# EpiC South Africa: Improving the Affordability and Availability of Liquid Oxygen in South Africa

## Background and Context

South Africa is an upper-middle-income country with advanced health technology, a robust medical oxygen supply landscape, and an extensive and developed road network. Despite these advantages, some health facilities experience constrained access to medical oxygen because of long distances from oxygen production sources. During the peak of the COVID-19 pandemic, South Africa, like many sub-Saharan African countries, experienced critical oxygen shortages as some regions faced a more than three-fold increase in consumption.

**KEY ACCOMPLISHMENTS**

- Conducted assessments of 106 hospitals in 34 districts across six provinces to document oxygen needs and critical infrastructure gaps
- Developed a report outlining tailored oxygen supply solutions for selected health facilities in South Africa
- Engaged with National Treasury and NDOH Infrastructure Unit to get consensus on monitoring of oxygen supply and expenditure

Given the substantial oxygen production capacity in South Africa and an existing institutionalized procurement process for medical and industrial gases, EpiC proposed using the national medical gases tender process to facilitate transparency of supplier prices for medical gases, especially oxygen, to drive competitive pricing of liquid oxygen (LOX) within South Africa and throughout Southern African Development Community (SADC) countries. EpiC also sought to strengthen the National Department of Health's (NDOH) capacity for supplier engagement and performance monitoring and support the NDOH to develop a framework for expanding oxygen supply to remote areas of the country.

## South Africa's Oxygen Landscape

### *Supply and Distribution*

Sources of medical oxygen in South Africa include cylinders filled at air separation units (ASUs), on-site generation through pressure swing adsorption (PSA) plants, and liquid oxygen produced at ASUs. ASUs are extensive facilities that either produce medical LOX to be transported and stored in bulk tanks at hospitals or transform oxygen into a gaseous state to be delivered to hospitals in cylinders that supply the piping network or directly to patient bedsides. The supply of LOX produced at ASUs is primarily handled by a limited number of companies in South Africa including African Oxygen Ltd (Afrox), Air Liquid, and Air Products.

## COMMON OXYGEN SOURCES

### *Cylinders*


*A 15-ton Afrox supplied liquid oxygen tank at a hospital*

Cylinders are the most used delivery mechanism for medical oxygen in district hospitals. While available in various sizes, the standard in South Africa is 10.2 kg cylinder. Medical oxygen produced at ASUs is distributed in cylinders to all facilities including district rural facilities. The cost-effectiveness of this solution depends on distance from the nearest ASU, local road infrastructure, oxygen demand in health facilities, and the ability to meet higher oxygen demands to allow for a sustainable, long-term supply chain. In situations with higher oxygen demand, facilities benefit more from bulk delivery than cylinder delivery. Supplying oxygen through cylinders requires moving many units, losing cost efficiency with volume, whereas LOX is more cost effective in bulk quantities. Additionally, a cylinder truck has limited capacity and can only transport a finite number of cylinders per trip, resulting in multiple charges per trip compared to a single charge for one bulk LOX delivery.

### *Pressure Swing Adsorption (PSA) Plants*

PSA plants are responsible for producing gaseous medical oxygen, typically directly on hospital premises. PSA plants produce gaseous oxygen for distribution through piping or cylinders; they are suitable for hospitals far from LOX producers or with unreliable supply routes. PSA plants require a reliable power source and consistent maintenance, making them unsuitable for hospitals lacking these resources. In 2022, the NDOH put out a tender to install 60 PSA plants in hospitals across the country.

### *Bulk Liquid Oxygen (LOX)*

Afrox has historically maintained the central LOX supply system of hospitals. Timely deliveries of bulk LOX are facilitated through an automated center that remotely monitors tank levels at all bulk installations in hospitals. According to the Afrox database, 38% of the 404 hospitals across the country were supplied with LOX. The supply of medical oxygen to public health facilities is solicited through a national tender published every three years.

