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EpiC
Meeting Targets and Maintaining Epidemic Control

Strengthening Medical Oxygen Ecosystems

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Overview

Medical oxygen is critical for the treatment of severe cases of COVID-19 and other life-threatening conditions such as severe pneumonia, severe malaria, sepsis (from bacteria and viruses), trauma, complications of birth or pregnancy, and surgery. The COVID-19 pandemic highlighted the importance of ensuring medical oxygen capacity and availability worldwide. An assessment of more than 530 hospitals across 26 countries conducted in January 2022 by the United States Agency for International Development (USAID)-funded Meeting Targets and Maintaining Epidemic Control (EpiC) project revealed gaps in capacity to provide medical oxygen. Not only was medical oxygen available less than 50% of the time when it was needed, but a gap in technical training was also evident.

USAID and other donors are making significant investments to improve the medical oxygen ecosystem in low-and middle-income countries (LMICs), which is critical to strengthen health systems to be better prepared for future public health emergencies. The EpiC project, led by FHI 360 with partners Population Services International (PSI), Palladium, and Right to Care, is working to strengthen the global oxygen ecosystem through infrastructure investment, market shaping activities, technical assistance, training, and other local initiatives in 24 countries (Figure 1). EpiC collaborates with multiple partners to implement this work, including the Clinton Health Access Initiative (CHAI) and Assist International, two global leaders in strengthening oxygen ecosystems, and other global stakeholders such as Unitaid and World Health Organization (WHO). Collaboratively with USAID, EpiC works with local ministries of health (MOHs) to strengthen their respective medical facilities to have both the infrastructure and technical expertise to expand and manage their medical oxygen systems in a safe, efficient, and cost-effective manner.

Figure 1. EpiC supports 24 countries to strengthen their oxygen ecosystems through infrastructure improvements, market shaping, procurement, and more.

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Assessment and Planning

Multicountry liquid oxygen assessment

In December 2021, EpiC conducted an assessment on the availability and feasibility of scaling up the use of medical liquid oxygen (LOX) in 26 countries. The objectives were to examine availability of LOX infrastructure (tanks, piping, etc.) and oxygen supply gaps at the country level; government commitment for investments in LOX; availability of LOX suppliers in country or regionally; and complementarity to other LOX assistance activities. To rapidly collect data from a range of stakeholders, EpiC developed the toolkit Assessing the Medical Oxygen Ecosystem: Tools from National to Primary Health Care Levels. USAID used the results of the assessment to select countries to receive follow-on technical and financial support to expand use of LOX.

In 115 hospitals across 10 countries (Jamaica, Côte d'Ivoire, Democratic Republic of the Congo [DRC], Eswatini, Malawi, Mozambique, Nigeria, Tanzania, Papua New Guinea, and Vietnam), **EpiC's LOX infrastructure improvements** will result in piping oxygen to an additional **7,363 patient beds.**

By equipping these hospitals with improved infrastructure, hospitals will have greater capacity to treat patients with medical oxygen.

Infrastructure improvements

Since 2021, EpiC has supported investments in infrastructure in 19 countries spanning Africa, Asia, Europe, and the Caribbean, with the goal of building resilient health systems capable of meeting surges in demand for medical oxygen. In 10 of those countries, EpiC's work focuses on improving LOX infrastructure, including facility site preparation, procurement of LOX cryogenic tanks, vaporizers and compressors, installation of medical gas piping, and procurement of LOX-required consumables and commodities. Figure 2 depicts a LOX ecosystem within a hospital.

