Assessment and recommendations to increase access to oxygen and pulse oximetry in Kenya

MARCH 2018

MAILING ADDRESS
PO Box 900922
Seattle, WA 98109
USA

ADDRESS
2201 Westlake Avenue
Suite 200
Seattle, WA 98121
USA

TEL: 206.285.3500
FAX: 206.285.6619

www.path.org

This report was written by PATH and supported by a grant from the Bill & Melinda Gates Foundation. The views expressed herein are solely those of the authors and do not necessarily reflect the views of the Gates Foundation.

Suggested citation:

PATH. *Assessment and recommendations to increase access to oxygen and pulse oximetry in Kenya*. Seattle: PATH; 2018.

Contact information:

Lisa Smith, Market Dynamics Officer, PATH
Email: lsmith@path.org

Contents

Abbreviations 4
Executive summary 5
Background information 7
Project background 7
Kenya project work 7
Current status of safe oxygen delivery 9
Oxygen delivery methods 9
Oxygen availability in Kenya 10
Pulse oximetry 12
Supply landscape 12
Procurement landscape 14
Guidelines 15
Regulatory landscape 16
Future developments 16
Quantification of need 17
Maintenance 19
Financing landscape 20
Key stakeholders and roles 21
Market analysis 25
Recommended activities and next steps 28
Appendix A. Contacts and interviews 29
Appendix B. Available devices in Kenya 31
Appendix C. Summary of oxygen plants 35
References 39

Abbreviations

BOC	British Oxygen Company
CE	Conformité Européene
CHMT	county health management team
CPHD	Center for Public Health and Development
EML	essential medicines list
IMCI	Integrated Management of Childhood Illnesses
KEBS	Kenya Bureau of Standards
KEMSA	Kenya Medical Supplies Authority
KES	Kenyan shilling
KHSSP	Kenya Health Sector Strategic Plan
LPM	liters per minute
MES	Managed Equipment Services
MEDS	Mission for Essential Drugs and Supplies
MOH	ministry of health
PPB	Pharmacy and Poisons Board
PPPU	Public Private Partnership Unit
PSA	pressure swing adsorption
SpO2	peripheral capillary oxygen saturation
UNICEF	United Nations Children's Fund

Executive summary

PATH is working to identify market-based solutions to ensure high-quality oxygen is readily available and properly used with pulse oximetry where it is most needed. This project is global in scope, with a focus on four countries—Ethiopia, India, Indonesia, and Kenya. The objective is to gain insights that will enable low- and middle-income countries to improve access to oxygen and pulse oximetry in their public health systems. The information in this report focuses on oxygen access in Kenya and was collected through a combination of desk research and in-country stakeholder interviews and observations. It is intended to guide key decision-makers in Kenya as they work to improve access to safe oxygen delivery, which is defined as the presence of an operational oxygen generating, or reliably filled, oxygen source with trained health care workers and supporting devices such as pulse oximeters.

Oxygen availability in Kenya varies depending on the location and the type of facility. Although there are many oxygen and pulse oximeter suppliers selling products in the global market, their use is not widespread in public health facilities, and most oxygen in the Kenyan public health system is delivered using cylinders. Previously, British Oxygen Company (BOC) was the only oxygen cylinder provider, but the number of private-sector cylinder suppliers has grown in recent years. There is also significant interest to increase the number of government-owned oxygen plants.

Multiple oxygen generation plants have been installed in the last three years, and at least seven more are currently under construction. This is due in part to the success of two unique programs: an oxygen plant operating as a public-private partnership in Siaya County and a medical equipment leasing program. Both of these programs were launched in 2015 and are receiving attention as examples of models that could be scaled further in Kenya and emulated in other countries.

Because health care decision-making and management lies with county health management teams in each of the 47 counties in Kenya, planning for a large-scale oxygen infrastructure program can be challenging. If the counties in Kenya continue to scale oxygen infrastructure, it is recommended that they work together to ensure they right-size oxygen delivery solutions. For example, if each county builds a large-scale oxygen generation and cylinder filling system, they may struggle to utilize the installed production capacity and take full advantage of their capital investment unless they can distribute cylinders to facilities across surrounding counties.

Stakeholders in Kenya acknowledge the value and importance of pulse oximeters, but they are not frequently found outside of larger health facilities. This could be improved by refining the *Health Infrastructure Norms and Standards* to include pulse oximetry at lower levels of care and explicitly outline oxygen requirements at each tier of the health system. Advocacy could also help by promoting the inclusion of pulse oximeters in existing clinical policies and guidelines (e.g., *National Guidelines on Essential Newborn Care* and *Basic Pediatric Protocols 2016*) to ensure there is adequate funding and regular procurement.

In general, Kenya has a well-functioning regulatory system. The Pharmacy and Poisons Board (PPB) manages medical device registration as well as registration for cosmetics, biological products, and medicinal products. However, the government is restructuring the regulatory body to create an independent national authority, which will be known as the Health Products and Technologies Body. The

government also seeks to improve regulatory processes by harmonizing regulations with the East African Community. Both of these activities, while in the early stages, will eventually help to streamline the medical device registration process.

In summary, Kenya is making progress to increase access to oxygen by using novel methods to procure and operate oxygen generation plants. As Kenya continues to scale oxygen availability, it is important to consider the country's total need and the most appropriate mix to meet its need. It is also important to improve the use of pulse oximeters and provide training on the proper administration of oxygen once it is made available.

Background information

Project background

"Addressing market inefficiencies to improve health outcomes" is a three-year (2016–2019) project being implemented by PATH. The project is funded by a grant from the Bill & Melinda Gates Foundation (Gates Foundation). The oxygen project is one of five projects funded under that grant, and its purpose is to build on earlier technical work done around oxygen delivery devices and to identify market-based solutions to ensure high-quality oxygen is readily available and properly used where it is most needed.

By leveraging global insights along with detailed assessments conducted in four focus countries—Ethiopia, India, Indonesia, and Kenya—PATH intends to further assess and propose solutions to the unique market challenges for oxygen delivery devices and pulse oximeters in low- and middle-income countries. Project activities include in-depth assessments of the supply and demand of oxygen delivery devices and pulse oximeters to determine the levels of, and any potential barriers to, product availability, uptake, and use, followed by the development of a global strategy that will include recommendations to overcome identified barriers to access.

The following Kenya market assessment was developed through a combination of desk research and in-country stakeholder interviews and observations. The project team collected information on the current need for and availability of medical oxygen, common oxygen delivery methods, relevant policies and regulations, procurement methods, and available financing. Based on this information and conversations with key stakeholders, the project team developed the recommendations for key activities to increase access to safe oxygen delivery[a] in Kenya. Recommendations were shared with key decision-makers in country.

Kenya project work

Countries were selected for local market assessments based on a number of factors, which are described in more detail in Table 1. In general, the project team sought to identify four focus countries with key differences in order to draw conclusions based on a range of scenarios and experiences.

PATH's oxygen work in Kenya was led by representatives in PATH's Kenya Country Program and by a project team based in Seattle, Washington. The country office in Kenya began the first phase of this assessment by collecting relevant documentation and developing a landscape of relevant stakeholders. During the second phase, the Seattle-based project team visited Kenya and partnered with the country office to meet with key stakeholders and discuss the current state of oxygen delivery, including any barriers and potential opportunities for improvement.

[a] Safe oxygen delivery is defined as the presence of an operational oxygen generating, or reliably filled, oxygen source with trained health care workers and supporting devices such as pulse oximeters.

Table 1. Focus country selection criteria.

CRITERIA	GENERAL DESCRIPTION	BACKGROUND DETAILS FOR KENYA
Potential for impact	Assessment of the public health need based on key health metrics, including burden of acute respiratory infections, under-five mortality ranking, etc.	Kenya has made progress over the past decade, but diseases of the respiratory system and malaria still account for 55.2 percent of the total disease-caused morbidity and, in 2016, remained the leading diseases. Oxygen is an important component of treatment for respiratory infections and for severe malaria.[*] Utilization of essential health services has improved, but access to essential medicines and quality of care is a weakness. Increasing access to oxygen could improve this.[†]
Potential market size	Assessment of the local market opportunity based on population size, gross domestic product, qualitative assessment of local market maturity, etc.	Kenya's health care market is one of the fastest growing in the African continent. It is expected to register strong, double-digit growth through 2018.[‡] Kenya is considered a target market by some due to its expanding population, the number of hospitals being built and equipped with medical devices, and, more generally, the government's prioritization of improving health care. Kenya is also a key logistical entry point for penetrating the larger, regional East African market.
Decision-making authority	Assessment of local decision-making authority, particularly for the procurement of medical devices (e.g., decentralized versus centralized).	Since the devolution of governance officially began in 2013, decision-making authority in Kenya lies with the country's 47 counties. This structure provides an opportunity to understand the complexities of implementing market-based approaches in a system with decentralized budgeting and supply planning.
Available financial resources	Assessment of financial resources available for health care services (based on health care spending as a percentage of gross domestic product), country income classification, etc.	Despite outside funding supporting 33 percent of its 2016/2017 health care budget, Kenya is now classified as a lower-middle-income country and has the capability to support many of its own health programs. Kenya is also a Global Financing Facility funding recipient, with a US$40 million grant currently in its implementation stage.
Other unique factor(s): *for Kenya, decentralized decision-making, increasing momentum, potential for impact, and regional relevance*	Determined according to the country under consideration.	Kenya's vibrant private sector and socially mindful health care business solutions make it an ideal location to identify innovative market-based approaches to improve access to medical devices. The groundwork for oxygen scale-up has been laid in Kenya. The Hewa Tele plant in Siaya County is a high-profile project that has inspired further investment in oxygen plants in Nakuru and Nairobi counties. Other, large-scale initiatives around maternal and child health provide platforms for prioritizing and including safe oxygen delivery.

[*] World Health Organization (WHO). *Management of Severe Malaria: A Practical Handbook*. 3rd ed. Geneva: WHO; 2012. Available at http://apps.who.int/iris/bitstream/10665/79317/1/9789241548526_eng.pdf.