## CHALLENGES TO ADEQUATE OXYGEN ACCESS

Despite a mature LOX production landscape and increasing awareness of the importance of reliable oxygen supply, there are still substantial gaps in the medical oxygen ecosystem that expose the health system to risks of acute shortages as experienced during the COVID-19 pandemic. These gaps include:

- Long distances from ASUs and poor road conditions in rural areas disrupt provision of LOX for many remote and rural health facilities. Additionally, the provision of oxygen using large cylinders connected to a manifold has significant limitations as experienced during COVID-19. For hospitals equipped with LOX systems, approximately 66% had tank sizes not appropriately matched to number of beds or the oxygen consumption demand. It is crucial to select appropriate tank sizes to avoid problems such as excess pressure build-up and wastage through boil-off in oversized tanks.
- Fragmented supply chains, unreliable energy resources that impede oxygen production by PSA plants, and limited critical infrastructure such as appropriate piping, storage, and transportation hinder access to medical oxygen.
- At the national level, implementation of national oxygen strategic plans often faces financial constraints. At subnational levels, public facilities grapple with a lack of proper training and technical support for oxygen equipment that leads to idle equipment awaiting repairs. Most of the infrastructure, including oxygen infrastructure, within hospitals is not up to standard. Issues include:
    - Neglecting basic repairs and maintenance of hospital infrastructure leading to leaks in the oxygen piping and delivery system
    - Lack of built-in oxygen points in patient care areas
    - Poorly designed hospital layouts resulting in oxygen points being located far from where they are needed for patients
    - Poorly maintained or inadequate roads hamper transportation of oxygen supplies between wards
    - Lack of dedicated storage facilities for oxygen cylinders, increasing risk of incidents

Despite these challenges, compared to most sub-Saharan African countries, South Africa has an advanced LOX production landscape and an established procurement process for this commodity. EpiC's objective was to support the NDOH to increase oxygen access by providing technical assistance for the medical gases procurement process and conducting facility assessments to identify barriers affecting oxygen use to formulate tailored solutions for each hospital.

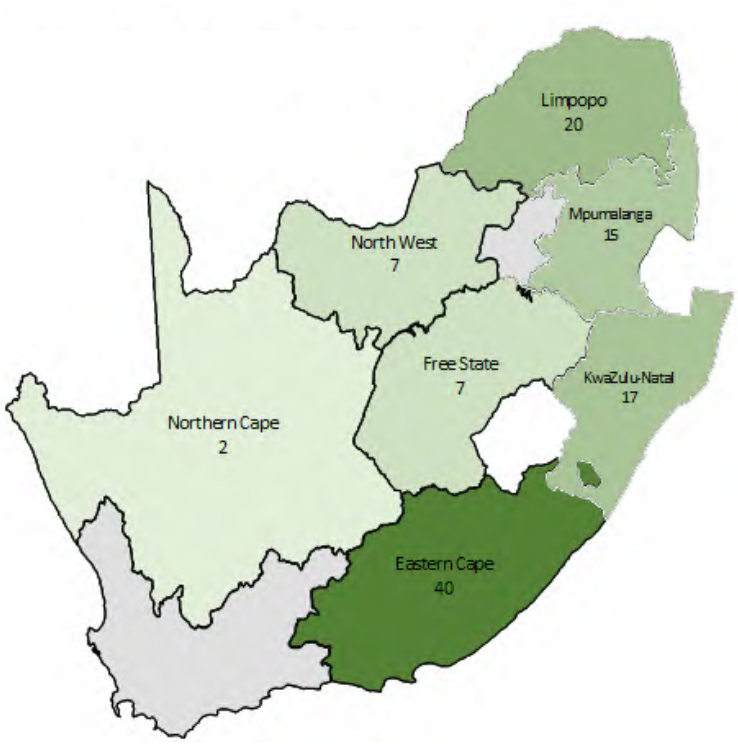
## Interventions

To increase the affordability of medical oxygen in South Africa and scale up access in remote areas, EpiC South Africa conducted the following activities:

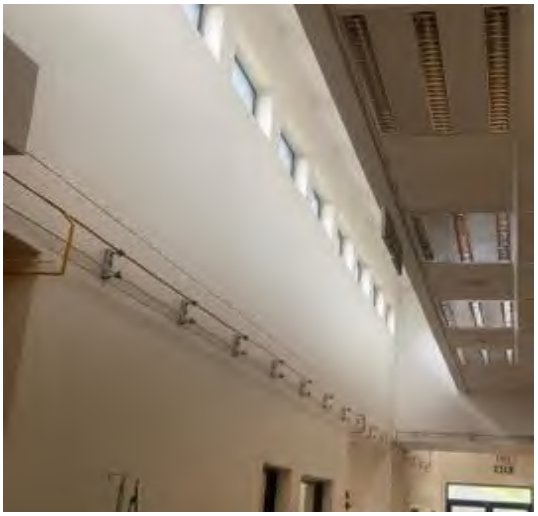
### FACILITY ASSESSMENTS

EpiC conducted facility assessments at selected public health facilities to document oxygen needs and infrastructure gaps and formulate oxygen solutions. From July 2022 to December 2022, EpiC assessed 106 facilities in six provinces to inform the design and implementation of catalytic interventions to increase sustainable access to medical oxygen, with a focus on intensifying efforts to further LOX as a viable option.