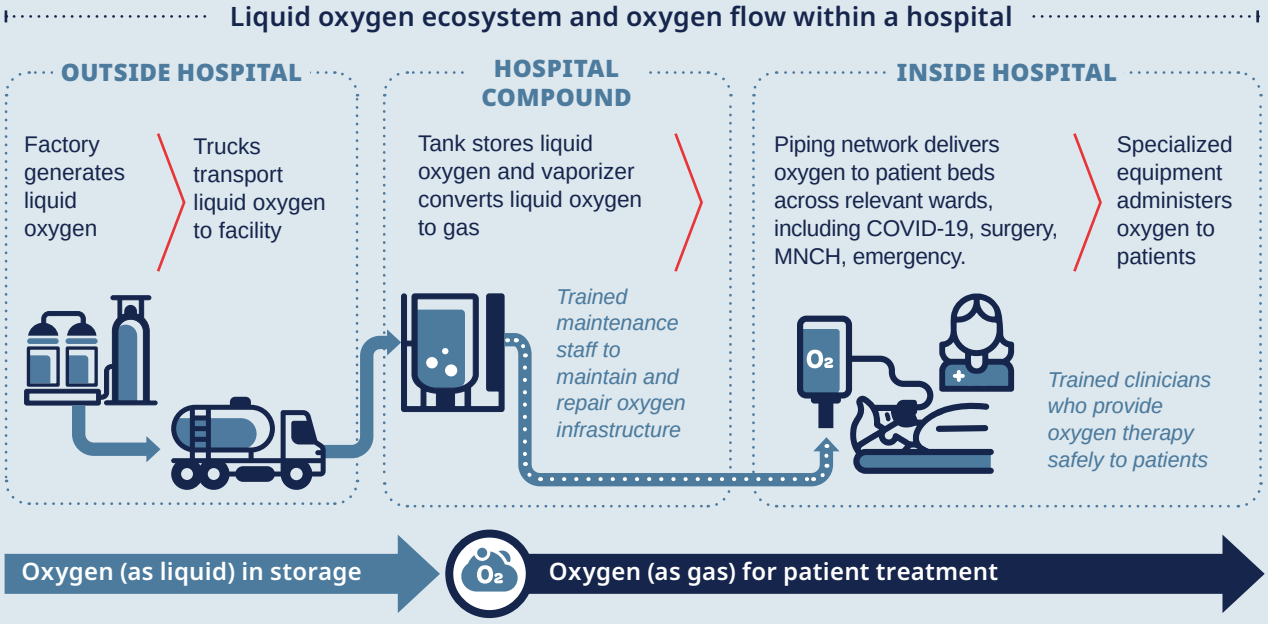

Figure 2. LOX ecosystem and oxygen flow within a hospital

As medical LOX systems are rare or, in some cases, nonexistent, EpiC supported two rounds of LOX infrastructure learning exchanges: one for six African countries to visit South Africa and one for the Papua New Guinea team to visit Vietnam. Participants included both EpiC staff and MOH colleagues to better understand how to operate and manage LOX systems. The exchanges had two main objectives: understanding LOX hardware, and understanding LOX systems, including management of contracts, maintenance approaches, training and capacity development, and sustainability. These exposure visits enabled EpiC teams and MOH partners to recognize what they were working toward in their respective countries and how to move forward when they returned home.

Infrastructure investments and support for infrastructure strengthening are accompanied by country-level sustainability planning to ensure these investments are maintained and managed in the long term. Country sustainability plans include details specific to country contexts on needs such as human resources, financial commitment, maintenance of technical knowledge, and more.

Preparing three hospitals for oxygen-producing PSA plants in Tajikistan

In Tajikistan, EpiC prepared the Central City Hospitals of Bokhtar, Panjakent, and Konibodom to receive pressure swing adsorption (PSA) oxygen generation plants donated by the U.S. Government through USAID. Work at the three sites included site preparation (installation of concrete pads, fences) and oxygen piping and electricity supply strengthening to ensure oxygen delivery from PSA plants could be as safe and efficient as possible. Modifications—based on health facility assessments—included attaching oxygen piping to facility walls to transport oxygen from the PSA to patient rooms, adding electrical connections to ensure stable operation of the PSA components, and making changes to the surface or concrete to manage PSA installation.

Upon completion of this work, EpiC had successfully installed 47 oxygen supply points across all three hospitals, capable of providing oxygen simultaneously for a total of 94 patients in intensive care, surgery, endocrinology, therapy, gastroenterology, and infectious disease units. These improvements made it possible for the hospitals to guarantee oxygen supply in their own wards as well as supply other nearby health facilities by refilling their oxygen cylinders.

> **“Oxygen is life. With EpiC project support we now have more of it, which means we will save more lives.”**
>
> – Firdavs Yusufov, Director of Interregional Cardiology Center of Panjakent, Tajikistan

A new PSA plant at Panjakent Central City Hospital. Photo by EpiC Tajikistan.