[†] The World Bank. *International Development Association Project Appraisal Document Proposed Credit in the Amount of SDR 105.9 Million (US$150 Million Equivalent) and a Proposed Grant in the Amount of US$40 Million From the Global Financing Facility and a Proposed Grant in the Amount of US$1.1 Million From the Japan Policy and Human Resources Development Fund to the Republic of Kenya for a Transforming Health Systems for Universal Care Project*. Report No: PAD1694. Washington, DC: The World Bank; 2016. Available at http://documents.worldbank.org/curated/en/215261467995371106/pdf/PAD1694-PAD-P152394-IDA-R2016-0122-1-Box396259B-OUO-9.pdf.

[‡] Healthcare Resource Guide: Kenya page. Export.gov website. Available at http://2016.export.gov/industry/health/healthcareresourceguide/eg_main_108594.asp. Accessed May, 2017.

In-country work for this project began in October 2016 and continues in the form of ongoing technical assistance. At the time this report was written (December 2016–June 2017), the team had met with more than 50 stakeholders in the private and public sectors. The full list of contacts and interviews is included in Appendix A. Findings from these meetings, combined with desk research and analysis of more than 30 documents, form the basis of this report. Due to limited resources at the time of fieldwork, this report does not include systematic information on device inventory and availability in facilities or input from a large sample of health facility staff.

Current status of safe oxygen delivery

The current state of safe oxygen delivery in Kenya is described below. These findings are based on the PATH team's discussions with key stakeholders, including the Ministry of Health, members of the county health management team (CHMT) in four counties, the United Nations Children's Fund (UNICEF), the Kenya Pharmacy and Poisons Board (PPB), oxygen cylinder distribution companies, and medical device distribution companies. A full list of stakeholders can be found in Appendix A.

Oxygen delivery methods

Oxygen sources include cylinders, filled with either liquid or gaseous oxygen, or on-site oxygen generation. Oxygen gas cylinders come in a wide variety of sizes. They can be used to provide oxygen directly to the patient or to power a centrally located manifold system. Gas cylinders are generally refilled by transporting them to an oxygen depot that is supplied with oxygen from a larger oxygen generation plant. Liquid oxygen tanks are typically larger, weighing at least 55 kg (120 lb) and standing more than 0.75 m (30 in) in height. They provide the supply for a centrally located oxygen piping system. Liquid oxygen tanks are generally stationary and are filled by a provider using a filling truck. Oxygen in Kenya is most commonly available in gas cylinders (Figure 1, below). Liquid oxygen plants exist in Kenya; however, they are less common, of a larger capacity, and used for wide-scale bulk distribution of oxygen. The benefit of liquid gas is that it can be transported in bulk quantities as it is denser than gas oxygen and is 99 percent pure oxygen, whereas cylinders filled at a plant using pressure swing adsorption (PSA) technology generally average 93 percent pure oxygen. However, from a medical point of view, there are no serious issues to preclude the use of 93 percent oxygen.[1]

Oxygen generation devices typically use PSA to produce a continuous stream of oxygen (85 to 95.5 percent pure) from room air. These devices can be small enough to provide oxygen to a single patient or large enough to provide oxygen to a 2,000-bed hospital. Oxygen generation devices include portable self-contained devices, generally referred to as oxygen concentrators, and larger oxygen plants that, once installed, are not easily mobile. There are two basic types of oxygen concentrators, stationary and portable. Portable units are typically battery operated and lightweight, with oxygen output between 1 to 3 liters per minute (LPM), which is sufficient for one adult. Portable units are generally not considered suitable for facility settings in low- and middle-income countries, as they cannot support multiple patients and are relatively expensive. Stationary units are still mobile but are larger and heavier (30–100 lb) than their portable counterparts and have greater oxygen output capacity (3–12 LPM).

Figure 1. Oxygen equipment available in Kenya.

Cylinders

- Available in multiple sizes.
- Found in all levels of the health system.

Manifold system

- Oxygen source can be liquid tank or gas cylinders.
- Generally, only in medium to large facilities.

Concentrator

- From 5 liters per minute up to 90 liters per minute.
- Can serve up to 15–17 adults at the same time.

Plant/liquid

- Generally, in large facilities.
- Can serve 20 to 2,000 beds.
- Customized to meet specific need.

A subcategory of stationary concentrators is larger still and is capable of output up to 90 LPM. Oxygen concentrators are capable of supporting multiple patients, and some can provide oxygen at high enough pressure to support peripheral devices, such as anesthesia and continuous airway pressure devices. PSA technology can also be scaled to service an entire facility. These large units are referred to as PSA oxygen plants, and they can supply oxygen directly to a facility, fill cylinders, or both. There is currently a great deal of interest in building PSA oxygen plants in Kenya. This is in part due to the innovative business model and early success of the Hewa Tele plant in Siaya County.

Oxygen availability in Kenya

Based on interviews with key stakeholders and observations in the field, most oxygen is currently delivered using cylinders, and availability varies depending on the county and the level of facility. In general, oxygen is less available in lower-level facilities (health centers and health dispensaries) and in more remote areas. This is due in part to the expense and logistical/supply chain challenges associated with refilling cylinders. In February 2017, the Kenya Ministry of Health (MOH) published *Health Infrastructure Norms and Standards*, which defines required medical equipment for each tier of care. The standards mirror the existing availability trends in that cylinders are listed more commonly than oxygen concentrators, which are only mentioned once.

In Kenya, there has been interest in exploring alternative sources for oxygen, particularly through oxygen generation plants, for a number of years. The Medical Engineering and Technologies Unit analyzed oxygen delivery in eight level 5 hospitals in 2000 and found that the cost of installing oxygen plants in these hospitals could be recovered in 24 months.[2] A more recent assessment was done in

2012. This report was not available, but in an interview conducted in March 2017, a member of the assessment team relayed the findings that (a) documentation needed to be improved to understand actual costs and (b) despite the lack of documentation, small oxygen plants were an effective solution to improve oxygen availability.

As of March 2017, 35 of the 47 counties in Kenya already had at least one oxygen plant or were in the process of acquiring or procuring one. There were 22 counties in Kenya with installed oxygen plants of various sizes. Seven of the installed plants were provided through the Managed Equipment Services (MES) program. There are an additional six plants with installation plans—four through the MES program in Garissa, Kisumu, Mombasa, and Nyeri counties and two planned with Nakuru and Nairobi counties in partnership with the Center for Public Health and Development (CPHD). A summary of the existing plants identified through interviews and Internet research can be found in Appendix C.

Oxygen concentrators are in use throughout Kenya; however, they are less common than cylinders. Maintenance of oxygen concentrators remains a challenge, along with electricity availability and quality in more remote areas. The Kisumu CHMT expressed the concern that oxygen concentrators could only service one or two patients. It is possible that the larger, 30 L and higher concentrators could be a good solution to this if electricity is managed properly (both sags and spikes in electricity as well as consistent availability). Kakamega County has relied more heavily on oxygen concentrators to increase oxygen availability in its health facilities. The Kakamega CHMT shared that they are using concentrators in all but three of their high-volume health centers due to the expense and logistical challenges of ensuring consistent access to cylinders. Kakamega's experience with oxygen concentrators may provide a useful example to other counties interested in non-cylinder oxygen solutions.

Increased interest in improving oxygen availability has led to progress, most notably through two unique projects: the MES program and the Hewa Tele oxygen plant. MES provides oxygen plants for intensive care units in 11 level 5 hospitals across Kenya through a leasing mechanism (7 of the 11 plants were installed at the time of this report). The MES program is interesting in that it leverages a leasing model to finance and maintain medical equipment. Often, public-sector entities have a preference toward full equipment ownership, and private-sector companies are reluctant to broker leasing or rental agreements with developing countries due to the risk and/or limited backing from a financing institution. The MES program procured five lots of essential medical equipment through leasing agreements; lots included equipment for intensive care, operating theater, radiology, sterilization, and nephrology units. Oxygen plants were leased and sized to serve the need of intensive care units, which has limited the impact for broader oxygen access. Plants leased through this arrangement do not have installed capacity to provide oxygen to the rest of the hospital or to fill cylinders.

Other oxygen plant installations are due in part to the success of the Hewa Tele oxygen generation plant in Siaya County. This facility was started by the Nairobi-based Center for Public Health and Development (CPHD), using funding from GE Foundation, and in partnership with the Siaya CHMT. It provides cylinders to three counties in Western Kenya—Siaya, Kakamega, and Kisumu. The Hewa Tele project is a public-private partnership between Siaya County and CPHD. The partnership agreement is structured such that CPHD will build and operate the plant and that ownership will transfer to the county once the initial startup and operating costs are recovered by CPHD. The partnership model for the Hewa Tele plant has received considerable attention, including that of multiple county health management teams and

Margaret Kenyatta, the First Lady of Kenya. The Hewa Tele model is being replicated in Nakuru and Nairobi counties, where oxygen plants are currently being installed using county funds and support from UNICEF and CPHD.

The Hewa Tele plant is capable of producing 900 LPM of oxygen. The plant fills cylinders, which are then used to provide oxygen directly to patients or to provide a supply for manifold systems. This is a promising model; however, when considering investing in an oxygen plant, counties should consider their own oxygen need/consumption to determine the size of plant most appropriate. Hewa Tele is capable of supplying oxygen for multiple counties; however, if each county were to have its own plant with the same capacity, the demand would not be sufficient to sustain all the plants. For this reason, **it is important for counties to realistically quantify their total oxygen need and, when appropriate, work together to develop a comprehensive oxygen scale-up plan across counties to leverage oxygen plant investments most effectively**.

Pulse oximetry

The importance and value of pulse oximetry is widely recognized by most stakeholders in Kenya. However, pulse oximetry is not widely available in the public health system, and most pulse oximeters are found only in higher-level facilities. In some cases, pulse oximetry is already available through multi-parameter devices found in operating theaters and intensive care units. The MES program includes multi-parameter devices that monitor peripheral capillary oxygen saturation levels (SpO2) in its leased equipment. As efforts to improve access to SpO2 monitoring progress, it will be important to thoughtfully plan procurement based on the appropriate uses of multi-parameter devices versus standalone pulse oximeters.

In the *Health Infrastructure Norms and Standards*, pulse oximetry is only included for tiers 3 and 4 (formerly levels 4, 5, and 6) of care. With support for increased coverage of these devices among national and county leadership, it would be feasible to expand access within tier 2 (primary health services) in country. Some stakeholders stated that they would like to see pulse oximetry available at the health dispensary level, but policy would need to be put in place to support this. Some clinical guidelines do mention the need to check oxygen saturation, but pulse oximetry is not explicitly stated. However, the MOH recognizes the need to increase pulse oximetry in clinical guidelines. For example, work is underway to include pulse oximetry in the updated *Child Survival and Development Strategy* published by the Kenya MOH. Additional opportunities will arise as other guidelines come up for revision. These policy measures are a necessary first step, but further advocacy will be needed to encourage the use of pulse oximeters in lower-level facilities and to ensure budget is allocated for procurement and training at the county level.