Figure 1. Number of facilities assessed per province



*Facility Assessment Findings*



*Oxygen reticulation pipes running through a ward at a hospital in KwaZulu-Natal*

1. **Medical Gas Pipeline Systems:** Medical gas pipeline systems in most hospitals were old and outdated. There were visible refurbishments of oxygen reticulation in hospitals that had improved piping due to increased demand during the COVID-19 pandemic. Oxygen reticulation refers to the distribution system that supplies oxygen from a central source to various points of use within the facility. The reticulation system ensures a consistent and reliable supply of oxygen to various endpoints, such as patient beds and operating rooms. A few hospitals had new structures for isolation wards, most of which remain unused as the work has not been completed or the structures have not been commissioned for use.
2. **PSA Plants**: The production of medical oxygen by PSAs is not widespread in the South African public health system. Of the facilities assessed, only six of 106 reported having a PSA plant; these plants were supplied by Intaka Investments, installed on site, and all located in KwaZulu-Natal Province. However, when analyzing these plants further, it was found that only some were operational, while others produced oxygen with a purity level below the World Health Organization guidelines or had challenges meeting facility oxygen demands.[1] EpiC teams did not assess the causes as this would require a more detailed biomedical engineering firm to investigate the mechanical reasons for failure. However, in all locations, the supplier is responsible for the maintenance of the plants as the facilities do not have the necessary capacity, and challenges are not uncommon with these vendors. Even an active service contract or scheduled maintenance does not guarantee functionality for PSA plants. Table 1 lists hospitals identified with PSA plants in Kwa-Zulu Natal Province with only two having purity levels above 94%.

Table 1. Hospitals with PSA plants

| Province | District Hospital | Functionality |
|---|---|---|
| KwaZulu-Natal | Catherine Booth Hospital | 32% purity level |
| KwaZulu-Natal | East Griqualand Usher Memorial | Not coping, due to high demand |
| KwaZulu-Natal | Nkandla Hospital | 81% purity level |
| KwaZulu-Natal | Rietvlei Mission Hospital | Not operational |
| KwaZulu-Natal | St. Apollinaris Hospital | 94.70% purity level |
| KwaZulu-Natal | Untunjambili Hospital | 94.70% purity level |

[1] World Health Organization guidelines for the use of PSA technology to produce medical oxygen from ambient air specifies a purity level of 93%±3.

3. **Customized bulk tank sizes:** The assessments provided a clear indication that sizing of LOX tanks was not standardized or informed by hospital requirements. The biggest challenge for more than 11% of the assessed facilities was poor road conditions, while 29% (31) had usable bed numbers less than 50. One hospital had a 15-ton LOX tank with less than 50 inpatient beds.
4. **Access to medical air for continuous positive airway pressure (CPAP) in neonatology:** Access to medical air for neonatal CPAP is another significant challenge in rural hospitals. CPAP has been demonstrated to significantly reduce morbidity and mortality in premature babies. Additionally, the administration of high levels of pure medical oxygen to neonates can cause blindness due to retinopathy of prematurity (ROP). As such, access to medical air, consisting of a mixture of oxygen and nitrogen, is essential to administer CPAP while reducing the risk of ROP. Of the 106 assessed hospitals, 56% did not have access to medical air for this purpose, meaning neonatal patients would be at risk of inadequate care.
5. **Oxygen monitoring:** The assessments revealed that oxygen consumption is not being tracked at the facility level. Facilities faced difficulties in knowing their oxygen consumption and have relied on suppliers for volume history, which can be inaccurate. Tracking facility-level consumption trends can help identify wastage, plan for periods of high use, and pinpoint key drivers of increased consumption. Accurate forecasting and budgeting provide better insights into oxygen expenditure; engagements and activities through EpiC have helped NDOH understand the necessary tools for effectively monitoring oxygen expenditure.
6. **Wall-mounted oxygen outlets**: The assessments revealed that 35 of 106 hospitals had fewer than 50% of beds equipped with dedicated oxygen outlets. As a result, many patients lack timely access to oxygen when needed. This shortage of oxygen access points poses a significant challenge for health care providers, who must often transport oxygen tanks to patients' bedsides, complicating and delaying essential care.

