portable oxygen cylinders and oxygen concentrators can be used to supplement additional oxygen demands. Portable cylinders can also be used for patients transport between hospital departments or different wards. A summary of this level's oxygen supply system is provided below.

Portable cylinder for emergency, anaesthesia, and ambulatory use	Oxygen concentrator	Oxygen cylinder manifold system as backup (size dependent on bed occupancy rate and bed type)	Either PSA oxygen production plant (size dependent on oxygen demand) or Bulk liquid oxygen tank. They should have cylinder filling capacity for regional supply.

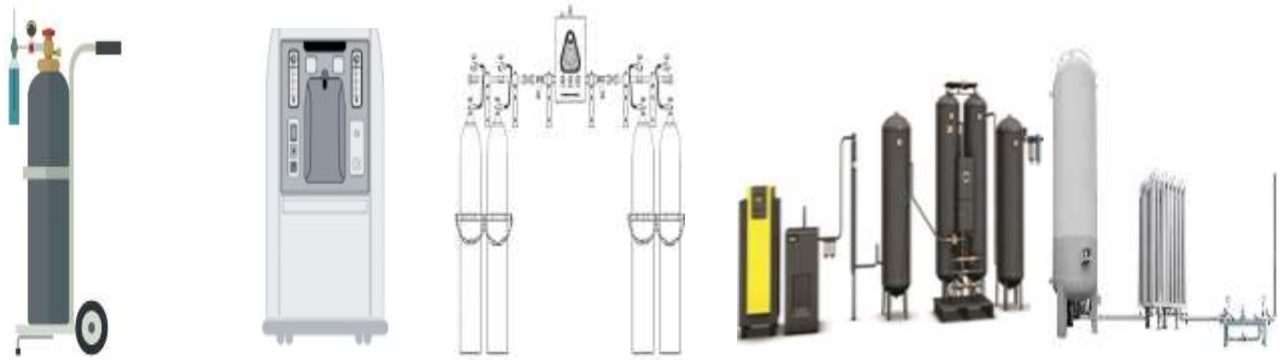


Figure 11: Oxygen Supply System for Tertiary Health Facilities

5.4 Ambulances

Patients are often transferred in an ambulance. Patients may be hypoxemic or develop Hypoxemia during transfer, hence continuous monitoring and the availability of supplemental oxygen are required.

Small and medium sized cylinders (Sizes 'E' and 'F'), as well as oxygen concentrators (mostly as backup), are typically used in ambulances due to space and portability

Small- or medium- sized cylinder	Oxygen concentrator (mostly used as backup)

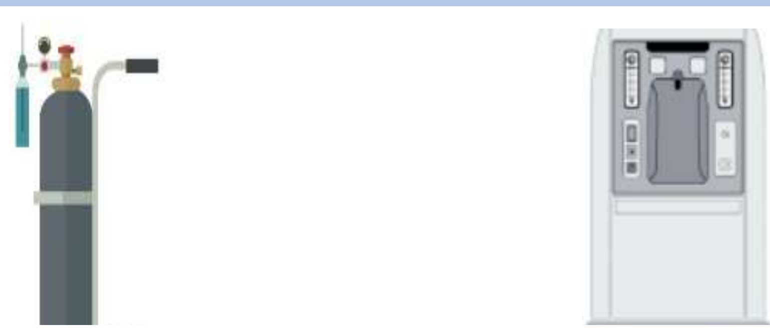


Figure 12: Oxygen supply system for ambulances

constraints. Most of the times diagnosis of Hypoxemia and oxygen therapy monitoring in an ambulance is done with handheld or fingertip pulse oximeters. Ambulances may also utilize multiparameter patient monitors with backup batteries for patient monitoring. Figure 12 provides a summary of the oxygen supply system for ambulances.

6 NATIONAL MEDICAL OXYGEN SUPPLY MODEL

The current oxygen storage and generation sources (refer to Figure 13) has the capability to be expanded in the following way:

1. Direct piping to patient bedside from onsite PSA oxygen generation units or bulk LOX tanks.
2. A hub-and-spoke delivery system for oxygen cylinders filled at a PSA medical oxygen producing plant and delivered to facilities within a catchment region.
3. Filling oxygen cylinders with converted gaseous oxygen from bulk LOX tanks for distribution.

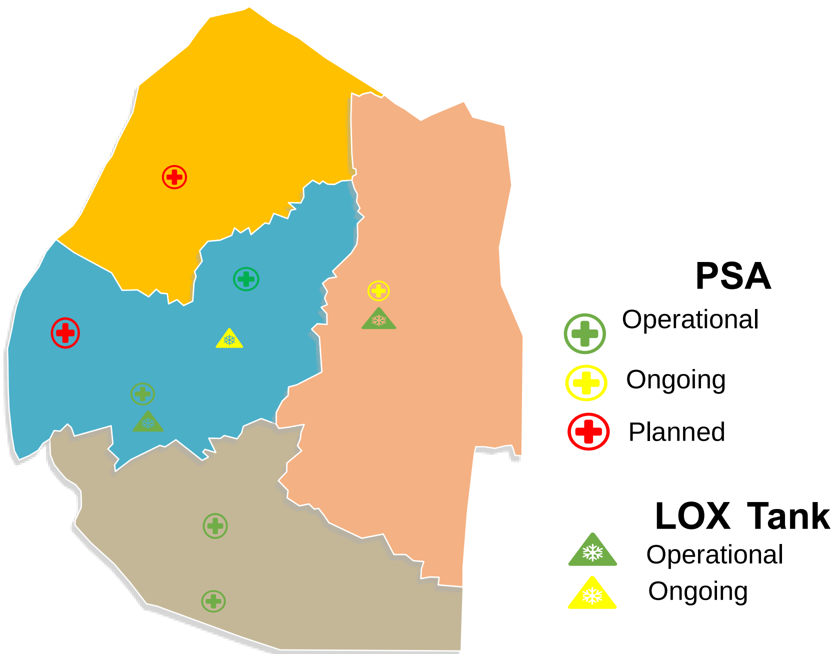


Figure 13: Functionality status of oxygen storage and supply sources in Eswatini

The national oxygen supply model will leverage the above three options and incorporate a central monitoring and reporting system to ensure:

1. Supply reliability
2. Quality of delivered oxygen
3. Effective use of current oxygen installations in the country
4. Cost effectiveness
5. Sustainability

This is made possible by the ability to meet the country's oxygen demand during no-surge periods using the PSA and LOX options available in-country. Any increase in the demand of oxygen, such as during surge periods, can be met by increasing LOX refill frequency.[16] LOX ordering and PSA production will be maintained at optimal rates to ensure supply chain efficiency and cost-effectiveness, including distribution of products and maintenance of minimum order volumes to attain favorable pricing from suppliers.

Ordering and monitoring of cylinder movement or oxygen would be done through the central monitoring and reporting center that would be established.

6.1 Regional Hub

The country's oxygen system would be managed centrally, with regional hubs utilising a hub-and-spoke routing structure (See Figure 14). Regional distributed oxygen bulk storage and production sources would enable greater access to oxygen.