Installing LOX systems at 13 facilities across Vietnam

In Vietnam, EpiC conducted a rapid assessment of sites that would benefit from investment in medical oxygen infrastructure. Vietnam has dozens of suppliers providing medical grade LOX, but during the peak of the pandemic, most local health facilities did not have any way to safely store liquid oxygen, convert it to gas, and deliver it to patients. Provincial general hospitals were the primary facilities with liquid oxygen systems, and demands on those systems were high due to the inordinate number of severe COVID patients. EpiC worked with the MOH, provincial departments of health, and facilities to scope and install new systems for 13 high-demand facilities. EpiC worked with a qualified vendor to determine the needs of each supported site. The overall size of the facility, number of beds dedicated to priority groups for medical oxygen, and proximity to other sites with liquid oxygen infrastructure were used to determine tank size, number of beds with bedside piping, and required accessories. Each system included a cryogenic liquid oxygen storage tank of five to 20 cubic meters, an appropriately sized vaporizer, safety regulators, and a piping system linked to between 20 and 80 beds. Upon completion of work at these sites, EpiC began installing LOX systems at 10 additional facilities.

Building Capacity to Maintain Investments and Safely Provide Oxygen to Patients

To ensure investments in oxygen systems are maintained and clinicians can safely and effectively provide oxygen to patients, EpiC builds capacity of both clinical and technical staff (including biomedical engineers, technicians, and maintenance personnel). Through rapid assessments and discussions with MOH representatives, EpiC country teams identified underlying gaps and challenges in the capacity for handling and managing oxygen systems. The absence of training curricula and lack of knowledge and skills in using, managing, and maintaining liquid oxygen systems were identified as areas requiring improvement.

EpiC is developing training curricula to address gaps in the knowledge and skills of health care workers on topics including essential components of the medical oxygen ecosystem; hazards and safety of liquid oxygen systems; maintenance and repair of LOX systems, manifolds, and medical gas pipeline systems; and supply chain management of liquid oxygen systems. Two training modules on introducing medical oxygen ecosystems and their hazards and safety have been developed so far. EpiC is finalizing training materials for the remaining topics, which will be shared with country teams for adaptation and use to conduct capacity building.

A liquid oxygen tank installed at a high-demand facility. Photo by EpiC Vietnam.

Training interdisciplinary teams of health care workers in Nigeria on provision of medical oxygen

In Nigeria, EpiC is supporting expanded access to LOX through infrastructure improvements in eight health facilities. To ensure the investments will benefit patients, EpiC trained interdisciplinary teams of health care workers (including physicians, nonphysician providers, nurses, and maintenance staff) on diagnosis and treatment of patients suffering from hypoxemia. In-person trainings at facilities featured case studies and practical demonstrations that stimulated discussion and promoted interdisciplinary teamwork. A total of 218 staff members were trained, including 70 physicians, 91 nurses, and 23 biomedical engineers and technicians.

Promoting a culture of safety and excellence for medical oxygen maintenance personnel in Panama

Safe delivery of oxygen therapy relies not only on the availability of trained clinicians and equipment at the bedside, but also on trained technical and maintenance personnel to handle oxygen during its production, transportation, and distribution to health care facilities, and maintain the oxygen-related infrastructure. EpiC's assessment of 18 facilities in Panama found that while oxygen production and distribution is sufficient to meet the needs of the population, only one person among all oxygen cylinder transportation, delivery, and maintenance personnel had received dedicated training on medical oxygen equipment infrastructure and safety. Recognizing the vital role that this cadre of health facility personnel plays in safely maintaining the oxygen ecosystem, EpiC addressed the gap by developing and implementing a dedicated medical oxygen training for nonclinical health facility staff in Panama.

Biomedical Engineer and trainer Miguel Vergara explains valve systems on oxygen cylinders. Photo by Sofía Córdova, PSI Centro América.

EpiC Panama designed and delivered a comprehensive training on the principles of medical oxygen starting with what oxygen is, why it is an essential medicine, how it is delivered, how tanks and cylinders work, how to calculate oxygen availability at different oxygen flow rates, how to read manometers (which regulate the flow of oxygen from cylinder to patient), and the do's and don'ts of oxygen management. The training emphasized the importance of safety and security as a core principle of oxygen ecosystem management.