*Hospital oxygen bank connected to a manifold*

7. **Lack of standardization of oxygen banks or manifold systems**: The NDOH does not provide policy guidance on how the number of beds and oxygen points influence bank size for a facility.
8. **Distance from ASUs:** Many hospitals are located far away from ASUs, which are responsible for producing oxygen. LOX produced at ASUs can be transported in cryogenic tankers in liquid form, then stored in vacuum-insulated evaporator (VIE) tanks at the facility and vaporized for use. LOX can also be produced at the ASU and converted into gas for storage in smaller cylinders for distribution to facilities, where it can be used bedside for patients or, often in the case of larger tanks, connected to a manifold at the facility. The quality of access roads in rural areas can be poor, making travel difficult for cyrogenic tankers and for transport of oxygen cylinders.

### *Oxygen Consumption Analysis*

An in-depth analysis of oxygen consumption was conducted at the 106 hospitals to determine appropriate tank sizes for low and high flow rates. In South Africa, typically, bulk tanks range from 2 to 20 tons in size. As per identified consumption trends, the majority of facilities opted for customized bulk tanks less than 5 tons. The analysis assumed that consumption levels between 500 to 5,000 kg of LOX could justify tank capacities ranging from 3 to 10 tons. Based on oxygen requirements, 16 hospitals were identified as requiring LOX as the preferred solution. Facility-based solutions for tank sizes were recommended.

## TECHNICAL ASSISTANCE FOR THE RT50 NATIONAL TENDER

EpiC added customized facility requirements information into the National Medical and Industrial Gases tender evaluation process to enable the selection of a supplier with sufficient geographic reach to deliver LOX at a transparent and affordable price for the public sector.

The contracting of medical gases by national government departments is governed by the Republic of South Africa National Treasury, allowing different suppliers to provide medical oxygen to various regions across the country. The RT50 tender is a negotiated government contract that departments can buy from instead of negotiating a new contract. The current RT50 tender, while directed toward the NDOH and National Treasury, also allows other government departments to purchase medical and industrial gases as it is not limited to the health department. This tender for the supply of industrial and medical gases was published in February 2023. In June 2023, the National Treasury awarded the medical oxygen supply tender to Afrox Oxygen and Air Liquide Healthcare to begin in October 2023. Under the award terms, Afrox will supply five out of nine provinces, while Air Liquide will supply four provinces. This tender will run to June 2028. Awarding RT50 to two vendors broke the monopoly that Afrox previously had and will encourage future competition and more players to enter the South African oxygen supply market. Afrox was previously the sole provider of all medical oxygen to NDOH and essentially decided the pricing structure. The selection of two suppliers breaks up that monopoly some and demonstrates to other suppliers possible future government contract opportunities.

During formulation of EpiC's scope of work in South Africa, it was envisioned that EpiC would have visibility in drafting the national tender and could use the opportunity to advocate for a detailed breakdown of suppliers' financial offers so that the tender evaluation committee would have insight into drivers of unit prices of LOX including transportation and equipment rental, taxes, duties, and other fees. However, due to sensitivities of the tender process, EpiC was not able to provide technical assistance in that area but was instead invited to provide input into appropriate systems for monitoring to keep suppliers accountable to their prices as well as other delivery terms as committed to the government. Post tender award, EpiC has reiterated the need to ensure tender monitoring and has engaged the National Treasury on the need to share supplier data for effective supplier and oxygen expenditure monitoring by NDOH.

## SUPPLIER MONITORING

EpiC engaged with NDOH and the National Treasury to support the monitoring of supplier performance, including getting consensus on a government-owned platform for real-time monitoring of oxygen deliveries by the suppliers and its use by health facilities.

The RT50-2023 tender effectively started in October 2023 due to delays in evaluation and adjudication thus affecting EpiC's ability to collaborate with stakeholders to fully develop and operationalize a government-owned monitoring system within the project's period of performance. During implementation, EpiC held an inaugural meeting with NDOH, National Treasury, and other stakeholders to develop a framework for supplier monitoring. EpiC proposed using an oxygen dashboard accessible to NDOH and Provincial Heads of Departments to enable transparency in access, utilization, and supply of oxygen to public hospitals. To ensure sustainability and continuity, EpiC worked closely with NDOH and transitioned its role to the Hospital Infrastructure Director.