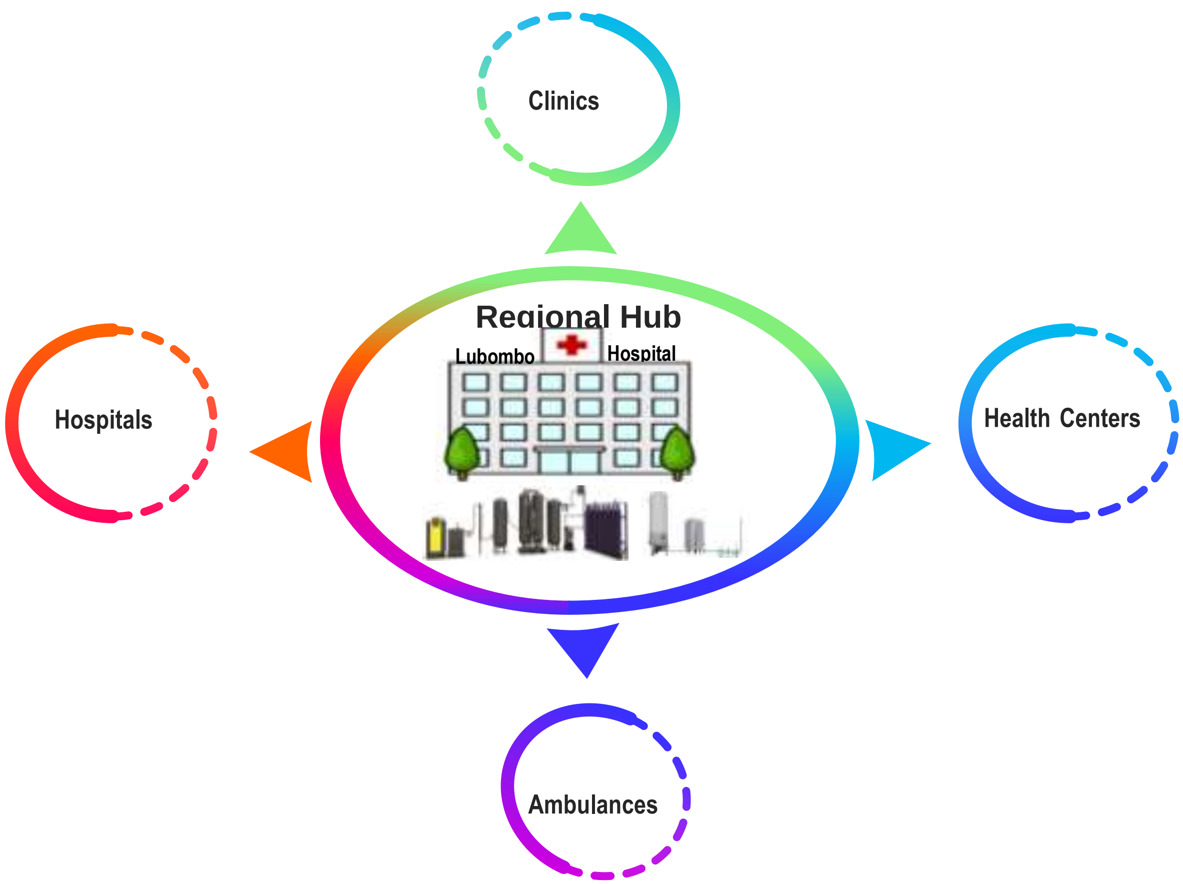


Figure 14: Regional Oxygen Distribution Model

[16] Ministry of Health Eswatini. National medical oxygen situational analysis report. 2022.

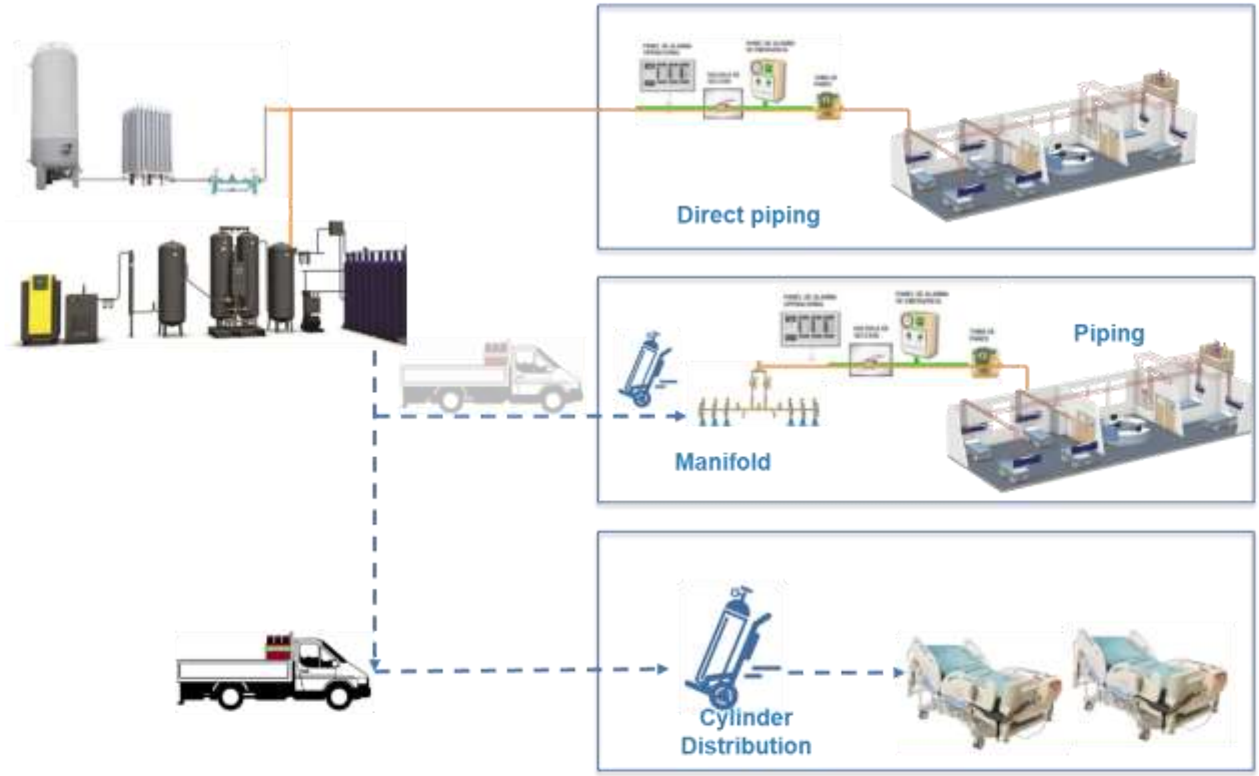


Figure 15: Regional Hub Oxygen Supply Components

Regional hubs would have a PSA plant and a LOX tank. Both PSA plants and LOX tanks would directly supply their host facility through direct piping. It would also be connected to oxygen cylinder filling plant for filling of cylinders to be distributed to other facilities in the area. Refer to Figure 15.

The regional oxygen distribution is presented in Table 4.

Table 5: Regional Hubs and cost per cylinder for facility served

Region / Area of Support	Hub Name	Service	Supporting facilities
Lubombo	Lubombo Referral Hospital (LRH)	Supply oxygen to the host facility, LRH, through direct piping Support facilities in the Lubombo Region through filled oxygen cylinder distribution	Lubombo Referral Hospital
			Good Shepherd Hospital
			Ubombo Clinic
			Royal Sugar Eswatini Clinic
			Sithobelweni Health Centre

Region / Area of Support	Hub Name	Service	Supporting facilities
Manzini	The Luke Commission Hospital (TLC) & Raleigh Fitkin Memorial (RFM) Hospital	Oxygen supply to host facility, TLC, through direct piping Support facilities in the Manzini Region through filled oxygen cylinder distribution	The Luke Commission Hospital Manzini NCD Referral Hospital Mkhiwa Clinic Philani Clinic Mankayane Government Hospital Raleigh Fitkin Memorial Hospital* Women and Children's Hospital
Shiselweni	Hlathikhulu Government Hospital (HGH)	Oxygen supply to the host facility, HGH, through direct piping Support some facilities in the Shiselweni Region through filled oxygen cylinder distribution	Hlathikhulu Government Hospital Nhlangano Health Centre* Matsanjeni Health Centre
Hhohho	Central Medical Stores (CMS)	Support facilities in the Hhohho Region through filled medical oxygen cylinder distribution	Manzana Clinic Medsun Clinic Mbabane Government Hospital* Pigg's Peak Government Hospital Emkhuzweni Health Centre Dvokolwako Health Centre
Ambulance Services	Eswatini Dairy Board (EDB)	Filling of cylinders for distribution to the ambulance services	MOH's Emergency Preparedness and Response Unit

**Facilities with oxygen generation or bulk storage tanks*

CMS will oversee and manage a central ordering, monitoring and reporting system. The personnel at the various regional hubs will ensure that cylinders are transported to facilities within their region. Ordering for oxygen cylinders will be the responsibility of health facilities.

