Medical Oxygen Supplier Landscape in Vietnam

December 2021
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The work described in this report was carried out as part of PATH’s COVID-19 Respiratory Care Response Coordination project, which is a partnership between PATH, the Clinton Health Access Initiative, and Every Breath Counts Coalition to support country decision-makers in the development and execution of a comprehensive respiratory care plan to meet the demands of COVID-19. The project is also pursuing strategies to help prioritize and improve access to oxygen therapy and other essential equipment involved in respiratory care as an integral part of health systems strengthening, beyond the pandemic response.

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## Abbreviations

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<th>Description</th>
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<tr>
<td>BEIT</td>
<td>Biomedical Equipment Inventory Tool</td>
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<tr>
<td>BR-VT</td>
<td>Bà Rịa–Vũng Tàu</td>
</tr>
<tr>
<td>CAPEX</td>
<td>capital expenditure</td>
</tr>
<tr>
<td>COVID-19</td>
<td>coronavirus disease 2019</td>
</tr>
<tr>
<td>DAGASCO</td>
<td>Da Nang Industrial Gas Joint Stock Company</td>
</tr>
<tr>
<td>ESFT</td>
<td>Essential Supplies Forecasting Tool</td>
</tr>
<tr>
<td>GoV</td>
<td>Government of Vietnam</td>
</tr>
<tr>
<td>HCMC</td>
<td>Ho Chi Minh City</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
<tr>
<td>km</td>
<td>kilometer</td>
</tr>
<tr>
<td>L</td>
<td>liter</td>
</tr>
<tr>
<td>LOX</td>
<td>liquid oxygen</td>
</tr>
<tr>
<td>m³</td>
<td>cubic meter</td>
</tr>
<tr>
<td>MOH</td>
<td>Ministry of Health</td>
</tr>
<tr>
<td>NA</td>
<td>not applicable</td>
</tr>
<tr>
<td>OPEX</td>
<td>operating expense</td>
</tr>
<tr>
<td>PSA</td>
<td>pressure swing adsorption</td>
</tr>
<tr>
<td>VIE</td>
<td>vacuum insulated evaporator</td>
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<td>WHO</td>
<td>World Health Organization</td>
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# Glossary

*Definition of terms commonly used subsequently in this report*

**Manufacturer**  
Shortlisted for liquid oxygen manufacturers. Referred to companies that have the capability to produce and distribute liquid oxygen. May or may not distribute oxygen directly to health facilities.

**Distributor**  
Any companies that distribute medical oxygen in liquid or gas form to health facilities, but do not produce liquid oxygen. May or may not have the capacity to vaporize liquid oxygen to gas and compressed gas oxygen into cylinders.

**Supplier**  
Both manufacturers and distributors that distribute medical oxygen in liquid/gas form. May or may not have the capacity to produce liquid oxygen.

**Storage tank/Bulk tank**  
Cryogenic tanks, often of size 6m³ or larger, used to store liquid oxygen at very low temperature.

**Lorry tank/Tanker truck**  
Vehicles used to transport liquid oxygen. Comprised of a cryogenic vessel to store liquid oxygen.

**Oxygen cylinders- size 10L**  
Equivalent to 1.5 cubic meter gas of oxygen.

**Oxygen cylinders- size 40L**  
Equivalent to 6 cubic meter gas of oxygen.
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Executive summary

Overview

Oxygen therapy has long played a critical role in health care. Medical oxygen is a World Health Organization essential medicine, needed for many acute and chronic conditions, such as pneumonia, newborn conditions, asthma, heart failure, and obstetric emergencies. Nevertheless, consistent access to medical oxygen is not available in all countries due to production scarcities, logistical failures, and many other additional circumstances. The recent COVID-19 pandemic has further stressed both the importance of oxygen and the severe consequences that the lack of oxygen access may have, as many countries around the world experienced shortages of oxygen following surges in COVID-19 cases.

In 2020, the government of Vietnam (GoV) successfully prevented widespread transmission of the COVID-19 virus in the country, thus avoiding an oxygen shortage crisis, through implementation of an effective prevention strategy. However, since July 2021, the Delta variant of the COVID-19 virus has caused the number of cases to sharply increase. Between August and September, cases rose to levels of approximately 10,000 to 14,000 per day. This rapid rise in cases resulted in a proportional surge in demand for oxygen and health care services. Despite the decline in case numbers in October following the GoV’s management measurements and the growing vaccination rate, cases are starting to rise again as the country enters the new “normal” phase, similar to what has been observed in many other countries, such as Singapore, Israel, and the United Kingdom. Therefore, it is crucial to understand Vietnam’s oxygen supply capacity to effectively respond to any challenges that the COVID-19 pandemic or another disease outbreak of a similar scale may bring in the coming months or years.

This report examines the state of medical oxygen supply in Vietnam and offers insights into the strengths and weaknesses of the oxygen supply system. In addition, the document provides an overview of medical oxygen consumption in Vietnam before and during the COVID-19 outbreak, as well as recommendations for enhancing equitable oxygen access. Information in this report may be used by local government decision-makers for oxygen planning purposes, as well as other low- and middle-income country decision-makers intending to implement oxygen solutions in their respective countries in the near future.

Key findings

Key findings on medical oxygen supply and demand are as follows:

- The maximum daily production capacity (for both medical and industrial usages nationally) by 8 liquid oxygen manufacturers is approximately 1,129 cubic meters (m³), with 92.4 percent of the capacity concentrated in the Northern and Southern regions.

- Prior to the fourth wave of COVID-19 (starting in April 2021), medical usage was estimated to be 92 m³ of liquid oxygen (LOX), or approximately 10 percent of average daily production capacity.

- Together, 993 hospitals in Vietnam have enough storage capacity for 1,629 m³ of LOX and 177,000 m³ of gas for oxygen cylinders (equivalent to 206 m³ of liquid).

- During the fourth wave of COVID-19, the demand for medical oxygen has increased 11 times to approximately 1,040 m³ per day, 92 percent of the maximum production capacity.

Key findings on the distribution of medical oxygen are as follows:
• LOX is distributed to hospitals by 46 liquid oxygen suppliers. These 46 suppliers are present in 27 of the 63 provinces.

• The oxygen cylinder distributor network is denser than the network of liquid oxygen suppliers, with 200 cylinder suppliers located in 55 of 63 provinces.

• Oxygen suppliers are often clustered in larger cities and not present in small provinces, particularly in the Northwest and Mekong Delta areas.

• The average delivery distance between a hospital and the respective LOX provider is 74 kilometers, while that between a hospital and the respective cylinder provider is 51 kilometers.

Key findings on the refill cost of medical oxygen and availability of oxygen storage equipment are as follows:

• The median price for LOX reported by hospitals is US$0.30/m³ of gas (or $240.00/m³ of liquid), while the median price of gas oxygen is approximately double that, at $0.70/m³ of gas (or $4.30 / 40-liter cylinder).

• Prices may vary between region and hospital types, depending on usage, negotiation power, and many other factors. Hospitals with more beds and those that purchase directly from the manufacturers may often pay a lower refill price.

• Storage equipment such as cylinders and cryogenic tanks in Vietnam are often imported and thus involve a long order time of two to three months.

• Most of the suppliers surveyed keep inventory of the storage equipment. As of August 2021, approximately 144 tanks and 55,000 cylinders are available locally.

Recommendations

Based on these findings, the project team has developed the following recommendations:

• Create an emergency plan to address surging medical oxygen need during a disease outbreak:
  o Enhance production flexibility by creating a plan for quickly reallocating and ramping up oxygen supply during a disease outbreak.
  o Create a coordinating mechanism to ensure the distribution network runs efficiently and all hospitals receive stable supplies of oxygen.
  o Consider importing oxygen when demand significantly exceeds supply capacity.

• Strengthen medical oxygen access in vulnerable provinces, particularly in Mekong Delta, Central, and Northwest provinces:
  o Enhance oxygen production capacity in Central provinces.
  o Install LOX tanks at large hospitals that have a refill center within proximity and sufficient infrastructure, as LOX offers the most affordable cost-per-liter pathway for facilities with high demand.
  o Equip smaller hospitals that are located 100 kilometers or more from oxygen suppliers with oxygen concentrators as a backup oxygen source for cylinders or LOX.
  o Inform health facilities of the refill vendor network surrounding their regions.
Consider installing secondary and/or backup oxygen systems for large hospitals that are last lines of treatment for severe COVID-19 patients

- Enhance awareness of safe oxygen usage:
  - Provide training for hospital staffs on oxygen system operation and basic knowledge of oxygen
  - Issue a national technical standard of medical oxygen and working instruction for staffs handling oxygen.
  - Spontaneous oxygen charity units (e.g., ATM) must be managed by a competent authority to ensure quality of product and equipment as well as safety and security for users.

