The Federal Democratic Republic of Ethiopia
Ministry of Health

National Medical Oxygen and Pulse Oximetry Scale Up Road Map (2016-2020/21)

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Foreword

Hypoxemia, below normal level of oxygen in tissue, is commonly associated with mortality in developing countries, yet feasible and cost effective ways to address hypoxemia receive little or no attention in current global health strategies. Oxygen treatment has been used in medicine for almost 100 years, but in developing countries like Ethiopia, most seriously ill newborns, children and adults do not have access to oxygen or the simple test that can detect hypoxemia. The cost-effectiveness of an oxygen systems strategy compares favorably with other higher profile child survival interventions, such as new vaccines. In addition to its use in treating acute respiratory illness, oxygen treatment is required for the optimal management of many other conditions in adults and children, and is essential for safe surgery, anesthesia and obstetric care.

There have been multiple initiatives by the FMoH and RHBs to improve oxygen facilities, including procurement and distribution of cylinders to health centers and more recently, establishment of oxygen plants in some referral hospitals. Despite the efforts, the majority of health facilities, health centers in particular, in Ethiopia have limited availability and functionality of oxygen and pulse oximeters. Limitations in supply chain systems and logistics, poor maintenance and spare parts availability, huge demand for oxygen with compared to very few number of oxygen plants, low health care workers awareness as well as the unreliability of grid power limits the functionality of oxygen concentrators, cylinders and pulse oximeters.

The FMOH recognizes these existing challenges and the need to develop a comprehensive road map for ensuring accelerating access to Oxygen supply and Pulse oximeter at different levels of health care system that considers the local context and health system capacity. This road map is developed as part of realizing the ambitious targets of Health Sector Transformation Plan (HSTP) and related program strategies including Maternal, Newborn/Child health and safe surgery efforts with focus on quality and equity of health service, in particular.

Hence, this roadmap is intended to guide scale-up of oxygen/Pulse oximeter as well as standardize the need for comprehensive approach at program management and implementation levels throughout Ethiopia. The road map will serve as an implementation framework, resource mobilization and guide subsequent development of necessary implementation tools including guidelines, standard operating procedures and technology specifications and standardizations considering local resource settings.

The FMOH urges all care providers and implementing partners to focus and refer this road map during resource mobilization and implementation efforts.

Kebede Worku, MD, MPH

State Minister of Health,
Federal Democratic Republic of Ethiopia

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Result for Development Institute

Save The Children International

PATH

UNICEF

USAID

Assist International

Ayder Referral hospital/Mekelle University

St Paul's Millennium Medical college referral hospital

Gonder University hospital

Chora Medical Gas Plc

Adama General Hospital Plc

Centre for International Child Health, University of Melbourne

Bill and Melinda Gates Foundation

Acronyms

ARI	Acute Respiratory Infection
ARDS	Adult Respiratory Distress Syndrome
BEmOC	Basic Emergency Obstetric Care
CEmOC	Comprehensive Emergency obstetric Care
CPAP	Continuous positive airway pressure machine
CSA	Central Statistics Agency
DTC	Drug and Therapeutic Committee
ED	Emergency department
EDHS	Ethiopian Demographic Health Survey
FHB	Fetal Heart Beat
FMoH	Federal Ministry of Health
GTD	Gestational Trophoblastic Disease
HC	Health Center
HMIS	Health Management Information System
HP	Health Post
HSDP	Health Sector Development Plan
HSTP	Health Sector Transformation Plan
ICU	Intensive Care Unit
IMCI	Integrated Management of Childhood illness
IPD	Inpatient Pediatric Department
IPLS	Integrated pharmaceutical and logistics management System
MCHD	Maternal and Child Health Directorate
MDG	Millennium Development Goal
MDSR	Maternal Death Surveillance & Response
MSD	Medical Service Directorate
NICU	Neonatal Intensive Care Unit
NRFHR	Non Reassuring Fetal heart rate
PFSA	Pharmaceuticals Fund and Supply Agency
PHCU	Primary Health Care Unit
PLMU	Pharmaceutical Logistics Management Unit
POP	Pelvic Organs Prolapse
RDF	Revolving Drug Fund
RHB	Regional Health Bureau
RMNCAH	Reproductive, Maternal, Neonatal, Child, Adolescent Health
SOP	Standard Operating Procedures
U5MR	Under-Five Mortality Rate
UN	United Nations
WHO	World Health Organization

Executive Summary

The ability to detect and treat hypoxemia is critical to patient care in all medical care units and ensures quality of services, especially for children and neonates and oxygen should be available in all hospitals and many Health Centers. Oxygen is vital to combat pneumonia and neonatal related under five children mortality and morbidity, for treatment of many obstetric emergencies, including cardiac arrest, acute blood loss, shock, dyspnea (breathlessness), pulmonary edema, unconsciousness, convulsions (eclampsia), and fetal distress during labor. There are three main models for oxygen supply: cylinders, concentrators and oxygen generators.

There have been multiple initiatives by the FMoH and RHBs to improve oxygen facilities, including procurement and distribution of cylinders to health centers and more recently, establishment of oxygen plants in some referral hospitals. Despite the efforts, the majority of health facilities, health centers in particular, in Ethiopia have limited availability and functionality of oxygen and pulse oximeters. Oxygen concentrators and cylinders are the main form of oxygen supply in Ethiopia. However, limitations in supply chain systems and logistics, poor maintenance and spare parts availability, huge demand for oxygen with compared to very few number of oxygen plant, low health care workers awareness as well as the unreliability of grid power limits the functionality of oxygen concentrators, cylinders and pulse oximeters. Only very few number of teaching hospitals have or are going to establish oxygen plant for their own consumption.

In a 2016 baseline assessment conducted by FMOH/PFSA/CHAI, a very small amount of health centers manage oxygen (11%), with even fewer (2%) maintaining a functional cylinder or concentrator. At the hospital level, most hospitals reported that they managed oxygen and had a functional cylinder or concentrator available. However, only 62% had sufficiently equipped or filled oxygen devices in the pediatrics IPD, and fewer had pulse oximeters available (45%).Furthermore, lack of clear and optimal policies and guidelines, standard operating procedures/job aids and limited financing system contribute to low levels of availability and utilization as it was identified in the FMOH/CHAI/PFSA baseline assessment, providing oxygen therapy at service delivery points. There is a need to assign well-trained bio-medical engineers who can provide preventive and treatment maintenance service at service delivery points.

Improving access to oxygen and pulse oximetry has demonstrated a reduction in mortality from childhood pneumonia by up to 35% in high-burden child pneumonia settings. The cost-effectiveness of an oxygen systems strategy compares favorably with other higher profile child survival interventions, such as new vaccines.

The 2015-2020 FMoH health sector transformation plan has set ambitious goal to improve equity, coverage and utilization of essential health services, improve quality of health care, and enhance the implementation capacity of the health sector at all levels of the system. Addressing maternal and child health mortality drivers will continue to be a top priority as a part of Reproductive, maternal, newborn, child, adolescent health and nutrition over the next 5 years in the HSTP. Furthermore, the FMoH launched the 2015-2020 National Newborn and Child Survival Strategy with ambitious morbidity and mortality reduction targets where oxygen scale up will be important in meeting the targets and its roll out should ensure regular availability and functionality. The FMoH is significantly expanding newborn

corners/NICUs which require sustainable oxygen supply. Referral sites using CPAP interface to manage complications of prematurity are rapidly expanding where FMoH has recently procured 875 CPAP machines to be used in more than 180 hospitals and these need regular external oxygen supply system.

Thus, building on its many successful initiatives and other experiences, the FMoH wants to dramatically improve oxygen availability in health facilities with focus on maternal and child health, which will help the FMoH to replicate in other programs as well. This requires a road map with long term multi-year plan that guides the concept and roll out comprehensively. Hence, intensively working at different levels on the following six major areas could be anticipated with high return of investment in saving life: (1) setting policy basis at higher level, coordination and decision support to health facilities to scale up oxygen supply, (2) designing, setting up and rollout of supply chain system and logistics to ensure sustainable oxygen supply. (3) ensuring sustainable supplies for hypoxemia diagnostics and related consumables at service delivery points, (4) establish a mechanism for maintenance of oxygen equipment, and supply of spare parts (5) instituting a system for building a capacity of health care workers in health facilities on supply chain management, utilization and basic maintenance skill of oxygen equipment and (6) ensuring sustainable financing to support oxygen supply system.

This roadmap generally will focus on scale up of oxygen concentrators in both health center and hospital level and establishment of 13 oxygen plants in different region as well as pulse oximeter scale up at all levels. With this scenario, the initial investments could cost $~50Million with annual running cost of 7million by 2021 and it requires well designed implementation plan with phased based approaches for the scale up.

1. Introduction

1.1 Newborn and Child Health in Ethiopia

Ethiopia is the second most populous country in Africa with a total population of more than 95 million, of which more than 83% live in rural areas. Ethiopia's population is young, with 45% of the population under the age of 15 and 14.6% (13.2 million) under the age of 5. Health and health services have improved significantly in Ethiopia since 2000, despite Ethiopia remaining a low-income country.

The national 2015-2020 Health Sector Transformation Plan, a part of Ethiopia's second growth and transformation plan (GTPII), has set ambitious goals to improve equity, coverage and utilization of essential health services, improve quality of health care, and enhance the implementation capacity of the health sector at all levels of the system. Reproductive, maternal, newborn, child, adolescent health and nutrition will continue to be top priority for the next 5 years.

The national health delivery is a three-tier system which is characterized by a first level of a Woreda/District health system comprising a primary hospital (with population coverage of 60,000-100,000 people), health centers (1/15,000-25,000 population) and their satellite health posts (1/3,000-5,000 population) that are connected to each other by a referral system. A primary hospital, health center and health posts form a Primary Health Care Unit (PHCU), with each health center having five satellite health posts. The second level in the tier is a general hospital with population coverage of 1-1.5 million people; and the third a specialized hospital that covers population of 3.5-5 million. There is a rapid expansion of facilities, where about 349 hospitals and 3,600 health centers are expected to be functional by end of 2016.

Within this health system and program, one of the major focuses is the maternal and child health services where significant achievements have been made in improving access during implementation of HSDP-IV in particular. In Ethiopia, the under-five mortality rate has declined by two thirds - from 204/1,000 live births in 1990 to 68/1,000 in 2012 - thus meeting Millennium Development Goal 4 (MDG 4) on Child Survival three years ahead of time. However, the mortality reduction was not uniform across the different childhood age groups, geographic and socio-demographic population groups.

Despite this success in reducing under-five mortality rates in Ethiopia, there is still an estimated 196,000 (UN-IGME, 2014) children who are dying each year. There is wide regional variation in mortality with U5MRs ranging from as low as 53 in the capital city of Addis Ababa to as high as 169 in Benishangul-Gumuz and 127 in Afar, the two developing regional states of the country (CSA, 2011).Over two-thirds of childhood deaths in Ethiopia are caused by a limited number of easily preventable conditions; mainly infections, neonatal conditions and malnutrition. The major top five direct causes of under-five mortality, based on the 2014 WHO/CHERG estimates are pneumonia (18%), diarrhea (9%), prematurity (11%), newborn infection (9%) and asphyxia (14%).

To achieve significant reduction in child mortality, it is important to give due emphasis to child health problems that are readily preventable or treatable with proven, cost-effective interventions that can significantly contribute to the reduction of under-five mortality by 2020 and beyond. Toward this, the government has brought maternal, newborn and child health as priority political agenda and maintained its commitment to improving the health and survival of women and children in the country. This has been demonstrated by massively expanding access to and utilization of key health care services through HEP, the government's flagship program, and the expansion of primary and secondary level health care through accelerated expansion of health centers and hospitals throughout the country. The country also managed to equip a large proportion of these facilities with basic equipment and supplies along with staffing them with trained health workforce who can run the facilities.

To build on the successes while addressing these challenges, the Federal Ministry of Health (FMoH) formulated an ambitious National Newborn and Child Survival Strategy (2015/16-2019/20) with the goal of reducing under five mortality from 64/1,000 (2013) to 29/1,000 by 2020; the infant mortality rate from 44/1000 to 20/1000; and the neonatal mortality rate from 28/1,000 to 11/1,000.

Furthermore, to address Newborn and Pneumonia related deaths specifically, and further reduce the mortality, development of an *Oxygen Road Map*, to guide the national implementation of an oxygen supply system, will be important. This road map will be focus on access, oxygen supply system (logistics and infrastructure), HR/ biomedical services, diagnostic availability and related systems.

1.2 Oxygen Therapy and Child Health

Every year, 5.9 million children die mostly from preventable or treatable diseases, and more than 95% of these deaths occur in developing countries (WHO 2015). Pneumonia is the leading cause of death in children under 5 years of age, and is responsible for an estimated 18% of all deaths in this age category (WHO, 2015).

Hypoxemia (insufficient oxygen in the blood) is a major fatal complication of pneumonia, and the risk of death increases with increasing severity of hypoxemia. In a recent systematic review of more than 16,000 children with acute pneumonia or other lower respiratory tract infections, the median hypoxemia prevalence of children with severe pneumonia requiring hospitalization was 13.3% (interquartile range of studies 9.3–37.5%)[1]. On the basis of an estimated 11–20 million children admitted to hospital with pneumonia each year, this corresponds to 1.5–2.7 million cases of hypoxemic pneumonia presenting to health facilities; countless more do not make it to the health facilities. A further 23% of the 5.9 million annual child deaths result from neonatal conditions such as birth asphyxia, sepsis and low birth weight, all of which can lead to hypoxemia[2]. These add to the substantial burden of hypoxemia, especially in developing countries including Ethiopia. Thus, the ability to detect and treat hypoxemia from pneumonia and LRTIs as well as neonatal condition is critical in children and neonates and oxygen should be available in all hospitals and HCs.

Improving access to oxygen and pulse oximetry has demonstrated a reduction in mortality from childhood pneumonia by up to 35% in high-burden child pneumonia settings[3]. The cost-effectiveness of an oxygen systems strategy compares favorably with other higher profile child survival interventions, such as new vaccines.

[1]Subhi R, Adamson M, Campbell H, et al.The prevalence of hypoxaemia among ill children in developing countries. Lancet Infect Dis. 2009;9
[2] Oxygen Therapy in Children, World Health Organization
[3]T.Duke et el, Oxygen is an essential medicine: a call for international action: Int J Tuberc Lung Dis. 2010 Nov; 14(11): 1362–1368.

Oxygen is included on the World Health Organization (WHO) list of essential medicines. In its guidelines, the WHO emphasizes the importance of oxygen within the necessary package of providing care for seriously ill children, and for emergency, anesthesia and surgical services.

Administration of oxygen at the point of care requires a source, such as an oxygen concentrator or cylinder, and equipment for delivery, such as tubing, face mask or nasal prongs. Oxygen concentrators provide the most consistent and least expensive source of oxygen in health facilities where power supplies are reliable. Oxygen concentrators are sustainable in developing country settings if a systematic approach in its management involving nurses, doctors, technicians and administrators is adopted. Although this treatment is a basic requirement to save the lives of seriously ill patients, oxygen is rarely available in health centers and is often lacking in primary hospitals in developing countries like Ethiopia. Health authorities should ensure that oxygen equipment is available and included in their health planning budget for any health facility where seriously ill patients may present. There is also a need to address systems for oxygen delivery as one of the vital health commodities at country's program level through focusing on policy level, technology selection and integrating with the existing systems at service delivery points for its supply chain management and rational use.