6.2 Inter-Regional Supply

Should a regional hub be unable to meet its own facility and the region's demand, cylinders can be made available from another regional hubs via the CMS. The inter-regional distribution of cylinders is shown in Figure 16 below.

Figure 16: Inter-Regional Distribution of Cylinders

6.3 Intra-Facility Supply

Facilities that have PSA plants or LOX tanks would receive oxygen via direct piping (See Figure 17). Such facilities would only receive supply from their regional hub if their oxygen generation plant or LOX tank is not able to provide them with oxygen.

They may also receive supplemental oxygen through cylinders during periods of surge.

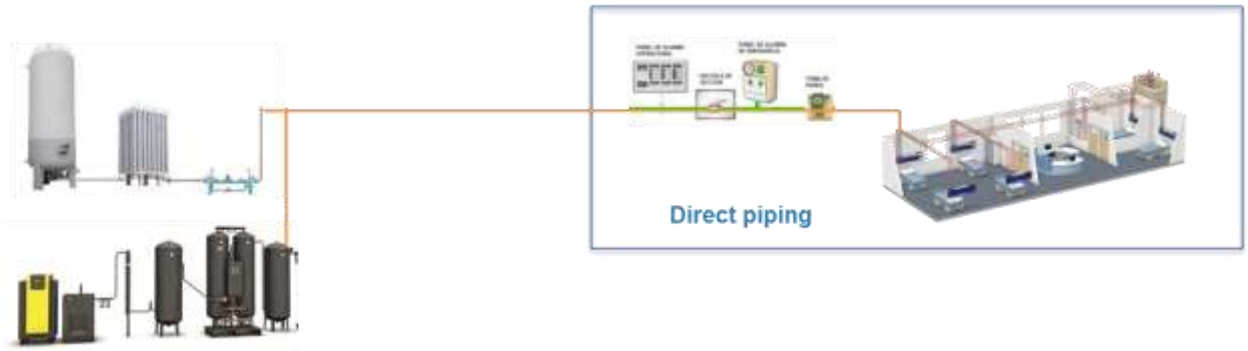


Figure 17: Direct piping from PSA plant or LOX tank to host facility

7 ENMOOP IMPLEMENTATION STRATEGY

This ENMOOP expands on existing infrastructure by providing a framework for addressing challenges in the oxygen ecosystem. It also supports investment optimization and will guide future investments from government, partners, and private-sector actors.

The document guides scaling up oxygen access at all levels of the country's healthcare system. The anticipated implementation of this ENMOOP spans from 2023 to 2025.

7.1 Objectives of the ENMOOP

This operational plan aims to improve access to Medical Oxygen for all people in Eswatini and ensure effective use to save lives by the year 2025, in accordance with four key strategic objectives in the following areas:

1. Create enabling environment for scaling up sustainable oxygen supply system.
2. Implement optimal oxygen production and distribution model.
3. Improve oxygen supply chain and monitoring systems.
4. Improve the capacity for delivering oxygen therapy.

7.2 Implementation Strategy

ENMOOP 2023-2025 includes a full implementation plan, which can be found below. The implementation plan describes the timeframe, activities, people in charge, indicators, and outputs for easy evaluation of their implementation.

Table 6: Strategic framework for implementation

Item	Strategic Objectives & Key Activities	Indicator	Output	Lead Person/Group	Timeline											
					2023				2024				2025			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1.0	**Create an enabling environment for scaling up sustainable oxygen supply systems**															
1.1	**Coordination**															
1.1.1	Disseminate the operational plan to key stakeholders to guide implementation of oxygen related activities in Eswatini	Number of national and regional dissemination meetings	5 dissemination meetings (one national and four regionals)	TWG Chair, Case Management Focal, Head of Biomed	X											
1.1.2	Conduct annual reviews to monitor implementation of the operational plan	Number of annual reviews conducted	3 annual review report	TWG Chair, Case Management Focal, Head of Biomed			X				X				X	
1.1.3	Develop annual workplans to be informed by annual reviews	Annual workplans	3 annual workplans	TWG Chair, Case Management Focal, Head of Biomed				X				X				X
1.1.4	Coordinate quarterly national oxygen technical working group	Quarterly TWG meetings	12 TWG meetings	TWG Chair, Case Management Focal, Head of Biomed	X	X	X	X	X	X	X	X	X	X	X	X
1.1.5	Ensure completion of partner supported projects within set timelines	Number of projects completed within set timelines	Projects completed	TWG Chair, Case Management Focal, National Biomed	X	X	X	X	X	X	X	X	X	X	X	X
1.2	**Policies and Guidelines**															

Item	Strategic Objectives & Key Activities	Indicator	Output	Lead Person/Group	Timeline											
					2023				2024				2025			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1.2.1	Develop/Review policies, standards, and guidelines for medical oxygen (standard operating procedures (SoPs), job aides, and guidelines).	Developed / Reviewed policies, standards, and guidelines available	List of policies, standards and guidelines developed	TWG Chair, Case Management Focal, Hed of Biomed	x	x										
1.2.2	Disseminate policies, standards, job aides, OHPS, CPD and guidelines	Number of national and regional dissemination meetings	5 dissemination meetings (national and 4 regional)	TWG Chair, Case Management Focal, Hed of Biomed			x	x								
1.2.3	Monitor implementation policies, standards, and guidelines	Number of supportive supervisions conducted - quarterly	12 supportive supervisions	TWG Chair, Case Management Focal, Hed of Biomed	x	x	x	x	x	x	x	x	x	x	x	x
1.2.4	Develop an MOU between MOH and Private facilities on oxygen supply. 1 meeting for TWG sub-committee	Signed MOUs	7 MOUs	TWG Chair, Case Management Focal, Hed of Biomed	x	x	x									
1.3	**Leveraging of available resources**															
1.3.1	Mobilize resources for all activities that are in the operational plan	Annual funding gap	3 annual funding gap reports	TWG Chair, Case Management Focal, Head of Biomed			x				x				x	
1.3.2	Coordinate partner support for oxygen interventions	Matrix to visualize partner support coverage developed	3 annual updated matrices	TWG Chair, Case Management Focal, Head of Biomed				x				x				x
1.3.3	Identify technical and funding opportunities (develop and submit proposals)	Number of proposals submitted	Proposals submitted	TWG Chair, Case Management Focal, National Biomed	x	x	x	x	x	x	x	x	x	x	x	x
1.3.4		Number of proposals funded	Proposals funded	TWG Chair, Case Management Focal, Head of Biomed	x	x	x	x	x	x	x	x	x	x	x	x