Supply landscape

Domestic manufacturing of medical devices is limited in Kenya, but there are many medical device distributors that carry a variety of products. Medical device registration has recently been enacted by PPB, but the registration data were not publicly available at the time this report was written. Because of this, our assessment of available supply is based on desk research and interviews with manufacturers, local distributors, and programmatic decision-makers. Through these methods, we identified 21 models

of oxygen concentrators from 12 different manufacturers and 30 models of pulse oximeters and multi-parameter devices from 20 manufacturers.

We confirmed approval from the US Food and Drug Administration or Conformité Européene, or European Conformity (CE), mark for all but one of the identified devices. This indicates that there is considerable supply of high-quality devices available for sale on the market in Kenya. However, we acknowledge there are manufacturers and models that are not captured in our data. These devices are likely provided via donation and/or through distributors with which we were not able to speak, and the devices likely span a wide range of quality. See Appendix B for a full list of identified manufacturers and devices.

Until recently, Kenya depended almost completely upon BOC for medical oxygen cylinders. BOC has received criticism for having higher prices, inconsistent delivery services, requiring additional deposits for cylinders, and not providing oxygen if an outstanding balance is due. Service interruptions due to outstanding balances is a frequent cause of oxygen stockouts, as the government often processes payments slowly. However, BOC relayed that not providing oxygen on accounts with outstanding balances is a recent change after years of managing its business with outstanding payments for 300–600 days at a time. Competition now exists in the form of government-operated oxygen plants (such as those provided through the MES program) as well as private-sector suppliers (such as Crown Gases, Noble Gases, and Oxyplus) or partnerships (such as Hewa Tele). These newer market entrants typically provide oxygen at lower rates. For example, Noble Gases provides oxygen to Kenyatta National Hospital at the cost of Kenyan shilling (KES) 57 per liter, whereas the BOC price is KES 126 per liter. It is unclear whether new market entrants will face the same challenges as BOC with outstanding payments. It is also unclear how competitors in this market compare on product (oxygen) and service quality, particularly at scale as BOC still maintains the majority market share.

Procurement landscape

The devolution of Kenya's governance to the county level was officially implemented in 2013. This distributed the majority of responsibility for health product procurement to the 47 CHMTs. However, confusion remains around the delineation of roles and responsibilities between the national government and the counties. Table 2 shows the division of responsibility and the shared areas where further clarification is needed.

Table 2. Responsibilities of the national- and county-level governments.

Agency	Responsibilities
National government	Policy and regulation. Norms and standards. National referral hospitals. Selected national institutions. Capacity-building of and technical assistance to counties.
County government	Health facilities in their territory. Curative, preventive, and promotive health services. Environmental health services.
Shared	Resource mobilization. Health infrastructure maintenance. Medical equipment and devices. Human resources for health management. Monitoring and evaluation.

Source: The World Bank. *International Development Association Project Appraisal Document Proposed Credit in the Amount of SDR 105.9 Million (US$150 Million Equivalent) and a Proposed Grant in the Amount of US$40 Million From the Global Financing Facility and a Proposed Grant in the Amount of US$1.1 Million From the Japan Policy and Human Resources Development Fund to the Republic of Kenya for a Transforming Health Systems for Universal Care Project*. Report No: PAD1694. Washington, DC: The World Bank; 2016. Available at http://documents.worldbank.org/curated/en/215261467995371106/pdf/PAD1694-PAD-P152394-IDA-R2016-0122-1-Box396259B-OUO-9.pdf.

While each county may vary slightly, procurement is typically managed by the county procurement office in collaboration with the county pharmacist and CHMT and can be done by issuing tenders or by ordering from approved distribution companies such as the Kenya Medical Supplies Authority (KEMSA) or the Mission for Essential Drugs and Supplies (MEDS) with technical specifications provided by a biomedical engineer. However, KEMSA and MEDS focus most of their attention on pharmaceutical products, which leaves a gap when it comes to purchasing medical devices such as oxygen concentrators and pulse oximeters. Therefore, medical device procurement is often done at the county or facility level through the tender process. Similarly, oxygen cylinders are not provided by the KEMSA or MEDS. The responsibility for procuring cylinders lies with the individual facilities.

Facilities often face cylinder stockouts because some suppliers will not refill oxygen cylinders if an account has an outstanding balance. The government payment cycle is often longer than the cylinder refill rate, leading to gaps in access. For medical devices, large volumes of concentrators and pulse oximeters would likely be procured at the county level. However, smaller quantities (or individual purchases) can be procured at the facility level, which further fragments demand. Decentralized ordering to this extent also makes it difficult to coordinate the use of technical specifications, leverage reference pricing, and efficiently provide training to end users and maintenance professionals. For example, hospitals can procure medical equipment independently using their own budgets. They may leverage the county procurement office and biomedical engineer to advise on procurement and technical specifications; however, this is not a formal requirement.

If product variants and supplier agreements were managed using a method similar to the online procurement catalog system developed by the government of Indonesia (e-Katalog), the market impact could be significant; an online platform could potentially:

- Harmonize product variants to increase purchase volumes, as well as simplify ongoing maintenance and spare parts purchases.
- Consolidate market intelligence to more effectively select appropriate products as well as negotiate on prices.
- Support continued decentralized decision-making with guiderails to optimize procurement.

Outside **pooled or harmonized procurement**, there remain areas where the procurement system could be strengthened. For example, **reference pricing** (e.g., a combination of past purchase prices, global retail prices, and manufacturer quoted price information) could provide a guide for procurement agents as they negotiate prices for oxygen concentrators, plans, and pulse oximeters, and a **centralized technical specification library** (e.g., an online repository managed centrally with updated technical specifications and key considerations for essential medical devices) could reduce the burden on local procurement agencies while also improving the appropriateness of procured devices. Both suggestions would require considerable sensitization of resources with individuals that procure at all levels of the system, which would be a sizable undertaking. In addition, while the aforementioned recommendations are specific to an assessment of oxygen delivery devices and pulse oximeters, they have broader applicability for county-level procurement of most medical devices.

Guidelines

Kenya has several guidelines that influence the health care system and oxygen delivery. These guidelines are an important step to sustainable access to oxygen and pulse oximetry in the long term. Inclusion of safe oxygen delivery in key planning and guidance documents ensures decision-makers consider oxygen and pulse oximetry when creating budgets and operational plans. A review of two pediatric guidelines (*Basic Pediatric Protocols 2016* and *National Guidelines on Essential Newborn Care*) showed that while oxygen is recommended for multiple indications, there is room to improve the inclusion of pulse oximetry to determine when and how much oxygen is delivered. For example, the neonatal guidelines say that about one-fourth of resuscitated babies require oxygen after four to five minutes of resuscitation, but they do not indicate the use of pulse oximetry nor the use of an oxygen blender to avoid the risk of retinopathy of prematurity as a result of over oxygenation.[3] The *Basic Pediatric Protocols* document does instruct the heath care worker to check the oxygen saturation but does not explicitly state to use pulse oximetry.[4] A third guide, *Standards for Maternal Care in Kenya*, lists the equipment recommended for a delivery room. Oxygen is listed in the anesthesia section, but pulse oximetry is not.[5] **The MOH website indicates this guideline is under review, which provides an excellent opportunity to include pulse oximetry prior to publication.**

Guidelines and strategies can also inform the type of equipment that should be included in each level of facility. The *Norms and Standards for Health Service Delivery 2017* document by the MOH is a high-level guide that describes the required infrastructure, equipment, and types of services for health facilities. A document of this nature that details which types of equipment are required for each level of health

facility provides important support for facility managers to prioritize limited financial resources. **However, there are opportunities for clarifying the guidelines generally and specifically by expanding inclusion of oxygen and pulse oximetry throughout the standards.**

These guidelines also provide insight into the government's priorities and plans and are a valuable resource for outside agencies as they try to support resource prioritization with supplemental funds. Examples of documents that guide implementation and provide insight into potential need include:

- *Kenya Health Sector Strategic Plan 2014–2018* (KHSSP). This plan describes which services should be available at each level of the health system and improvement plans for the health system, which provides insight into potential equipment needs.[6]
- Kenya Essential Medicines List (EML). Oxygen is listed in the EML under general anesthetics. This list helps guide county and facility administrators as they prioritize resources to procure essential medicines.[7] A similar list is under development for essential medical devices in Kenya; however, it was not publicly available at the time this report was prepared.

Regulatory landscape

The Kenya PPB is responsible for registering all medical devices, cosmetics, biological products, and medicinal products. Medical device regulation, however, is divided between PPB, the Kenya Bureau of Standards, and the Kenya Radiation Protection Board. The National Commission for Science, Technology and Innovation—in its mandate to regulate and assure quality in the science, technology, and innovation sector—provides regulatory oversight.

Kenya's regulations cover premarket, marketing, and post-market activities. Premarketing includes laws, regulations, and technical evaluations. Marketing controls include licensing, importation guidelines, and manufacturer registration. Post-marketing controls include ongoing surveillance and vigilance.

Medical device registration fees differ based on risk class categorization, as shown in Table 3. Once an application is accepted and evaluation fees are paid, application processing typically takes 90 calendar days. A registration certificate, once granted, is valid for five years, unless significant changes are made to the approved application data.

Table 3. Risk classifications and fees.

Risk class	Initial registration fee	Evaluation fee	Renewal fee	Change notification fee
Class A	US$25	None	US$20	US$10
Class B	US$150	US$200	US$100	US$20
Class C	US$200	US$250	US$150	US$50
Class D	US$250	US$350	US$200	US$70

Source: Medical devices page. Pharmacy and Poisons Board website. Available at pharmacyboardkenya.org/?p=459. Accessed May 2017.

Future developments

The KHSSP includes goals to improve policy development for and regulation of health products and technologies. One goal within this area is to restructure the present regulatory institution, PPB, into a

comprehensive national regulatory authority similar to the US Food and Drug Administration. The Health Bill, 2016 (N.A./B/No. 14/2015) was passed in June 2017 and harmonizes national policies related to food and drug regulation, creating an independent national authority; the institution will be known as the Health Products and Technologies Body.