Several studies and experiences from other countries have shown that it is possible to improve oxygen supply and therapy in resource-limited settings given appropriate support for training on case management and maintenance of equipment: In Egypt, oxygen concentrators were successfully introduced into small hospitals[4]. In Papua New Guinea, pneumonia mortality decreased by 35% after the introduction of an improved oxygen system. In Malawi, introduction of oxygen concentrators in all district hospitals saw a fall in pneumonia case fatality rates from 18.6% to 8.4% of total admitted pneumonia patients[5]. While most research on hypoxemia has been in pediatric pneumonia, the positive impact of (targeted) oxygen therapy for neonatal conditions and in trauma and surgery patients of all age groups is widely accepted. For Ethiopia, it is critical that the threshold for giving oxygen is lower at a higher altitude. Severe pneumonia can progress more quickly to severe hypoxemia, so it is more likely that oxygen would be required (WHO 2015).

As pulse oximetry is the most accurate non-invasive method for detecting hypoxemia, oxygen saturation should be checked by pulse oximetry in all breathless and acutely ill patients, urgent blood gas analysis should be undertaken when necessary. The inspired oxygen concentration should be recorded on the observation chart with the oximetry result. It is used to measure the percentage of oxygenated hemoglobin in arterial blood (SpO2).As not all patients with signs associated with hypoxemia (such as the inability to drink in children) will have hypoxemia, the use of oximetry can also reduce unnecessary oxygen use. A highly cost-effective intervention in facilities that care for large numbers of children with acute respiratory disease, pulse oximetry technology is robust and becoming increasingly affordable as the price of oximeters decreases. The reliability, durability and replacement costs of oximeter sensors has been a limiting factor in pulse oximetry being sustained as a clinical tool in resource-poor health facilities, but there are now many examples of achieving sustainability and measuring effect on clinical outcomes. The WHO in its recent guidelines for oxygen therapy in children recommends performing pulse oximetry in patients with respiratory illness, emergency signs or any sign of hypoxemia.

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[4]T Duke et al, An evaluation of oxygen systems for treatment of childhood pneumonia: BMC Public Health. 2011; 11(Suppl 3): S28
[5]Enarson et al, Development and Implementation of a National Programme for the Management of Severe and Very Severe Pneumonia in Children in Malawi.

1.3 Benefit of Oxygen in Obstetrics and Gynecology

The female population accounts in slightly more than half of the population and 23.4 % of the population account to men of reproductive age group. Nearly 3.4 million births occur each year. The most recent UN estimate of 2015 shows a maternal mortality ratio of 353 per 100,000 livebirths in Ethiopia. The 2007 Ethiopian Fiscal year HMIS report shows skilled birth at attendance of 60.7%. A marked improvement in expansion in hospitals and health centers and the health extension program in Ethiopia significantly shows an improved access and utilization to gynecology and obstetrics services. Though the WHO recommendation for cesarean section rate for any country to be between 5-15%, the Ethiopian cesarean section rate is around 3 %. The national reproductive health strategy for the period of 2015/16- 2020 plans to achieve a cesarean section rate of 8% by 2020. In the national fistula and pelvic organ prolapse elimination effort, the demand for surgeries would be huge as the backlog for fistula and POP is high. According to one study, the prevalence of obstetric fistula and POP in Ethiopia is 10 and 100 per 100,000 women of reproductive age respectively.

Oxygen in Obstetrics

The following conditions demand use of oxygen for saving the lives of the mother and newborn:

- NRFHR during labor and delivery
- Basic newborn resuscitation
- Obstetric shock including hemorrhagic, anaphylactic shock and septic shock
- Preeclampsia and eclampsia
- Cesarean section for different indications

At least one third of the fetus during in labor and delivery face some form of fetal heart abnormalities. As standard of practice, it is recommended to position the woman that increases uterine perfusion, hydration of the women and administration of oxygen to the mother to manage FHB abnormalities. The national MDSR data shows that 60% of maternal deaths due to hemorrhage. As component of management of shock in obstetrics, administration of oxygen of 6-8 liters using nasal prongs is mandatory. Other causes of shock other than hypovolemic shock need the use of oxygen too. Moreover, the MDSR data also shows that preeclampsia and eclampsia accounts to 12 % of review maternal deaths. Cases of eclampsia and/or severe preeclampsia with pulmonary edema or ARDS require the administration of pure oxygen. The target for cesarean section is more than double by 2020. Though, most cesarean sections (80 %) shall be done using spinal anesthesia, the demand for pure oxygen would be high. Moreover, due to epidemiologic transition, there would be more obstetric cases with non-communicable diseases that require the use of oxygen for such cases. Furthermore, tertiary hospitals require establishing an obstetric ICU to improve the quality of care decrease the case fatality rate. Therefore, the demand for oxygen in obstetrics is immense ranging from concentrator to pure oxygen.

Oxygen in Gynecology

Women in the reproductive age group of the population account to large share of the Ethiopian population size. This huge segment of the population is at risk of developing emergency gynecologic problems such as abortion & its complications, ectopic pregnancy and GTD and chronic gynecologic problems such as myoma, ovarian tumors, endometrial tumors, fistula and POP. The management of both emergency and chronic conditions requires surgical interventions. It is clear that surgery requires pure source of oxygen at the time of operation and post-surgery in the recovery or ICU unit. Therefore, many gynecologic conditions require oxygen source of supply to have good surgical outcomes to clients/patients.

1.4 Oxygen for Medical and Surgical Care

HYPOXAEMIA is a major cause of morbidity and mortality associated with acute and chronic lung disease in adults & can lead to death irrespective of age, sex, aetiology, geographic region or clinical presentation of a patient. The predominant causes of hypoxaemia in adults are chronic obstructive pulmonary disease, acute asthma and pneumonia. Hypoxaemia also occurs in clinical conditions like sepsis, shock, major trauma, anaphylaxis, acute heart failure, pulmonary embolism, pleural effusion, pneumothorax, lung fibrosis, carbon monoxide poisoning and surgical emergencies[1]. From surgical perspective, Oxygen is very important in operating theatres and anaesthesia procedures as well as during recovery periods in intensive care units.

Therefore to avert the morbidity and mortality related with hypoxaemia, Oxygen therapy will be a core requirement in the management of medical illnesses, safe surgery, anaesthesia and it is critical to ensure that health facilities have effective oxygen systems for the only drug with no alternative agent. Despite its importance in virtually all areas of acute severe illness, hypoxaemia is often not well recognised or managed in settings where resources are limited. Therefore for a timely identification, prevention and management of hypoxaemia; the presence of easier to use and reliable diagnostic modalities like pulse oximeter is highly important and contributes significantly to the quality of care. Pulse oximetry can ensure the most efficient use of oxygen therapy and monitor the response to treatment, which is especially important in resource-limited countries like Ethiopia. But to the contrary there is lack of policies and implementation strategies on the sustainable supply of pulse oximeter, oxygen systems and rational use of oxygen targeted for servicing the needs of all acute/chronic care disciplines and all age groups in Ethiopia.

Improving access to hypoxaemia detection and oxygen treatment should already be an undebatable priority to provide adequate oxygen across all hospitals & health centres and its benefits to the overall system should further boost support for broader availability. Programmes that emphasise the use of oxygen cylinders, concentrators and pulse oximetry are an entry point for improving the overall quality of health care.

Much of the evidence and experience on rational oxygen use comes from the care of sick children, because young children are affected disproportionately by hypoxaemia and most research on hypoxaemia has been in paediatrics. The principles, however, are equally relevant to setting up and managing services for adults; the use of oxygen in trauma and surgery is relevant to all age groups, and there is now increasing experience in managing hypoxemic illnesses in adults. In the United Kingdom (UK) approximately 34% of ambulance journeys involve oxygen use at some stage and national audit data suggest that 18% of hospital inpatients are being treated with oxygen at any given time[2]. Therefore the benefits of a functioning oxygen system cut across various programmes involving several disciplines: internal medicine, paediatrics, obstetrics, anaesthesia, surgery, trauma and burns. To implement and maintain oxygen concentrators requires strengthening of health systems and building capacity and collaboration among clinicians, administrators and technicians.

Training for clinicians across all services and technicians is also necessary for the implementation of an effective oxygen system. Clinical training should include indications for and how to give oxygen therapy, supportive care for seriously ill patients, screening and monitoring using pulse oximetry, and simple maintenance and cleaning of oxygen equipment.[3]

Therefore policies and strategies regarding the use of medical Oxygen should encompass all health care service outlets.

2. O2 Supply System Capacity & Structure in Ethiopia - A Situational Analysis

In the Ethiopian health system, pulse oximetry and oxygen use have been part of the national equipment list and emergency medicine list mainly available at hospital level. Health centers have been supplied with oxygen cylinders in the last three years, but functionality has been an issue since refilling is a critical challenge.

Furthermore, the FMoH Ethiopian Hospitals Reform Implementation Guide (EHRIG), having thirteen service areas and pioneering implementation reform to improve quality curative and rehabilitative service provision in hospitals, improving oxygen availability has been a key focus under its facility management (Chapter 8) stated as *Oxygen Availabilities and Patient Safeties.* However, *implementation* remains a major challenge.

In Ethiopia, there are no systemic studies that have been conducted around barriers to an oxygen supply system, but a recent 2015 Master's Thesis by Girma Lemma in tertiary and referral hospitals in Addis Ababa showed that there is a clear knowledge, attitude and practice gap among nurses who were working in Emergency Departments (ED). The possible associated factors were also identified, which includes lack of oxygen therapy training and guidelines, high workloads, and inadequate supply of oxygen and delivery devices[6]. It is recommended that nurses be given training on oxygen therapy and be updated. The national oxygen therapy guideline and Hospital protocol must also be developed. Oxygen supply and delivery devices should always be adequate and be used properly.

Taking the limited information exists in Ethiopian context, the Clinton Health Access Initiative (CHAI), in collaboration with the FMoH and PFSA, has recently conducted an oxygen and pulse oximetry availability and functionality assessment in more than 300 health centers and 110 hospitals as a part of its project baseline assessment. The key findings are presented below.

2.1 Oxygen Availability

Oxygen availability varied widely across regions, and between facility types (hospitals vs. health centers). As shown in the figures below, availability was generally higher at the hospital level. Concentrators appeared to be consistently more functional, although Amhara and Oromia health centers did not have

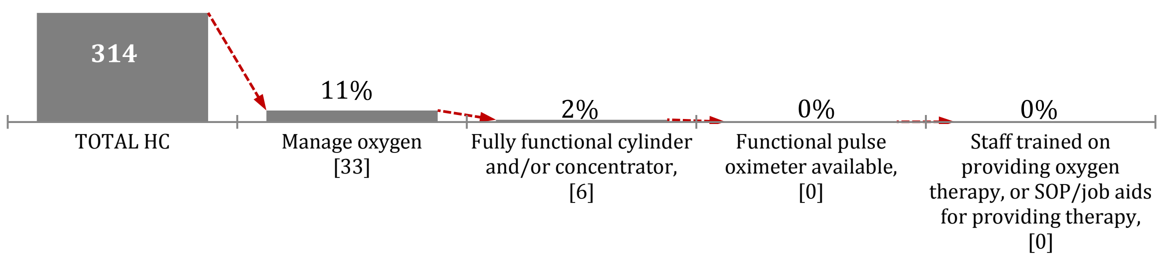
[6]Girma et al: Assessment of Nurses KAP about Oxygen Therapy at Emergency Departments in Addis Ababa hospitals , 2015

concentrators. From figures below, knowledge and training on the proper management of oxygen was shown as a critical gap at both the hospital and health center level.

As assessment findings, although about 262 (83%) of health centers and 106 (96%) of hospitals are connected to the central electrical supply, over 90% of both HCs and hospitals report having power interruptions of at least two hours in the last week. 45% of HCs and 95% of hospitals have alternative sources of power.

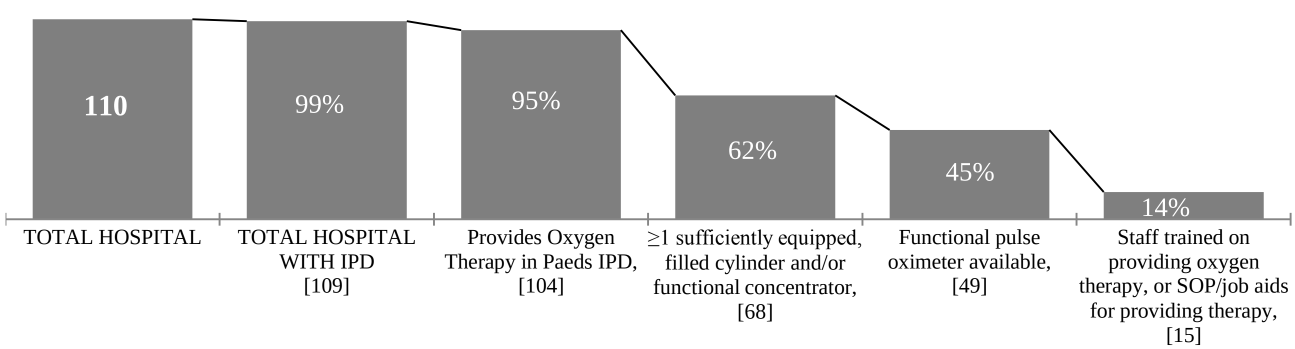
At the health center level, a very small amount of health centers manage oxygen (11%), with even fewer maintaining a functional cylinder or concentrator. Staff members were generally untrained on providing oxygen therapy and health centers lacked SOPs/job aids for providing oxygen therapy (Figure 1 below).

Figure 1: Overall Oxygen Availability, Health Centers



At the hospital level, most hospitals reported that they managed oxygen and had a functional cylinder or concentrator available. However, only 62% had sufficiently equipped or filled oxygen devices in the pediatrics IPD, and fewer had pulse oximeters available (45%). Finally, only 15 of the 109 hospitals had a staff member who had been trained on providing oxygen therapy or had SOPs/job aids available for providing the therapy (Figure 2).

Figure 2: Overall Oxygen Availability at Hospitals (Pediatric, IPD)



Furthermore, having an appropriate supply monitoring practice and timely refilling system is critical at the facility level. However, from Table 1 below, only 3% of health centers and 26% of hospitals have regular practice of oxygen consumption and stock monitoring mechanism, while 9% of health centers and 47% of hospitals think there are enough refilling sources for oxygen, which shows a need to expand supply base for oxygen supply both for health centers and hospitals. Except one hospital already functioning, and a few others under construction, there is no public oxygen refiling center. The few private medical & non-medical oxygen suppliers are located in Addis Ababa, in which accessibility is one of the critical challenges so far observed; some health facilities are supposed to travel more than 800km for refilling.

While there are no biomedical technicians at the health center level that can perform maintenance on oxygen equipment currently, the relatively higher proportion (41%) at hospitals with this expertise could help if new graduates who could be assigned at zonal health department in consideration of the workload as incase of Oromia region for quick experience of maintenance in remaining hospitals and health centers.