Supplier monitoring involves sharing supplier data on deliveries and product costs. To facilitate the process as agreed at the inaugural meeting, the Director General of Health will request the Director General of Treasury to share information specific to the NODH purchasing and supply of oxygen. The data request in the long run will align with Goal 3 of the Annual Performance Plan and Strategic Plan of the NDOH, which ensures "quality improvement in the provision of care." The aim is to make consistent improvement in the health care delivery system by focusing on the effective monitoring and sustainable supply of oxygen in all health facilities. Data-sharing agreements will enable managers at different levels in the health system to view and regularly monitor oxygen data to improve management of oxygen as a resource in patient care. EpiC supported the Director General in coordinating and submitting their proposal to the Treasury, including supplier monitoring of oxygen into RSA Pharma.

RSA Pharma is a South African pharmaceutical-tracking database developed in 2014 to embed systematic supplier relationship management (SRM) strategies in NDOH through business process automation. Through digitization of historical and current data relevant to pharmaceutical order-delivery cycles, RSA Pharma has enabled effective stock management and the evaluation of supplier performance by contract managers since the project's inception. The goal is to leverage the success of existing and proven pharmaceutical supply chain systems, such as RSA Pharma, to enhance contract management efforts and supplier performance for nonpharmaceutical national contracts. For oxygen, this underscores the intent to optimize the monitoring of stock levels and establish a robust evaluation system to assess supplier performance from initiation to end of the tender life cycle.

## Reflections and Lessons Learned

While South Africa did not experience a significant oxygen supply crisis during the height of the COVID-19 pandemic, the oxygen ecosystem can be improved with a clear understanding of demand and consumption at the facility level. Ensuring continuity of oxygen supply at a central level alone does not improve access to oxygen therapy. Effective access also requires robust infrastructure, including properly maintained and adequate connections among oxygen tanks, wards, operating theaters, and intensive care units. Without addressing the quality and reliability of infrastructure, patients may still face difficulties in receiving timely and sufficient oxygen therapy.

Lack of understanding of oxygen demand results in ineffective and inefficient use. This has the potential to undermine price savings. Several measures can be implemented to improve access and build efficiencies in expenditure.

### PROPOSED STRATEGIES TO ENHANCE SUSTAINABLE ACCESS TO OXYGEN

Selecting the most effective oxygen supply source(s) for a hospital depends on several factors such as clinical demand, cost, existing infrastructure, electricity reliability, skilled personnel availability, and local supply chains. After conducting market shaping activities including facility assessment and review of the new tender pricing, the following strategies were proposed:

- To optimize efficiency, facilities should consider customized tank sizes ranging from 3 to 10 tons to meet their specific consumption needs. Table 2 illustrates optimal tank sizing per assessed facility. Clustering smaller tanks (e.g., 3 to 10 tons vs. some of the larger sizes seen at some facilities) can facilitate more efficient delivery of LOX. This approach helps manage smaller quantities effectively and ensures continuous supply without overburdening delivery logistics.

Table 2. LOX tank size analysis (3 tons and higher)

| Province | Hospital | Low | High | Avg. | Low liters/ min | High liters /min | Tank Size kg | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Low | High |
| Eastern Cape | Port Alfred Hospital | 3,427 | 7,976 | 5,500 | 63 | 148 | 1,714 | 3,988 |
| Kwazulu-Natal | Amajuba Gedenk Hospital | 2,939 | 6,887 | 4,954 | 54 | 128 | 1,470 | 3,444 |
| Kwazulu-Natal | East Griqualand Usher Memorial | 1,510 | 7,385 | 4,467 | 28 | 137 | 755 | 3,693 |
| Kwazulu-Natal | KwaZulu Hospital | 1,030 | 6,049 | 2,769 | 19 | 112 | 515 | 3,025 |
| Kwazulu-Natal | Manguzi Hospital | 2,768 | 8,237 | 1,737 | 51 | 153 | 1,384 | 4,119 |
| Kwazulu-Natal | Nkandla Hospital | 1,367 | 7,640 | 3,681 | 25 | 141 | 684 | 3,820 |
| Limpopo | Ellisras Hospital | 4,743 | 8,191 | 6,313 | 88 | 152 | 2,372 | 4,096 |
| Limpopo | Groblersdal Hospital | 3,356 | 6,100 | 4,987 | 62 | 113 | 1,678 | 3,050 |
| Limpopo | Siloam Hospital | 3,639 | 9,019 | 5,391 | 67 | 167 | 1,820 | 4,510 |
| Mpumalanga | Bernice Samuel Hospital | 3,499 | 6,385 | 5,061 | 65 | 118 | 1,750 | 3,193 |
| Mpumalanga | Embhuleni Hospital | 4,100 | 7,670 | 5,722 | 76 | 142 | 2,050 | 3,835 |
| Mpumalanga | Kwa Mhlanga Community Hospital | 3,233 | 8,922 | 5,760 | 60 | 165 | 1,671 | 4,461 |
| Mpumalanga | Kwa Mhlanga Hospital | 4,154 | 9,162 | 6,441 | 77 | 170 | 2,077 | 4,581 |
| Mpumalanga | Piet Retief Hospital | 10,671 | 14,968 | 12,287 | 198 | 277 | 5,336 | 7,484 |
| Mpumalanga | Tintswalo Hospital | 3,338 | 6,643 | 5,060 | 62 | 123 | 1,669 | 3,322 |
| North West | Ganyesa District Hospital | 6,633 | 8,887 | 7,307 | 123 | 165 | 3,317 | 4,444 |
| North West | Nic Bodenstein Hospital | 3,550 | 7,701 | 5,498 | 66 | 143 | 1,775 | 3,851 |