A second activity outlined in KHSSP is to harmonize regulations with the East African Community—an economic community that includes six partner states (Burundi, Kenya, Rwanda, Tanzania, Uganda, and South Sudan). This will be accomplished through the East African Community Medicines Regulatory Harmonization initiative. Through joint assessment and approval of applications for medicines registration, harmonization aims to decrease registration time, reduce duplicative efforts of national regulatory authorities, and streamline the use of resources. Recently, the East African Community Medicines Regulatory Harmonization initiative expanded its scope to include harmonization of medical devices. The PPB leads the East African Community Medicines Regulatory Harmonization initiative's technical working group on quality management systems, which developed a compendium to enable partner states to adopt standard quality systems requirements.[8]

Quantification of need

Due to the variety of oxygen delivery technologies available in the market and the range of settings in which they are used, thoughtful analysis of product mix and deployment is essential when designing health system solutions. Each county will have unique requirements in terms of the amount of oxygen it requires and the most appropriate product mix to meet that need. Ideally, counties would have the ability to track their oxygen usage in order to determine their actual oxygen need. One example of how this can be done is in Siaya County. Siaya County's partnership with the Hewa Tele oxygen plant facilitates data collection on oxygen purchases. Based on this historical data, Siaya County uses an average of 6,000 L of oxygen per month. These data can then be used to budget for oxygen and to estimate an increase or decrease in demand based on seasonal disease burden and planned facility expansions or closures.

In the absence of access to actual data, PATH developed a model to estimate the quantity of oxygen and pulse oximeters required to meet the need in the public health care systems of several high-priority focus countries—Indonesia, India, Ethiopia, and Kenya. The model first estimates the volume of oxygen currently required in the public health system. Based on this, the model can then estimate the total number of oxygen delivery devices necessary to meet the total oxygen need.

The model consists of two main steps: 1) estimate the total oxygen need for the health system based on the number of facilities and the estimated coverage of oxygen at those facilities and 2) estimate the product mix needed to deliver the total oxygen estimated in step one. In step one, eight factors are considered to estimate the total oxygen available in the health system: the number of facilities at each level of the health system, the percent of facilities at each level that have access to oxygen delivery technology, types of wards, number of beds, occupancy rates, percent of people that require oxygen, oxygen flow rate, and hours of operation per day. PATH used data from government and academic sources in Kenya whenever available and adjustable assumptions for factors where there was limited real-world data. Adjustable inputs are also helpful as a decision tool. For example, the percent of facilities that have access to oxygen can be varied to estimate the current coverage of oxygen.

Table 4 shows the number of facilities,[b] average number of beds for each level of health facility, and the estimated amount of oxygen in liters required by each level of facility annually. Depending on available infrastructure and resources, there are a number of different product mix solutions that can be deployed to meet this need. As an example, Table 4 also shows the number of concentrators and the number of cylinder refills required to meet the annual need for each level of facility, assuming that oxygen would only be available in facilities with inpatient capabilities.

Table 4. Facilities and average oxygen need.

Facility type	Number of facilities	Average number of beds	Estimated oxygen need per facility (liters/year)	Estimated cylinder refills, per year, per facility*	Estimated number of concentrators per facility†
Level 1: Community units	439	0	0	0	0
Level 2: Dispensaries	3,676	0	0	0	0
Level 3: Health centers	1,064	13	932,527	138	1
Level 4: Primary hospitals	554	48	7,747,100	1,140	4
Level 5: Secondary hospitals	44	130	21,217,730	3,121	9
Level 6: Tertiary hospitals	9	306	49,082,297	7,218	20

* 6 M^3 cylinder.

† 5 liter-per-minute concentrator.

Using the total number of facilities reported and the calculations in Table 4, the total amount of oxygen required to meet the need of the Kenyan health system is estimated to be 6.7 billion liters of oxygen each year. Similarly, quantification for pulse oximeters is tied to the type of facility and number of wards or beds. A recommended number of pulse oximeters per facility was determined by looking at the average number of beds in each type of facility. The total number of pulse oximeters was then calculated by multiplying the recommended number of pulse oximeters per facility by number of facilities at each level. Table 5 shows that 2,615 pulse oximeters would be required to meet the needs of all health facilities that are level 3 and above. Levels 1 and 2 were not estimated as they typically would not have inpatient beds or oxygen available. These calculations assume no oxygen or pulse oximeters are currently available in the system. However, if the availability of oxygen delivery devices (facilities with pulse oximeters, oxygen cylinders, concentrators, or plants, and the functional status of those items) is known, the gap in availability can be more accurately determined. The gap in oxygen availability can then inform a strategy to address the gap and improve access to safe oxygen delivery. However, information about oxygen availability was not known at the time this report was written.

[b]At the time of PATH's quantification analysis, health facility information was reported by levels (1–6), rather than tiers (1–4) as is reflected in policy changes made in 2017.

Table 5. Pulse oximeters required to meet need in facilities level 3 and above.

Facility type	Number of facilities	Average number of beds	Pulse oximeters per facility	Estimated total number of pulse oximeters required
Level 1: Community units	439	0	N/A	N/A
Level 2: Dispensaries	3,676	0	N/A	N/A
Level 3: Health Centers	1,064	13	1	1,064
Level 4: Primary hospitals	554	48	2	1,108
Level 5: Secondary hospitals	44	130	7	308
Level 6: Tertiary hospitals	9	306	15	135

Maintenance

Medical device maintenance is a challenge in Kenya due to limited funding and human resources, competing priorities, and the variation of equipment between regions. There are biomedical engineering units at both the national and county levels; however, the majority of day-to-day maintenance and repairs falls to the county unit.

At the national level, the responsibilities of the Medical Engineering and Technologies Unit have changed since the devolution of Kenya's governance to the counties. Prior to the devolution, this unit was responsible for tracking the location and status of equipment and the availability of tools through a monthly equipment report. The Medical Engineering and Technologies Unit is now mainly responsible for policy and guideline development and enforcement, training and capacity-building, process and systems, and program monitoring and evaluation.

The responsibility of day-to-day maintenance and tracking now falls within the county jurisdiction. Given multiple competing priorities, previous maintenance and tracking systems are thought to be inconsistently used. The transition has also been difficult because many CHMTs do not include a biomedical engineer. However, stakeholders within the national Medical Engineering and Technologies Unit indicated that a policy was being written that would ensure biomedical engineers are included as a standard member of CHMTs.

Practically speaking, engineers in the field are responsible for most equipment repairs. Biomedical engineers in lower-level facilities are typically generalists whereas specialized engineers are found in higher-level facilities where a maintenance unit could have dedicated staff to service equipment in a particular ward. For example, a biomedical engineer at a level 5 facility might manage only the equipment in the imaging unit, whereas a biomedical engineer for a lower-level facility might be asked to fix a variety of devices, including incubators, autoclaves, blood pressure machines, oxygen concentrators, and suction machines. Although these devices are typically less complex, this can complicate training and hamper the biomedical engineer's effectiveness, particularly if there is a great deal of model variation within a particular category of device.

The *Health Sector Human Resources Strategy 2014–2018* specifies two categories of medical engineering technicians: medical engineering technologists and medical engineering technicians.[9] According to this report, there is a shortage of both. Staffing guidelines call for 1,187 technologists and 847 technicians

nationally. There are only 169 technologists and 167 technicians currently in position. This leaves a gap of 1,018 technologists and 680 technicians. Projections in *Health Sector Human Resources Strategy 2014–2018* estimate that this gap will be filled by 2030.

The MES program has addressed the issue of maintenance by including the cost of maintenance in the total cost of the contract. This method ties the payment for a medical device to its uptime and thus puts the responsibility of regular and preventative maintenance on the supplier. In theory this should create an incentive for the supplier to maximize uptime. At the time this report was researched, the MES program was in the early implementation phase, so it was unclear how effectively this approach was executed.

Financing landscape

Financing allocation begins with the national government collecting revenue from individual counties and then redistributing funds to the county governments based on an allocation formula. The financing allocation formula takes six parameters into account, as detailed in Table 6. The goal of the formula is to ensure the funds are allocated fairly, to those counties with the highest need. Health care financing for medical devices comes from multiple sources: the national government, county governments, revenue from services provided at individual health facilities, and loans and grants from donor agencies.

Budgets for equipment are generally estimated during procurement planning, which is done annually, beginning with requests from lower-level facilities being sent to the county level. The CHMT then submits combined requests in the form of a procurement plan and formal budget request to the county government. County governments finance the majority of county health care spending; however, the central government allocates additional funding based on the previously described national formula. Another source of funds is through facility improvement funds, which are collected at public health facilities as fees paid for services. The distribution of these funds varies by county. Some counties allow facilities to retain the funds they generate and use them at their own discretion. Other counties collect these funds at the county level and then redistribute them.

Table 6. County budget allocation formula.

No.	Parameter	Allocation
1	Population	45%
2	Basic equal share	26%
3	Poverty	18%
4	Land area	8%
5	Fiscal responsibility	2%
6	Development factor	1%
	Total	**100%**

Source: Brief on the second basis for equitable sharing of revenue among the county governments [blog post]. Commission on Revenue Allocation blog. March 10, 2016. Available at http://www.crakenya.org/cra-brief-on-the-second-basis-for-equitable-sharing-of-revenue/.

Kenya budgeted KES 60.3 billion for preventative and curative health services in 2016/2017.[10] This is an increase from the KES 59 billion that was budgeted for 2015/2016. Of the 2016/2017 budget, KES 29.1 billion is designated for recurrent costs, such as providing free health services, and KES 31.2 billion is allocated for the development budget, which is used for nonrecurring capital expenditures on long-term items like construction and equipment.[11] Procurement of medical equipment is included in the development budget. Oxygen equipment and pulse oximeters are considered a development expense.

County governments allocated a total of KES 92 billion to health in 2016/2017. This is an 8 percent increase from the previous year. The majority of the health budget went to recurrent expenses (79 percent) while the remainder went to development (21 percent). This is slightly off from the recommendations in the Public Finance Management Act of 2012, which recommend 70 percent to recurrent and 30 percent to development. The largest share of the county health development budgets was dedicated to rehabilitation of buildings and medical equipment, which indicates a priority toward improving infrastructure.