Table 1: Other Key Issues with Current Oxygen Supply System

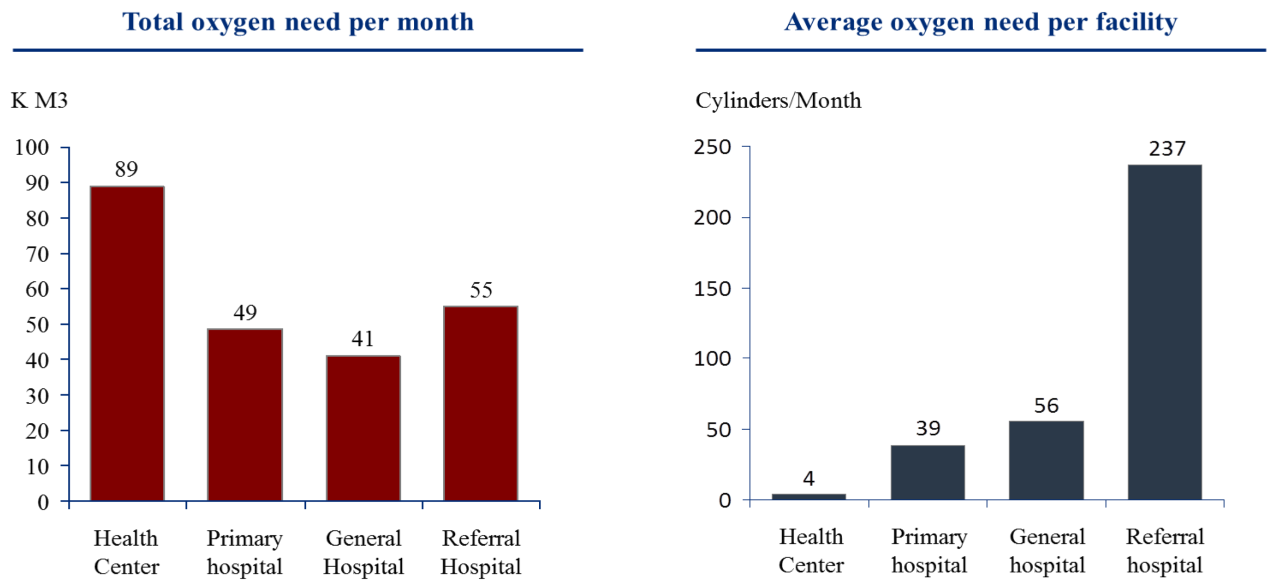
Issue	Facility	%
Proportion of facilities that have oxygen consumption and stock monitoring mechanism	Health center	3%
	Hospital	26%
Proportion of facilities that have trained biomedical engineers or technicians that can perform oxygen equipment maintenance	Health center	0%
	Hospital	41%
Proportion of facilities that have any SOP or job aid on how to provide oxygen therapy?	Health center	0%
	Hospital	8%
Proportion of facilities that think that there are enough re-filling sources as needed?	Health center	9%
	Hospital	47%
Types of oxygen therapy used at health centers?	Cylinder	7%
	Concentrator	2%
	Plant	0%
Types of oxygen therapy used at hospitals?	Cylinder	90%
	Concentrator	97%
	Plant	2%

From qualitative interventions, obtaining spare parts (e.g., flow regulators, good quality fuses, filters) are challenges for hospitals. Furthermore, there is a lack of manuals provided with the equipment. As a result, it is often unclear how best to maintain and repair the equipment which includes training or directions on the need to regularly clean filters.

National Medical Oxygen Demand

There are strong initiatives by the FMoH to expand oxygen supply at various levels, especially at the hospital level. Oxygen plants are being established in different referral hospitals in the country, while concentrators are being procured and distributed to hospitals. However, there is no regional or national level demand forecast available, which will be important in guiding expanding the service. Based on recent CHAI quantification exercise, at current occupancy, Ethiopia would need 234 K M3 per month (~1240 cylinders/day) by end of 2016 to fulfill its oxygen requirement with nearly 15% being driven by child/neonatal consumption while it might need close to 1 B liters per month (equivalent of ~4,700 large cylinders/day) to fulfill its oxygen requirement by FY 2020/21 with expected infrastructure expansion driven by primary hospitals as well as improved health service utilization.

Figure 3: Current estimated total oxygen need per month at different health care levels, end of 2016

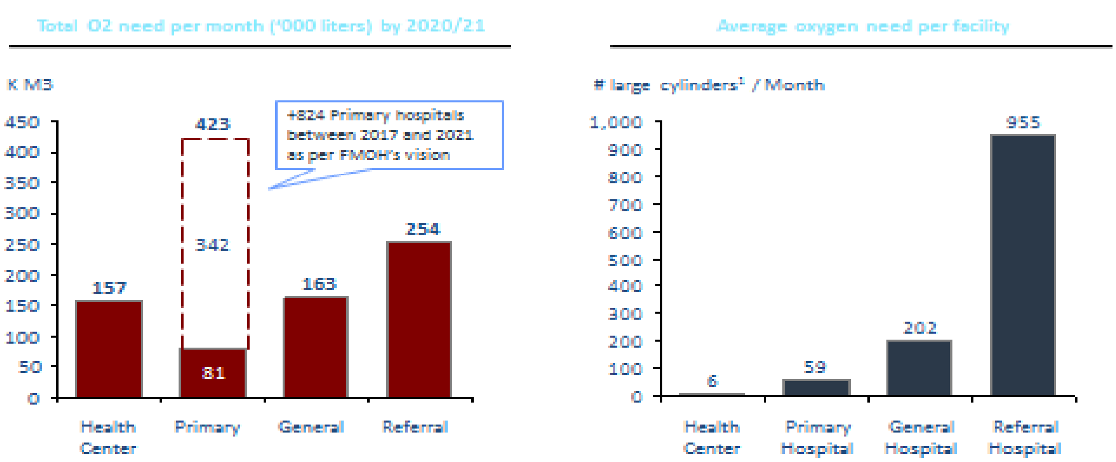


However, the current oxygen production is not adequate and plant distribution is concentrated in few areas as shown in Figure 5 below.

Furthermore, the oxygen demand will continue to increase significantly over next five years with more facilities to be built and starting providing service as shown in Figure 4 below.

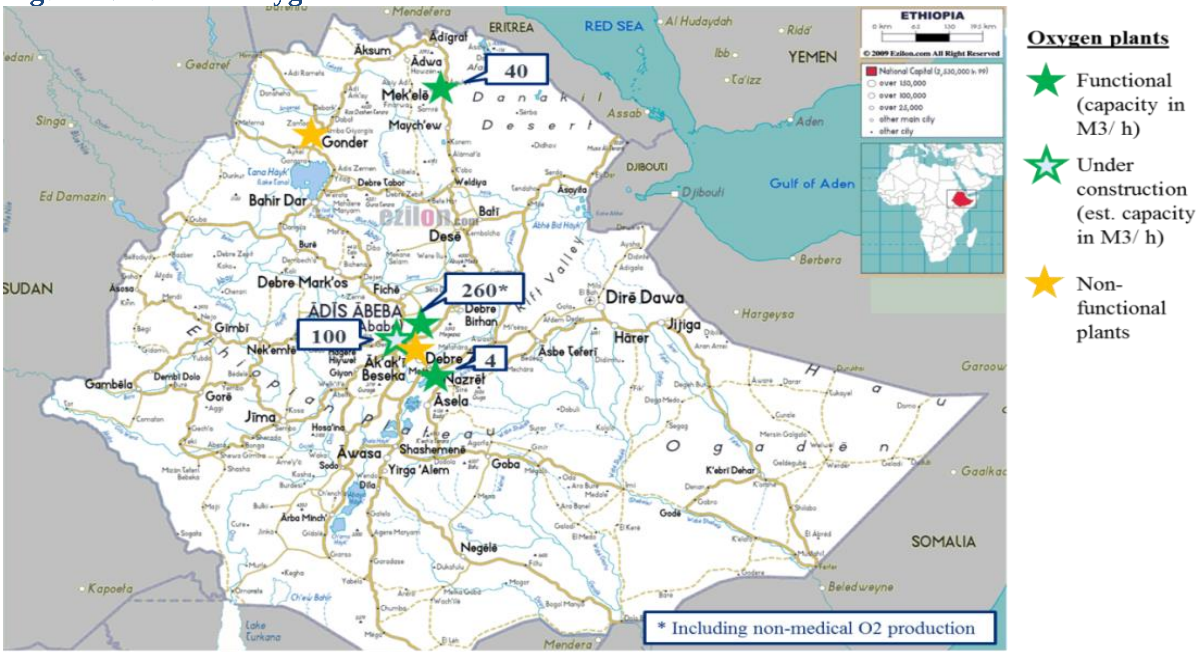
Figure 4: National Oxygen Demand at Various Level by 2020/21

With FMOH plan to achieve one primary hospital for ~100,000 population, there will be estimated ~825 newly built by 2020/21 which will drive oxygen consumption.



1: Large cylinders: 7,000 Liters (typical G-size cylinder)

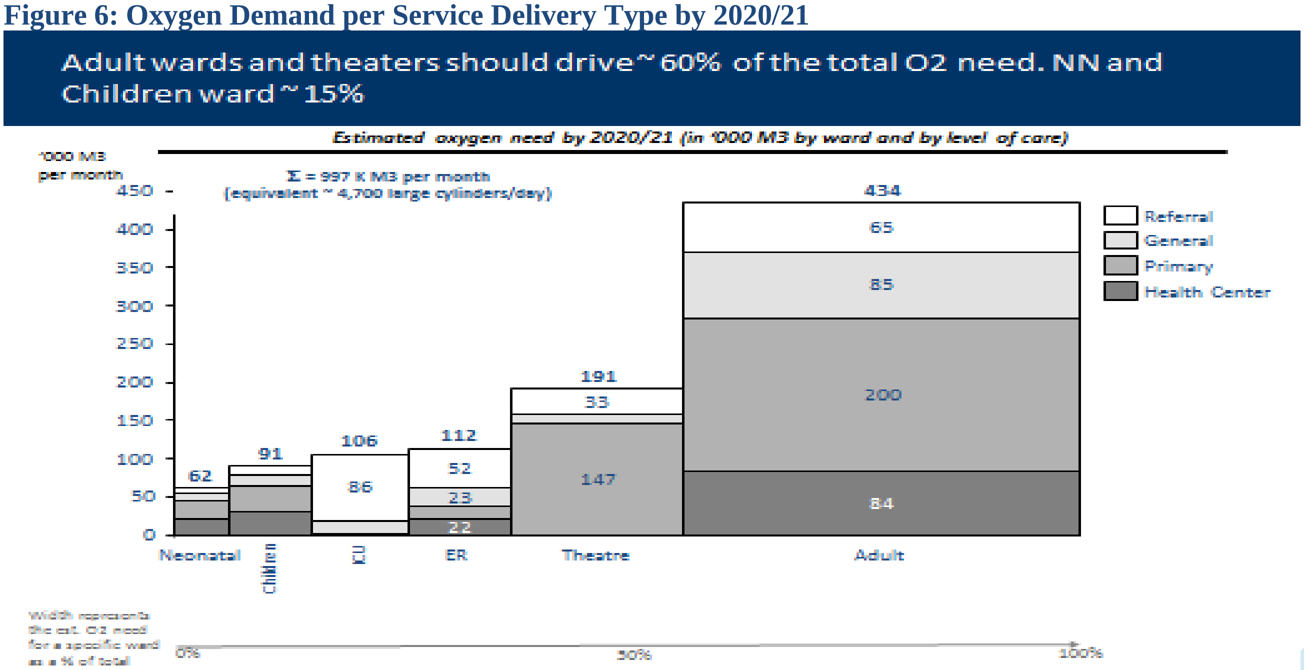
Figure 5: Current Oxygen Plant Location



Source: Interviews with key hospital directors and Chora Gas managers (March 2016)

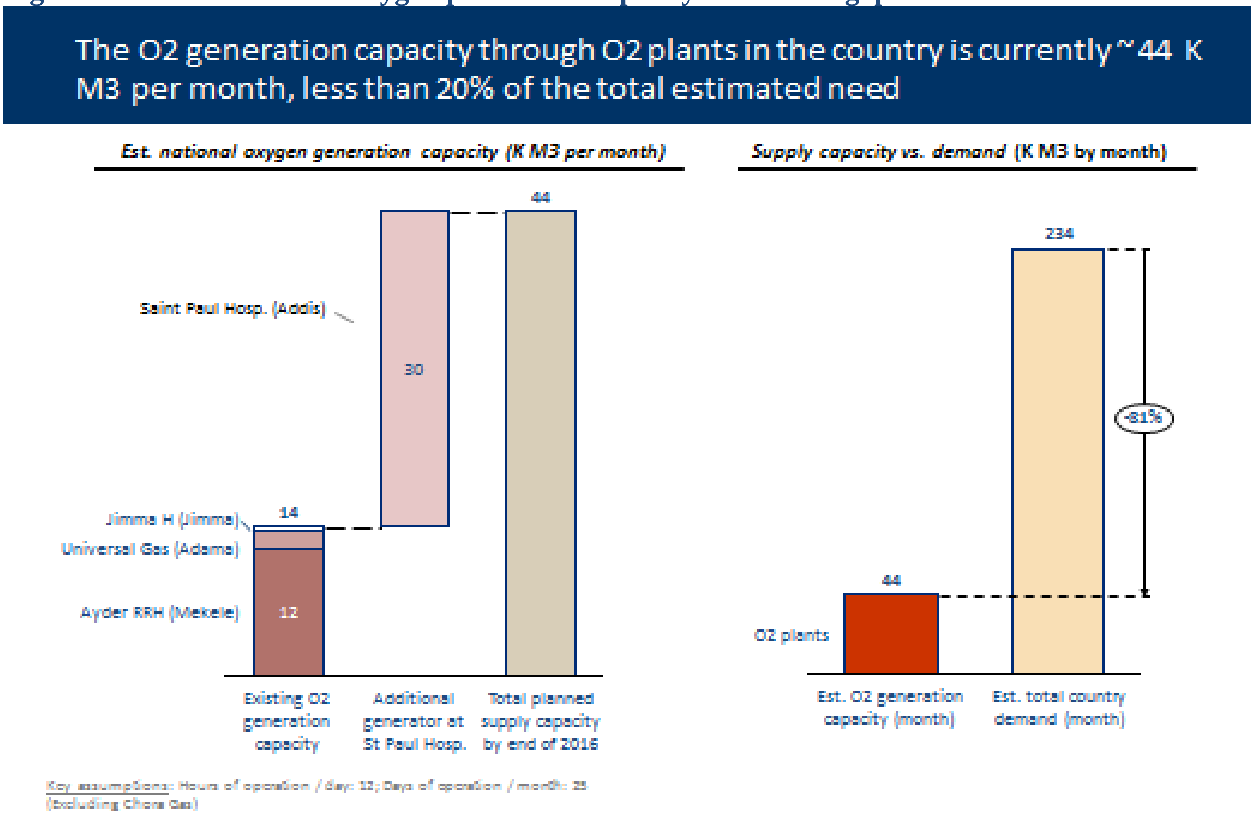
As shown in Figure 6 below, the overall national oxygen demand is driven by hospitals. The major consumption units are Intensive Care Units and Operating theaters, and therefore hospitals should drive ~84% of the total demand and ~80% of the need should be located in 4 regions: Oromia, Amhara, SNNPR and Tigray. The neonatal and child health demand will be around 15% of the total national oxygen demand by 2020.

Figure 6: Oxygen Demand per Service Delivery Type by 2020/21



There is a significant gap b/n current oxygen demand and supply with the gap continues to grow unless addressed in a planned way as in Figure 7 below.