Item	Strategic Objectives & Key Activities	Indicator	Output	Lead Person/Group	Timeline											
					2023				2024				2025			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1.4	**Sustainability of funding**															
1.4.1	Develop a sustainable funding source for the national medical oxygen infrastructure and related equipment	Documented proof of available funding	Oxygen infrastructure and related equipment funded	TWG Chair and Case Management Focal	X	X			X	X			X	X		
1.4.2	Create funding mechanism to act as reserve of funds in a trust that can be used as collateral with vendors in the event of sudden, unexpected demand.	Documented proof of trust fund with money	Funding mechanism created	TWG Chair and Case Management Focal			X				X				X	
1.5	**Infrastructure**															
1.5.1	Setting up cylinder painting booth	Available and operationalization of national cylinder painting booth	Compliance of cylinders to international standards	TWG Chair and Case Management Focal	X	X	X	X	X	X						
1.5.2	Setting up cylinder pressure testing and certification capacity in country	Setup and operationalization of national cylinder pressure testing and certification center	Compliance of cylinders to international standards	TWG Chair and Case Management Focal	X	X	X	X	X	X						
1.5.3	Making available reliable and efficient alternative sources of electrical supply, solar energy, to PSA buildings to reduce running cost, ensure smooth and efficient operation of PSA plants	Alternative electrical source; solar energy, in place and powering PSA plant	Low cost, effective and efficient operation of PSA units	TWG Chair and Case Management Focal	X	X	X	X	X	X						
2.0	**Implement optimal oxygen production and distribution models**															

Item	Strategic Objectives & Key Activities	Indicator	Output	Lead Person/Group	Timeline											
					2023				2024				2025			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
2.1	**Ensuring availability of oxygen**															
2.1.1	Setup regional production depots with enough capacity to meet regional oxygen needs	Number of regional depots setup	4 regional oxygen distribution depots	TWG Chair, Case Management Focal, Head of Biomed	X	X			X	X			X	X		
2.1.2	Ensure enough locally owned cylinders to meet oxygen distribution needs	Quantity of cylinders owned	Cylinder distribution able to meet country needs	TWG Chair, Case Management Focal, National Biomed		X				X				X		
2.1.3	Setup locally owned (with no monthly rental charges) liquid oxygen (LOX) tanks at depots with no LOX tanks. These backup tanks can be quickly filled to meet demand in surge	Regional depots equipped with LOX tank	4 regional depots equipped with a LOX tank	TWG Chair, Case Management Focal, National Biomed		X				X				X		
2.2	**Optimize intraregional and interregional distribution chains**															
2.2.1	Equip each regional depot with trucks and other necessary equipment required to facilitate and guarantee continuous oxygen delivery to health facilities in the region that uses oxygen	Number of regional depots equipped with: i. Cylinder distribution truck ii. Cylinders for distribution iii. Cylinder palettes iv. Cylinder trolleys v. Forklift vi. Oxygen analyzers	Effective and efficient operation of regional depots	TWG Chair, Case Management Focal, National Biomed	X				X				X			
2.3	**Maintenance and supply of spare parts**															
2.3.1	Develop and maintain local biomedical engineering	Number of local biomed capacitated	48 Local biomed capacitated	National Biomed	X				X				X			

Item	Strategic Objectives & Key Activities	Indicator	Output	Lead Person/Group	Timeline											
					2023				2024				2025			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
	capacity for maintaining oxygen sources and related equipment															
2.3.2	Setting up an asset management system to help improve equipment management; data base, maintenance scheduling and recording, logistics and supply chain	Improved supply chain and equipment maintenance	Asset management system in place	TWG Chair, Case Management Focal, National Biomed		x										
2.3.3	Retooling and/or setting up workshops in the four regions and national biomed office. This would help the Biomed unit be able to meet service demands.	Number of regions with workshops retooled or set up	Extended equipment longevity	National Biomed	x											
2.3.4	Equipping biomed with the requisite tools, test equipment and simulators to aid biomed perform maintenance activities	Number and type of tools, test equipment and simulators provided	Improved maintenance and servicing outcomes	TWG Chair, Case Management Focal, National Biomed		x										
3.0	**Improve oxygen supply chain and monitoring systems**															
3.1	**Ensure consistent and adequate supply and distribution of oxygen, oxygen-related equipment, and oxygen accessories to point of use**															
3.1.1	Plan and implement the acquisition and distribution of oxygen-related equipment.	Oxygen related equipment available at all levels of care	Oxygen equipment inventory	TWG Chair, Case Management Focal, National Biomed	x				x				x			

Item	Strategic Objectives & Key Activities	Indicator	Output	Lead Person/Group	Timeline											
					2023				2024				2025			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
3.1.2	Plan and execute the acquisition and distribution of vital oxygen accessories.	i. Vital oxygen accessories available at all levels of care i. Development of inventory management system to monitor and maintain stock	Vital oxygen accessories inventory	TWG Chair, Case Management Focal, National Biomed	X				X				X			
3.1.3	Procure and install oxygen piping system and/or cylinder manifold to improve the efficiency of oxygen delivery from the source to the patient's bedside.	Report on health facility infrastructure	Improved oxygen delivery at bedside	TWG Chair, Case Management Focal, National Biomed	X				X				X			
3.1.4	Establish national network for distribution of cylinders from plants to health facilities	Oxygen cylinder distribution system from production sites to health facilities	Oxygen availability at all levels of the healthcare system	TWG Chair, Case Management Focal, National Biomed		X				X				X		
3.1.5	Review/development of standard equipment list; to guide future procurement of respiratory care equipment and supplies	Document of policy disseminated at all levels of the healthcare system	Information guided procurement	TWG Chair, Case Management Focal, National Biomed	X					X			X			
3.2	**Enhancing monitoring and evaluation of oxygen systems**															
3.2.1	Setting up a central monitoring and reporting center to ensure real-time central monitoring and reporting of all oxygen distribution needs to allow for timely intervention in the event of a demand surge or interruption	Central monitoring and reporting center	Real time monitoring and reporting of all oxygen distribution needs	TWG Chair, Case Management Focal, National Biomed	X											

Item	Strategic Objectives & Key Activities	Indicator	Output	Lead Person/Group	Timeline											
					2023				2024				2025			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
3.2.2	Establishment of indicators for oxygen use and system status in the health management information systems (HMIS).	Oxygen indicators integrated into HMIS	Accurate monitoring of Hypoxemia cases	Case Management Focal	X											
3.2.3	Develop measures to track oxygen use and other metrics associated with respiratory care.	Continuous collection of data on oxygen and respiratory care	Improved monitoring and reporting on oxygen consumption	TWG, and Case Management Focal	X	X	X	X	X	X	X	X	X	X	X	X
3.2.4	Review/development of supervision protocols for healthcare managers.	Developed supervision protocol	Improved supervision protocols	Case Management Focal				X				X				X
3.2.5	Assess the effect of improved oxygen systems on key indicators.	Evaluation workshops and production of reports	Real time monitoring and reporting of all oxygen distribution needs	TWG Chair, Case Management Focal, National Biomed				X				X				X
4.0	**Improve capacity for the delivery of oxygen therapy**															
4.1	**Training of clinicians, biomed, pharmacists and other healthcare workers**															
4.1.1	Training needs assessment to identify knowledge/skills gaps on relevant staff	Training gaps identified	Training needs assessment report	TWG Chair, Case Management Focal, Head of Biomed	X				X				X			
4.1.2	Develop/review curriculum on oxygen and training healthcare professionals	i. Developed national oxygen training curriculum i. Number of healthcare professionals trained	Trained healthcare professionals	TWG Chair, and Case Management Focal		X				X			X			

Item	Strategic Objectives & Key Activities	Indicator	Output	Lead Person/Group	Timeline											
					2023				2024				2025			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
4.1.3	Developing/reviewing a system that allows for continuous professional development (CPD) in oxygen systems	Establishment of a CPD system accessible to all health care professionals	Enhanced skills and reduction in knowledge shortfalls	TWG Chair, Case Management Focal, National Biomed		X				X				X		
4.1.4	Develop/review plans for the health and safety of workers using oxygen in the workplace	Developed plan	Improved safety at workplace	TWG Chair, Case Management Focal, National Biomed	X				X				X			
4.2	**Advocate for HR recruitment**															
4.2.1	Quantification of staffing needs for various health facilities, Doctors, nurses, maintenance unit, pharmacists, and other healthcare personnel.	i. Number of staff employed ii. Number of staffing gaps to be bridged	Availability of knowledge and resource materials	TWG Chair, Case Management Focal, Head of Biomed	X	X			X	X			X	X		
4.2.2	Recruitment of adequate staff personnel according to the health facility needs	i. Number of people employed ii. Remaining staffing gaps	Improved staff to patient ratio	SMT	X				X				X			

7.3 Roles and Responsibilities

The ability to successfully address challenges in the oxygen ecosystem within the next three years is largely contingent upon the effective implementation of the ENMOOP strategies. This requires that stakeholders execute their roles and responsibilities proficiently.