Development partners contributed KES 19.8 billion, or 63 percent, of the development budget, which is 33 percent of the total 2016/2017 MOH budget. The majority of the development budget is earmarked to provide free maternity service (38 percent) and for the MES program (39 percent).

Operations and maintenance are included in the recurrent budget and estimated based on historical expenditures. This category accounts for 13 percent of the county recurrent budget allocations, which is up from 9 percent in 2015/2016. Maintenance is accounted for in various ways depending on its type. For example, routine maintenance is included in the biomedical engineer's salary and specialized repair is tendered, which can take up to 90 days for a local service order. Spare parts are also included in the budget. Kisumu County Referral Hospital noted that maintenance for medical devices is estimated as KES 240,000 per quarter for spare parts. If the budget is not used in a particular year, the funds will theoretically roll over to the next year, although it is unclear if that happens in practice.

Funding for facilities comes from different sources depending on their level in the health system. Level 6 hospitals like Kenyatta National Hospital and Moi Teaching and Referral Hospital are fully funded by the national government. Lower-level hospitals, sub-county hospitals, health centers, and dispensaries are fully funded by the county governments. Level 5 hospitals and high-volume level 4 hospitals are funded by the counties and also obtain grants from the national budget on an annual basis. Facility improvement funds are generally used to cover day-to-day expenses and to purchase emergency supplies. For example, Nakuru Provincial General Hospital utilizes national government grants to budget for bulk purchasing of medical equipment, non-pharmaceuticals, and oxygen. It utilizes facility improvement funds for recurrent costs, including electricity, water, food for patients, contracted services, drugs, non-pharmaceuticals, and development.

Multiple sources of financing makes it difficult not only to quantify the current total spend on medical devices, but it also makes it difficult to identify gaps in financing. As device purchases are typically made less frequently, streamlining the financing for and procurement of medical devices has the potential to increase the overall efficiency and transparency of the market. New solutions to streamline both processes require further thought.

Key stakeholders and roles

There are many stakeholders in Kenya that affect access to safe oxygen delivery.

- **Industry:** There are a variety of stakeholders in the medical device industry in Kenya. Medical gas distribution and installation companies play an important role in oxygen cylinder delivery. However, given the costly nature and logistical challenges of servicing remote regions of the country, access in these areas remains less consistent. The same limitations are true for medical device distributors that sell oxygen concentrators and pulse oximeters. Further work needs to be done to align business incentives with public health objectives to improve access in all parts of the country.

- **Manufacturers:** Manufacturing of medical devices is not a significant industry in Kenya. Most medical devices are imported from global manufacturers through local or regional distributors. Some larger companies (e.g., GE Healthcare, Philips) have established offices in Kenya that are used as a hub for business throughout all of East Africa.

- **Medical device distribution companies:** There are a number of medical device distributors in Kenya. These companies play an integral role between manufacturers and end users. Distributors are typically responsible for registering a product with regulatory bodies, interacting with purchasers, and completing any after-sales services required. Dependent upon the manufacturing company's strategy, they may elect to sell their products through more than one distributor.

- **Medical gas distribution and installation companies:** Medical gas production and distribution companies supply a portion of oxygen in Kenya. Previously, BOC was the only oxygen cylinder provider in Kenya, but the number of private-sector cylinder suppliers has grown in recent years. These companies provide oxygen in both gas and liquid forms. There is also significant interest to increase the number of government-owned oxygen plants. Implementing partners like the CPHD and UNICEF have helped install oxygen plants in several counties across Kenya. Many of the government-owned oxygen plants are designed to distribute oxygen cylinders to surrounding health facilities.

- **Kenya Bureau of Standards (KEBS):** KEBS is a statutory body mandated to provide standardization and conformity assessment services through promotion of standardization in commerce and industry, provision of testing in calibration facilities, and product and system certification. KEBS has developed a Kenyan standard for oxygen concentrators and currently leverages the ISO standard for pulse oximeters. In principle, KEBS would develop a standard for every product. However, prioritization of specific device standards is indicated by the MOH to KEBS.

- **Ministry of Health (MOH):** The national MOH in Kenya is responsible for setting health policies and regulations, managing national referral health facilities, capacity-building, and providing technical assistance to counties. The MOH produces the guidelines that inform the structure and operation of the health system at the county level. The MOH is divided into six departments: the Department of Standards and Quality Assurance and Regulations, the Department of Preventative and Promotive Health, the Department of Curative and Rehabilitation Health Services, the Department of Policy, Planning and Health Financing, the Department of Health Sector Coordination and Inter Governmental, and the Department of Administrative Services.

    - **Neonatal, Child and Adolescent Health Unit:** The Neonatal, Child and Adolescent Health Unit in the Division of Family Health under the Department of Promotive Health has been active in the oxygen space for some time as child health is often a key entry point for oxygen advocacy work. For example, this unit conducted an assessment of oxygen availability in 2011/2012 to support the installation of oxygen plants in 24 hospitals. This unit is also responsible for updating Integrated Management of Childhood Illnesses (IMCI) and pediatric care guidelines to include oxygen and is currently working to implement Global Financing Facility investments in the country.

- **Medical Engineering and Technologies Unit:** The Medical Engineering and Technologies Unit operates centrally and develops resources that may be leveraged by county health management teams across the country. The core activities of this group include policy and guideline development, ensuring compliance with guidance, process and systems of management, capacity-building, and monitoring and evaluation. This unit has been integral in elevating awareness of oxygen use and medical devices more broadly. The Medical Engineering and Technologies Unit led the development of the MES program, which established equipment leasing agreements for five wards in two referral hospitals in all 47 counties. Oxygen plants and multi-parameter monitors, which include SpO2 monitoring, are included in this agreement. The Medical and Engineering Technologies Unit was also involved in conducting an assessment for building 11 oxygen plants in hospitals across the country, which included conducting a survey to evaluate current oxygen availability.

- **Pharmacy and Poisons Board (PPB):** The PPB is the drug regulatory authority in Kenya overseeing both pharmaceutical and medical device products. The guidelines for submission of documentation for registration of medical devices was first published in September 2011. This policy was officially enforced with all devices requiring registration by 2016. However, the list of devices that are registered in country is not publicly available at this time. This information would help to better understand access to devices and competition in the country.

- **County health management teams (CHMT):** Since the devolution of the Kenyan government in 2013, CHMTs have played an increasingly integral role in establishing health care priorities, procuring medicines and medical equipment, and implementing programs. CHMTs are typically composed of 15 individuals including (but not limited to) a country director of health, clinical service coordinator, procurement coordinator, county nurse, county pharmacist, county nutritionist, and county physiotherapist. Scale-up efforts for oxygen will require engaging CHMTs to allocate financing and prioritize procurement and train clinicians/health care workers on continued use of devices. Activities and priorities within each CHMT vary widely depending on the needs of the specific county. For example, two counties in Western Kenya have taken different approaches to meet their oxygen needs. Kakamega County procured oxygen concentrators, while Siaya County partnered with CPHD to build an oxygen plant. Similarly, the systems for monitoring and managing information around specific health needs like oxygen vary across counties. Coordination across counties is limited; however, work with the national Department of Health Sector Coordination and Intergovernmental Affairs and its quarterly health sector intergovernmental consultative forums may provide an opportunity to share best practices, leverage learnings, and coordinate infrastructure planning.

- **Department of Health Standards, Quality Assurance and Regulation:** Oversaw the development of the *Health Infrastructure Norms and Standards* 2017. The department coordinated a stakeholders' workshop in Naivasha in November 2014 to update the 2006 retired guideline on this same topic. A technical working group was then developed to refine the updated norms and standards document. This ministry department has also been

instrumental in developing guidelines for human resource requirements at each tier of the health system.

  - **Health Sector Coordination and Intergovernmental Affairs Division:** This division of the MOH is tasked with coordinating health-sector intergovernmental consultative forums. Forums are intended to bring together technical and non-technical county representatives to discuss best practices and high-priority investments. Within the forum, there are committees focused on specific topic areas, including health products and technologies, health financing, health service delivery, and health monitoring and evaluation. Consultative forums and committee groups may provide an ideal platform for coordinating safe oxygen delivery scale-up across Kenya and for sharing best practices.

- **Center for Public Health and Development (CPHD):** CPHD is a nonprofit entity that is working to improve health systems by developing local capacity and implementing solutions for human resources in health, medical equipment repair maintenance and training, and research and development of public policies. The nonprofit has programs focused on maternal and child health care (the cornerstone focuses of CPHD's work), safe surgery, and critical care. CPHD has developed several social enterprises including Community Health Partners, which is a pharmaceutical and diagnostics services franchise, MediQuip Global, which is focused on comprehensive solutions for medical equipment management, and Hewa Tele, which is a public-private partnership agreement with Siaya County that established a sustainable business model for oxygen manufacture, supply, and distribution. CPHD is a key stakeholder in oxygen scale-up work throughout Kenya.

- **United Nations Children's Fund (UNICEF):** Two groups within UNICEF are engaged with oxygen scale-up activities. The supply division at UNICEF primarily provides technical assistance and leverages long-term agreements with suppliers to provide medical equipment and supplies. It procured oxygen concentrators and pulse oximeters in 2015. Generally, UNICEF has an ongoing partnership with KEMSA since 2016. If KEMSA does not have the capacity to purchase, UNICEF can act as a procurement agency for the government and procure on its behalf. The programmatic division works in five counties and leads a variety of maternal and child health initiatives, specifically working to improve skills, equipment availability, and infrastructure development. It has supported scale-up of oxygen equipment including oxygen concentrators and oxygen plants previously. In collaboration with CPHD, it is currently supporting installation of an oxygen plant in Mama Lucy Hospital in Nairobi County.

- **Clinton Health Access Initiative (CHAI):** Through an investment from the IKEA Foundation, CHAI is collaborating closely with the MOH to scale diagnosis and treatment of pneumonia, particularly for children under five. A portion of this work includes inventorying available oxygen supply across the country and supporting the MOH to develop a road map for improving access. Once finalized, CHAI will help the government implement on and monitor progress of its road map. CHAI is performing a similar function in support of the MOH in Ethiopia and Nigeria with funding from the Bill & Melinda Gates Foundation.