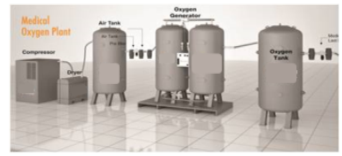
Figure 7: National current Oxygen production capacity Vs current gap



Oxygen Scale Up: Meeting the Demand through Optimized Supply System

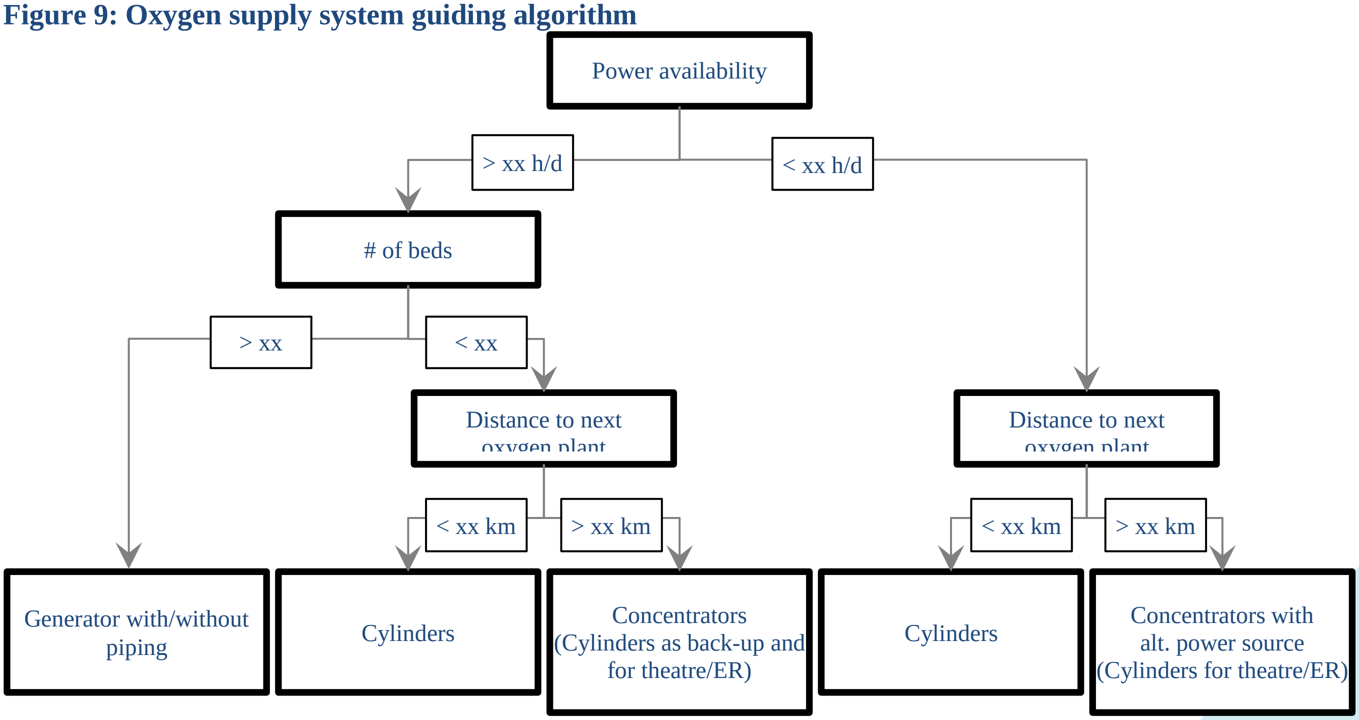
In order to ensure reliable supply, oxygen needs to be addressed systemically and the supply model needs to be backed up by maintenance, training, financing, organization etc., which will require an understanding of the functionality of existing cylinders, along with the plan to phase into concentrators. Oxygen can be supplied through cylinders, concentrators or central oxygen generators (see Annex 1 for a more detailed list of pros and cons of each system).

Figure 8: Main Oxygen Supply Types

	Oxygen cylinders	Oxygen concentrators	Central oxygen source / Oxygen plant
			
Description	High pressure gas supplied via portable canisters delivered to facilities	Oxygen enriched gas is supplied by entraining air from the environment	Oxygen is provided via a large central source on-site
Current usage	Prevalent in many Hospitals, but transport only reliable to higher levels	Prevalent in many hospitals, but usage often affected by lack of power	Only plant at Hayer Hospital in Mekele and Adama (plant at Saint Paul and Jimma hospitals under construction)
Advantages / Draw-backs	+ No need for electricity – High cost of transport	+ Low running cost – **Max flow rate 5 L / min (not recommended for surgery)** – Requires access to uninterrupted power – Service and supply of spare parts needed	+ Most cost effective for larger facilities – High capital investment – Need for adequate infrastructure

In Ethiopia, these three options are used in combined fashion to ensure both access and cost effectiveness at various levels. Although there is no SOP or algorithm currently guiding what type of supply needs to be used at what level, the model in figure 7 below mainly relies on power availability, although the best method of oxygen supply for a facility depends on several variables.

Figure 9: Oxygen supply system guiding algorithm



Based on this algorithm and national direction, a mixed system will be used, and there could be multiple options of a supply system to meet the current demand, with two major scenarios being:

	1 Higher reliance on cylinders	2 Higher reliance on concentrators
% of O2 need supplied through cylinders	Hospitals: 60% -80% Health Centers: 20%	Hospitals: 30% - 50% Health Centers: 0%
# of concentrators required by HF	Hospitals: 1 - 2 Health Centers: 1	Hospitals: 2 - 9 Health Centers: 1
# of cylinder refills required per month by HF	Hospitals: 50 - 120 Health Centers: 1	Hospitals: 20 - 45 Health Centers: 0

Solar powered concentrators for HC with limited access to grid power

✓ Costing and investment plan presented in this document are based on option 2

Option #2 with a higher emphasis on concentrators generates slightly higher CAPEX but ~ 60% less OPEX vs. option #1 (mainly due to lower transport cost)

Higher Dependence on Cylinders (Scenario #1)

In this scenario, the health centers, which are out of the O_2 plant catchment area, are expected to totally rely on concentrators while those within 30km radius will be heavily rely on cylinders in order to maximize oxygen access. Almost all health centers, especially those found at most remote locations are expected to have back-up cylinders when electricity is off and concentrators cannot be used. Similarly, primary and general hospitals found in the plant catchment area will receive a significant proportion of their needs through cylinders, which have the advantage of being able to deliver high O2 flow rate (crucial for surgery). The main drawback of this scenario is its recurring costs: annual running cost (OPEX) is significantly high, primarily driven by refill and transport costs especially with increased number facilities in the future.

Figure 10: Oxygen supply for Health Centers-2016/17 (Scenario 1)
(Depending on distance from the nearest O2 plant, three supply options have been used for health centers)

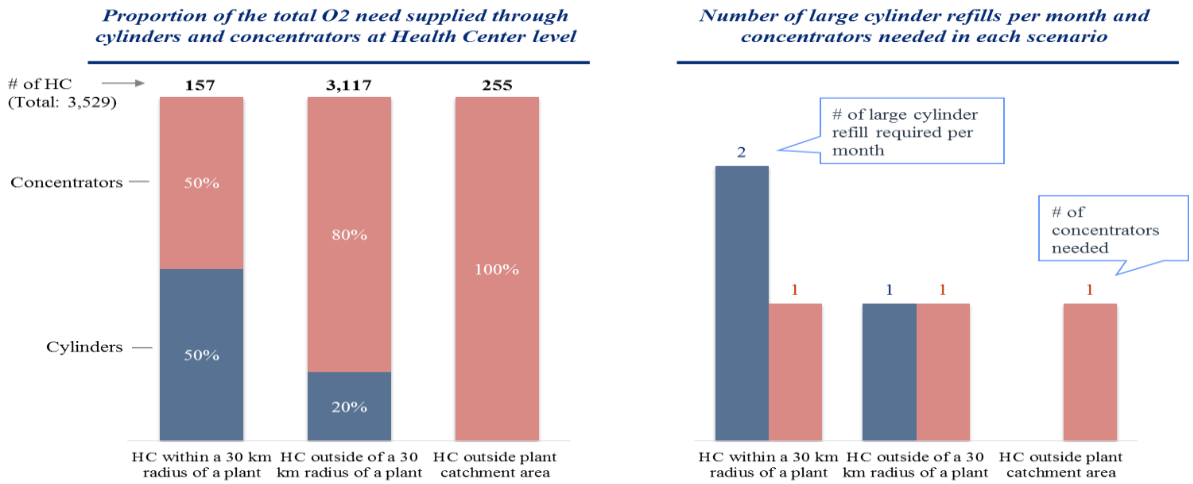
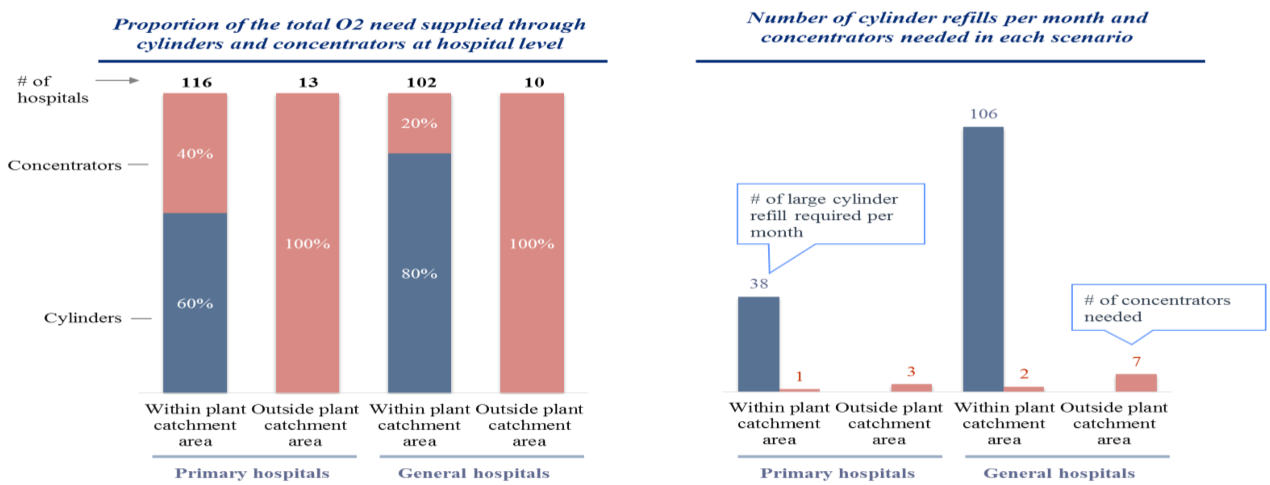


Figure 11: Primary/General Hospitals Oxygen Supply-2016/17 (Scenario 1)
(Depending on whether or not a primary/general hospital is located within a plant's catchment area, two supply options have been used)



Low dependency on cylinders and phasing in to concentrators at all health centers level (Scenario #2)

In this scenario, health centers within 5KM of the O2 plant catchment are expected to be 50% reliant on cylinders or concentrators. However, health centers those beyond 5km and the catchment area of the oxygen plant will be completely (100%) reliant on concentrators. This option considers also health centers in very remote areas where no power is available, which are expected to use solar-power-based concentrators. The initial investment of this scenario would be relatively higher mainly driven by concentrator costs, but the running cost is significantly lower than Scenario 1.

Figure 12: Oxygen Supply for Health Centers-2016/17 (Scenario 2)

(Depending on distance from the nearest O2 plant, three supply options have been used for health centers)

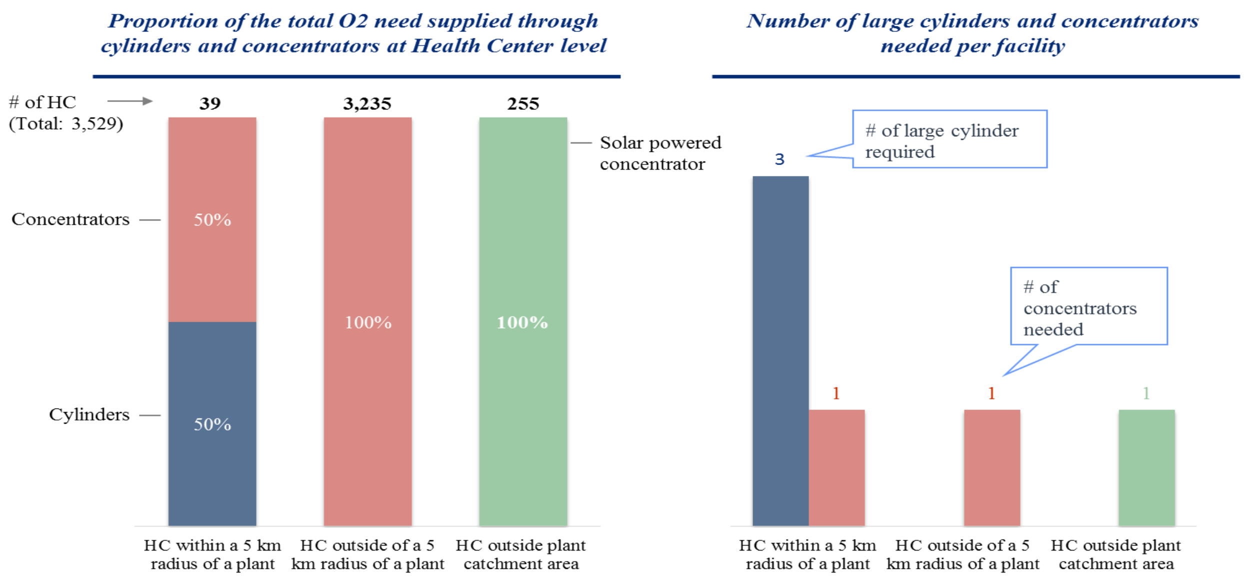
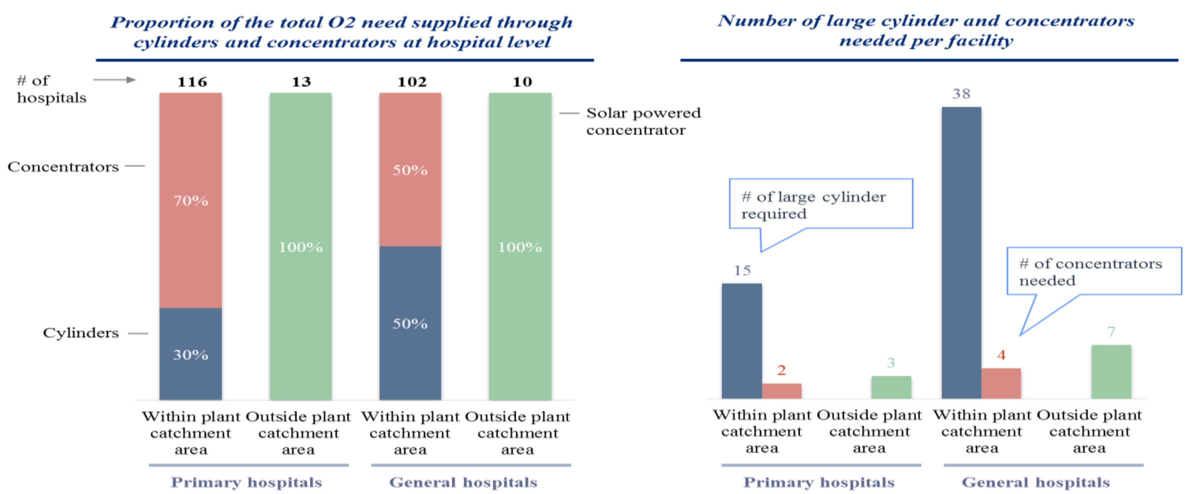