The MOH is responsible for overseeing the plan's rollout on a national scale. The roles and responsibilities of different players in carrying out the plan's implementation will need to be clarified. This makes dissemination workshops for the operational plan essential. Finally, activity leaders must establish connections between their implementation activities and monitoring and evaluation (M&E) indicators.

7.3.1 Ministry of Health

The MOH is primarily responsible for the development of policy and guidelines. The development of the components will be assisted by various MOH departments. The MOH will also oversee providing supervision. This includes keeping records, conducting random checks to ensure progress, evaluating the plan, and enforcing compliance with guidelines. The MOH will also coordinate and host review meetings to monitor implementation progress of the operational plan.

7.3.2. Oxygen Taskforce

This team will oversee:

1. Developing and revising guidelines.
2. Organizing technical working group (TWG) meetings
3. Coordinating partner roles and responsibilities
4. Reviewing operational plan implementation progress.
5. Identifying and sharing the most recent technical research in the field of critical and respiratory care.
6. Policy implementation monitoring.
7. Providing progress report to the case management team.

The same groups should be established at the regional and facility levels to assume responsibility for the implementation processes. Such regional and facility-based ownership of the operational plan will be critical for supply planning, financing, and data management.

7.3.3. Implementing Partners

The provision of adequate technical support is essential to the successful execution of the ENMOOP. Implementing partners (IPs) are responsible for providing this support to the MOH. In close collaboration with the MOH, IPs will provide:

1. Resources for policy development and operational plan activity implementation.
2. Facility-level mentorship.
3. Implementation-related training.
4. Curriculum development.
5. Equipment supply, procurement, and maintenance.
6. Data collection and analysis.

They are required to mobilise additional resources to support nationwide implementation of efficient and effective oxygen delivery systems.

7.3.4. Private Health Facilities

These facilities play a critical role in the healthcare system and responsible for:

1. Supporting the Continuing Professional Development (CPD) of their staff.
2. Trainings on oxygen therapy.
3. Support the dissemination of clinical guidelines for the detection and treatment of Hypoxemia.
4. Ensure standards are followed.
5. Ensure referral of patients to the appropriate level of health system for escalation or de-escalation of care.
6. Build linkages with public facilities as well as key MOH structures.
7. Encourage the development of a robust and fully functional culture of oxygen device maintenance, including the utilization of maintenance records.
8. Increase effectiveness of monitoring and evaluation by strengthening reporting to the applicable state Health Management Information System (HMIS) platforms that collect data on Hypoxemia and oxygen use.

7.3.5. Private Sector

To implement the ENMOOP, oxygen equipment suppliers need to collaborate with the MOH to create mechanisms, such as maintenance contracts and training for technicians and biomedical engineers, to keep medical devices and facilities running smoothly. They must also give long-term funding mechanisms and resource to keep medical oxygen devices operational and stocked with replacement parts.

8 MONITORING AND EVALUATION (M & E)

Improving the oxygen system relies on reliable monitoring and evaluation (M&E).

Clinical supervision and mentoring should be combined at facility level. The process should include evaluation of compliance with protocols and work aids.

Implementing oxygen production and distribution equipment monitoring (including pulse oximeters, oxygen accessories, oxygen concentrators, and PSA plants) is crucial at all levels. Parallel to this, biomedical engineering oversight should be put in place, which includes equipment maintenance, inspections, and stock monitoring. Such information should be consolidated and reviewed at the highest levels of the MoH. This is crucial for understanding the health system's successes and failures, tracking where improvements are needed, determining if oxygen provision is sufficient and directing policy to strengthen oxygen systems in places where standards are not fulfilled.

8.1 Review and Planning

The Oxygen TWG will oversee an annual planning exercise at the national level to assess how well the operational plan is being implemented, how far along the country is in reaching the set milestones, and to determine resource allocations to initiatives accordingly. The national coordinating mechanism will use the key performance indicators specified in the performance indicator framework to evaluate the effect of mobilized resources on the oxygen ecosystem as part of its planning process. To evaluate how well the country is doing in terms of milestones for enhancing the oxygen ecosystem, they will be analyzing data collected from sub-working groups and health facilities across the country.

8.2 Core Indicators

As additional information becomes available on the oxygen production, supply, distribution, and usage landscape across facilities in Eswatini, the TWG will review the indicator baselines, targets, and priority rankings, as shown in the figure below.

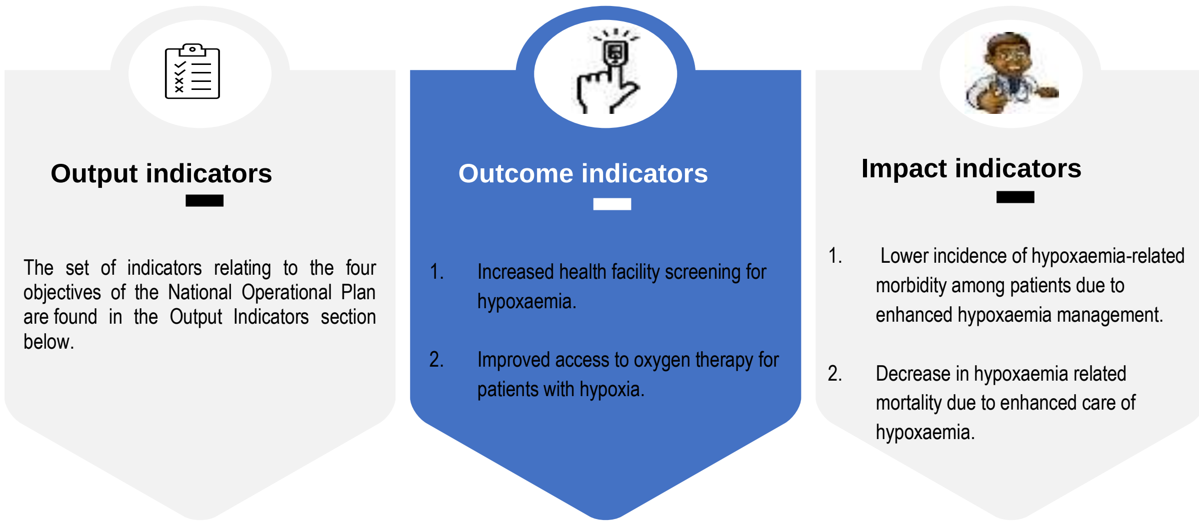


Figure 18: Suggested core National Oxygen Operational Plan indicators

8.3 Output indicators

Figure 19: Output indicators

9 BUDGET ESTIMATE

Implementing the interventions described in the framework above will necessitate significant investment over the next three years, with an estimated cost of US$ 15,648,353.00 (SZL 278,540,691.00). These estimated costs for the three-year implementation period are shown in Table 4.