- **Public Private Partnership Unit of the National Treasury of the Government of Kenya:** The Public Private Partnership Unit (PPPU) was established under the Public Private Partnerships Act of 2013 as a special purpose unit within the National Treasury. The mandate of the group is to establish and manage engagement between the public and private sectors. Private-sector participation in health services are outlined as building construction, supply of medical equipment, and capital financing. High-priority health care projects include equipment lease and infrastructure improvement, a 3,000-bed hospital at Kenyatta National Hospital (KNH) Private Wing, Information Computing Technology at KNH, and oxygen plant installation in 11 hospitals. However, the equipment lease and infrastructure improvement program was decoupled from the PPPU to expedite its implementation and the oxygen plant installation program has yet to move forward.

- **Kenya Medical Supplies Authority (KEMSA):** KEMSA is a state organization under the MOH that procures warehouses and distributes drugs and medical supplies for public health programs. It has a national network of storage, packaging, and distribution facilities. It supports county governments to establish and maintain appropriate supply chain systems and provide regular reports to national and county governments. KEMSA currently focuses on providing pharmaceuticals and medical supplies such as band aids, gloves, beds, laboratory supplies, etc. KEMSA does not currently procure or distribute durable medical goods like oxygen concentrators, oxygen plants, or pulse oximeters.

- **Global Financing Facility (GFF):** GFF, housed at the World Bank, is contributing a US$40 million grant to the Transforming Health Systems for Universal Care project. This project also includes a loan from the International Development Association in the amount of US$150 million, and a grant in the amount of US$1.1 million from the Japan Policy and Human Resources Development Fund. Funds from this project support an investment framework for reproductive, maternal, newborn, child, and adolescent health. There may be opportunities to leverage the investment framework to also improve access to safe oxygen delivery for these high-priority population groups.

Market analysis

Market dynamics is a set of skills and approaches that are used to evaluate access to products and services as a function of regular interactions among key stakeholders (e.g., producers, purchasers, and consumers) on the supply and demand sides of the market. In a market analysis, interactions are assessed by the effectiveness and efficiency of key attributes of market health: affordability, availability, assured quality, appropriate design, and awareness. In global health, market analyses help inform market-shaping interventions, where time-bound investments are made to proactively influence market conditions in order to improve health outcomes. These investments are typically made after the current market is thoroughly assessed, key market inefficiencies are identified, and potential interventions to address inefficiencies are short-listed by their feasibility and potential for positive impact.

Market-shaping efforts in global health seek to support sustainable access to medicines and technologies by catalyzing new market development and/or improving existing ones. The PATH team is using a market dynamics perspective to identify potential methods for improving access to oxygen in Kenya. Each of the market attributes assessed is described in Table 7 below.

Table 7. Summary of strengths and weaknesses of the Kenyan market for oxygen delivery devices.

Market area	Strengths	Weaknesses
AWARENESS *Extent to which end users, health care providers, and key influencers can make informed choices about product use.*	Health-sector intergovernmental consultative forums may serve as a platform for sharing product information with key health care decision-makers. The GE Foundation/Assist International/Center for Public Health and Development project partnership to develop the Hewa Tele plant in Western Kenya (Siaya County) has raised awareness of safe oxygen delivery across the country and motivated other counties to action.	Kenya is focused on developing oxygen plants, and individual counties are especially keen to develop their own oxygen generation capabilities. However, oversaturation of the oxygen plant market could impact the business sustainability of each. Strategic planning and appropriate plant sizing are required across counties; however, there is limited incentive for counties to collaborate.
AFFORDABILITY *Extent to which the price point maximizes market efficiency between payers and suppliers to support health outcomes.*	Stakeholders acknowledged the value of pulse oximetry and that it should be prioritized in budgeting. It remains feasible to scale pulse oximetry with implementation and policy support. Oxygen concentrators are seen as a positive alternative to oxygen cylinders in more remote counties. The medical leasing program includes seven-year lot contracts for sets of specialized equipment; these contracts include an agreed-upon fee structure and regular maintenance schedule.	There is poor transparency around pricing for oxygen concentrators and pulse oximeters at the county or hospital level, where procurement of health equipment takes place. In certain parts of the country, the distribution network for cylinders is complicated, which results in higher prices and slower deliveries. It is unclear how much counties are spending on oxygen presently as record-keeping of past purchases is poor; this makes it difficult to compare oxygen delivery and pulse oximetry solutions. Current budgeting practices do not account for medical device operating costs over time and instead emphasize only the initial capital investment. Payments through the public health sector are often delayed, which results in oxygen cylinder shortages.
AVAILABILITY *Capacity and stability of global supply to meet demand and consistency of local access at service delivery points.*	A harmonized regulation intended to streamline registration processes for pharmaceuticals, medical devices, and other health products was approved in the Health Bill 2016. The central government has developed a medical leasing program for high-priority areas within hospitals across the country. Pulse oximetry in a multi-	The current system for medical device standards and registration is owned by multiple entities that charge separate fees for use of product (e.g., Kenya Bureau of Standards, Pharmacy and Poisons Board, Nursing Council of Kenya, Laboratory Equipment Association).

Market area	Strengths	Weaknesses
	parameter device is included in the set of leased products, as are oxygen generation plants for intensive care units. There are relatively good data for the number of health facilities in each county and the associated characteristics of each level of health facility. National child health policies recommend pulse oximetry for diagnosis of hypoxemia. The *Health Infrastructure Norms and Standards* (2017) provides an outline of required medical equipment at each tier of health care.	Procurement was decentralized to the county health management team in 2012. This makes communicating to decision-makers difficult and increases transaction costs. There have been varying degrees of success for appropriate procurement across all 47 counties. Decentralization has fragmented demand, limited the potential for pooling procurement, and added costs to marketing. The *Health Infrastructure Norms and Standards* could highlight oxygen and pulse oximetry use at each tier of the health system clearer. The Pharmacy and Poisons Board recently began requiring medical device registration (August 2016); however, its data are not cleaned or public at this time.
ASSURED QUALITY *Level of evidence that a product is consistently efficacious and safe.*	Private-sector innovation is common in Kenya; MediQuip Global, a Kenyan social enterprise, is one example of a private-sector model for medical device maintenance that has succeeded across the East African region. Kenya is developing guidelines to regulate medical device donations. The MES program includes training of local technicians upon installation of the leased medical devices as well as annual maintenance checks of manufacturers.	Donated equipment has increased the product variants that technicians must learn to maintain, and often, device information and user manuals are printed in another language. Effectiveness of the national Medical Engineering and Technologies Unit is limited due to the devolution of maintenance responsibility and decision-making to the counties. In the absence of standardized device management resources, each county is left to determine an appropriate model for maintenance.
APPROPRIATE DESIGN *Degree to which possibilities of technology maximize cultural acceptability.*	CPHD has assisted with the selection and procurement of several PSA oxygen plants in Kenya; CPHD's additional technical expertise has helped with selecting appropriating devices.	Although there are limited data on current devices in use throughout Kenya, stakeholders consistently expressed concern about the inappropriateness of medical device donations. Most of the existing oxygen concentrators were donated and have not been well maintained, which has skewed consumer preference.

Abbreviations: CPHD, Center for Public Health and Development; MES, Managed Equipment Services; PSA, pressure swing adsorption.

Recommended activities and next steps

In general, Kenya has made important advancements to improve access to safe oxygen delivery technologies. However, oxygen availability in the public health system highly depends on a facility's geographic location. In urban centers and higher-population regions, oxygen is more readily available. In remote areas, supply chain/logistical challenges and infrastructure limitations (e.g., electricity access) limit access to oxygen. Recommendations to improve access include activities that PATH is well positioned to support as well as activities that would be best led by local stakeholders, including the Kenya Ministry of Health, local organizations, and global health partners.

There are a number of potential interventions that stakeholders in Kenya can undertake to improve access to safe oxygen. Interventions range from the national to county level down to the facilities. National-level interventions include updating policies and guidelines such as the *National Guidelines on Essential Newborn Care* and the *Health Infrastructure Norms and Standards* to more clearly include oxygen. County-level interventions include adding biomedical engineers to CHMTs to ensure technical aspects of the health system are considered. Finally, a national survey of medical devices should be conducted at the facility level to determine actual availability in the health system. Kenya, with the support of global partners, is in the process of developing a road map to scale oxygen. This road map was discussed, and immediate next steps were shared during the final day of the Accelerating Access to Oxygen Convening that was held in Dubai in November 2017.

A2O2—Accelerating Access to Oxygen Convening

In November 2017, PATH held a stakeholder convening, with support from the Gates Foundation. This convening brought together industry representatives (manufacturers and distributors), country stakeholders from a variety of low- and middle-income countries (regulators, procurers, policymakers), and global partners (PATH, the Gates Foundation, UNICEF, WHO, CHAI) to share information and discuss opportunities for improving access to oxygen delivery technologies and pulse oximeters. This convening was an opportunity for stakeholders in Kenya to share ideas with their peers and discuss next steps within the delegation. Kenya was well represented at this meeting. The MOH sent four representatives including the Director of Medical Services and the heads of the Medical Engineering and Technologies, the Division of Family Health, and the Neonatal, Child and Adolescent Health units. To represent the county perspective, the Medical Superintendent from a hospital in Nakuru County, which is installing an oxygen plant, also joined. Kenya also had a strong representation from global partners including members from the CHAI and UNICEF country offices.