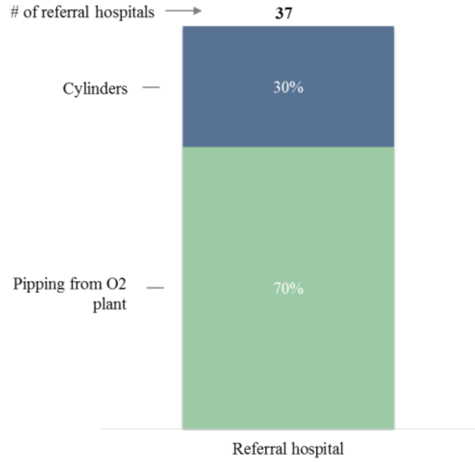
Figure 13: Oxygen Supply for Primary/General Hospitals-2016/17 (Scenario 2)

(Depending on whether or not primary/general hospital is located within a plant's catchment area, two supply options have been used)



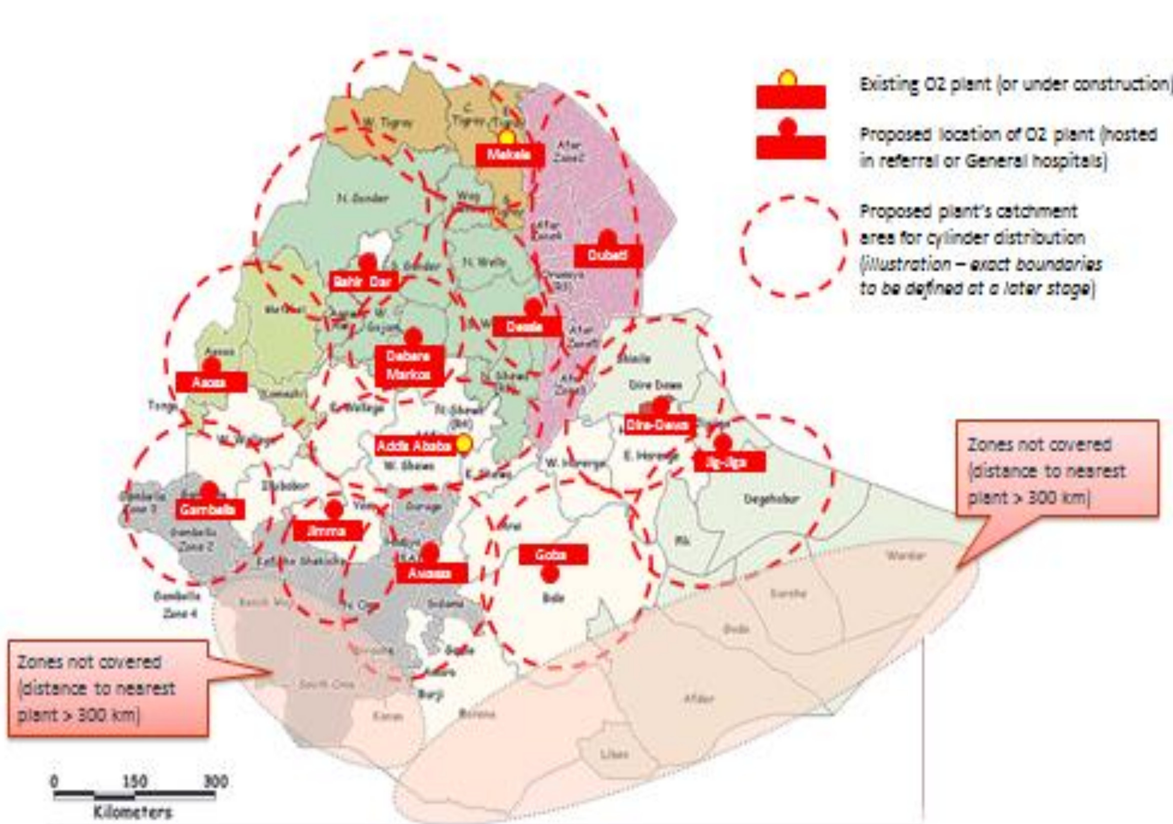
In both scenarios of oxygen supply at referral hospitals, it is expected to be an oxygen plant with back up cylinders in a proportion of 30/70 percent supply of cylinder and oxygen plant respectively. Under both scenarios, it is assumed that all referral hospitals will have an O2 plant in order to be self-sufficient and save on cylinder transport cost.

Figure 14: Proportion of Oxygen Supply for Referral Hospitals with O2 Plant



Furthermore, and to meet the current demand for medical oxygen need, it is proposed to set up 13 regional plants and corresponding catchment areas shown in figure below:

Figure 15: Proposed/Planned Oxygen Plant Sites



2.2 Pneumonia Diagnostics Availability

Pulse oximetry is an important diagnostic and monitoring tool in the treatment and referral of severe pneumonia cases. The baseline findings show that it is unavailable (0%) at the health center or health post level; but hospitals appear to have higher levels of pulse oximeter availability, ranging from 73% in Tigray to 93% in Amhara. However, there is a need to consider its availability and functional issues at all departments which include NICU, LD/PED or EOPD, ICU and OR. Pulse oximeters are not included in the national medical equipment procurement list for health centers in particular.

The baseline also examined availability of other diagnostic devices, such as clocks, watches, timers and special devices for respiratory rate counting (including counting beads). Special devices for respiratory rate measurement (such as counting beads) were found in only small amounts at the health post level probably piloted by implementing partners.

In consideration of the 2015-2020 National Newborn and Child Survival Strategy formulated by the FMoH as great opportunity to meet the ambitious mortality reductions, there is a need to have oxygen scale up plans the rollout, which should ensure regular availability and functionality. There is also a need to align the expansion plan for newborn corners/NICUs by FMoH with sustainable oxygen supply. Furthermore, referral sites using CPAP interface to manage complications of prematurity are rapidly expanding where FMoH has recently procured 875 CPAP machines to be used in more than 180 hospitals and which need regular external oxygen supply system.

3. Purpose of the Road Map

The overall objective of the roadmap is to build on the FMoH's many successful initiatives and other experiences, and to provide direction to dramatically improve oxygen availability in health facilities with a focus on maternal and child health, which the FMoH will also be able to replicate in other programs. This requires a road map with long term multi-year plan that guides the concept and roll out oxygen supply comprehensively.

The major focus and objectives of this road map are:

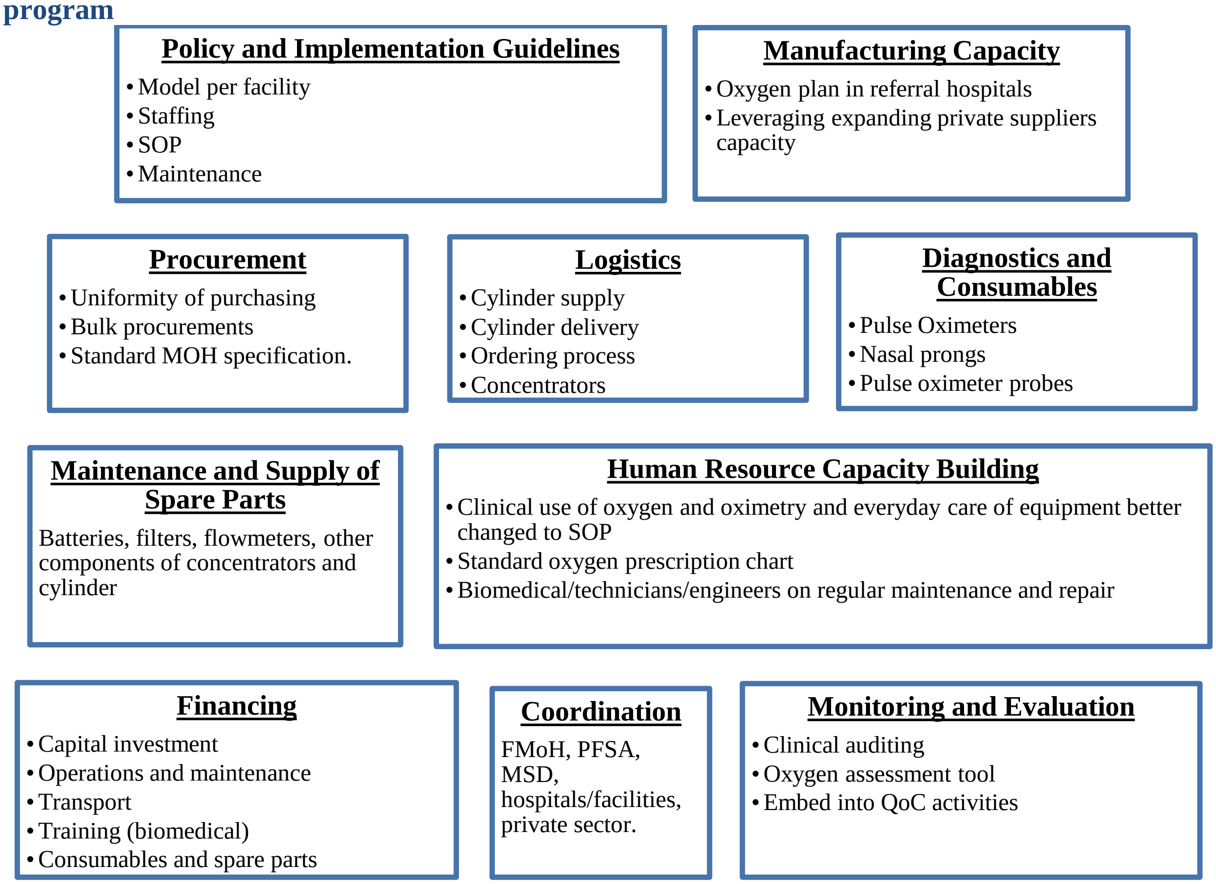
- To provide policy basis, decision and coordination support to health facilities to scale up oxygen supply;
- To design, develop and roll out supply chain management system and logistics to ensure sustainable oxygen supply;
- Ensuring sustainable supplies of diagnostics and related consumables;
- Establish a mechanism for maintenance of oxygen equipment and supply of spare parts;
- Institute a system for building capacity (awareness) of health care workers in facilities on appropriate utilization of oxygen;
- Increasing sustainability for the oxygen supply system; and
- Ensuring mechanisms are in place for sustainable funding and implementation of the oxygen supply system.

4. Implementation

4.1 The Concept and Roll Out of the Oxygen Supply System in Ethiopia

In order to ensure reliable supply, which could meet the continuous increment of oxygen demand in the country, there is a need to establish a supply model, which is backed up by policy and implementation guidelines, skilled manpower, maintenance, training, financing, coordination, strong monitoring and evaluation, as shown in Figure 14 below. This will require an understanding of the functionality of existing cylinders, along with the plan to phase in concentrators.

Figure 16: O_2 supply model | key points to consider when implementing an oxygen scale up program



Policy and Implementation Guidelines

There will be policy and consecutive implementation guidelines, as well as SOPs, which the FMoH will need to develop in close consultation with all stakeholders. These guides would include:

- Setting standards for better and optimized technologies at various levels;
- Need for biomedical staffing;
- Maintenance SOPs;
- Guideline development/adopting oxygen therapy in children;
- Training guides; and

- Defining roles and responsibilities at different levels.

The FMoH will work to further standardize the supply system with current recommendations, including: use of concentrators (including solar powered where there is limited power supply) at health center level, concentrators at primary/general hospital level, and oxygen plants in selected referral hospitals, including where the policy and guideline development. There are solar powered generators entering the market, which can be considered for supply system at health center level. The FMoH and its partners will translate best practices in cold chain (vaccines) to oxygen device maintenance through policy guides.

Operational policies of importing diagnostic and treatment equipment, such as guiding the brands coming into the country in the form of donation or purchase, are also needed. The FMoH and FMHACA will set standards related to product selection, procurement, and after sale services.

Given oxygen scale up could be a capital intensive implementation (both in terms of Capex, Opex), FMOH will prioritize the scale and level scale. FMOH will develop guidance where to prioritize the focus (mostly on hospitals) based on consumption and catchment population of hypoxemic cases. Decision/guidance needs to be made on how to guide the scale up in hard to reach areas where mortality is high including considering depos and solar panel concentrators in short term while planning for O2 plants in primary hospitals in these areas with catchment HCs to be served. Importantly, there is a need to decide for biomedical staffing for PHCU including considering placing a biomedical engineer each primary hospital who will service the HCs/HPs. FMOH will decide/guide level and scope of private sector engagement for both public (PPP) and private facilities: policy in place but scope and coverage TTBD (e.g 10-15%)

Supply Chain Management and logistics for O2 supply

The provision of complete health care necessitates the availability of safe, effective and affordable vital & essential health commodities and related supplies of the required quality and in adequate quantity at all times through its strong supply chain management system.

A well-functioning O2 supply system should be a combined result of different components, such as an effective Logistics Management Information System (LMIS), inventory control system; adequate production capacity, adequate financing, human resources and distribution capacity among others. This requires standardizing the types of oxygen supply systems at various facility types, improving the supply base, procurement, setting for systems for refilling cylinders and supply related information management. The FMoH and PFSA will work to design and implement all necessary activities towards this as in highlighted below. PLMU and PFSA, along with partners, will assess if the current national IPLS can integrate the oxygen/diagnostics supply and logistics system to regularly maintain availability at service delivery points as well as ensure utilization via making it the agenda of Drug and Therapeutic Committee (DTC) which can include establishing oxygen therapy sub-committee at facility level . The current less coordinated distribution system needs to be optimized to ensure sustainable oxygen supply system at service delivery point. FMOH , RHBs and relevant agencies should consider one or mix of the following options in distributing and refilling of Oxygen:

- Hospitals & Health centers own the fleets & handle refilling by themselves from nearby hospital with oxygen plant

- Hospital with oxygen plant will have responsibility to coordinate demand and schedule for resupply nearby hospitals & HCs
- PHC approach – Hospital will aggregate demand for the back-up cylinders to oxygen plant for resupply & take the lead to refill for itself & the surrounding HCs
- Build capacity & Certification of private sectors with oxygen plants to handle the refiling operations

As a new program, there is a need to design and distribute registers that will be used at health facilities to guide the consumption and requisition based on the need. The consumption data will be captured from this source. The FMoH and PFSA will explore options for inclusion of oxygen as part of the reporting and request formats.

Oxygen Supply Types

Oxygen can be supplied through cylinders, concentrators or central oxygen generators. The ideal supply model combines these three options to ensure both access and cost effectiveness. While the FMoH will phase in concentrators at health centers and majority of the hospitals, it is worth to look into pros and cons of the three types of oxygen supply system exists (please look into Annex 1).

Cylinder Based Supply

A complete system for using oxygen in cylinders requires:

- Reliable source of oxygen supply in cylinders;
- Transport to get the cylinders to the hospital;
- Person with clinical training to give the correct amount of oxygen, in the correct manner, to the patients who need it;
- Person with technical training to inspect the apparatus, maintain it in good condition and repair it when necessary;
- Adequate budget to ensure the consistent availability of the oxygen supply;
- Procedures to ensure that the hospital orders the appropriate amount of oxygen; and
- Regular availability of adequate apparatus to deliver oxygen from the cylinder to the patient which includes:
  - Suitable regulator , Flow meter , Oxygen delivery tubing , Humidifier; and
  - Tube to carry oxygen to the patient's face , Nasal catheter (or mask) to deliver the oxygen to the patient's airway.