Summary

Overall, these analyses indicate that Vietnam has plentiful LOX production capacity, as well as an established distribution that allows oxygen to be delivered to most health facilities. However, it should be emphasized that, despite these capacities in production and distribution, many challenges were still observed during the recent COVID-19 surge. As COVID-19 cases increased, substantial efforts to mobilize oxygen production and distribution, as well as to expand oxygen storage to meet demand were needed. Therefore, decisive actions to extend oxygen access to more health facilities, particularly those in smaller and more vulnerable provinces, may greatly aid the health care system in the future during disease outbreaks or other emergency situations.
Objective

The key objective of this document is to describe the landscape for medical oxygen suppliers in Vietnam, with an emphasis on the production, distribution, and cost associated with liquid oxygen (LOX) and gas cylinders in Vietnam. In addition, the report examines the capacity to meet medical oxygen demand by health facilities, particularly during a disease outbreak.

Audiences who may find this report useful include local government decision-makers, such as ministries of health; health facility procurement platforms; and global organizations, such as multilateral agencies. Information in this report could facilitate better understanding of oxygen supply and need, as well as oxygen financing for emergency and general planning purposes.

The document may also benefit distributors and wholesalers of oxygen who can derive a deeper knowledge of the competitive landscape for their services and potential market opportunities.
Data sources

Oxygen Supplier Survey
A paper-based questionnaire was designed by PATH and the Vietnam Ministry of Health (MOH) Cabinet Officer to collect comprehensive information about the production and distribution of medical oxygen in the country. The aim is to use the gathered information to provide an understanding of the medical oxygen supply and the country capacity in meeting oxygen demand before and during the COVID-19 pandemic. Additional information regarding the survey can be found in Appendix 1.

Oxygen supplier interviews
Phone interviews were conducted with sales managers from three leading LOX manufacturers to gain an in-depth knowledge of the fixed and variable costs that may incur for hospitals operating on LOX or cylinders, the oxygen supply chain, and the oxygen market in Vietnam. Refer to Appendix 2 for more information.

In addition, representatives from Asia Industrial Gases Association provided qualitative feedback regarding medical oxygen production capacity in Vietnam.

Biomedical Equipment Inventory Tool (BEIT) survey
The BEIT survey was conducted jointly by PATH and the Vietnam MOH Cabinet Office to quantify the amount of respiratory care equipment and medical oxygen available in health facilities in January-February 2021. In total, 993 health facilities, 75% of the total number of hospitals in Vietnam, completed the questionnaire. All 993 hospitals participated were designated to treat COVID-19 patients. More information regarding this survey results can be found in PATH’s Oxygen and Respiratory Care Equipment for COVID-19 Patient Management in Vietnam report.¹

MOH database of oxygen manufacturers in Vietnam
This database was collected by the MOH and updated August 2021 to coordinate oxygen production in response to the fourth wave of COVID-19 starting in April 2021. The database contains information on the largest LOX manufacturers and distributors in Vietnam. Refer to Appendix 3 for more details.

Presentation materials from the MOH’s Enhancing Medical Oxygen Supply and Usage conference
The conference was conducted on September 13, 2021 to train health care decision-makers for medical oxygen supply planning in response to COVID-19 outbreaks. Refer to Appendix 4 for the conference content.
Overview of medical oxygen

Every year, millions of patients with pneumonia, obstetric emergencies, and other respiratory illnesses are treated with oxygen. For years, oxygen therapy has been a lifesaving health care intervention for people with hypoxemia, a symptom where the oxygen concentration in the blood becomes abnormally low. Due to the recent COVID-19 pandemic, the role of oxygen has become even more critical. Many countries around the world—such as India, Peru, and Indonesia, as well as hospitals in the United Kingdom, United States, and Russia—have all seen shortages in medical oxygen when surging COVID-19 cases rapidly use up available supply for crucial oxygen therapy. Due to its vital role in many health care-related situations, the World Health Organization (WHO) added medical oxygen gas to its Model List of Essential Medicines in 2017.

According to WHO, oxygen delivered to patients must be high-quality medical grade. The purity must be at least 82 percent, with no contamination, and the oxygen must be produced by an oil-free compressor. In Vietnam, hospitals use either LOX, oxygen cylinders, oxygen concentrators, pressure swing adsorption (PSA) plants, or a combination of two or three types for patient treatment, as shown in the BEIT survey results. Among the four oxygen sources, LOX and oxygen cylinders are used most frequently by health facilities of all sizes in Vietnam. All 993 hospitals analyzed in the BEIT survey use oxygen cylinders and 199 hospitals are equipped with liquid oxygen storage tanks. However, out of these 993 hospitals, only 7 used PSA plants, 3 of which were on islands where access to LOX or cylinder is limited. Therefore, this report will primarily explore the supply of, distribution of, and demand for LOX and gas cylinders, as well as the cost associated with these two oxygen sources. Figure 1 highlights the pathways from oxygen production to distribution, then storage, and finally, delivery to the patient.
Figure 1. A snapshot of oxygen production and delivery methods.

https://path.azureedge.net/media/documents/O2_Business_models_brief_PATH_FINAL.pdf#page=2.
Medical oxygen supply analysis

While medical oxygen could also come from PSA plants or concentrators, the primary sources of medical oxygen in Vietnam are from LOX and oxygen cylinders. LOX is used to fill most gas cylinders: it is vaporized into gas and then compressed into cylinders. Therefore, in this section, we will only cover the manufacturing landscape and production capacity of LOX.

Overview of LOX production and applications

LOX in Vietnam is produced via an air separation unit, and oxygen is often a minimum 99.5 percent on up to 99.9 percent purity, as per the supplier survey results. Besides being used for medical purposes, LOX has wide industrial applications, such as in steel manufacturing, welding, wastewater treatment, and even rocket launches. Oxygen for medical use can be supplied directly in liquid form and stored in large cryogenic tanks installed at hospitals or in gas cylinders.

As LOX can be transported and stored in a greater quantity than oxygen cylinders, it is usually preferred over oxygen cylinders by large facilities, such as provincial and national hospitals. However, oxygen cylinders are used by the majority of district hospitals, as well as by higher-level facilities as a backup source. Also, thanks to their compact size and flexibility, cylinders are frequently used when transporting patients within a facility or across different health facilities within a referral network.

LOX production capacity

Based on Asia Industrial Gases Association (AIGA) Vietnam’s presentation in MOH Enhancing Medical Oxygen Supply and Usage conference, there are 8 main LOX manufacturers in Vietnam. In total, these manufacturers have 14 plants that cover all regions of Vietnam and a maximum production capacity of approximately 1,129 m³ per day. However, manufacturers do not always operate at full capacity. On average, 915 m³ of LOX, or 81 percent of the maximum capacity, is produced per day, according to the database.

While there are production plants in all three of the main regions of Vietnam (North, Central, and South), 91.5 percent of the production capacity is concentrated in the North and South (Table 1). Specifically, most production capacity is located in provinces within close proximity to Hanoi and Ho Chi Minh City (HCMC)—namely, Hai Duong and Bac Ninh in the North and Bà Rịa–Vũng Tàu and Binh Duong in the South. More details regarding LOX manufacturers are summarized in Table 2.

Table 1. Daily liquid oxygen production capacity in Vietnam, by provinces

<table>
<thead>
<tr>
<th>Company name</th>
<th>Max daily production capacity (m³ liquid)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>North</td>
</tr>
<tr>
<td>Total capacity (m³)</td>
<td>461 (40.8%)</td>
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</table>
Table 2. Liquid oxygen manufacturers in Vietnam

<table>
<thead>
<tr>
<th>Company name</th>
<th>Ownership</th>
<th>Plant</th>
</tr>
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<tbody>
<tr>
<td>Messer Hai Phong</td>
<td>Foreign</td>
<td>Hai Duong, Quang Ngai</td>
</tr>
<tr>
<td>Air Liquide</td>
<td>Foreign</td>
<td>Bac Ninh (2), HCMC</td>
</tr>
<tr>
<td>Nippon Sanso</td>
<td>Foreign</td>
<td>BR-VT (2), Dong Nai, Hung Yen</td>
</tr>
<tr>
<td>Sovigaz</td>
<td>Local</td>
<td>Binh Duong</td>
</tr>
<tr>
<td>Linde Gas</td>
<td>Foreign</td>
<td>BR-VT</td>
</tr>
<tr>
<td>Industrial Gas Airwater</td>
<td>Foreign</td>
<td>BR-VT</td>
</tr>
<tr>
<td>Sing Industrial Gas</td>
<td>Foreign</td>
<td>Binh Duong</td>
</tr>
<tr>
<td>Bac Ha</td>
<td>Local</td>
<td>Bac Giang</td>
</tr>
</tbody>
</table>

Abbreviations: BR-VT, Bà Rịa–Vũng Tàu; HCMC, Ho Chi Minh City.