- Plan installation of these tanks so they can be serviced efficiently on a single delivery route by large trucks. This minimizes transportation costs and ensures a sustainable pricing structure for oxygen supply. By clustering tanks and optimizing delivery routes, facilities can also contribute to sustainability goals by reducing carbon emissions associated with transportation.
- Regular monitoring of oxygen consumption trends and periodic adjustment of tank sizes based on actual usage can further enhance efficiency and cost effectiveness over time. Hence, adopting customized bulk tank sizes under 5 tons and clustering them strategically can significantly improve the efficiency and sustainability of oxygen supply in healthcare facilities. Monitoring enables NDOH and facilities to identify potential bottlenecks early. Holding supplier companies accountable and monitoring their performance can promote consistent delivery. The recent tender offers an opportunity to enhance market transparency through supplier performance monitoring. Recognizing this necessity underscores the strategic importance of maintaining supplier transparency and adherence to quality standards, which can shape future tendering processes and improve oxygen delivery to public health facilities. By overseeing the entire supply chain from source to end-user, the system remains secure and enables the identification and resolution of any supply chain bottlenecks. It is recommended to align performance management approaches with national supply systems such as RSA Pharma.
- Prioritize access to medical air in all district hospitals, including access to necessary equipment and resources. This step is needed for provision of optimal care for newborns.
- Procure and supply bulk LOX as a viable option for making medical oxygen more affordable for rural facilities (provided they have the necessary piping infrastructure). Customized tank sizes based on oxygen demand are necessary to maintain heat and pressure balances on LOX cryotanks and prevent liquid oxygen "boil off."

These measures can improve access to affordable LOX, ensuring South Africa’s health system is better equipped to respond to current and future health care challenges.

## STEPS FOR SUCCESS

EpiC maintained collaboration and coordination with the National Department of Health. The most important aspect of the program was the ability of EpiC to conduct physical assessments of all the identified facilities and provide an assessment report for each site that the NDoH and provinces can reference. The recommendations included proposing customized solutions for each facility. During the assessments, facilities could also identify some of the challenges outside of the provision of LOX, which included the unavailability of medical air in more than 50% of the facilities. The program was also implemented in response to medical oxygen shortages and access challenges that were revealed during the COVID-19 pandemic. As such there was urgency from EpiC to ensure that funding was made available to urgently assess and support elements of oxygen provision in District hospitals. While implementation of recommendations has been slow, EpiC has extensively engaged with NDoH to ensure that oxygen supply and monitoring is prioritized going forward.

## CONCLUSION AND FUTURE DIRECTIONS

The assessments were very useful in informing the challenges in District Hospitals and supporting improvements in oxygen supply and pricing. The assessment findings have been shared with the Hospital Services Directorate at the National Department of Health. However, funding to address some of the identified challenges has not been solidified. EpiC cannot influence budgeting or allocation of funding, but the recommendations presented here will allow the Department of Health to start prioritizing oxygen infrastructure in their internal infrastructure

budget, which would require ensuring that provinces and districts are encouraged to include oxygen as a separate budget line item. EpiC will further disseminate the results from the facility assessments, advocating for resource mobilization to address the identified challenges and constraints. This activity also led to the realization that there is potential over expenditure resulting from the supply of excess oxygen due to improper sizing of LOX tanks. Given the opportunity, EpiC would further engage with the facilities to allow them to make evidence-based decisions for the oxygen solutions relevant to their establishments versus putting the decision making into the hands of th e suppliers.

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