Concentrator Based Oxygen Supply

A complete system for oxygen delivery based on concentrators, may require:

- Reliable manufacturer and supplier of concentrators;
- Electricity in the hospital: either mains electricity or a generator;
- System to ensure that a sufficient supply of major spare parts is purchased and stored centrally and an adequate supply of minor spare parts, such as air intake filters, is available at each hospital
- Person with clinical training to give the correct amount of oxygen, in the correct manner, to the patients who need it;
- For successful use in a district hospital, a concentrator must be capable of functioning in adverse circumstances:

  - – Ambient temperature up to 40 °C
  - – Relative humidity up to 100%
  - – Unstable mains voltage
  - – Extremely dusty environment
- Be capable of delivering an oxygen concentration of less than 70% oxygen; and
- Apparatus to deliver oxygen from the concentrator to the patient, which includes:
  - Flow meter, Oxygen delivery tubing , Humidifier; and
  - Tube to carry oxygen to the patient's face , Nasal catheter (or mask) to deliver the oxygen to the patient's airway.

Expanding oxygen manufacturing capacity

The FMoH will provide guidance, and support all relevant authorities, in order to increase manufacturing capacity at national level. As discussed above, oxygen plants for medical gas need to be built in 13 selected referral and university hospitals with a centrally planned and guided procurement process to ensure high-quality and sustainable equipment. This can be phased in, with priorities in high volume hospitals and close work with the regional health bureaus and facilities. These hospitals will use oxygen for their own consumption, as well as refill nearby health centers and hospitals with cylinders, or could also sell to private facilities. Going forward, the designing and building of new facilities will take the oxygen supply system including piping into consideration which will be coordinated by infrastructure department.

Strategic engagement and support to private medical gas suppliers (e.g Chora Medical gas) is also important to expand their coverage beyond Addis Ababa to regions, as well as quality improvement of their current supply. It will also be important to bring-in multiple new private suppliers to invest in the area through showing them market opportunities.

Developing and implementing oxygen logistics

While health centers will add cost effective and appropriate concentrators besides cylinders in a phase based manner and over the longer term, ensuring the functionality of existing cylinders at health centers is important. Currently there is no organized and standardized system of refilling and distributing of cylinders at health centers in particular. As discussed above, only 2% of cylinders at health centers are currently functional. This is mainly related to poor logistics systems and its related transport costs, as all cylinders needs to be sent to Addis Ababa for refilling. For example, refilling of a cylinder in Tigray HC costs ~USD $25, while it is around USD $7 in Addis Ababa, where multiple refilling systems exist and there isn't a significant transport cost. While almost all health centers will phase in concentrators, which will have also added cost benefit compared to cylinders, and with the construction of oxygen plants at hospitals and more private sector engagement, there will still be some health centers and hospitals who will continue to use cylinders. Improvement of the logistics system can occur by potentially integrating into the IPLS supply system or into routine facility RDF supply mechanism of health facilities. With further decentralization of additional plants, the FMoH anticipates the access will increase while the transport costs will decrease.

An appropriate and proactive facility level oxygen supply forecast is an additional logistics challenge that needs support and attention from RHBs and PFSA. Through support and guidance from the FMoH, PFSA along with RHBs, will be responsible to centralize the ordering process and ensure transport of cylinders from the working plants to peripheral facilities while facilities are responsible for ordering oxygen cylinders and refills as part of other vital and essential medicine through IPLS.

Procurement

Procurement planning and the procurement process are important activities that ensure the correct oxygen supplies are available at service delivery points. Building tools and technical expertise within the FMoH PLMU, FMHACA and PFSA on specifications, procurement and installation of oxygen equipment that includes concentrators and plants, will allow achieving cost savings and ensuring quality of equipment. With current directions and thinking of scaling up concentrators at health centers, having detailed specifications and optimized technology recommendations are critical (see Annex 2 for concentrator specifications recommendation).

Setting a system for appropriate forecasting and selection of equipment needs at all levels, with leadership of the Child Health program, PLMU and PFSA, will lead to an optimal procurement process. A central procurement process by PFSA will allow leveraging economies of scale and procuring high-quality and sustainable equipment, including oxygen plants, concentrators and diagnostic devices. The procurement will take the current stock on hand and already distributed devices into consideration during the actual supply planning process.

A hospital with no oxygen plant or not in the plant catchment and health center (with power) will need at least six (6) and one (1) concentrators respectively to address their oxygen demand. Through phase based implementation, nearly all health centers and hospitals will have concentrators for the supply system for their newborn and child health services, with exception of HCs within 5KM of oxygen plant. While there are ~250 hospitals (including primary hospitals), the number is expected to increase to 349 by end 2016[7] and the health centers are expected to be 3,529. With this assumption, and as shown in Table 2 below, nearly 8,000[8] concentrators are required by end of 2016 at HC, primary and general hospital level, which requires strong procurement planning and management (See Annex 3 for cylinders and plants details). PFSA, through its medical equipment and procurement directorates, will lead the procurement process by integrating into its existing medical supplies procurement system and SOPs. Furthermore, procurement of oxygen plants to be installed by referral and university hospitals will be centrally procured by PFSA, based on FMoH/RHB specifications and forecast over next 3-5 years.

In addition, and while the number of pulse oximeter per hospitals to be determined, a minimum of two are required per each facility including health centers, as per the FMoH expert recommendations, which could mean nearly 7,800 of these devices are required as an initial investment.

[7] Regional health bureau plans.
[8] This number doesn't take the existing concentrators at primary and general hospital which needs inventory.

Table 2: Estimated minimum Oxygen Concentrators Demand and Procurement (HC, primary/general hospitals) with current infrastructure

Health facility level & its location with respective to O_2 Plant site	Concentrators required/ facility	Total # Health Facility	Total # Concentrators required	Notes
Health centers within 5km radius of plant (50%)	1	39	20	
Health centers outside of 5km radius of plant but accessible (100%)	1	3,255	3,255	
Health center outside of oxygen plant catchment & inaccessible-preferred to have solar based power (100%)	1	255	255	Solar based preferred.
Total Health Centers		**3,549**	**3,530**	
Hospitals (primary) within oxygen plant catchment (70%)	2	218	305	Solar based preferred
Hospitals (primary) outside oxygen plant catchment (100%)	3	13	39	
Total Hospital (Primary)		**231**	**344**	
Hospitals (general) outside of oxygen plant catchment (50%)	4	102	204	Solar based preferred
Hospitals (general) outside of oxygen plant catchment (100%)	7	10	70	
Total Hospital (General)		**112**	**274**	
Total (ALL)		**3,892**	**7,951**	

4.2 Ensuring Sustainable supplies for Hypoxemia Diagnostics and Related Consumables

Pulse Oximetry

Pulse oximetry is the best and simplest way to detect and monitor hypoxemia. Hand held pulse oximeters should be available in all facilities with oxygen equipment, in all necessary units, including the OPD, maternal and pediatric wards. Low cost and innovative pulse oximetry selection and procurement should be made based on specifications developed nationally through the FMoH and FMHACA. Similar to that of concentrators, the MNCH contact points at facility are LD, OR, NICU, PED ward, PED EOPD (as a minimum number is five in hospital, and two in health centers).

In addition, availing simple and user friendly pulse oximetry to diagnose hypoxemia at facilities that do not have oxygen equipment (such as health posts) should be evaluated and scaled up with a strong referral network in place. By the end of 2018, all health posts should be equipped with low cost and user friendly pulse oximeters, which greatly reduce child mortality in Ethiopia.

Peripheral Oxygen Equipment

In many facilities, oxygen equipment cannot be used, because peripheral equipment is missing. Based on the 2015/2016 CHAI-Ethiopia baseline assessment, a significant number of oxygen cylinders and concentrators at health centers and hospitals are not functional because of a lack of simple accessories (i.e. gauges, regulators and related equipment).

Integrating important spare parts and diagnostic equipment into the regular PFSA and FMoH supply chain will facilitate the ordering process for facilities and help avoid supply chain issues. This equipment includes oxygen regulators, pulse oximeters, nasal prongs and filters for concentrators.

4.3 Mechanism for Maintenance of O2 Equipment and supply of spare parts

Building a system and capacity for maintenance and repair within the current government system, i.e. hospitals, RHBs and PFSA, is crucial for regular functionality of the devices. Preventive maintenance and regular checkup equipment's functional status is essential and failure to provide this will likely result in expensive repairs and reduced functionality of equipment. Based on the 2015/2016 CHAI baseline assessment, a significant number of cylinders and concentrators are not functional due to lack of necessary spare parts in the market and limited capacity to maintain these devices.

In summary, the current challenges include but not limited to:

- Health facilities lack any routine maintenance; this is a challenge across types of medical equipment not just oxygen delivery equipment and pulse oximeters
- There is no supply system for spare parts
  - No clear policy for oxygen equipment
  - No accountable organization for managing spare parts
- There are not enough BMEs with appropriate training available
  - Need more BMEs and more frequent BME trainings for medical devices
  - Need specific training for oxygen delivery equipment and pulse oximeters
  - Need maintenance tools for BMEs – calibration, testing tools, etc.
- Health facility staff have limited understanding of device maintenance
  - Health system employees are often not trained in simple short-term maintenance
  - No contract management for maintenance; someone in the facility needs to be responsible for managing this contract to ensure devices get the maintenance they need

To address these challenges, targeting the four below areas will have high impact outcomes in terms of creating a sustainable maintenance program for oxygen delivery equipment as well as broader medical devices to improve treatment of hypoxemic patients:

Table 3: Target Areas to address challenges of maintenance for oxygen delivery equipment

Category	Activities
Managing Data	Inventory and assessment of oxygen devices
	Create an online maintenance management software structure and upload oxygen device information
Managing Labor	Guideline development for routine maintenance of biomedical equipment
	Curriculum development for maintenance training
	Create standard operating procedures (SOPs) for maintenance of oxygen devices
	Company training to BMEs and Biomedical technicians
	BME training of health facility staff
Managing Spare Parts & Service Information	Manage contract agreements to include clause for oxygen device spare parts (as per the spare part list from the manufacturer)
	Introduction and uptake of service and operation manuals (field guide)
Managing Workplace, Tools, and Testing Equipment	Create hospital workshops in each region
	Roll out mobile maintenance program (van)
	Procure maintenance tools for maintenance workshops and mobile maintenance program

Maintenance of oxygen equipment and supply of spare parts lie within the responsibility of the FMoH health infrastructure department, FMoH/PMED, PFSA and the regional health bureau maintenance systems and teams. Expanding the scope of the existing structures within the FMoH, PFSA, RHBs and facility maintenance teams, as well as training these relevant stakeholders, will help to increase functionality of existing oxygen equipment and prolong the lifespan of new equipment.

A critical step for sustainability is the integration of oxygen maintenance into the currently ongoing other devices initiatives and workshops, such as cold chain trainings for facility biomedical technicians by revising the necessary training curriculums and job aids. Furthermore, there will be work with universities and TVETs to integrate oxygen device maintenance in pre-service trainings. The FMoH and PFSA along with partners will ensure maintenance/service packages are in procurement agreements for devices in centralized and pooled procurement.

4.4 Institute a System for Building the Capacity of Health Care Workers

Human Resource Trainings

In order to ensure duration of equipment and utilization of available equipment, it is essential that health workers are trained in the clinical use of oxygen and pulse oximetry and the day-to-day appropriate use and care of oxygen equipment.

The broader objectives should target and focus on:

- Awareness creation for program managers on technical aspect of oxygen supply chain, accessories and requirement.
- Train health workers on the detection of hypoxemia and clinical use of oxygen and its monitoring.
- Training of workers on basic equipment care.

Trainings on the use of oxygen and pulse oximetry should be provided in form of sensitizations or trainings integrated into various existing related clinical trainings (initially with focus on child health) covering or emphasizing the following elements but not limited to:

- Relevance and detection of hypoxemia;
- Usage of pulse oximetry;
- Oxygen equipment and how it works; and
- Equipment care, basic maintenance and safety.

These elements should also be included in pre-service training for nurses, midwives, health officers and doctors where it isn't currently the case. Under possible circumstances, on sites trainings are encouraged to train multiple health care workers as well as to make use of practical exercise at facilities. FMOH along with its partners and agencies will develop/adopt necessary trainings and sensitization guides related to use at various levels to standardize the approach and ensure efficiencies.

Targeted Initial Mentoring

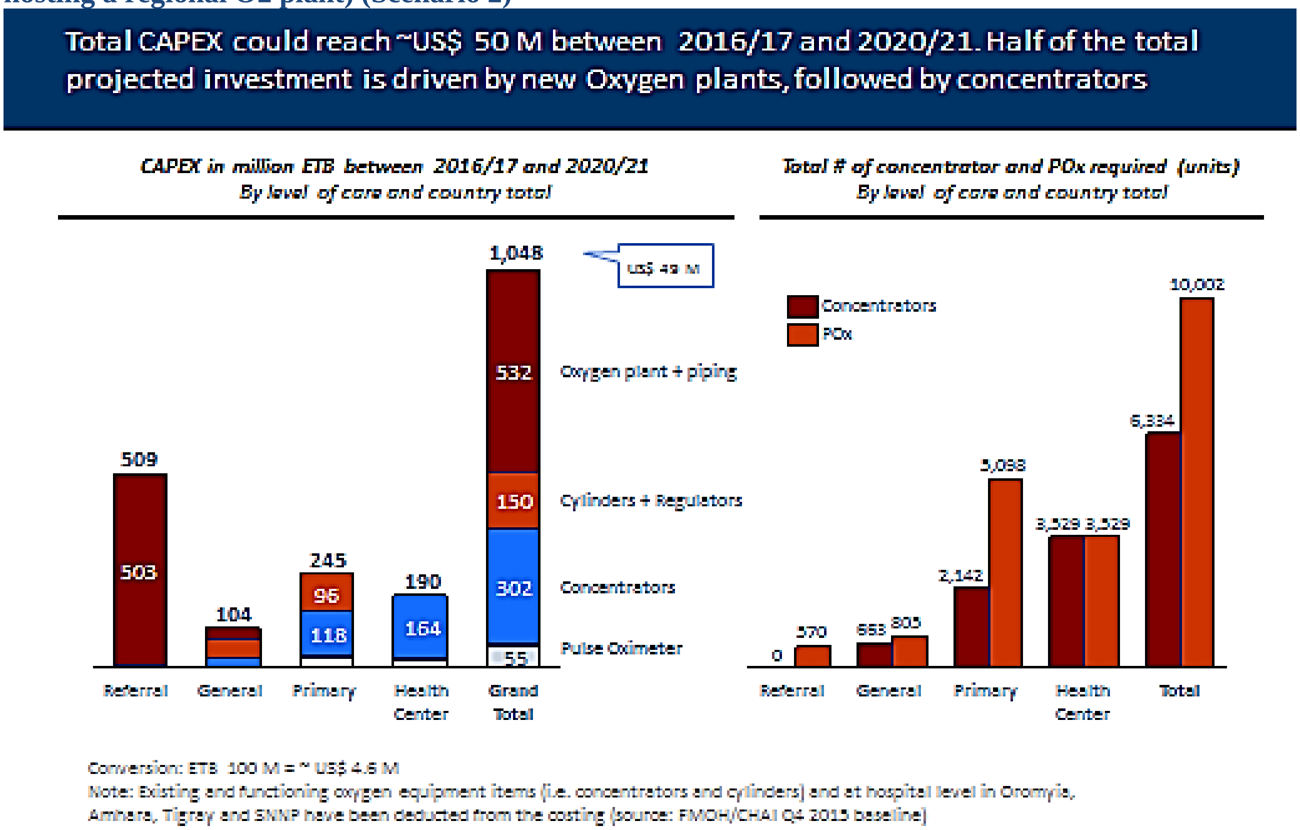
Targeted mentoring can be put in place on the utilization of oxygen devices, as well as a maintenance system, where there are critical gaps and facilities are utilizing higher volumes. This can be integrated into existing and ongoing programs like IMCI, BEmOC and CEmOC, as well as clinical mentoring for TB/HIV and PMTCT services.