Appendix A. Contacts and interviews

Organization	Role
Achelis Kenya Ltd	Business Development Manager Healthcare & Scientific Division
British Oxygen Company Gases	Regional Engineer
British Oxygen Company Gases	Managing Director
British Oxygen Company Gases	Sales Manager
Center for Public Health and Development	Executive Chair
Center for Public Health and Development	Managing Director
Crown Healthcare	Sales & Marketing Manager
Global Financing Facility (World Bank)	Health Specialist, Health, Nutrition, & Population
Harley's Limited	Head of Medical Equipment
Hewa Tele Oxygen Plant	Plant Manager
Homa Bay County Biomedical Engineer	Engineer
Homa Bay County Health Management Team	County Clinical Officer
Jaramogi Oginga Odinga Referral Hospital	Hospital Director/Medical Superintendent
Kakamega County Biomedical Engineer	County Biomedical Engineer
Kakamega County Health Management Team	RMNCH Coordinator
Kehnts Medical Equipment (Medequip)	Director
Kenya Bureau of Standards	Standards Officer
Kisumu County Biomedical Engineer	County Biomedical Engineer
Kisumu County Health Management Team	County Director of Health
Kisumu County Health Management Team	County Clinical Coordinator
Kisumu County Health Management Team	County Medical Laboratory Services Officer
Kisumu County Health Management Team	Quality Improvement Focal Person
Kisumu County Health Management Team	WASH Program In-Charge
Kisumu County Health Management Team	Nursing Officer in Charge of Beyond Zero Clinics
Kisumu County Health Management Team	County Malaria Coordinator
Kisumu County Health Management Team	Nursing Officer In Charge, Commodity
Kisumu County Referral Hospital	Procurement Officer
Medical Engineering and Technologies Unit	Department Head
Medical Engineering and Technologies Unit	Engineer
Medical Engineering and Technologies Unit	Department Deputy Head
Medical Equipment Services	Interim Head of Monitoring and Evaluation
MEDS	Project Officer
Ministry of Health	Head Neonatal, Child, Adolescent Health Unit
Ministry of Health	Head of Specialized Clinical Services
Ministry of Health	Head of Division of Health Sector Intergovernmental Affairs
Ministry of Health	Department of Standards and Quality Assurance and Regulations
Monks Medicare Africa Ltd	Sales
Nairobi Capital Projects Team	Health Administrative Officer

Nairobi County Health Management Team	County Pharmacist
Nairobi County Biomedical Engineer	County Biomedical Engineer
Nairobi Enterprises Limited	General Manager
PATH Kakamega County Office	County Project Coordinator Kakamega
Pharmacy and Poisons Board	Head of Medical Devices and Diagnostics
Philips Kenya	Senior Scientist
Philips Kenya	Research Scientist
Pulse Healthcare	Managing Director
Pulse Medics Equipment Ltd	Managing Director
Rachuonyo Sub-County Hospital	Former Deputy Matron
Siaya County Biomedical Engineer	County Biomedical Engineer
Siaya County Health Management Team	Deputy County Director of Health
Siaya County Health Management Team	County Pharmacist
Siaya County Health Management Team	Deputy County Director of Health
UNICEF Supply Division	Procurement Specialist
UNICEF Maternal Child Health Unit	Health Specialist—MNH
World Bank (Global Financing Facility)	Health Specialist, Health, Nutrition, & Population

Abbreviations: MNH, Maternal Neonatal Health; UNICEF, United Nations Children's Fund.

Appendix B. Available devices in Kenya

Device	Country of origin	Company name	Registered local supplier	Model	Source
Oxygen concentrator	USA	AirSep	Crown Solutions Ltd., Crown Healthcare Division	AirSep VisionAire Single Flow 5 Liter	Interview With Crown Healthcare/Website
Oxygen concentrator	USA	AirSep	Crown Solutions Ltd., Crown Healthcare Division	AirSep VisionAire Single Flow 10 Liter	Interview With Crown Healthcare/Website
Oxygen concentrator	USA	AirSep	Crown Solutions Ltd., Crown Healthcare Division	AirSep NewLife Elite Dual Flow 5 Liter	Interview With Crown Healthcare/Website
Oxygen concentrator	USA	AirSep	Crown Solutions Ltd., Crown Healthcare Division	AirSep NewLife Elite Dual Flow 10 Liter	Interview With Crown Healthcare/Website
Oxygen concentrator	USA	AirSep	Crown Solutions Ltd., Crown Healthcare Division	AirSep Focus Portable	Interview With Crown Healthcare/Website
Oxygen concentrator	USA	AirSep	Medequip Kenya	TBD	Medequip Kenya Website
Oxygen concentrator	USA	AirSep	Pulse Medics Equipment Ltd.	AirSep VisionAire 2 Pediatric 2 LPM	Pulse Medics Equipment Ltd. Website/Facebook
Oxygen concentrator	USA	AirSep	Pulse Medics Equipment Ltd.	AirSep NewLife Elite 5 LPM	Pulse Medics Equipment Ltd. Website/Facebook
Oxygen concentrator	USA	DeVilbiss Healthcare	Nairobi Enterprises Ltd.	DeVilbiss Compact 525	Interview With Nairobi Enterprises Ltd./Website
Oxygen concentrator	USA	DeVilbiss Healthcare	Nairobi Enterprises Ltd.	DeVilbiss 525 Ds	Interview With Nairobi Enterprises Ltd./Website
Oxygen concentrator	USA	DeVilbiss Healthcare	Nairobi Enterprises Ltd.	DeVilbiss iGo Portable	Interview With Nairobi Enterprises Ltd./Website
Oxygen concentrator	USA	DeVilbiss Healthcare	Nairobi Enterprises Ltd.	DeVilbiss iFill Personal Oxygen Station	Interview With Nairobi Enterprises Ltd./Website
Oxygen concentrator	USA	DeVilbiss Healthcare	Pulse Healthcare Limited	DeVilbiss Compact 525KS 5 Liter Single Flow	Interview With Pulse Healthcare Limited/Website
Oxygen concentrator	USA	DeVilbiss Healthcare	Medequip Kenya	TBD	Mediquip Global Website
Oxygen concentrator	UK	DiaMedica	Achelis Kenya	TBD	Achelis Kenya Website
Oxygen concentrator	USA	Inogen	TBD	TBD	Inogen Website
Oxygen concentrator	USA	Invacare	TBD	TBD	Invacare Website

Device	Country of origin	Company name	Registered local supplier	Model	Source
Oxygen concentrator	China	Longfian Scitech	Harley's Limited	Longfian JAY-5 Single Flow	Interview With Harley's Limited/Website
Oxygen concentrator	China	Longfian Scitech	Harley's Limited	Longfian JAY-8 Dual Flow	Interview With Harley's Limited/Website
Oxygen concentrator	China	Longfian Scitech	Nairobi Enterprises Limited	Longfian JAY-10	Interview With Nairobi Enterprises Ltd./Website
Oxygen concentrator	China	Longfian Scitech	Mediquip Global	TBD	Mediquip Global Website
Oxygen concentrator	USA	Nidek Medical	TBD	TBD	Nidek Medical Website
Oxygen concentrator	USA	On Site Gas Systems	TBD	TBD	On Site Gas Systems Website
Oxygen concentrator	USA	Oxus	Harley's Limited	Oxus Portable	Interview With Harley's Limited/Website
Oxygen concentrator	USA	OxyAir	TBD	TBD	Interview With Kakamega CHMT
Oxygen concentrator	USA	Philips Respironics (Novametrix)	TBD	TBD	Philips Respironics (Novametrix) Website
Patient monitor	China	Shenzhen Comen Medical Instruments Co., Ltd.	Nairobi Enterprises Limited	Comen STAR8000H Transport Patient Monitor	Interview With Nairobi Enterprises Limited/Website
Patient monitor	China	Shenzhen Comen Medical Instruments Co., Ltd.	Nairobi Enterprises Limited	Comen STAR8000C Multi-Parameter Monitors	Interview With Nairobi Enterprises Limited/Website
Patient monitor	China	Shenzhen Comen Medical Instruments Co., Ltd.	Nairobi Enterprises Limited	Comen STAR8000A	Interview With Nairobi Enterprises Limited/Website
Patient monitor	China	Shenzhen Comen Medical Instruments Co., Ltd.	Nairobi Enterprises Limited	Comen C50 Multi-Parameter Patient Monitor	Interview With Nairobi Enterprises Limited/Website
Patient monitor	China	Shenzhen Comen Medical Instruments Co., Ltd.	Nairobi Enterprises Limited	Comen C60 Neonatal Patient Monitor	Interview With Nairobi Enterprises Limited/Website
Patient monitor	China	Shenzhen Comen Medical Instruments Co., Ltd.	Nairobi Enterprises Limited	Comen ICU Monitor C80	Interview With Nairobi Enterprises Limited/Website
Patient monitor	China	Mindray	Megascope	Mindray BeneView	Megascope Website
Pulse oximeter	Germany	Beurer	TBD	TBD	Beurer Website
Pulse oximeter	China	Biolight Co. Ltd.	Pulse Healthcare Limited	Biolight M800 Hand Held Pulse Oximeter	Interview With Pulse Healthcare Limited/Website
Pulse oximeter	China	Biolight Co. Ltd.	Pulse Healthcare Limited	Biolight M70 Finger Tip Pulse Oximeter	Interview With Pulse Healthcare Limited/Website

Device	Country of origin	Company name	Registered local supplier	Model	Source
Pulse oximeter	Italy	Cami	Crown Solutions Ltd., Crown Healthcare Division	Cami O2-Easy Fingertip Oximeter	Interview With Crown Healthcare/Website
Pulse oximeter	China	Shenzhen Comen Medical Instruments Co., Ltd.	Mediquip Global	TBD	Mediquip Global Website
Pulse oximeter	Germany	Draegerwerk AG & Co. KGaA	Mediquip Global	TBD	Mediquip Global Website
Pulse oximeter	China	Edan Instruments, Inc.	Harley's Limited	Edan H100B Handheld	Interview With Harley's Limited/Website
Pulse oximeter	China	Edan Instruments, Inc.	Harley's Limited	Edan H10 Fingertip	Interview With Harley's Limited/Website
Pulse oximeter	Germany	GETEMED	TBD	TBD	GETEMED Website
Pulse oximeter	China	Shanxi Jerry Medical Instruments Co., Ltd	Pulse Medics Equipment Ltd.	JERRY-F New Fingertip	Pulse Medics Equipment Ltd. Website/Facebook
Pulse oximeter	China	Shanxi Jerry Medical Instruments Co., Ltd	Pulse Medics Equipment Ltd.	JERRY-II Handheld	Pulse Medics Equipment Ltd. Website/Facebook
Pulse oximeter	China	General Meditech Inc.	Nairobi Enterprises Limited	TBD	Interview With Nairobi Enterprises Limited/Website
Pulse oximeter	China	Mindray	Crown Solutions Ltd., Crown Healthcare Division	Mindray PM-60 Handheld Oximeter	Interview With Crown Healthcare/Website
Pulse oximeter	USA	Nidek Medical	TBD	TBD	Nidek Medical Website
Pulse oximeter	Japan	Nihon Kohden	Nairobi X-Ray Supplies Ltd	Nihon Kohden BluPRO Handheld	Nairobi X-Ray Supplies Ltd Website
Pulse oximeter	USA	Nonin Medical, Inc.	TBD	TBD	Nonin Medical, Inc. Website
Pulse oximeter	Germany	Rudolf Riester GmbH	TBD	TBD	Rudolf Riester Gmbh Website
Pulse oximeter	Switzerland	Schiller AG	TBD	TBD	Schiller Ag Website
Pulse oximeter	USA	Smiths Medical (BCI)	TBD	TBD	Smiths Medical (BCI) Website
Pulse oximeter	TBD	TBD	Bakpharm	TBD	Bakpharm Website
Pulse oximeter	TBD	TBD	HealthSCOPE Healthcare	TBD	Healthscope Healthcare Website
Pulse oximeter	TBD	TBD	Monks Medicare Africa Ltd.	TBD	Monks Medicare Africa Ltd. Website
Pulse oximeter	TBD	TBD	Total Hospital Solutions	TBD	Total Hospital Solutions Website
Pulse oximeter	South Korea	TRISMED	TBD	TBD	TRISMED Website
Pulse oximeter	UK	ViaMed	Pulse Healthcare Limited	ViaMed-2101 Fingertip Pulse Oximeter	Interview With Pulse Healthcare Limited/Website
Pulse oximeter	UK	ViaMed	Pulse Healthcare Limited	ViaMed-2105 Fingertip Pulse Oximeter	Interview With Pulse Healthcare Limited/Website

Device	Country of origin	Company name	Registered local supplier	Model	Source
Pulse oximeter	UK	ViaMed	Pulse Healthcare Limited	ViaMed-2160 Hand Held Pulse Oximeter	Interview With Pulse Healthcare Limited/Website

Abbreviations: ICU, intensive care unit; TBD, to be determined; UK, United Kingdom; USA, United States of America.