Besides the 8 key manufacturers, according to MOH Decision 4308 (Oxygen Emergency Response Plan), selected steel manufacturers in Vietnam also possess LOX manufacturing capacity. According to AIGA Vietnam, Formosa Steel could produce approximately 26 cubic meters of liquid oxygen per day. Nonetheless, there has been no data on the total LOX production capacity of these steel manufacturers.

**LOX manufacturers**

Among the 8 LOX manufacturers, two are locally owned and six are foreign-owned companies (Table 2). They all produce oxygen for both medical and industrial purposes, and the ratio of medical-to-industrial oxygen production varies from company to company. Foreign-owned companies, accounting for 88 percent of national production capacity, often distribute medical oxygen via local distributors. On the other hand, local manufacturer Sovigaz often distributes directly to hospitals and is estimated to capture 47 percent of the medical oxygen market, volume wise.
Distribution of medical oxygen

In Vietnam, to provide oxygen to hospitals, companies are required to go through a public bidding process for a one-year contract. Medical oxygen is primarily supplied to hospitals via distributors. While there are a limited number of LOX manufacturers located in provinces with large metropolitan areas (i.e., Hanoi, HCMC, Danang), Vietnam has a dispersed network of LOX and cylinder distributors that can reach most provinces.

Liquid oxygen could be delivered directly from manufacturers to health facilities. Alternatively, liquid oxygen is transported to distributors from manufacturers, stored at distributor's site and delivered to hospitals whenever needed. Based on the MOH database, oxygen manufacturers and distributors could store in total 12,500 cubic meters of liquid oxygen ⁸ (See Appendix 6 for more information).

Liquid oxygen could also be converted to gas cylinder before being distributed to health facilities. To produce oxygen cylinders, oxygen gas is first vaporized from LOX and subsequently compressed into medical grade cylinders. All manufacturers of LOX, except Linde Gas and Air Liquide, possess the capacity to vaporize and fill cylinders. Besides these manufacturers, there is a vast network of distributors that purchase LOX from the LOX manufacturers to fill into cylinders and sell to hospitals.

It is critical to understand the distribution of LOX and gas cylinders, as both need to be periodically refilled to avoid disruption to patients' treatment. In this section, the distribution landscapes of both LOX and gas cylinders will be discussed in detail.

**LOX distribution**

In larger facilities where cryogenic tanks are installed, oxygen is often stored in liquid form. Liquid oxygen can also be stored in cryogenic cylinders, often of size 175L (equivalent to 145 cubic meters of oxygen gas). At health facilities, liquid oxygen is then vaporized into gas form and delivered to patients via a central piping system.

**Overview of LOX suppliers**

Overall, the analysis of the BEIT survey shows that there are 46 LOX suppliers located in 27 provinces supplying LOX to 199 hospitals. Among these 46 suppliers, only 3 produce liquid oxygen. As shown in Figure 2, the supplier network is well established in larger metropolitan areas, such as Hanoi, HCMC, Danang, Nghe An, and Thanh Hoa, and less developed or nonexistent in Northwest, Central Coast, and Southwest (Mekong Delta) provinces.
Of the hospitals with LOX storage capacity, 56 percent are supplied by 4 companies, Sovigaz (28 percent), ThanhGas (13 percent), Oxy Dong Nai (7 percent) and Industrial Gas Nghe An (8 percent). Regionally, the market share distribution differs significantly. In Northern Vietnam, the LOX supplier landscape is very fragmented, with 28 companies supplying 74 hospitals. ThanhGas, the biggest distributor in the North, supplies only 26 percent of the hospitals. On the other hand, in Central Vietnam, the market is slightly less dispersed. Among 16 suppliers identified, the 3 biggest companies supply 60 percent of the market, and the 5 biggest companies supply nearly 80 percent. Last but not least, the
Southern Vietnam market is the most concentrated, with 8 identified companies supplying 69 hospitals, while 84 percent of the hospitals are served by 2 suppliers (Sovigaz and Oxy Dong Nai). Further detail of the key suppliers for each of the three main regions (North, South, Central) can be found in Figure 3.

Figure 3. Key suppliers of liquid oxygen and their client share, by region.

* “N” indicates the number of health facilities in the Biomedical Equipment Inventory Tool survey that use liquid oxygen.

Abbreviation: DAGASCO, Da Nang Industrial Gas Joint Stock Company.
Delivery capacity of key suppliers

LOX is delivered to health facilities in tanker trucks with a capacity of 8 to 20 m³. Refilling is often performed at a periodic interval (for example, on a weekly basis)—depending on usage and the contract with the supplier—and preferably before the level of LOX falls below 10 percent.

According to the results of the survey of oxygen suppliers, companies can deliver LOX to facilities within a 500-kilometer distance. Nevertheless, it was found that mean delivery distance is 73 kilometers. Fifty percent of hospitals are within a 50-kilometer distance from their LOX supplier, and 70 percent are within a 100-kilometer distance. It is also worth highlighting that the maximum distance is up to 380 kilometers, and 10 hospitals are over 240 kilometers away from their LOX supplier. Most of those hospitals are located in provinces where there are no LOX distributors.

The 6 biggest suppliers in the three regions (Figure 3) own 41 tanker trucks for LOX transportation. If each truck makes one delivery per day, these 6 companies can deliver up to 631 m³ of oxygen daily. Besides these 6 companies, other liquid oxygen manufacturers and distributors also possess delivery vehicles. Therefore, the quantity of LOX that can be transported per day is expected to be significantly higher.

Gas cylinder distribution

In Vietnam, comparing to liquid oxygen, oxygen cylinders are used by a significantly higher number of hospitals at all levels due to their versatility. Hospitals that have an LOX system installed also often store oxygen cylinders as a backup source. In smaller facilities, cylinders represent a low-investment option for supplying oxygen to patients.

Overview of oxygen cylinder distributors

According to the BEIT survey results, there are 200 suppliers of cylinders in the whole country, providing cylinders to 878 hospitals. Among these 200 suppliers, 2 are manufacturers of LOX, and the rest are purely distributors. Compared to the LOX distribution network, the cylinder network is much more dispersed and developed, due to the higher number of hospitals using cylinders. On average, there is at least 1 cylinder distributor in 55 of the 63 provinces.

However, the cylinder distribution network is not equally established across provinces. The survey results show that there are a substantially higher number of suppliers in larger metropolitan areas with a high population (e.g., Hanoi, HCMC, etc.). In particular, there are 8 provinces, mostly in the Northwest and Mekong Delta areas, that do not have any supplier, and thus hospitals from these provinces often rely on delivery from larger suppliers in nearby regions. Figure 4 further illustrates the network of oxygen cylinder suppliers in Vietnam, by province.
Due to the large number of suppliers, the cylinder market share is relatively diluted, and each vendor has less than 10 percent of the market share except Sovigaz (serving approximately 18 percent of hospitals). Regionally, the market distribution resembles that of the LOX market. In Northern Vietnam, there are 90 suppliers present, and the largest supplier, ThanhGas, only has 9 percent of the market share. Similarly, in Central Vietnam the market is relatively dispersed, with 57 suppliers providing oxygen to approximately 300 hospitals. Most suppliers have less than 10 percent of the market share, except Industrial Gas Nghe An (at 19 percent). In contrast, the Southern market is dominated by 3 companies: Sovigaz (52 percent of the clients), Can Tho Mechanical Joint Stock Company (13 percent), and Oxy Dong Nai (10 percent). Further details of the key suppliers for each region can be found in Figure 5.
Figure 5. Key suppliers of cylinders and their client share, by region.

**North**
- N= 322
- 91%: Others
- 9%: Thanhgas (9%)

**South**
- N= 262
- 52%: Sovigaz
- 13%: CAMEMCO (13%)
- 10%: Oxy Dong Nai (10%)
- 25%: Others

**Central**
- N= 294
- 42%: Sovigaz
- 9%: Thanhgas
- 8%: Oxy Long Phat
- 9%: DAGASCO
- 7%: Maritime Services Co
- 7%: Industrial Gas Nghe An
- 5%: Others
- 3%: Oxygen Tuan Anh Gia Lai

**90 suppliers**

*“N” indicates the number of health facilities in Biomedical Equipment Inventory Tool that use gas cylinders. Abbreviations: DAGASCO, Da Nang Industrial Gas Joint Stock Company; CAMEMCO, Can Tho Mechanical Joint Stock Company*
Filling capacity
Due to the established network of oxygen cylinder suppliers, the total estimated filling capacity of all companies in Vietnam is significant. According to the MOH’s database, the 9 biggest cylinder suppliers, which account for 55 percent of the hospital’s volume (Figure 5), have a combined filling capacity of approximately 27,500 cylinders per day (equivalent to 165,500 m³ in gas). As there are 200 vendors identified, the aggregate filling capacity is estimated to be much higher than that.