4.5 Increasing Sustainable Funding to Support the Oxygen Supply System

Ensuring sustainable budgeting for all the objectives above will be crucial for realizing the rollout of this strategy and ensuring sustainable supply of oxygen. The FMoH will work to allocate the necessary budget, as well as mobilize additional resources from its donors and implementing partners for procurement of technologies, maintenance and spare parts as well as trainings the human resources. Health facilities will use their health care finance for refilling of cylinders and procurement of some spares required, which will be availed through PFSA.

Setting up and maintaining the system mentioned above, establishment of additional oxygen plants and equipping all health centers with concentrators as well as pulse oximeters b/n 2016/17 to 2020/21 will cost[9] an estimated initial capital (CAPEX) investment of $50Million and running (OPEX) cost could reach ~7Million per year towards end of investment year, 2021. (see Figure 15 in cost section below). The key cost drivers expected to be considered at all levels are procurement of pulse oximeters, concentrators and establishment of plants with limited cylinders procurement as long cylinders have already been in the system (see Annex 3 for detail quantification and costing with focus on Scenario 2). This costing doesn't include health post level pulse oximeter scale up as that needs initial proof of concept or piloting.

Figure 17: Average CAPEX and annual OPEX per facility by level of care (excluding hospitals hosting a regional O2 plant) (Scenario 2)

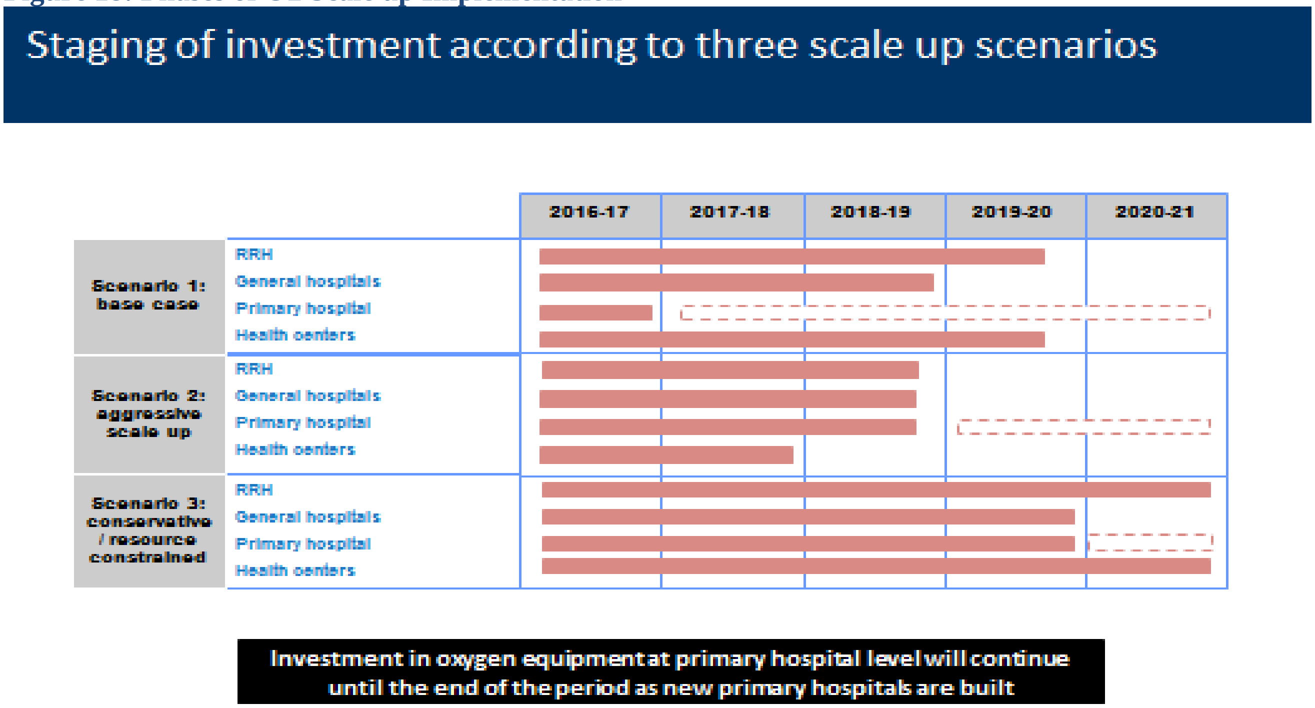


Phases of implementation

Given ensuring planned sustainable supply of Oxygen could be expensive, it is advisable and cost effective in phase based approach. Accordingly, while this road map contains aggressive scale up plan, it recommends starting with base scenario and build experience for rapid scale up later in the period.

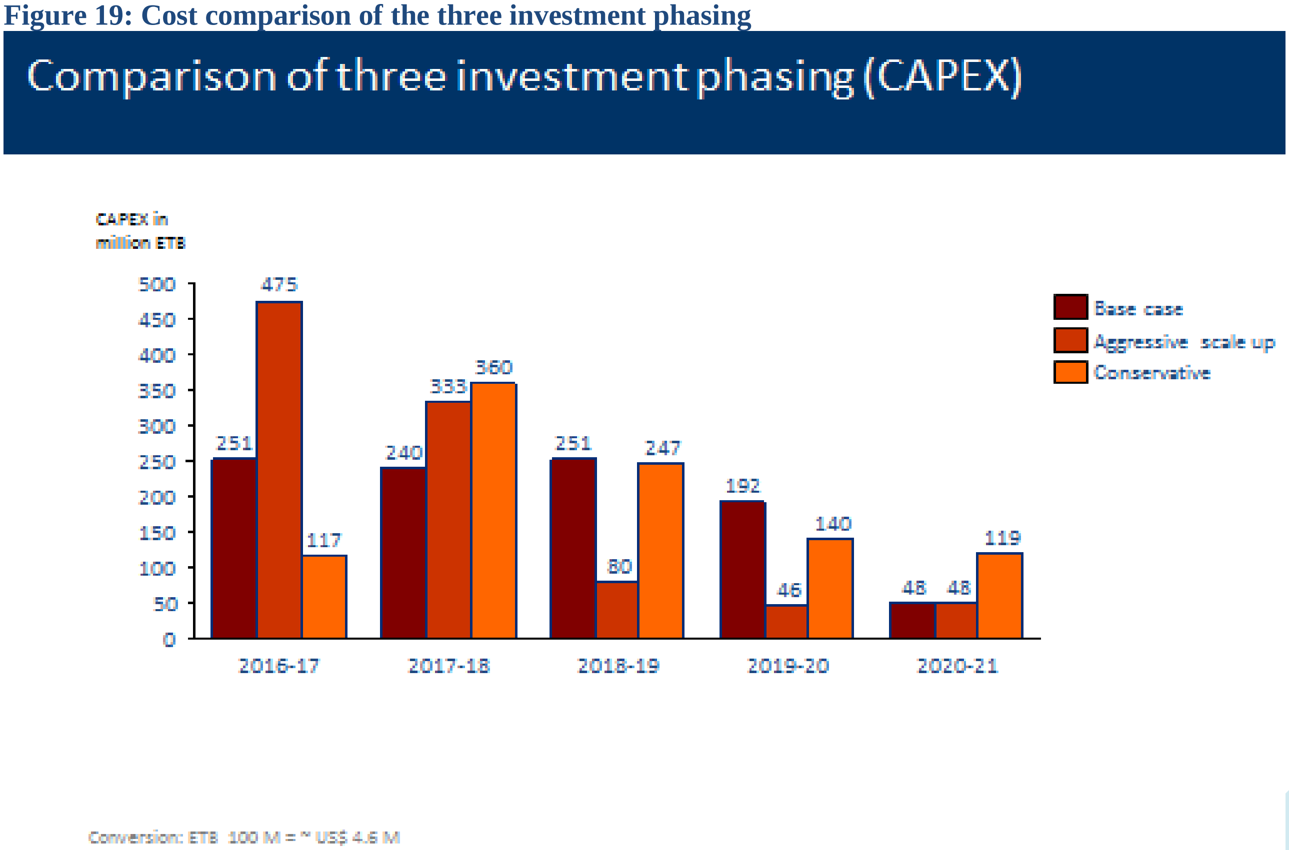
[9] This cost doesn't include trainings and supportive supervision and only refers to technology cost

Figure 18: Phases of O2 Scale up Implementation



The necessary investment cost for the above scenarios are described as in figure below:

Figure 19: Cost comparison of the three investment phasing



4.6 Coordination

Coordination at different levels is one of the major technical areas which help stakeholders to maximize their efforts and minimize duplication of resources. For rapid scale up of oxygen and smooth implementation, it may require more effort from the FMoH in ensuring the engagement and coordination of all stakeholders. While the implementation will be standing agenda within existing child survival TWG, the MCHD/FMoH could establish a taskforce (TF) that including MSDG, infrastructure, PFSA, PLMU as well as key NGO partners which will advise the high level engagements like resource mobilization. The TF will provide technical guidance in developing necessary implementation and policy tools on comprehensive oxygen supply system. There is also a need from FMoH to closely work with RHBs to make sure there will be a working group to oversee and advise on the adoption and implementation of strategies.

FMOH will coordinate support from key implementing partners and donors working in MCH, safe surgery and clinical service improvement in quick scale up of oxygen and pulse oximeter. The major support will likely be human resource training, maintenance system establishment, technology procurement and optimizing PSM through their existing platforms or mobilizing additional resources. FMOH will guide and welcome any pilot /operational researches that target access and quality of Oxygen and pulse oximeter services.

5. Implementation Plan

Table 4: Medical Oxygen and Pulse Oximetry Scale up Multi-year implementation plan (2016-2020/21)

Strategic objective and key activities	Indicator	Target	Timeframe					Responsible Body
			2016	2017	2018	2019	2020/21	
1. Provide policy basis and decision support to health facilities to scale up oxygen supply								
1.1 Develop O2 implementation policy in health facilities	Policy in place		X					FMOH
1.1.1 Develop Guides on specification and type of supply system at various level (cylinder, concentrator, central pipe system-plant)	Specification guide for each supply system in place	1	X					FMOH
1.1.2 Develop Guide on biomedical staffing and trainings (structure, level of competency, deployment…)	Biomedical staffing and training guide developed	1	X	X				FMOH
1.1.3 Develop Maintenance SOPs	SOP on maintenance developed	1	X	X				FMOH

Strategic objective and key activities	Indicator	Target	Timeframe					Responsible Body
			2016	2017	2018	2019	2020/21	
1.1.4 Adopt Guidelines development/adopting oxygen therapy in children;	Oxygen therapy in children adopted and distributed	1		X				FMOH
1.1.5 Develop/adopt training guides/SOPs	Training SOPs developed	2	X	X				FMOH
1.2. Integrate the O2/Pox road map implementation and coordination in existing MCHD and MSDG relevant TWGs	TWG meeting with O2/Pox agenda and follow up	1	X	X	X	X	X	FMOH
1.3. Integrate the O2/Pox road map implementation and coordination in existing regional MCH & relevant TWGs	TWG meeting with O2/Pox agenda and follow up	1	X	X	X	X	X	RHB
2. Set up and roll out supply and logistics chain systems for oxygen supply								
2.1 Explore options and Revise the current national system PSM system to integrate O2 supply as vital and essential medicine	Revised national PSM with O2 system	1		X	X			FMOH
2.2 Establish national and regional systems and capacity for O2 and related devices quantification	O2 quantification in place	5		X				FMOH
2.3 Develop a robust and standardized oxygen procurement mechanism at national/facility level	O2 procurement guide developed	1		X	X			FMOH
2.4.Conduct inventory to identify the quantity of finctional oxygen concentrator	Inventory of oxygen & pulse oximeter	5						RHB/FMOH/Partners
2.5. Procure and distribute O2 concentrators to >3500 health centers	# of HCs equipped with concentrators	1 per HC		X	X			FMOH/RHB
2.6. Guide procurement and installation of O2 plants in regions as per recommendations	# of O2 plants established	13	X	X	X			FMOH
2.7. Develop and distribute O2 service utilization registration book for facilities for integration into LMIS	O2 service utilization log books developed and availed	1		X				FMOH/RHB
2.8. Ensure appropriate supply and utilization of O2/devices through facility logistics platforms like DTC	DTC incorporated O2 utilization	Revised DTC ToR		X	X			RHB
Explore innovative distribution and refilling systems for O2 including PPP	Distribution & refilling system identified with route map for each health facilities	1 route map		X	X			RHB

Strategic objective and key activities	Indicator	Target	Timeframe					Responsible Body
			2016	2017	2018	2019	2020/21	
Standardize O2 plants specifications and procurement systems	Specification & procurement guide developed for oxygen plant	1		X				FMOH/Univesity Hospitals/RHBs
3. Ensuring sustainable supplies for Hypoxemia diagnostics and related consumables								
3.1 Purchase and distribute at least one low cost and innovative pulse oximeters to each HP via program or RDF scheme (PFSA & MOH)	% of HPs with functional pulse oximeters	15,000		X	X			PFSA/FMOH/RHBs
3.2 Purchase and distribute at least two low cost and innovative pulse oximeters to HCs via program or RDF scheme (PFSA & MOH)	% of HCs with functional pulse oximeters	>7000		X	X			PFSA/FMOH/RHBs
3.3 purchase and distribute pulse oximeters to all hospitals MCH departments based on gaps identified	% of hospitals with functional pulse oximeters	>1000		X	X			FMOH/Hospitals
3.4 Ensure functionality and utilization of pulse oximeter at each health facility through integration into existing system E.g. Site Supportive Supervision, inventory , reporting, review meeting…	# of HFs with functional pulse oximeter at all service delivery points			X	X	X	X	FMOH/RHB/ZHD/HFs
4. Establish a mechanism for maintenance of oxygen equipment and supply of spare parts								
4.1 Building a system and capacity for maintenance and repair of medical O2 devices in the government system	Total # of professionals trained on maintenance and repair of medical O2 devices # of biomedical technicians assigned & currently working in the system	800		X	X	X		FMOH/RHB/IP
4.2 Integrate O2 service and O2 equipment maintenance into the existing training system (pre/in-service and on-job, E.g cold chain system)	#/%Training curriculum/institutions integrating O2 device maintenance	1			X	X		FMOH/RHB
4.3 Ensure availability of adequate spare parts for medical O2 devices in HFs	% of met demands of spare parts for medical O2 devices by HFs				X	X	X	FMOH/RHB/PFSA
5. Institute a system for building a capacity of health care workers in facilities on utilization of oxygen								

Strategic objective and key activities	Indicator	Target	Timeframe 2016	2017	2018	2019	2020/21	Responsible Body
5.1 Build capacity of health care providers on the clinical use of oxygen and pulse oximetry	# of HCWs trained/oriented on clinical use of oxygen and pulse oximetry	3,400 HCWs		X	X	X	X	FMOH/RHB/Partners
Provide orientation for 8000 Managers	# of Managers trained/oriented on clinical use of oxygen and pulse oximetry	800		X	X	X	X	FMOH/RHB/Partners
Provide training for 1600 Clinicians	# of Clinicians trained/oriented on clinical use of oxygen and pulse oximetry	1600		X	X	X	X	FMOH/RHB/Partners
Provide training for 1000 Biomeds (1/Hospital +200 RHB & colleges/university)	# of Biomeds trained/oriented on clinical use of oxygen and pulse oximetry	1000		X	X	X	X	FMOH/RHB/Partners
5.2 Integrate O2 service and O2 equipment maintenance into the existing health care system (E.g cold chain system)	# number of integrated training organized # of integrated supportive supervisions conducted with O2 related questions in the checklist				X			FMOH/RHB/Partners
6. Increasing sustainable funding to support oxygen supply system (all five objectives)								
6.1 Ensure adequate budgeting for realizing the rollout of O2 strategy and ensuring sustainable supply of oxygen	National , regional and partners plan with dedicated budget for O2 scale up	100%	X	X	X	X	X	FMOH/RHB/IP
6.1.1 Estimated initial capital (CAPEX) investment	amount budget mobilized/allocated	$49 million		X	X	X		
6.1.2 Running (OPEX) cost	amount budget mobilized/allocated	$ 7 million per year		X	X	X	X	
Coordination and Monitoring & Evaluation								
1. Coordination at national and regional levels (Planning, budgeting, integration…)	National and Regional TWGs - alignment of activities		X	X	X	X	X	FMOH/RHB/IP
2. Monitoring and evaluation (supervision, review meeting, performance reporting, and Baseline, Mid line and end line evaluations conducted..)			X	X	X	X	X	

6. Monitoring and Evaluation

For the road map, it is critical to have special indicators to assess the input, output, outcome and impact of scaling up. Tracking service statistics at facility level using registers, standard supportive supervision tools, reporting formats, and an established schedule for regular supportive supervision will be very important. Furthermore, the FMoH, in coordination with stakeholders, will conduct special studies and local assessments. Through this process, all indicators and registers will be integrated with the existing HMIS. Parallel to this, oxygen service achievement should be integrated and presented in all performance review meetings (annual or biannual). It is also important to ensure optimal use of pulse oximeters or respiratory counters at health post level through conducting piloting/implementation coaching of HEWs via integrating with outreach activities of the nearby HCs.