Table 7: Estimated budget

		SZL				USD			
		Grand Total	2023	2024	2025	Grand Total	2023	2024	2025
		278,540,691	**197,235,794**	**41,734,201**	**39,570,697**	**15,648,353**	**11,080,663**	**2,344,618**	**2,223,073**
Objective 1	Create an enabling environment for scaling up sustainable oxygen supply systems	91,188,968	82,369,149	8,248,829	570,989	5,122,976	4,627,480	463,417	32,078
Objective 2	Implement optimal oxygen production and distribution models	108,108,551	53,468,738	24,562,738	30,077,074	6,073,514	3,003,862	1,379,929	1,689,732
Objective 3	Improve oxygen supply chain and monitoring systems	72,094,675	59,015,074	6,539,800	6,539,800	4,050,263	3,315,454	367,405	367,405
Objective 4	Improve capacity for the delivery of oxygen therapy	7,148,498	2,382,833	2,382,833	2,382,833	401,601	133,867	133,867	133,867

10. CONCLUSION

Eswatini's oxygen ecosystem has been under increased stress for the past year due to the spread of COVID-19. It is therefore important for the country to maintain and increase investments in the oxygen ecosystem in the coming years, even though the international community has provided support and domestic stakeholders have worked tirelessly to prioritize improving the country's oxygen ecosystem. The medical devices used in the various health facilities across the country for diagnosing, treating, preventing, curing, or mitigating health conditions will become nonfunctional if not serviced periodically. If clinical and biomedical staff numbers are not increased and supported with training, the procured medical devices would be underutilized and used wrongly. Newly installed PSA plants may also be underutilized when staff are not trained and equipped with the requisite tools of work. Finally, while COVID-19 has undoubtedly raised awareness of the importance of oxygen around the world, the availability of grants and other forms of financing for oxygen research may be decreasing as focus shifts.

MOH should appoint champions of this ENMOOP 2023-2025 document, including the TWG on oxygen, to ensure it is read widely and discussed by a variety of stakeholders with financing and policymaking capabilities, to bring it to life. As part of a cost-effective strategy for the oxygen ecosystem, Eswatini should continue to invest in opportunities related to infrastructure, capacity building, and cost-effective supply chain and logistical solutions for the oxygen ecosystem. At both the national, regional and facility levels, there needs to be the appointment of leaders who can direct teams to finish the implementation activities mentioned in Chapter 7 implementation strategies, evaluate progress, and assist in handling obstacles. The baselines and targets for the indicators outlined in Chapter 8 need to be established through the organization of workshops; if these are not done, the implementers will not have any reference points by which to measure their progress or assess the impact of their work. Finally, to facilitate project management, it is necessary to develop responsibilities and mechanisms for supervision and monitoring.

APPENDICES

Appendix I: Eswatini National Medical Oxygen Operation Plan Contributors

Table 8: Major Contributors to the Development of the Document

Name	Position	Organisation
Mr. Themba Motsa	Dept. Director CMS	MOH
Dr. Debrah Vambe	PMDT - Technical Advisor	MOH
Mr. Vusumuzi Dlamini	Biomedical Engineer	MOH
Miss Nomcebo Magagula	Biomed Technician	MOH
Dr. Lukhele Nomthandazo	NCD/TB/HIV National Program Officer	WHO
Sifiso David Sabelo Dlamini	Cold Chain Specialist	UNICEF
Elvis Oheneba Manu	Biomedical Engineer – Consultant	UNICEF
Hyacinthe Mushumbamwiza	Reg. Medical O_2 Ecosystems Technical supp.	UNICEF
Khumbulani Moyo	Manager	Right to Care
Peter Schilder	Consultant Professional Mechanical Engineer	Right to Care
Cliffs Wagbafor	Biomedical Engineer	Right to Care
Qhubekani Mpala	Oxygen Program Manager	CHAI
Mpumelelo Ndlela	Oxygen Program Officer	CHAI
Philisiwe Dlamini	Cap. Development	FHI 360
Normusa Musarapasi	Associate Technical Director	Georgetown University
Sam Riggleman	Engineer	TLC
Mpumelelo Ncube	Engineer	TLC

Appendix II: Oxygen Consumption for COVID Scenario

Table 9: Oxygen consumption for COVID scenario

Facility Name	Est. number of hypoxemia cases per year	Est. number of hypoxemia cases per month	Est. daily oxygen demand (in Litres per day)	Est. monthly oxygen demand (in Litres per month)
Dvokolwako Health Centre	879	74	111,689	3,350,678
Emkhuzweni Health Centre	166	14	33,874	1,016,207
Good Shepherd Hospital	3,574	298	1,162,567	34,876,998
Hlathikhulu Government Hospital	2,428	203	222,174	6,665,218
Lubombo Referral Hosp.	13,979	1165	6,463,051	193,891,537
Mankayane Government Hospital	2,871	240	447,760	13,432,814
Manzana Clinic	60	5	8,318	249,540
Manzini clinic	832	70	328,189	9,845,665

Matsanjeni Health Centre	645	54	63,394	1,901,807
Mbabane Clinic	726	61	80,947	2,428,398
Mbabane Government Hosp.	5,535	462	925,595	27,767,851
Nhlangano Healthcare Centre	1,751	146	323,275	9,698,238
Pigg's Peak Government Hospital	3,292	275	526,161	15,784,822
Psychiatric hospital	468	39	5,112	153,346
Raleigh Fitkin Memorial	4,328	361	1,101,768	33,053,045
Royal Eswatini Sugar Medical Services	94	8	25,283	758,486
Sithobelweni Health Centre	734	62	76,062	2,281,863
The Luke Commission Hosp.	6,733	562	2,306,752	69,202,569
Ubombo Clinic	463	39	5,277	158,317
Medisun Clinic	254	22	4,505	135,144

Mkhiwa Clinic	244	21	15,250	457,506
Philani Clinic	298	25	115,374	3,461,213
USDF Phocweni Clinic	1,655	138	1,477	44,310
Emergency Preparedness and Response (EPR)	732	61	2,630	78,914

Appendix III: Oxygen Consumption for Non-COVID Scenario

Table 10: Oxygen consumption for non-COVID scenario

Facility Name	Est. number of hypoxemia cases per year	Est. number of hypoxemia cases per month	Est. daily oxygen demand (in L/d)	Estimated monthly oxygen demand (in L/d)
Dvokolwako Health Centre	519	44	7,062	211,873
Emkhuzweni Health Centre	59	5	2,805	84,152
GSH	1,453	122	41,931	1,257,929
Hlathikhulu Government Hospital	1,854	155	55,844	1,675,322
LRH	1,759	147	46,964	1,408,907
Mankayane Government Hospital	1,495	125	48,663	1,459,904
Manzana Clinic	37	4	1,532	45,967
Manzini clinic	642	54	128,206	3,846,191
Matsanjeni Health Centre	461	39	9,975	299,264

Facility Name	Est. number of hypoxemia cases per year	Est. number of hypoxemia cases per month	Est. daily oxygen demand (in L/d)	Estimated monthly oxygen demand (in L/d)
Mbabane Clinic	497	42	14,450	433,505
MGH	4,021	336	293,336	8,800,092
Nhlangano Healthcare Centre	698	59	17,935	538,062
Pigg's Peak Government Hospital	1,687	141	60,567	1,817,019
Psychiatric hospital	468	39	5,112	153,346
RFM	3,275	273	409,799	12,293,966
Royal Eswatini Sugar Medical Services	10	1	783	23,494
Sithobelweni Health Centre	506	43	10,059	301,764
TLC	3,180	265	309,709	9,291,270