Appendix C. Summary of oxygen plants

This summary of existing oxygen generation plants is based on preliminary research and is not considered exhaustive or reflective of all of Kenya.

COUNTY (LISTED FROM THE HIGHEST TO THE LOWEST IN POPULATION)	POPULATION CENSUS (2009)	COUNTY FACILITY/FACILITIES	OXYGEN PLANT (#)	LOCATION	CAPACITY	NOTES
Nairobi	3,138,369	Pumwani Maternity Hospital	Yes	Unknown	250 LPM	--
		Kenyatta National Hospital	Yes	Unknown	2,500 LPM	More than 20 years old. Currently out of service.
		Mama Lucy Kibaki	Planned	Unknown	Unknown	--
Kakamega	1,660,651	Kakamega Provincial General Hospital	Yes (2)	ICU (MES) Multiple (operating theater, HDU, and the children's ward	90 LPM 69 LPM	--
Kiambu	1,623,282	Thika Level 5 Hospital	Yes	ICU (MES)	Unknown	--
Nakuru	1,603,325	Nakuru Provincial General Hospital	Yes (3)	ICU (MES) Operating theater Multiple (planned)	85 LPM 95 LPM Unknown	--
Bungoma	1,375,063	Bungoma County Referral Hospital	Yes	Operating theater	20 LPM	--
Meru	1,356,301	Meru Level 5 Hospital	Yes (2)	ICU (MES) Unknown	90 LPM 69 LPM	--
Kisii	1,152,282	Kisii Level 5 Hospital	Yes (2)	ICU (MES) (planned) Multiple	80 LPM 150 LPM	Plant installation cost of KSh 22 million. The hospital previously spent KSh 1.2 million/month for oxygen.
Kilifi	1,109,735	Kilifi County Referral Hospital	Recently acquired	Unknown	The capacity is not known yet. Once installed, this will be known.	Not installed. Housing is currently being built.
Machakos	1,098,584	Machakos Level 5 Hospital	Yes	ICU (MES)	92 LPM	Oxygen plant has been delivered. Awaiting installation and pipe work;

						plans to equip the theaters and all wards with piped oxygen and also generate oxygen to other facilities.
Mandera	1,025,756	Mandera County Referral Hospital	Yes	Unknown	Unknown	Not operational. Staff requires training.
Kitui	1,012,709	Kitui County Referral Hospital	Yes	Planned	Unknown	--
Kisumu	968,909	Jaramogi Oginga Odinda Teaching and Referral Hospital	Yes (2)	ICU (MES) Serves several departments	80 LPM 1,000 LPM	--
Homa Bay	963,794	Homa Bay County Referral Hospital	Yes	Unknown	280 LPM	Oxygen plant installed but awaiting commissioning.
Murang'a	942,581	Murang'a County Referral Hospital	Yes	Unknown	69 LPM	--
Mombasa	939,370	Coast Provincial General Hospital	Yes (2)	ICU (MES) Serves pediatric, theater, and casualty department	80 LPM Unknown	--
Migori	917,170	Migori County Referral Hospital	Yes	--	8 LPM	Information obtained from website.
Uasin Gishu	894,179	Moi Teaching and Referral Hospital	Yes	Unknown	Unknown	--
Makueni	884,527	Makueni County Referral Hospital	Yes	Unknown	Unknown	Seen on the Deputy Governor's face book page on January 22, 2017.
Turkana	855,399	Lodwar County & Referral Hospital	Yes	Unknown	Unknown	--
Narok	850,920	Transmara County Referral Hospital	Yes	--	8 LPM	Information obtained from website.
Siaya	842,304	Siaya County Referral Hospital	Yes	Serves multiple departments	900 LPM	Hewa Tele plant.
Trans-Nzoia	818,757	Kitale County Referral Hospital	Planned	TBD	TBD	Tender for the supply, installation and commissioning of oxygen generating plant, March 24, 2016.
Nandi	752,965	Nandi Hills County Referral Hospital	No data	--	--	--
Kericho	752,396	Kericho County Referral Hospital	No data	--	--	--
Busia	743,946	Busia County Referral Hospital	Yes (2)	Operating theater	Unknown	Plan to sell oxygen to private-sector facilities.

				Maternity ward		
Bomet	730,129	Longisa County Referral Hospital	Yes (2)	Serves inpatient, theater, maternity, NBU, and renal departments ICU is not yet functioning	1,000 LPM 160 LPM	--
Nyeri	693,558	Nyeri Provincial General Hospital	Yes (2)	ICU (MES) Unknown	90 LPM 230 LPM	--
Kajiado	687,312	Kajiado County Referral Hospital	No data	--	--	--
Wajir	661,941	Wajir County Referral Hospital	Planned	TBD	TBD	Wajir County construction tenders 2016.
Kwale	649,931	Kinango Hospital	Yes	Unknown	Unknown	--
Garissa	623,060	Garissa Provincial General Hospital	Yes	ICU (MES)	80 LPM	--
Nyamira	598,252	Nyamira County Referral Hospital	No data	--	--	--
Nyandarua	596,268	Nyahururu County Referral Hospital	Yes	--	69 LPM	--
Baringo	555,561	Kabarnet County Referral Hospital	Planned	Unknown	Unknown	--
Vihiga	554,622	Vihiga County Referral Hospital	Yes	Unknown	Unknown	Procured using county funds.
Kirinyaga	528,054	Kerugoya County Referral Hospital	Yes	Unknown	Unknown	Tender for the supply, installation, and commissioning of oxygen generating plant, October 27, 2016.
Embu	516,212	Embu Provincial General Hospital	Planned	Multiple ICU (MES)	Able to fill 15 "H" cylinders/day Unknown	Will produce enough to supply the level 4 hospitals in the county—*The Star*, June 22, 2015.
West Pokot	512,690	Kapenguria County Referral Hospital	Planned	TBD	TBD	West Pokot County construction tenders 2016.
Laikipia	399,227	Nanyuki DH	Yes	--	80 LPM	Able to provide oxygen therapy to about 20 patients concurrently.

Elgeyo- Marakwet District	369,998	Chebiemit DH	Planned	TBD	TBD	--
Tharaka Nithi	365,330	Chuka DH	No data	--	--	--
Marsabit	291,166	Marsabit DH/Moyale DH	No data	--	--	--
Taita-Taveta	284,657	Wesu DH	No data	--	--	--
Tana River	240,075	Hola DH	No data	--	--	--
Samburu	223,947	Maralal DH	No data	--	--	--
Isiolo	143,292	Isiolo DH	Yes	Produces 2,300 liters/ week		Saves the county KSh 100,000.
Lamu	101,539	Mpeketoni DH	Planned	TBD	TBD	Invitation for prequalification from suppliers for repairs and servicing of their oxygen plant and 110KVA generator; closing date June 24, 2016.

Abbreviations: BOC, British Oxygen Company; DH, District Hospital; HDU, high dependency unit; ICU, intensive care unit; LPM, liter per minute; MES, Managed Equipment Services; MOH, Ministry of Health; NBU, Newborn unit.

References

[1] Prien T, Meineke I, Zuchner K, Boanta A, Rathgeber J. Oxygen 93: A new option for European hospitals. *British Journal of Anaesthesia*. 2014;113(5):886–887. doi:10.1093/bja/aeu359.

[2] Government of Kenya Medical Engineering and Technologies Unit. Unpublished report. 2000.

[3] Ministry of Health (MOH) of the Republic of Kenya. *National Guidelines on Essential Newborn Care.* Nairobi: Government of Kenya; 2015.

[4] Ministry of Health (MOH) of the Republic of Kenya. *Basic Pediatric Protocols for Ages up to 5 Years.* Nairobi: Government of Kenya; 2016.

[5] Ministry of Health (MOH) of the Republic of Kenya. *Standards for Maternal Care in Kenya*. Nairobi: Government of Kenya; 2002.

[6] Government of Kenya. *Kenya Health Sector Strategic and Investment Plan 2014–2018*. Nairobi: Government of Kenya; June 2014:25.

[7] Ministry of Health (MOH) of the Republic of Kenya. *Kenya Essential Medicines List 2016.* Nairobi: MOH; 2016.

[8] PATH. *Medicines Regulation in the East African Community*. Seattle: PATH; 2016. Available at www.path.org/publications/files/APP_eac_reg_summary.pdf.

[9] Ministry of Health (MOH) of the Republic of Kenya. *Health Sector Human Resources Strategy 2014–2018*. Nairobi: MOH; 2014. Available at http://www.health.go.ke/wp-content/uploads/2016/04/Kenya-HRH-Strategy-2014-2018.pdf.

[10] National Treasury of Kenya. *Kenya Budget Highlights 2016–2017*. Nairobi: National Treasury of Kenya; 2016.

[11] Ministry of Health (MOH) of the Republic of Kenya. *National and County Health Budget Analysis, FY 2016/17*. Nairobi: MOH.