Targeted integrated supportive supervisions

Supportive supervision is a strong monitoring tool for technical support to ensure program implementation at different levels, while building the capacity of the supervisee, when it incorporates on the job training. Hence, it is important to enforce sustainable supply and proper utilization of O_2 from decision makers of administrative bodies found at different levels. Oxygen service provision and management should be part of currently ongoing child health related supportive supervision (SS) to address ongoing challenges at all levels. FMoH and RHBs will make sure the SS tools incorporate key assessment areas, identify bottlenecks and put recommendations in place. The supply and logistics related supportive supervision system of PFSA should also integrate to regularly address on going challenges within the system. Meanwhile, the supportive supervision multidisciplinary team should incorporate senior biomedical professionals with expertise in O_2 equipment maintenance and repair. The team should give detailed information and establish a line of communication in order to troubleshoot repairs.

Key indicators suggested at this point will be:

Input indicators

- Number of concentrators procured and distributed;
- Number of pulse oximeter procured and distributed; and
- Amount of budget mobilized for oxygen scale up.

Output indicators

- Number of Oxygen plant established;
- Number of health care workers trained/oriented on maintenance and repair;
- Number of health care workers trained/oriented on oxygen use;
- Number of HFs with pulse oximeter / cylinder/concentrator/oxygen plant;
- Number of oxygen systems maintained;
- Number of guidelines developed & distributed;
- Number of SOPs developed & distributed;
- Number of biomedical technicians assigned & currently working in the system;
- Revised IPLS/RRF with O_2 in the SCM system; and
- Number of integrated supportive supervision conducted with O_2 related questions in the tool.

Outcome indicators

- Number of health facilities with functional oxygen service;
- Number of patients treated with oxygen per facility per annum; and
- % of met demands of spare parts for medical O2 devices by HF.

Annexes

Annex 1: Pros and Cons of Different Oxygen Supply Systems

Model	*Cylinders*	*Concentrators (Bedside & Portable)*	*Central Source (Liquid tank & O2 generator)*
Description	High pressure gas is supplied via portable canisters (typically 7,500L) and delivered to health facilities, which must exchange the empty cylinders	Oxygen enriched gas is supplied by entraining air from the environment and separating the nitrogen via pressure swing absorption (PSA)	Oxygen is provided via a large central source on-site, most often in addition to a manifold or network of copper pipes
Use case(s)	• Facilities without a reliable power source or in close proximity of a plant • Deliver medium-high output flow; well-suited for all 3 application areas	• Facilities with a reliable power source (or backup) • Deliver low output flow (~ 5L/min); well-suited for disease management but too low for emergencies	• Large facilities with reliable infrastructure and skilled technicians • Deliver high output flow and pressure; well-suited for all 3 application areas
Main advantages	• No need for electricity or highly skilled technicians • Low capital investment cost	• Can ensure continuous supply at low running cost • One concentrator can serve up to 4 beds	• Can ensure continuous supply at high pressure • Most cost effective system for larger facilities
Main disadvantages	• Supply is highly dependent on supplier availability • Cost of transport can lead to budget constraints • System is highly sensitive to leakage • Canisters are potentially hazardous (explosion risk) • Only one bed per cylinder	• Requires access to uninterrupted power • Service and supply of spare parts should be foreseen • Relatively low output often insufficient for emergency care (ICU)	• High capital investment • Requires access to reliable and sufficient power source • Need for skilled technicians and adequate infrastructure • System is potentially hazardous
Peripheral equipment necessary	• Manometer (Regulator, gauge, flowmeter) • Humidifier • Nasal prongs/catheter • Cylinder Key	• Humidifier • Nasal prongs/catheter	• Cylinders incl. peripheral equipment
Manufacturers (exemplary and refer Annex 1 for details)	• Oxygas • Oxygen [Chora] • Hospital	• DeVillbiss • AirSep	• OGSI • Oxymat • OzcanKardesler

Annex 2: Comparison of Oxygen Concentrators based on their Power Supply System

Focus area & Description	Oxygen concentrator (mains-powered)	Oxygen concentrator (solar-powered)
Rate of oxygen production and flow		
Minimum concentration of oxygen	0.82	0.82
Minimum flow rate	0.5 LPM or lower	0.5 LPM or lower
Flow rate adjustment intervals	0.5 LPM or lower	0.5 LPM or lower
Power required per L of oxygen	<70W per L	<70W per L
Number of oxygen outlets per product	2	2
Configuration of oxygen outlets	6mm barbed fitting or equivalent	6mm barbed fitting or equivalent
Amount of power needed		
Electricity	Continuous power (mains power with battery backup in case of power failure)	Continuous power (solar power with battery backup for night-time usage or on excessively cloudy days)
Backup battery: holdover	>3 days, running continuously for 10 hours per day	>3 days, running continuously for 10 hours per day
Solar panel specifications	TBD	TBD
Robustness to operating conditions		
Voltage stabilizers (for mains power)	Compliant with WHO PQS/E007/VS01 specifications	N/A
Temperature and humidity conditions	Capable of being stored and operated continuously in ambient temperature from 0C to 40C, RH from 15% to 95% and elevation from 0 to 2000 m	Capable of being stored and operated continuously in ambient temperature from 0C to 40C, RH from 15% to 95% and elevation from 0 to 2000 m
Temperature during shipping to countries	Capable of withstanding 70C shipping temperatures without impacting performance or lifetime once installed	Capable of withstanding 70C shipping temperatures without impacting performance or lifetime once installed
Vibration during transportation within countries	TBD	TBD
Solar panel robustness	TBD	TBD
IP rating for protection against moisture and dust	TBD	TBD
Ease of use		
Ease of installation, especially for solar panel mounts	N/A	"Plug and play" configuration, i.e., the wiring from the panels to the product must involve MC4 or equivalent connectors that are simple, intuitive, and error-proof

Focus area & Description	Oxygen concentrator (mains-powered)	Oxygen concentrator (solar-powered)
Theft protection for solar panels?	N/A	The panels and mount must be provided with a theft-deterrent measure (e.g., a screw that requires a special screwdriver or allen wrench to use)
Simple, intuitive controls	Controls for adjusting the oxygen flow rate, acknowledging (thereby silencing) the audio alarm, turning the product on or off when required	Controls for adjusting the oxygen flow rate, acknowledging (thereby silencing) the audio alarm, turning the product on or off when required
Audio-visual alarms	Alarms for low oxygen concentration (<82%), low battery, power failure, high temperature, low/high/no flow rate, low/high pressure	Alarms for low oxygen concentration (<82%), low battery, power failure, high temperature, low/high/no flow rate, low/high pressure
Noise level	<50 dB (A)	<50 dB (A)
Parameters to be shown in display	Hours of continuous operation of the concentrator, current oxygen flow rate, whether the filter requires changing	Hours of continuous operation of the concentrator, current oxygen flow rate, whether the filter requires changing
Portability	Easily movable by one person, therefore <27kg in weight; mounted on castor wheels for easy rolling	Easily movable by one person, therefore <27kg in weight; mounted on castor wheels for easy rolling
Minimal maintenance		
Long lifetime of backup battery	The battery must be warranted for at least 5 years	The battery must be warranted for at least 5 years
Long-lasting parts	All filters, oxygen outlet connectors, banking plugs/nozzles, etc. must be designed to require low rates of maintenance or replacement. [exact requirement TBD]	All filters, oxygen outlet connectors, banking plugs/nozzles, etc. must be designed to require low rates of maintenance or replacement. [exact requirement TBD]
Services		
Warranty duration	At least 2 years, ideally 5 years	At least 2 years, ideally 5 years
Minimum provisions in the warranty	Covers all costs of repair or replacement during warranty period	Covers all costs of repair or replacement during warranty period
Minimum service provisions to be provided	Spare parts for 5 years, technical support, training of MOH technicians at the national level	Spare parts for 5 years, technical support, training of MOH technicians at the national level
Additional options to be quoted	Service contract covering maintenance and repair	Service contract covering maintenance and repair
Additional components to be provided		

Focus area & Description	Oxygen concentrator (mains-powered)	Oxygen concentrator (solar-powered)
Spare parts	Minimum list of spare parts per unit of the product procured: • 15 x gross particle filters • 5 x intake filters • 5 x product filters • 15 x oxygen outlet connectors • Blanking plugs and nozzles, if using flow-splitter. Other spares that may be needed: circuit breaker, printed circuit board, sieve beds, compressor service kit, valves, wheels, motor capacitor, flowmeters and fan.	Minimum list of spare parts per unit of the product procured: • 15 x gross particle filters • 5 x intake filters • 5 x product filters • 15 x oxygen outlet connectors • Blanking plugs and nozzles, if using flow-splitter. Other spares that may be needed: circuit breaker, printed circuit board, sieve beds, compressor service kit, valves, wheels, motor capacitor, flowmeters and fan.
Accessories	For two or more simultaneous paediatric patients: - 1 x flowmeter stand with minimum range from 0 to 2 LPM; or - 1 x four-way flow splitter with 0.5, 1, 2 LPM nozzles and blanking plugs. Kink-resistant oxygen tubing with standard connectors (15 m each).	For two or more simultaneous paediatric patients: - 1 x flowmeter stand with minimum range from 0 to 2 LPM; or - 1 x four-way flow splitter with 0.5, 1, 2 LPM nozzles and blanking plugs. Kink-resistant oxygen tubing with standard connectors (15 m each).
Sterilization process for nasal prongs	Disinfection for nasal prongs	Disinfection for nasal prongs
Consumables / reagents	Five year supply of the following (quantities to be determined based on expected patient load and usage frequency): - nasal prongs or nasal catheters (each size for adult, child, infant); - child nasal prongs: distal diameter: 1–2 mm: - child/infant catheters: 6 or 8 French gauge.	Five year supply of the following (quantities to be determined based on expected patient load and usage frequency): - nasal prongs or nasal catheters (each size for adult, child, infant); - child nasal prongs: distal diameter: 1–2 mm: - child/infant catheters: 6 or 8 French gauge.
Manuals		
User, installation, maintenance, and technical	To be provided in the language of choice	To be provided in the language of choice

Annex 3: Forecasting and Procurement – Costing Model

1 Calculate the total O2 quantities required for a given health facility

- **B** Number of beds per ward **X** Hypoxemia prevalence per ward **X** Bed turnover ratio **=** # of hypoxemic cases per ward
- **B** # of hypoxemic cases per ward **X** O2 consumption in L per case **=** Total L consumed per ward
- **C** Sum the consumption of all wards

2 Repeat the above calculation for all facilities in the country → total O2 need in the country

3 Calculate the supply cost

- **A** Determine the cost of each of mode of supply and the supply mix for every health facility
- **B** Derive total CAPEX and OPEX costs from the above

ANNEX 4: List of Experts who have contributed in the preparation of this road map:

S/N	Name	Organization	Position
1	Dr. Daniel G/Michael	FMoH/MSGD	Director General
2	Dr. Ephrem Tekle	FMoH/MCHD	Director
3	Dr Desalegn Tigabu	FMoH/Clinical Services Directorate	Director
4	Mr. Meles Solomon	FMOH	MCHD-Child Health Case Team
5	Dr. Yigeremu Abebe	CHAI	Country Director
6	Dr. Lisanu Taddesse	FMOH	MCHD- Child Health Case Team
7	Dr. Habtamu Seyoum	CHAI	Senior Program Manager-Child Survival
8	Dr Anteneh Andualem	St. Paul Hospital	Pediatrician
9	Henock Hussien	Adama General Hospital	Bio Medical Engineer
10	Dr Amanuel Hadigu	Mekele University	Pediatrician
11	Dr Ashenafi Tekle	Mekele University	Department of Gyn/Obs
12	Edmalem Admasu	Amhara Regional Health Bureau	Core process owner-HMESSCP
13	Abenezer Asegid	PFSA- Central	Bio Medical Engineer
14	Berihu Mesfin	Tigray RHB	CR-Core process owner
15	Seyfe Asfaw	Chora Gas & Chemical	Production Manager
16	Wubshet Mekuria	SNNPR RHB	Core process owner-HMESSCP
17	Dr Zemene Tigabu	Gondar University	Pediatrician
18	Kefele Merera	FCBO	Bio Medical Engineer
19	Mered Paulous	Sunbird Trading	Manager
20	Anwar Mustefa	St. Paul MMC	Bio- Medical Engineer
21	Belete Tessema	PFSA- Central	Biomedical Coordinator
22	Hafty Abadi	Ayder Hospital/Mekele	Oxygen Consultancy Manager

S/N	Name	Organization	Position
23	Eyob Zenebe	Ayder Hospital/Mekele	Head Bio- Medical Engineering
24	Tegakiros Abrha	Ayder Hospital/Mekele	Oxygen Plant
25	Wondefrash Million	FMOH	Bio Medical Engineer
26	Abdelhak Mohammed	ORHB	BME coordinator
27	Viviana Rivas	R4D	Country Rep.
28	Pablo Galindo	BMGF	Strategy Officer
29	Katie Maloney	BMGF	Program Officer
30	Amy Ginsburg	SCI	
31	Dr. Yirga Ambaw	USAID	Program management team-Child health
32	Meron Paulos	PATH	Program Manager
33	Mike Ruffo	PATH	Associate
34	Mulugeta Mideksa	CHAI	Bio-Medical Engineer
35	Dr. Yared Tadesse	FMOH	MCH/ Child Health case team
36	Dr Hamish Graham	CICH/University of Melbourne	Pediatrician and researcher
37	Damien Kirchhoffer	CHAI	Director
38	Dr. Abeba Bekele	SCI	
39	Smith Lisa	PATH	Program Officer
40	James Stunkel	PPP-Assist International	Vice president
41	Asfaw Afwork	Black Lion Hospital	Biomedical Coordinator
42	Dinkineh Bikila	CHAI	Program manager
43	Dr. Berhanu Sendek	JSI	Advisor-Maternal Health