Delivery capacity of key distributors
Cylinder delivery does not require specialized trucks and thus is more easily fulfilled than LOX delivery. Vendors selling oxygen cylinders can either use their own trucks to transport cylinders to hospitals or engage a third-party logistic service. The 9 largest cylinder suppliers shown in Figure 5 altogether can deliver 7,400 cylinders per day, and the 4 liquid manufacturers (Messer, Sing Industrial Gas, Nippon Sanso, and Industrial Gas Airwater) can deliver 1,600 cylinders. Data regarding the delivery capacity of the remaining cylinder suppliers are not available. Nonetheless, it is expected that the combined capacity of all cylinder suppliers is well over 9,000.

Based on our survey results, the mean distance between a hospital and its respective cylinder vendor is 52 kilometers, much lower than that between a hospital and its LOX vendor, due to the much denser cylinder supplier network. Fifty percent of the hospitals are within 22 kilometers of their cylinder supplier, and 88 percent are within 66 kilometers. Nevertheless, there are still at least 60 hospitals that are located over 140 kilometers from their cylinder suppliers, half of which are from provinces with only 1 cylinder vendor, if any.
Medical oxygen demand analysis

This section analyzes the consumption of medical oxygen via liquid sources and gas cylinders before and during the fourth wave of COVID-19. Additionally, medical oxygen consumption and refill need were assessed against the supply and distribution capacity to identify whether there is any gap that needs to be addressed. In general, it is assumed that all oxygen consumed is solely produced via LOX and that all medical demand is met via LOX production output (in both liquid form and gas cylinder form).

Demand before the fourth wave of COVID-19

LOX needs for liquid tank refill

As revealed in the BEIT survey, LOX bulk tanks are installed in only 199 of the 993 hospitals assessed in the survey. Bulk tanks are more common in higher-level facilities, such as national and provincial hospitals. In total, 1,629 m³ of LOX could be stored by these hospitals.

Our survey shows that, prior to the fourth wave of COVID-19, on average, national hospitals required five to six refills per month; provincial hospitals, three refills per month; and district hospitals, one refill per month. Based on hospitals’ LOX storage and the refill pattern, it is estimated that about 73 m³ of LOX would have been consumed per day, or only 9 percent of the delivery capacity (see Appendix 7 for more information).

LOX needs for oxygen cylinders

Based on the findings, on average, national and provincial hospitals store the most cylinders (377 and 325 cylinders/hospitals), whereas district and private hospitals store 135 cylinders each. In total, 44,500 cylinders, equivalent to 177,000 m³ of gas, are stored by the 993 hospitals surveyed.

Before the fourth wave, provincial and district hospitals generally needed three to five refills per month, and national hospitals, one per month. Overall, approximately 4,000 oxygen cylinders (16,400 m³ of gas or 19 m³ of liquid) are consumed per day (see Appendix 8 for more information), which is only a fraction of the filling and delivery capacity of the 9 largest cylinder vendors in Vietnam.

Total LOX used for medical purposes

Combining the LOX used for liquid tank refills and cylinders, approximately 92 m³ of LOX were needed per day before the latest wave of the pandemic, of which 80 percent was via liquid tanks and only 20 percent via gas cylinders. This consumption is only 10 percent of the average daily production capacity of 915 m³ (see “Medical oxygen supply analysis” section), and the oxygen supply could easily meet this demand before the COVID-19 pandemic. However, as the BEIT survey only covered 75 percent of the health facilities in Vietnam, the actual liquid oxygen needed before the pandemic may be slightly higher than the estimated 92 m³.
Demand during the fourth wave of COVID-19

Background

Starting on April 27, 2021, Vietnam has experienced a fourth wave of COVID-19. This new outbreak has been more complex, characterized by many community-transmitted clusters and a high number of transmissions caused by the contagious Delta variant. New cases rapidly spread to 62 provinces, and by July 26, the total number of cases exceeded 100,000. Between August and September 2021, there were, on average, 10,000 to 14,000 COVID-19 cases per day and over 200,000 active cases in total, mostly in the Southern provinces, specifically HCMC and Binh Duong. According to the statistics reported by the MOH in the *Enhancing Medical Oxygen Supply and Usage* conference, approximately 13.6 percent of COVID-19 patients will require oxygen at 5 to 60 liters per minute, depending on the severity of their hypoxemia.

Estimated total LOX need for medical purposes

Based on PATH analysis using MOH statistics of a COVID-19 patient's oxygen need, 1,040 m$^3$ of LOX would be consumed per day when the total case load is at 200,000, 11 times more than before the latest outbreak (Figure 6). This projected oxygen surge is consistent with the 16-times increase in oxygen demand during the fourth wave as reported by the MOH on local television. Given this new estimated demand, 92 percent of the production output at the maximum capacity of 1,129 m$^3$ per day (see “Medical oxygen supply analysis” section) will potentially be diverted for medical usage. However, with the relatively large LOX storage capacity of 12,500 cubic meters, it is estimated that the largest oxygen suppliers could still meet the demand during this fourth outbreak for 12 days, thus temporarily relieving the pressure on to the production system.

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1 Assuming that liquid oxygen is stored at full capacity of 12,500 cubic meters.
Figure 6. Demand and supply of medical oxygen, before and during the fourth wave of COVID-19.

<table>
<thead>
<tr>
<th>Daily medical demand pre &amp; during COVID-19 (m³ liquid)</th>
<th>Total LOX supply (m³ liquid)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 4th wave (Jan-Feb 2021)</td>
<td>12,500</td>
</tr>
<tr>
<td>During the 4th wave</td>
<td></td>
</tr>
<tr>
<td>92</td>
<td></td>
</tr>
<tr>
<td>1,040</td>
<td></td>
</tr>
<tr>
<td>~10% of average production</td>
<td></td>
</tr>
<tr>
<td>~11.3x</td>
<td></td>
</tr>
<tr>
<td>915</td>
<td></td>
</tr>
<tr>
<td>1,129</td>
<td></td>
</tr>
<tr>
<td>Average daily capacity</td>
<td></td>
</tr>
<tr>
<td>Maximum daily capacity</td>
<td></td>
</tr>
<tr>
<td>LOX stored at plants</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: LOX, liquid oxygen; MOH, Ministry of Health; PSA, pressure swing adsorption; WHO, World Health Organization.

**Liquid tank refill need**

During the fourth wave of COVID-19, assuming that 80 percent of oxygen need is still supplied in liquid form and that all medical oxygen need is met via liquid tank or cylinders, it is expected that 832 m³ of LOX will be consumed per day by hospitals. Thus, it is most likely that refill frequency will be shortened significantly to at least 1 refill every 1.7 days if cases are evenly distributed across provinces and the storage capacity is not expanded (Figure 7). Based on the aggregate delivery capacity of the 5 largest LOX suppliers, 76 percent of this daily refill need could be covered, and the remaining need could likely be absorbed by smaller LOX suppliers. Nonetheless, absorptive capacity will rely on how established the distribution network is in provinces experiencing the outbreak. Capacity to accommodate this surge in demand may also differ substantially among LOX suppliers, depending on their client quantities and profiles.
Cylinders refill need

During the fourth wave, if 20 percent of the oxygen need were met by cylinders, the daily oxygen cylinder consumption would be 179,000 m$^3$ of gas, equivalent to nearly 30,000 cylinders of size 40L, which is still less than the total estimated filling capacity. Nonetheless, our assessment of the distribution network has shown that capacity may not be equally distributed across regions. Most refill centers are concentrated in big cities and the nearby regions. Thus, providing transportation to reallocate cylinders may be essential if the outbreak is in a region with less capacity.

In addition, as cylinder consumption surges, refill frequency will increase, as oxygen is rapidly used up by COVID-19 patients. Cylinders would possibly need to be refilled daily, or even more frequently, assuming cases are evenly distributed across provinces and the storage capacity is not expanded (Figure 8). Based on a high-level assessment, the delivery need may be met given the high number of vendors available and the more easily fulfilled requirement for cylinder transport vehicles. Yet, again, selected regions still may be more vulnerable, and an extremely high level of coordination will be essential to meet this abnormally high need.

Abbreviation: LOX, liquid oxygen.
Case study: Meeting oxygen demand in Ho Chi Minh City and Binh Duong during the fourth wave of COVID-19

Background
The fourth COVID-19 outbreak, starting April 27, 2021, was the largest COVID-19 outbreak in Vietnam to date, with almost 1 million cumulative cases up until November 2021. While most discussions in the report assume an equal distribution of cases nationally, in reality, Southern municipalities and provinces have been the most impacted during this outbreak—particularly HCMC and Binh Duong, with 70 percent of the total cases clustered in these two areas and a combined 9,000 to 11,000 new transmissions per day from late August through September. This case study therefore examines how oxygen supply in a specific region could easily be overwhelmed during an outbreak, despite the relatively large supply capacity nationally, as well as discusses the successful measurements by the GoV to address the surging oxygen demand for HCMC and Binh Duong during the peak period of the outbreak.