A total of 68 personnel from national hospitals in Panama City and the surrounding areas participated. They included oxygen system maintenance personnel, as well as paramedics and ambulance staff who provide oxygen to patients via cylinders. Participants were selected because they oversee oxygen systems (including tanks and cylinders), manipulate oxygen and related equipment directly, and transport oxygen cylinders and related equipment around a facility to the wards and bedsides of patients who need this essential medicine.

Market Shaping

In partnership with CHAI, EpiC is implementing a market-shaping initiative in collaboration with MOHs and other stakeholders to improve availability and affordability of LOX in nine eastern and southern African countries. The effort will secure a short-term supply of LOX at more affordable prices and foster more sustainable local oxygen markets through approaches such as establishing cost-effective LOX distribution arrangements and/or incentivizing supplier entry into medical LOX markets through volume guarantees or capital financing. Focus countries include Democratic Republic of the Congo, Eswatini, Lesotho, Malawi, Mozambique, Namibia, Tanzania, South Africa, and Zambia.

Lessons Learned and Recommendations

Medical oxygen ecosystems are complex. **Any significant investment in improving oxygen ecosystems should be based on an accurate and detailed assessment.** Assessment should be designed to understand local needs, capacity, equipment and infrastructure for production, supply, distribution, storage, maintenance, and delivery. Conducting such an assessment will identify the strengths and weaknesses in the ecosystem as well as key stakeholders who can play a role in strengthening the system.

Many LMICs lack governance structures, national level policies, and plans for medical oxygen. **Setting up governance structures and developing national policies based on evidence should guide the investment in medical oxygen both in the public and private sector.** A sustainable medical oxygen system requires careful consideration of different modalities of oxygen delivery at various levels of the health system to ensure access and improve patient outcomes. One size does not fit all. While concentrators could serve smaller needs, PSA plants may be a preferred option for larger rural health facilities with stable electricity, and LOX for larger hospitals with a better supply network.

Level of demand for medical oxygen depends on several factors and can suddenly increase during health emergencies and disease outbreaks. **MOHs should carefully estimate their medical oxygen needs for both situations and plan its procurement or local production accordingly.** Local production is not necessarily the cheapest option. Ensuring availability of appropriate quantities of oxygen during times of differing need will require engaging production capacity locally, regionally, or internationally.

Strengthen capacity to produce, distribute, and manage medical oxygen. Capacity building efforts should focus on both clinical and nonclinical staff. This includes training clinicians, biomedical engineers, administrators, oxygen equipment handlers, and storekeepers, as well as developing tools and resources and creating communities of practice.

Strengthen facility infrastructure, policies, and regulatory frameworks to ensure quality production, distribution, and use of medical oxygen. This initiative can be achieved through needs assessments, engaging stakeholders, and developing a national road map for medical oxygen.

Advocacy on the importance of medical oxygen among facility administrators, managers, and policymakers is critical. Despite medical oxygen being an essential lifesaving resource that can improve health care quality and outcomes, facility administrators, managers, and policymakers often have a limited understanding of its importance. This can lead to decisions that undervalue medical oxygen, which can have severe consequences for patients.

The COVID-19 pandemic has created significant challenges for the delivery of medical oxygen in developing countries. Governments have changed priorities, market dynamics have shifted, and demand has fluctuated. **In this context, it is essential for investments in medical oxygen to be flexible and adaptable to the changing needs.**

Strengthening all components of a medical oxygen ecosystem, including procurement and installation, production, distribution, and utilization, requires coordination and collaboration among multiple stakeholders. EpiC has engaged with key stakeholders such as MOHs, facilities, technical working groups, implementing partners, suppliers, and technical experts. This collaborative approach has proven effective in the successful implementation of various medical oxygen projects across developing countries.

Ongoing financing, operation, maintenance, and utilization of medical oxygen systems requires well-developed sustainability planning. This planning helps identify funding sources, ensures proper maintenance and operation, and promotes efficient use of systems. Most developing countries lack comprehensive planning to ensure sustainable access to and effective management of medical oxygen systems. EpiC provides technical assistance and guidance to health care facilities to develop their own long-term sustainability plans.

Ensuring access to quality medical oxygen requires local, national, regional, and international engagement. National governments, in collaboration with regional entities, have the potential to lead successful market-shaping interventions through longer term contracts, volume guarantees, and investment in production, supply, and storage of medical oxygen to reduce the price and ensure continuous availability even during high demand.

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