Facility Name	Est. number of hypoxemia cases per year	Est. number of hypoxemia cases per month	Est. daily oxygen demand (in L/d)	Estimated monthly oxygen demand (in L/d)
Ubombo Clinic	450	38	1,470	44,103
Medisun Clinic	254	22	4,505	135,144
Mkhiwa Clinic	206	18	4,322	129,660
Philani Clinic	165	14	16,073	482,188
USDF Phocweni Clinic	1,661	139	1,832	54,962
EPR	732	61	2,630	78,914

Appendix IV: Funding Gap

Table 11: Unfunded Activities

			Total Cost 2023 (SZL)	Total Cost 2024 (SZL)	Total Cost 2025 (SZL)	Total Cost 3 Years (SZL))	Total Cost 2023 ($)	Total Cost 2024 ($)	Total Cost 2025 ($)	Total Cost 3 Years ($)
			SZL 122,565,388.57	SZL 24,549,806.61	SZL 22,397,191.32	SZL 169,512,386.49	$ 6,973,173.48	$ 1,345,657.12	$ 1,086,019.97	$ 9,404,850.57
Level	**Item**	**Strategic Objectives & Key Activities**	**2023 Cost (SZL)**	**2024 Cost (SZL)**	**2025 Cost (SZL)**	**Total Cost (SZL)**	**2023 Cost ($)**	**2024 Cost ($)**	**2025 Cost ($)**	**Total Cost ($)**
Objective	1	Create an enabling environment for scaling up sustainable oxygen supply systems	SZL 46,120,305.08	SZL 8,245,525.44	SZL 573,389.44	SZL 54,939,219.96	$ 2,407,272.75	$ 477,831.63	$ 32,505.57	$ 2,917,609.94
Strategy	1.1	Coordination	SZL 196,720.00	SZL 146,600.00	SZL 146,600.00	SZL 489,920.00	$ 11,441.08	$ 7,762.09	$ 7,762.09	$ 26,965.25
Activity	1.1.1	Disseminate the operational plan to key stakeholders to guide implementation of oxygen related activities in Eswatini	SZL 67,620.00	SZL 17,500.00	SZL 0.00	SZL 102,620.00	$ 4,200.47	$ 1,015.03	$ 1,015.03	$ 6,230.53
Activity	1.1.2	Conduct annual reviews to monitor implementation of the operational plana.	SZL 17,100.00	SZL 17,100.00	SZL 17,100.00	SZL 51,300.00	$ 959.06	$ 959.06	$ 959.06	$ 2,877.17
Activity	1.1.3	Develop annual workplans to be informed by annual reviews	SZL 103,200.00	SZL 103,200.00	SZL 103,200.00	SZL 309,600.00	$ 5,788.00	$ 5,788.00	$ 5,788.00	$ 17,363.99
Activity	1.1.4	Coordinate quarterly national oxygen technical working group	SZL 8,800.00	SZL 8,800.00	SZL 8,800.00	SZL 26,400.00	$ 493.55	$ 0.00	$ 0.00	$ 1,480.65
Activity	1.1.5	Ensure completion of partner supported projects within set timelines	SZL 0.00	SZL 0.00	SZL 0.00	SZL 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00
Strategy	1.2	Policies and Guidelines	SZL 133,704.00	SZL 5,704.00	SZL 5,704.00	SZL 145,112.00	$ 7,744.10	$ 319.90	$ 319.90	$ 8,383.90
Activity	1.2.1	Develop/Review policies, standards, and guidelines for medical oxygen (standard operating procedures (SoPs), job aides, and guidelines)	SZL 103,200.00	SZL 0.00	SZL 0.00	SZL 103,200.00	$ 5,985.75	$ 0.00	$ 0.00	$ 5,985.75
Activity	1.2.2	Disseminate policies, standards, job aides, OHPS, CPD and guidelines	SZL 23,700.00	SZL 0.00	SZL 0.00	SZL 23,700.00	$ 1,374.64	$ 0.00	$ 0.00	$ 1,374.64
Activity	1.2.3	Monitor implementation policies, standards, and guidelines	SZL 5,704.00	SZL 5,704.00	SZ 5,704.00	SZL 17,112.00	$ 319.91	$ 319.90	$ 319.90	$ 959.71
Activity	1.2.4	Develop an MOU between MOH and Private facilities on oxygen supply	SZL 1,100.00	SZL 0.00	SZL 0.00	SZL 1,100.00	$ 63.80	$ 0.00	$ 0.00	$ 63.80
Strategy	1.3	Leveraging of available resources	SZL 0.00	SZL 0.00	SZL 0.00	SZL 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00
Activity	1.3.1	Mobilize resources for all activities that are in the operational plan	SZL 0.00	SZL 0.00	SZL 0.00	SZL 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00
Activity	1.3.2	Coordinate partner support for oxygen interventions	SZL 0.00	SZL 0.00	SZL 0.00	SZL 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00

Activity	1.3.3	Identify technical and funding opportunities (develop and submit proposals)	SZL 0.00	SZL 0.00	SZL 0.00	SZL 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00
Strategy	1.4	Sustainability of funding	SZL 0.00	SZL 0.00	SZL 0.00	SZL 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00
Activity	1.4.1	Develop a sustainable funding source for the national medical oxygen infrastructure and related equipment	SZL 0.00	SZL 0.00	SZL 0.00	SZL 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00
Activity	1.4.2	Maintain a reserve of funds in a trust that can be used as collateral with vendors in the event of sudden, unexpected demand.	SZL 0.00	SZL 0.00	SZL 0.00	SZL 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00
Strategy	1.5	Infrastructure	SZL 45,789,881.08	SZL 8,098,925.44	SZL 421,085.44	SZL 54,309,891.96	$2,388,087.57	$ 469,749.64	$ 24,423.58	$ 2,882,260.79
Activity	1.5.1	Setting up cylinder painting booth, Infrastructure for 2 booths	SZL 2,859,093.44	SZL 1,254,393.44	SZL 421,085.44	SZL 4,534,572.32	$ 165,831.64	$ 72,756.67	$ 24,423.58	$ 263,011.89
Activity	1.5.2	Setting up cylinder pressure testing and certification capacity in country	SZL 0.00	SZL 6,844,532.00	SZL 0.00	SZL 6,844,532.00	$ 0.00	$ 396,992.97	$ 0.00	$ 396,992.97
Activity	1.5.3	Making available reliable and efficient alternative sources of electrical supply, solar energy, to PSA buildings to reduce running cost, ensure smooth and efficient operation of PSA plants	SZL 42,930,787.64	SZL 0.00	SZL 0.00	SZL 79,180,931.40	$2,222,255.93	$ 0.00	$ 0.00	$ 4,212,855.93
Objective	2	Implement optimal oxygen production and distribution models	SZL 38,579,894.25	SZL 4,252,442.33	SZL 9,771,963.04	SZL 52,604,299.62	$2,501,470.20	$ 414,031.74	$ 599,720.65	$ 3,515,222.59
Strategy	2.1	Ensuring availability of oxygen	SZL 22,344,024.10	SZL 3,048,002.33	SZL 3,126,154.04	SZL 28,518,180.47	$1,716,734.21	$ 227,300.36	$ 231,833.27	$ 2,175,867.84
Activity	2.1.1	Setup regional production depots with enough capacity to meet regional oxygen needs	SZL 7,275,394.10	SZL 3,048,002.33	SZL 3,126,154.04	SZL 13,449,550.47	$ 891,733.94	$ 227,300.36	$ 231,833.27	$ 1,350,867.57
Activity	2.1.2	Ensure enough locally owned cylinders to meet oxygen distribution needs	SZL 5,022,880.00	SZL 0.00	SZL 0.00	SZL 5,022,880.00	$ 275,000.27	$ 0.00	$ 0.00	$ 275,000.27
Activity	2.1.3	Setup locally owned (with no monthly rental charges) liquid oxygen (LOX) tanks at depots with no LOX tanks. These backup tanks can be quickly filled to meet demand in surge	SZL 10,045,750.00	SZL 0.00	SZL 0.00	SZL 10,045,750.00	$ 550,000.00	SZL 0.00	SZL 0.00	$ 550,000.00
Strategy	2.2	Optimize intraregional and interregional distribution chains	SZL 3,920,167.85	SZL 0.00	SZL 0.00	SZL 3,920,167.85	$ 223,446.40	$ 0.00	$ 0.00	$ 223,446.40
Activity	2.2.1	Equip each regional depot with trucks and other necessary equipment required to facilitate and guarantee continuous oxygen delivery to healthcare facilities in the region that uses oxygen	SZL 3,920,167.85	SZL 0.00	SZL 0.00	SZL 3,920,167.85	$ 223,446.40	$ 0.00	$ 0.00	$ 223,446.40
Strategy	2.3	Maintenance and supply of spare parts	SZL 12,315,702.30	SZL 1,204,440.00	SZL 6,645,809.00	SZL 20,165,951.30	$ 561,289.59	$ 186,731.38	$ 367,887.38	$ 1,118,708.35
Activity	2.3.3	Retooling and/or setting up workshops in the four regions and national biomed	SZL 3,967,279.05	SZL 30,000.00	SZL 30,000.00	SZL 4,027,279.05	$ 218,478.59	$ 1,731.38	$ 1,731.38	$ 221,941.35