Medical oxygen supply in South Vietnam
According to our analyses, Southern Vietnam boasts the highest concentration of LOX production in the country, with a maximum of 582 m$^3$ produced per day. The region also has the most concentrated distribution market, with over 80 percent of the market share belong to three companies: Sovigaz, Oxy Dong Nai, and CAMEMCO. These three distributors, together, could deliver 190 m$^3$ of LOX and 3,200 cylinders per day (equivalent to 22 m$^3$ of liquid if all cylinders are of 40-liter capacity).

Oxygen demand during the fourth outbreak in HCMC and Binh Duong
Our survey results also showed that 41 hospitals in HCMC have an aggregated oxygen storage capacity of 16 m$^3$ of liquid in gas cylinders and 168 m$^3$ of liquid in cryogenic tanks, while the 6 hospitals in Binh Duong could together store 1 m$^3$ of liquid in gas cylinders. Thus, it is estimated that, in total, these 47 hospitals could store 185 m$^3$ of liquid (LOX and gas cylinders).

During the fourth outbreak, given that 70% of the cases are from HCMC and Binh Duong, it is estimated that these two areas will require approximately 730 m$^3$ of medical LOX daily, exceeding the Southern LOX production capacity by 27 percent. As oxygen suppliers in Southern Vietnam could store over 6,000 cubic meters of liquid oxygen, this oxygen reservoir could temporarily cater to the surging demand during the peak of the outbreak. Nevertheless, if all demand was to be met via LOX or gas cylinders, multiple refills per day would be needed, given the total storage capacity of only 185 m$^3$, putting a significant strain on the delivery system.

In order to mitigate the situation, rapid actions were taken by the GoV to guarantee access to oxygen by COVID-19 patients. Oxygen produced for industrial usage was diverted for medical purposes. Oxygen manufacturers expanded their production capacity by 50 to 100 percent, and the Department of Air Defense also implemented three LOX production lines with a capacity of 4,300 cylinders (40 liters each) per day, or approximately 30 m$^3$ of liquid, to support HCMC. Four "oxygen ATMs" (cylinder filling stations) were also created in HCMC, with LOX sources from Tan Thuan Steel Joint Stock Company, to provide oxygen cylinders for home care patients.

Furthermore, 20 field hospitals, with combined capacity of up to 50,000 beds, were constructed as treatment centers. LOX and gas cylinder storage capacity was substantially expanded. COVID-19 treatment centers in HCMC were equipped with 113 additional oxygen tanks (combined capacity of 831 m$^3$) and 10,000 cylinders (40 liters each). Additionally, oxygen concentrators are used as a backup source. According to MOH Decision 2626, all COVID-19 treatment centers should have at least five concentrators per 20 beds for patients with no symptoms and ten concentrators per 20 beds for medium-to-severe patients, in addition to the gas cylinders or LOX sources. As of August 2021, over 10,000 additional oxygen concentrators were procured for COVID-19 centers in Binh Duong and HCMC.
Availability of storage equipment

As shown in the previous section, refill need is highly dependent on the oxygen storage capacity at hospitals. During a disease outbreak when oxygen need surges, refill frequency will need to increase correspondingly, potentially putting the logistic services under severe pressure. In such a situation, it will be highly useful to have the option to quickly procure or rent additional storage equipment (cylinders or bulk tanks) to reduce the strain on the delivery system. In this section, thus, a brief overview of cylinders and bulk tanks’ availability in the market will be provided.

Cryogenic bulk tanks

LOX tanks are imported into Vietnam from foreign countries (e.g., United States, France, India, Malaysia, China, etc.) and most commonly from China. Therefore, a lead time of two to three months may be required per order if local stock is not available. Fortunately, most vendors surveyed reported that a LOX tank inventory is available. In total, according to the MOH database, there are 144 tanks with a capacity of 1 to 60 $m^3$ each that are stocked by 9 suppliers, as of August 2021.

Cylinders

Cylinders in Vietnam are typically imported from China. Our survey with suppliers shows that cylinders are often stocked by both LOX manufacturers and cylinder vendors. The 9 key cylinder suppliers (Figure 5) store, in total, 33,700 cylinders (80 percent of which are of 40 liters or larger), and the 2 foreign-owned manufacturers (Sing Industrial Gas and Airwater) own 18,200 cylinders (all of which are 40 liters or larger and are for industrial usage). The storage capacity of these suppliers combined is roughly 280,000 $m^3$. In addition, cylinders are stocked by a large number of other medical device shops and oxygen cylinder distributors. It is difficult to quantify cylinders stocked by all suppliers, particularly the number of certified medical cylinders; but it is estimated that the actual stock is over 53,000.
Cost of ownership

Each oxygen delivery method will entail distinct expenditure. It is essential to understand the total cost involving each oxygen source when planning for an existing or a new facility. This following section will provide key analyses regarding the operating expense (OPEX) and capital expenditure (CAPEX) that may incur for a hospital using oxygen cylinders or LOX. However, it should be noted that all prices quoted below are indicative and may vary significantly depending on many contextual factors.

LOX

Components

Related to CAPEX, hospitals using LOX must invest in a vacuum insulated evaporator (VIE) system, consisting of a cryogenic LOX, vaporizers, valves, piping, and a pressure control/relief system. Prior to the system installation, excavation, leveling, and concrete pouring are often required to prepare the installation site at the health facility. Additionally, the health facility will need to have bedside terminals for oxygen delivery to the patients. As such, initial investment to enable a hospital to use LOX includes cost of the equipment, installation, concrete work, and oxygen terminals. The equipment (bulk tank, vaporizers, and other regulating accessories), as well as the associated services (installation, training, maintenance), are often offered by the LOX suppliers. Hospitals have the possibility of purchasing or renting the equipment.

OPEX components include refill, cost of labor to manage the LOX system, and preventive/corrective maintenance (see Appendix 10 for full cost of the components).

For more information regarding to the VIE, please refer to PATH's Oxygen Generation and Storage brief series.

Refill cost

According to the survey results with oxygen suppliers, LOX prices range from US$110.00 to $290.00 per m³ (average price is $190.00). Hospitals participating in our survey reported that the average LOX refill price is $240.00 per m³ of liquid (or $0.30 per m³ of gas). Price may vary between region and hospital types, depending on usage, negotiation power, and many other factors. This analysis reveals that the price in South Vietnam is, on average, lower than prices in Central and North Vietnam (by 20 and 25 percent, respectively). Bigger hospitals, with more intensive care unit beds, also tend to pay a lower refill price. On average, those that purchase directly from an LOX manufacturer will enjoy a 10 percent lower price compared to those that purchase via a distributor.

Besides the refill cost, hospitals will have to pay the transportation fee, which is calculated per trip. Charge per kilometer is between $0.80 and $1.30. The cost per refill, therefore, will depend on both the bulk tank size and the distance from the refill center. For a hospital that has a 6 m³ tank and is 50 kilometers away from the refill center, the cost per refill may range from $1,400 to $1,800. For selected vendors, the refill price (per m³) is quoted inclusive of the delivery cost, in which case delivery cost is often approximately 10 percent of the total refill price.
CAPEX

In total, based on the interview results with LOX suppliers, the total CAPEX (including piping) for an LOX station would be approximately $235,000 if the equipment is purchased (see Appendix 8). If the equipment is rented, the initial CAPEX would be approximately $130,000; however, there would be an additional monthly rental cost of $450.00 to $650.00, depending on the tank size and the vaporizer capacity.

OPEX

OPEX, except refill cost, includes manpower to manage the equipment, maintenance fees, and a rental fee (if the equipment is leased). Hospitals that use LOX often engage a third party to inspect and provide maintenance services for LOX equipment at an interval in line with the local regulations. In general, it is recommended that the bulk tank and vaporizer are inspected every two to three months and the piping system every five to six months. The maintenance cost is estimated to be $395.00 (per service) and is incorporated into the rental cost if the equipment is leased. Repair and replacement costs may incur occasionally and are calculated on a case-by-case basis.

Oxygen cylinder

Components

Related to CAPEX, oxygen via gas cylinders can be delivered directly to patients (when placed close to the patients’ beds) or via a manifold system. If delivered directly, each oxygen cylinder only need be deployed with accessories such as pressure gauges, regulators, and flowmeters. On the other hand, if delivered via a manifold system, a permanent installation of copper piping with brazed copper fittings, built-in pressure regulation, and terminal units will be required. For hospitals using oxygen cylinders, the majority of the OPEX incurred comes from the refill cost. Fixed costs may include cost of cylinders (which could either be purchased or rented) and related accessories, such as pressure gauge and regulators, as well as copper piping for a manifold system.

Refill cost

The survey with suppliers shows that the refill cost ranges from $1.70 to $4.30 (median is $2.60) for a 10-liter cylinder and $3.00 to $6.00 (median is $4.30) for a 40-liter cylinder (equivalent to $0.70 to $1.70 per m³ of gas). The cylinder transportation fee is calculated per trip, as with LOX, and can be shared between hospitals. Approximately 20 to 30 cylinders could be delivered per trip, depending on the truck size. The charge per kilometer varies from $0.60 to $0.90 or is sometimes free if the hospital is located in the same city as the vendor. Thus, if the hospital is located 20 kilometers away from the cylinder refill vendor, an additional $0.40 to $0.90 would be incurred per cylinder. The longer the transportation distance, the higher the total refill cost for the health facilities.

CAPEX

The CAPEX for oxygen cylinder ownership is often lower compared to that of LOX. Key initial investment primarily comprises the cost of cylinders and related accessories, such as pressure regulator and gauges. A 40-liter cylinder often costs $87.00 to $107.00, and a 10-liter one costs $56.00. Hospitals could either purchase or rent cylinders and related accessories. If the equipment is rented, an initial deposit equal to the cylinder price is required, and the hospital will be charged a daily rental fee of $0.20 to $0.60 per day.
For hospitals using a manifold system, an additional cost of approximately $100,000 will be needed for the copper piping installation.

**OPEX**

OPEX, besides refill cost, includes labor, cylinder quality inspection (every five years), and piping system maintenance (every six months).
Discussion

Compared to other low- and middle-income countries, Vietnam has plentiful LOX production capacity. Its capacity per capita is almost twice that of Indonesia and India but much lower than that of the United States or Europe (see Appendix 5). In addition, there is a very strong and robust network of distributors that provide oxygen to most provinces. However, these analyses show that there are still vulnerabilities to the medical oxygen supply system, especially during a disease outbreak.

Firstly, while the LOX production capacity is significant, during the fourth wave of COVID-19, the demand for medical oxygen was estimated to reach 92 percent of the maximum capacity. In particular, as the outbreak often clustered in particular areas, as seen in HCMC and Binh Duong, oxygen demand may quickly exceed regional production capacity. Significant coordination effort was required to divert industrial production to cater to the surging medical need in those areas. It is worth highlighting that there were substantial efforts by the GoV to quickly increase access to oxygen. For example, it was reported by VNExpress that the MOH has worked with LOX manufacturers to guarantee that they could increase manufacturing output by 50 to 100 percent to meet demand when there is an outbreak.

Moreover, the Vietnam Steel Association has assured the GoV that LOX production output by steel manufacturers could be partially converted to support medical consumption when required. Even though it was illustrated that production capacity could be temporarily reallocated and stretched to a certain degree, there could possibly be bigger challenges to the medical oxygen supply if the system faces a larger-scale outbreak.

Secondly, production and distribution capacities were not equally established in all regions. Production output from the Central region is markedly lower compared to the Northern and Southern regions of the country, and distributors tend to be clustered in large metropolitan areas and big cities. Hospitals from smaller provinces, particularly in the Northwest and Mekong Delta areas, must rely on vendors located at a very far distance (up to 350 kilometers) for oxygen refill. Fortunately, previous COVID-19 outbreaks occurred mostly in larger cities or industrial zones, such as HCMC, Bac Ninh, Hai Duong, where there are LOX production hubs or distributors within proximity. A similar-scale outbreak in smaller provinces (e.g., Northwest, Mekong Delta, or Central Vietnam ones), though less likely to happen, will call for more extensive preparation and support.

Thirdly, the storage capacity in hospitals could also be a limiting factor in medical oxygen access. It was demonstrated in our analyses that daily refill, or even a higher frequency, was required during the fourth wave of COVID-19 to cope with the surge in oxygen demand, which possibly put a huge pressure on the delivery system. In response, the GoV swiftly procured additional storage equipment, such as cryogenic tanks, and cylinders used for industrial gases were converted for medical use to temporarily increase oxygen storage and prevent supply chain overload. For instance, VNExpress reported that 113 additional oxygen tanks, with combined storage capacity of 831 m³, has been installed in HCMC in response to the recent COVID-19 outbreak. As the country is reliant on import for storage equipment, a long order lead time may incur during the pandemic when demand for this equipment surges in many countries. Moreover, it was noted that, while most hospitals have cylinders, only 20 percent of hospitals are equipped with liquid tanks. However, 80 percent of medical oxygen consumed is via these tanks, and refill cost per m³ of gas for a liquid tank is only 50 percent of that for a 40-liter cylinder. Given that Vietnam has strong LOX production and distribution capacities, extending the availability of liquid tanks to more hospitals will both reduce refill cost and increase oxygen access.
Last but not least, due to the fragmented oxygen cylinder market in Vietnam, not all cylinders used may comply to international standards. In particular, during the fourth outbreak where the oxygen demand peaked, it was noted that there were unsafe oxygen cylinders handling practices, as well as non-suitable cylinders used (such as industrial cylinders not fully converted, fire extinguisher cylinders) to deliver oxygen to patients. In addition, while the ATM oxygens formed during the fourth outbreak were helpful in providing access to home-care patients, the oxygen quality of these spontaneous charity oxygen units were not verified by any approved authorities. Since oxygen is a high-risk commodity, it is highly recommendable that the quality and safe-handling aspects of oxygen are prioritized to avoid any undesired consequences for users.

In summary, for the past two years, the COVID-19 pandemic has constantly created unprecedented obstacles and tested the limit of the health care system, particularly the provision of medical oxygen. Understanding the strengths and weaknesses of the medical oxygen supply system, therefore, could allow decision-makers to better plan for and response to any future crises.
Recommendations

Based on the analyses in this report, the followings actions are recommended to increase medical oxygen access in health facilities, particularly during a disease outbreak in Vietnam:

- **Create an emergency plan to address surging medical oxygen need during a disease outbreak:**
  - Enhance production flexibility by creating a plan for quickly reallocating and ramping up oxygen supply during a disease outbreak.
  - Create a coordinating mechanism to ensure the distribution network runs efficiently and all hospitals receive stable supplies of oxygen.
  - Consider importing oxygen when demand significantly exceeds supply capacity.

- **Strengthen medical oxygen access in vulnerable provinces, particularly in Mekong Delta, Central, and Northwest provinces:**
  - Enhance oxygen production capacity in Central provinces.
  - Install LOX tanks at large hospitals that have a refill center within proximity and sufficient infrastructure, as LOX offers the most affordable cost-per-liter pathway for facilities with high demand.
  - Equip smaller hospitals that are located 100 kilometers or more from a refill center with oxygen concentrators as a backup oxygen source for cylinders or LOX when surging demand overwhelms the refill capacity.
  - Inform health facilities of the refill vendor network surrounding their regions.
  - Consider installing secondary and/or backup oxygen systems for large hospitals that are last lines of treatment for severe COVID-19 patients.

- **Enhance awareness of safe oxygen usage:**
  - Provide training for hospital staffs on oxygen system operation and basic knowledge of oxygen.
  - Issue a national technical standard of medical oxygen and working instruction for staff handling oxygen.
  - Spontaneous oxygen charity units (e.g., ATM) must be managed by a competent authority to ensure quality of product and equipment as well as safety and security for users.
Limitations of analyses

There are several limitations to keep in mind when considering the report’s key analyses:

- The supply and demand analysis only explored oxygen produced via an air separation unit. Even though this is the main source of medical oxygen in Vietnam, oxygen consumed could still be from output produced via PSA and oxygen concentrators, an option which was not included in the discussion. Thus, both the actual supply and actual demand of medical oxygen may be higher than that described in this report.

- WHO puts the number of hospitals in Vietnam at 1,332\(^2\); however, this report only accounts for 993 hospitals. Consequently, the demand projection of medical oxygen used may be underestimated.

- Data collected are primarily from the largest oxygen suppliers, who supply approximately 55 percent of the hospitals surveyed. The capacity of smaller vendors is largely unknown.

- There may be more vendors that provide oxygen to hospitals not included in the nationwide facility survey that are not yet identified.

- The capacity analysis and assessment were mainly performed at an aggregated level. Capacity at a regional/provincial level is not as thoroughly investigated.
Appendix 1: Oxygen Supplier Survey instrument

The Oxygen Supplier Survey was distributed to 17 oxygen suppliers via paper questionnaire. The list of suppliers was chosen based on three criteria: (1) the surveyed companies should include those from all regions of Vietnam; (2) companies that offer both liquid oxygen and oxygen cylinders are preferred; and (3) companies that have higher production capacity or larger client base are prioritized. Companies were given one month to complete the survey. By August 1, 2021, 15 out of 17 companies had turned in their responses.