		office. This would help the Biomed unit be able to meet service demands.								
Activity	2.3.4	Equipping biomed with the requisite tools, test equipment and simulators to aid biomed perform maintenance activities	SZL 8,348,423.25	SZL 1,174,440.00	SZL 6,615,809.00	SZL 16,138,672.25	$ 342,811.00	$ 185,000.00	$ 366,156.00	$ 896,767.00
Objective	3	Improve oxygen supply chain and monitoring systems	SZL 33,136,849.56	SZL 7,323,499.16	SZL 7,323,499.16	SZL 43,522,296.86	$1,916,922.53	$ 306,285.74	$ 306,285.74	$ 2,529,494.01
Strategy	3.1	Ensure consistent and adequate supply and distribution of oxygen, oxygen-related equipment, and oxygen accessories to point of use	SZL 19,655,275.90	SZL 4,297,156.03	SZL 4,297,156.03	SZL 23,988,036.94	$1,133,676.24	$ 137,209.68	$ 137,209.68	$ 1,408,095.60
Activity	3.1.1	Plan and implement the acquisition and distribution of oxygen concentrators and cylinders.	SZL 260,341.00	SZL 2,003,335.01	SZL 2,003,335.01	SZL 5,460.00	$ 15,024.93	$ 5,540.40	$ 5,540.40	$ 26,105.73
Activity	3.1.2	Plan and execute the acquisition and distribution of vital oxygen accessories.	SZL 19,008,448.89	SZL 1,907,335.01	SZL 1,907,335.01	SZL 22,823,118.91	$1,097,059.07	$ 110,077.04	$ 110,077.04	$ 1,317,213.15
Activity	3.1.5	Review/development of standard equipment list; to guide future procurement of respiratory care equipment and supplies	SZL 386,486.01	SZL 386,486.01	SZL 386,486.01	SZL 1,159,458.03	$ 21,592.24	$ 21,592.24	$ 21,592.24	$ 64,776.72
Strategy	3.2	Enhancing monitoring and evaluation of oxygen systems	SZL 13,481,573.66	SZL 3,026,343.13	SZL 3,026,343.13	SZL 19,534,259.92	$ 783,246.29	$ 169,076.06	$ 169,076.06	$ 1,121,398.41
Activity	3.2.1	Setting up a central monitoring and reporting centre to ensure real-time central monitoring and reporting of all oxygen distribution needs to allow for timely intervention in the event of a demand surge or interruption	SZL 8,946,828.65	SZL 1,026,000.00	SZL 1,026,000.00	SZL 10,998,828.65	$ 529,898.67	$ 57,320.68	$ 57,320.68	$ 644,540.03
Activity	3.2.2	Establishment of indicators for oxygen use and system status in the health management information system's (HMIS)	SZL 2,534,401.88	SZL 0.00	SZL 0.00	SZL 2,534,401.88	$ 141,592.24	$ 0.00	$ 0.00	$ 141,592.24
Activity	3.2.3	Develop measures to track oxygen use and other metrics associated with respiratory care.	SZL 833,968.48	SZL 833,968.48	SZL 833,968.48	SZL 2,501,905.44	$ 46,592.24	$ 46,592.24	$ 46,592.24	$ 139,776.72
Activity	3.2.4	Review/development and implementation of supervision protocols for healthcare managers.	SZL 816,069.21	SZL 816,069.21	SZL 816,069.21	SZL 2,448,207.63	$ 45,592.24	$ 45,592.24	$ 45,592.24	$ 136,776.72
Activity	3.2.5	Assess the effect of improved oxygen systems on key indicators.	SZL 350,305.44	SZL 350,305.44	SZL 350,305.44	SZL 1,050,916.32	$ 19,570.90	$ 19,570.90	$ 19,570.90	$ 58,712.70
Objective	4	Improve capacity for the delivery of oxygen therapy	SZL 4,728,339.68	SZL 4,728,339.68	SZL 4,728,339.68	SZL 14,185,019.04	$ 147,508.01	$ 147,508.01	$ 147,508.01	$ 442,524.03
Strategy	4.1	Training of clinicians, biomed, pharmacists etc.	SZL 4,187,359.76	SZL 4,187,359.76	SZL 4,187,359.76	SZL 12,562,079.28	$ 125,923.80	$ 125,923.80	$ 125,923.80	$ 377,771.40

Activity	4.1.1	Training needs assessment to identify knowledge/skills gaps on relevant staff	SZL 350,305.44	SZL 350,305.44	SZL 350,305.44	SZL 1,050,916.32	$ 19,570.90	$ 19,570.90	$ 19,570.90	$ 58,712.70
Activity	4.1.2	Develop/review curriculum on oxygen and training healthcare professionals	SZL 2,634,499.10	SZL 2,634,499.10	SZL 2,634,499.10	SZL 7,903,497.30	$ 39,184.48	$ 39,184.48	$ 39,184.48	$ 117,553.44
Activity	4.1.3	Developing/reviewing a system that allows for continuous professional development (CPD) in oxygen systems	SZL 386,486.01	SZL 386,486.01	SZL 386,486.01	SZL 1,159,458.03	$ 21,584.21	$ 21,584.21	$ 21,584.21	$ 64,752.63
Activity	4.1.4	Develop/review plans for the health and safety of workers using oxygen in the workplace	SZL 816,069.21	SZL 816,069.21	SZL 816,069.21	SZL 2,448,207.63	$ 45,584.21	$ 45,584.21	$ 45,584.21	$ 136,752.63
Strategy	4.2	Advocate for HR recruitment	SZL 386,486.01	SZL 386,486.01	SZL 386,486.01	SZL 1,159,458.03	$ 21,584.21	$ 21,584.21	$ 21,584.21	$ 64,752.63
Activity	4.2.1	Quantification of staffing needs for various health facilities.	SZL 386,486.01	SZL 386,486.01	SZL 386,486.01	SZL 1,159,458.03	$ 21,584.21	$ 21,584.21	$ 21,584.21	$ 64,752.63
Activity	4.2.2	Recruitment of adequate staff personnel according to the health facility needs	SZL 0.00	SZL 0.00	SZL 0.00	SZL 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00