The Oxygen Supplier Survey was designed with the following objectives:

- Identify a comprehensive list of suppliers of respiratory care equipment and medical oxygen in Vietnam and collect their production and distribution information.
- Understand the current situation and potential challenges of respiratory care equipment and medical oxygen suppliers.
- Contribute to the global supply landscape repository with data input and reports.
- Provide domestic suppliers with information about the global market via an online seminar.

The questionnaire includes the following sections:

- General information about the company.
- Production capacity.
- Delivery capacity.
- Customer types.
- Prices.
- Availability of storage equipment, maintenance, and installation services.
Appendix 2: Oxygen supplier interview

Phone interviews were conducted with sales managers from three oxygen suppliers: Air Liquide, Sovigaz, and ThanhGas. The interview's main aim was to gain an in-depth understanding of the oxygen market, as well as any cost that may be incurred for a hospital using oxygen.

The interview lasted for 30 to 45 minutes and covered the following topics:

- Overview of the oxygen supplier market and key players.
- Production capacity of and demand from the medical market.
- Supply chain for medical oxygen.
- Cost structures associated with liquid oxygen (LOX) and oxygen cylinders:
  - Capital expenditure for a full LOX system at hospitals and lead time for various equipment components.
  - Refill cost for hospitals using LOX or cylinders.
- Bottlenecks in medical oxygen distribution and production in Vietnam.
Appendix 3: Vietnam Ministry of Health database of oxygen manufacturers

The database was collected by the Ministry of Health to make a response plan for COVID-19 outbreaks in Vietnam. The database includes 21 manufacturers and distributors of oxygen. Data from this database were used to validify and complement the input collected from the Oxygen Supplier Survey. Parameters included in the database are shown in Table 3.

Table 3. Parameters for the Vietnam Ministry of Health's database of oxygen manufacturers.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production and storage capacity</td>
<td>Average LOX production capacity</td>
</tr>
<tr>
<td></td>
<td>Max LOX production capacity</td>
</tr>
<tr>
<td></td>
<td>LOX stored</td>
</tr>
<tr>
<td></td>
<td>Average compressed gas production capacity</td>
</tr>
<tr>
<td></td>
<td>Max compressed gas production capacity</td>
</tr>
<tr>
<td></td>
<td>Compressed gas stored</td>
</tr>
<tr>
<td>Filling capacity</td>
<td>Filling capacity (cylinders/day)</td>
</tr>
<tr>
<td>Delivery capacity (LOX)</td>
<td>Number of tanker trucks</td>
</tr>
<tr>
<td></td>
<td>Max delivery capacity within registered distance</td>
</tr>
<tr>
<td>Delivery capacity (cylinders)</td>
<td>Number of delivery vehicles</td>
</tr>
<tr>
<td></td>
<td>Max delivery capacity within registered distance</td>
</tr>
<tr>
<td>Area served</td>
<td>Covered geographic of clients</td>
</tr>
<tr>
<td>Availability of equipment supply</td>
<td>Bulk Tanks</td>
</tr>
<tr>
<td></td>
<td>Vaporizers</td>
</tr>
</tbody>
</table>

Abbreviation: LOX, liquid oxygen.
Appendix 4: Enhancing Medical Oxygen Supply and Usage conference

The conference was organized by the Ministry of Health and led by Deputy Minister of Health Tran Van Thuan to inform health care leaders of the implementation plan to enhance medical oxygen access in all provinces. The presentations included in the conference are summarized in Table 4.

Table 4. Summary of presentations at the Enhancing Medical Oxygen Supply and Usage conference.

<table>
<thead>
<tr>
<th>Content</th>
<th>Speaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhance medical oxygen access for COVID-19 treatments, implementation guideline</td>
<td>Mr. Nguyen Minh Tuan, Head of Medical Device Dept., MOH</td>
</tr>
<tr>
<td>Coordination to ensure oxygen supply for COVID-19 treatment centers</td>
<td>Dr. Luong Ngoc Khue, Head of Medical Services Administration Dept., MOH</td>
</tr>
<tr>
<td>Oxygen need and operation of the oxygen supply system in Binh Duong Intensive Care Unit Center</td>
<td>Dr. Nguyen Lan Hieu, Managing Director, Hanoi Medical University Hospital</td>
</tr>
<tr>
<td>Coordination to ensure oxygen supply for Hanoi</td>
<td>Leader from Hanoi Department of Health</td>
</tr>
<tr>
<td>Oxygen supply capacity for COVID-19 treatments</td>
<td>Oxygen supplier representative</td>
</tr>
<tr>
<td>Implementation guideline of the medical oxygen administration software</td>
<td>Mr. Nguyen Truong Nam, Deputy Head of the IT Dept., MOH</td>
</tr>
<tr>
<td>Procurement guidelines for oxygen storage system</td>
<td>MOH representative Finance Dept.</td>
</tr>
</tbody>
</table>

Abbreviation: MOH, Ministry of health.
# Appendix 5: Liquid oxygen production capacity in selected countries

Table 5 summarizes the production capacity of liquid oxygen in selected countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Capacity (ton)</th>
<th>Capacity (m³)</th>
<th>Population² (millions)</th>
<th>Capacity per million people (m³ per million capita)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vietnam</td>
<td>1,400</td>
<td>1,227</td>
<td>100.0</td>
<td>12.3</td>
</tr>
<tr>
<td>Indonesia</td>
<td>1,700&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1,490</td>
<td>273.5</td>
<td>5.4</td>
</tr>
<tr>
<td>India</td>
<td>8,000&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7,011</td>
<td>1,380.0</td>
<td>5.1</td>
</tr>
<tr>
<td>United States</td>
<td>31,200&lt;sup&gt;c&lt;/sup&gt;</td>
<td>27,344</td>
<td>329.5</td>
<td>83.0</td>
</tr>
<tr>
<td>Europe</td>
<td>31,000&lt;sup&gt;c&lt;/sup&gt;</td>
<td>27,169</td>
<td>764.4</td>
<td>35.5</td>
</tr>
</tbody>
</table>

Sources:


Appendix 6: Refilling, storage, and delivery capacity by region

Aggregated refilling, storage and delivery capacity of key oxygen suppliers and manufacturers are summarized in Table 6.

Table 6. Summary of oxygen supply capacity in Vietnam, by region

<table>
<thead>
<tr>
<th>Region</th>
<th>Liquid oxygen stored (m³ liquid)</th>
<th>Filling capacity (40L cylinders)</th>
<th>Filling capacity (XL45)</th>
<th>Tanker trucks</th>
<th>Cylinder delivery trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>3,235</td>
<td>3,800</td>
<td>280</td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td>Central</td>
<td>3,145</td>
<td>15,100</td>
<td>340</td>
<td>22</td>
<td>52</td>
</tr>
<tr>
<td>South</td>
<td>6,157</td>
<td>11,500</td>
<td>247</td>
<td>48</td>
<td>78</td>
</tr>
<tr>
<td>Total</td>
<td>12,536</td>
<td>30,400</td>
<td>867</td>
<td>91</td>
<td>149</td>
</tr>
</tbody>
</table>
Appendix 7: Key liquid oxygen and cylinder distributors in Vietnam

Table 7 summarizes the capacity and service offerings of key oxygen suppliers in Vietnam.

<table>
<thead>
<tr>
<th>Co. name</th>
<th>General information</th>
<th>Equipment and service offerings</th>
<th>Installation &amp; maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LOX producer</td>
<td>Vietnam region served</td>
<td>Export</td>
</tr>
<tr>
<td>Industrial Gas Nghe An</td>
<td>No</td>
<td>Central</td>
<td>Lao</td>
</tr>
<tr>
<td>Maritime Services Company</td>
<td>No</td>
<td>Central</td>
<td>Lao, Cambodia</td>
</tr>
<tr>
<td>CAMEMCO</td>
<td>No</td>
<td>South</td>
<td>No</td>
</tr>
<tr>
<td>DAGASCO</td>
<td>No</td>
<td>Central</td>
<td>No</td>
</tr>
<tr>
<td>Oxy Dong Nai</td>
<td>No</td>
<td>South</td>
<td>No</td>
</tr>
<tr>
<td>Sovigaz</td>
<td>Yes</td>
<td>All</td>
<td>No</td>
</tr>
<tr>
<td>ThanhGas</td>
<td>Yes</td>
<td>North, Central</td>
<td>No</td>
</tr>
<tr>
<td>Oxy Long Phat</td>
<td>No</td>
<td>Central, Highland</td>
<td>No</td>
</tr>
<tr>
<td>Oxygen Tuan Anh Gia Lai</td>
<td>No</td>
<td>Central, Highland</td>
<td>No</td>
</tr>
<tr>
<td>Nippon Sanso</td>
<td>Yes</td>
<td>All</td>
<td>NA</td>
</tr>
<tr>
<td>Messer</td>
<td>Yes</td>
<td>North, Central</td>
<td>NA</td>
</tr>
<tr>
<td>Air Liquide</td>
<td>Yes</td>
<td>North, South</td>
<td>NA</td>
</tr>
<tr>
<td>Linde Gas</td>
<td>Yes</td>
<td>South</td>
<td>NA</td>
</tr>
<tr>
<td>Sing Industrial Gas Vietnam</td>
<td>Yes</td>
<td>South</td>
<td>NA</td>
</tr>
<tr>
<td>Airwater Industrial Gas</td>
<td>Yes</td>
<td>South</td>
<td>NA</td>
</tr>
</tbody>
</table>

Abbreviations: DAGASCO, Da Nang Industrial Gas Joint Stock Company; CAMEMCO, Can Tho Mechanical Joint Stock Company; ISO, International Organization for Standardization; LOX, liquid oxygen; NA, not applicable.
Appendix 8: Estimation of medical liquid oxygen consumption

Before the fourth wave of COVID-19, a total estimated 92 cubic meters of liquid oxygen was needed daily for tanks and to fill gas cylinders (Tables 7 and 8).

Table 8. Estimation of pre-pandemic LOX capacity and need, per day.

<table>
<thead>
<tr>
<th></th>
<th>Pre-COVID-19 LOX consumption estimation</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOX storage capacity at hospital (m³ liquid)</td>
<td>1,629</td>
<td>Source: BEIT survey</td>
</tr>
<tr>
<td>Median refill frequency (days)</td>
<td>20</td>
<td>Assuming refilled when 10% storage left</td>
</tr>
<tr>
<td>Estimated LOX usage for liquid tank per day (m³ liquid)</td>
<td>73</td>
<td>LOX storage * 0.9 / refill frequency</td>
</tr>
</tbody>
</table>

*Abbreviations: BEIT, Biomedical Equipment Inventory Tool; LOX, liquid oxygen.

Table 9. Estimation of pre-pandemic oxygen cylinder capacity and need, per day.

<table>
<thead>
<tr>
<th></th>
<th>Pre-COVID-19 oxygen cylinder consumption estimation</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder storage capacity at hospital (m³ gas)</td>
<td>177,000</td>
<td>Source: BEIT survey</td>
</tr>
<tr>
<td>Estimated oxygen cylinder usage per day (m³ gas)</td>
<td>16,429</td>
<td>Source: BEIT survey</td>
</tr>
<tr>
<td>Estimated oxygen cylinder usage per day (m³ liquid)</td>
<td>19</td>
<td>1 m³ liquid = 861 m³ gas</td>
</tr>
</tbody>
</table>

*Abbreviation: BEIT, Biomedical Equipment Inventory Tool.*
Appendix 9: Cost of ownership associated with medical liquid oxygen

Various cost components for liquid oxygen are compiled in Table 8, based on the input from oxygen manufacturers. It should be highlighted that all prices are indicative and may vary depending on the equipment brand and size and the facility scale.

Table 10. Indicative cost components for LOX.

<table>
<thead>
<tr>
<th>Type of cost</th>
<th>Component</th>
<th>Note</th>
<th>Cost (equipment is purchased), in USD</th>
<th>Cost (equipment is rented), in USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPEX</td>
<td>Tank</td>
<td>size: 6 m³</td>
<td>$38,000.00</td>
<td>$0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>size: 10 m³</td>
<td>$58,000.00</td>
<td>$0</td>
</tr>
<tr>
<td></td>
<td>Vaporizer</td>
<td>capacity: 200 m³/hour</td>
<td>$4,300.00</td>
<td>$0</td>
</tr>
<tr>
<td></td>
<td>Pressure regulator</td>
<td></td>
<td>$4,300.00</td>
<td>$0</td>
</tr>
<tr>
<td></td>
<td>Piping system</td>
<td></td>
<td>$43,400.00</td>
<td>$43,400.00</td>
</tr>
<tr>
<td></td>
<td>Oxygen terminal</td>
<td></td>
<td>$43,400.00</td>
<td>$43,400.00</td>
</tr>
<tr>
<td></td>
<td>Other accessories</td>
<td>Humidifier, fencing, support stands, access gates, etc.</td>
<td>$22,000.00</td>
<td>$22,000.00</td>
</tr>
<tr>
<td></td>
<td>Installation</td>
<td>Incl. concrete work, LOX station (vaporizer, tank, fencing, etc.) and delivery to patients (piping system and terminal)</td>
<td>$22,000.00</td>
<td>$22,000.00</td>
</tr>
<tr>
<td>OPEX</td>
<td>Refill</td>
<td>Price per m³ liquid</td>
<td>$239.00</td>
<td>$239</td>
</tr>
<tr>
<td></td>
<td>Refill delivery</td>
<td>Price per km</td>
<td>$1.50</td>
<td>$1.50</td>
</tr>
<tr>
<td></td>
<td>Equipment maintenance</td>
<td>Per maintenance</td>
<td>$450.00</td>
<td>$0</td>
</tr>
<tr>
<td></td>
<td>Labor</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>Repair &amp; replacement</td>
<td>On case-by-case basis</td>
<td>On case-by-case basis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Equipment rental (tank, vaporizers, pressure regulators)</td>
<td>Tank size: 6 m³</td>
<td>$0</td>
<td>$520.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tank size: 10 m³</td>
<td>$0</td>
<td>$650.00</td>
</tr>
<tr>
<td>TOTAL</td>
<td>CAPEX</td>
<td>Assuming 6 m³ tank</td>
<td>$236,300.00</td>
<td>$130,800.00</td>
</tr>
<tr>
<td></td>
<td>OPEX per month</td>
<td>Assuming 50 km delivery distance; weekly refill for 6 m³ tank (6 m³/refill); maintenance twice yearly</td>
<td>$6,100.00</td>
<td>$6,600.00</td>
</tr>
</tbody>
</table>

Abbreviations: CAPEX, capital expenditure; LOX, liquid oxygen; NA, not applicable; OPEX, operating expense.
Appendix 10: Cost of ownership associated with oxygen cylinders

Various cost components for oxygen cylinders are compiled in Table 11, based on the input from oxygen manufacturers. It should be highlighted that all prices are indicative and may vary depending on the equipment brand and size and the facility scale.

Table 11. Indicative cost components for oxygen cylinders.

<table>
<thead>
<tr>
<th>Type of cost</th>
<th>Components</th>
<th>Note</th>
<th>Cost (equipment is purchased), in USD</th>
<th>Cost (equipment is rented), in USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPEX</td>
<td>Cylinders</td>
<td>Size: 10 L</td>
<td>$70.00</td>
<td>$0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Size: 40 L</td>
<td>$87.00</td>
<td>$0</td>
</tr>
<tr>
<td>Piping system</td>
<td>Optional (only if manifold system is used)</td>
<td></td>
<td>$43,400.00</td>
<td>$43,400.00</td>
</tr>
<tr>
<td>Oxygen terminal</td>
<td>Optional (only if manifold system is used)</td>
<td></td>
<td>$43,300.00</td>
<td>$43,400.00</td>
</tr>
<tr>
<td>Other accessories</td>
<td>Humidifier, pressure gauges, etc.</td>
<td>NA</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Installation of piping and terminal</td>
<td>Optional (only if manifold system is used)</td>
<td></td>
<td>$10,000.00</td>
<td>$10,000.00</td>
</tr>
<tr>
<td>OPEX</td>
<td>Refill</td>
<td>Price per refill (10 L cylinder)</td>
<td>$3.00</td>
<td>$3.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Price per refill (40 L cylinder)</td>
<td>$4.00</td>
<td>$4.00</td>
</tr>
<tr>
<td>Refill delivery</td>
<td>Price per km</td>
<td></td>
<td>$0.76</td>
<td>$0.76</td>
</tr>
<tr>
<td>Equipment maintenance</td>
<td>Every 5 years</td>
<td>NA</td>
<td>$0</td>
<td></td>
</tr>
<tr>
<td>Labor</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Cylinder rental</td>
<td>Rental charge/day</td>
<td></td>
<td>$0</td>
<td>$0.40</td>
</tr>
<tr>
<td>TOTAL</td>
<td>CAPEX (for 861 x 40 L cylinders – equivalent to one 6 m³ tank)</td>
<td>Without central piping</td>
<td>$74,870.00</td>
<td>$0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>With central piping</td>
<td>$171,570.00</td>
<td>$96,700.00</td>
</tr>
<tr>
<td></td>
<td>OPEX per month for 861 cylinders (size 40 L) – equivalent to a 6 m³ liquid tank</td>
<td>Assuming 20 km delivery distance; weekly refill; 20 cylinders delivered each trip</td>
<td>$17,385.00</td>
<td>$28,615.00</td>
</tr>
</tbody>
</table>

Abbreviations: CAPEX, capital expenditure; NA, not applicable; OPEX, operating expense.
References


