CRISIL
An S&P Global Company

Assessment of medical oxygen manufacturing industry in India

September 2022

Table of contents

1. Overview of the global and Indian economy

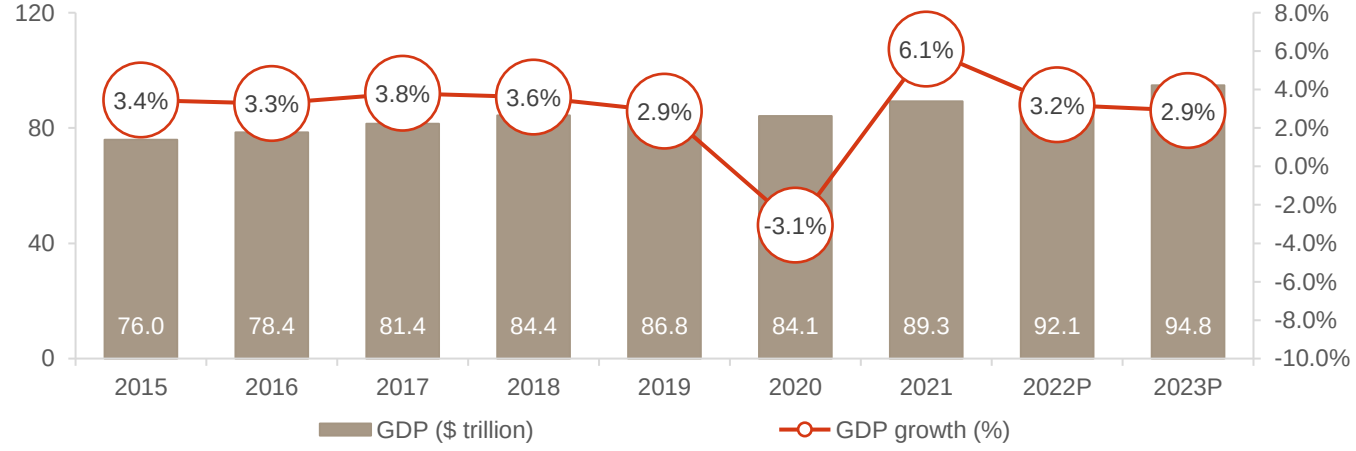
1.1 Global gross domestic product review and outlook

Global GDP rebounded strongly in 2021 on account of policy support and vaccination drives after dropping in 2020. GDP growth is expected to moderate to 3.2% y-o-y rise in 2022.

As per International Monetary Fund (IMF) July 2022 update, global growth is expected to moderate from 6.1% in 2021 to 3.2% in 2022 and 2.9% in 2023. This is 0.4% and 0.7 % points lower for 2022 and 2023 than projected in April 2022. Economic damage from the Russia-Ukraine conflict will contribute to a slowdown in global growth in 2022. According to IMF, the economic damage from the ongoing war in Ukraine has contributed to a slowdown in global growth and rising inflation causing damage to various countries. The war has caused a humanitarian crisis in Eastern Europe, and various sanctions being imposed on Russia to end hostilities. In addition, frequent and wider-ranging lockdowns in China have slowed activity as it is a major manufacturing hub, which could cause new bottlenecks in the global supply chain. Further, Russia is a major supplier of oil, gases and metals and Ukraine is a major supplier of wheat and corn, and an anticipated decline in the supply of these essential commodities is likely to spike up the prices in the global commodities market. Also record high inflation in last four decades for USA and some of the major European economies is expected to hit word economy. High uncertainty surrounds the current IMF forecast, and there are downside risks to the global outlook.

According to IMF (World Economic Outlook – July 2022), global growth prospects have changed markedly since beginning of the year owing to geopolitical issues. In CY2021, global growth rebounded with a robust growth of 6.1% from -3.1% the previous year, but it is expected to slow in calendar year 2022 to 3.2%.

Trend and outlook for global GDP (2015-23P, in $ trillion)



P: Projection

Source: IMF economic database, World Bank national accounts data, OECD national accounts data, CRISIL Research

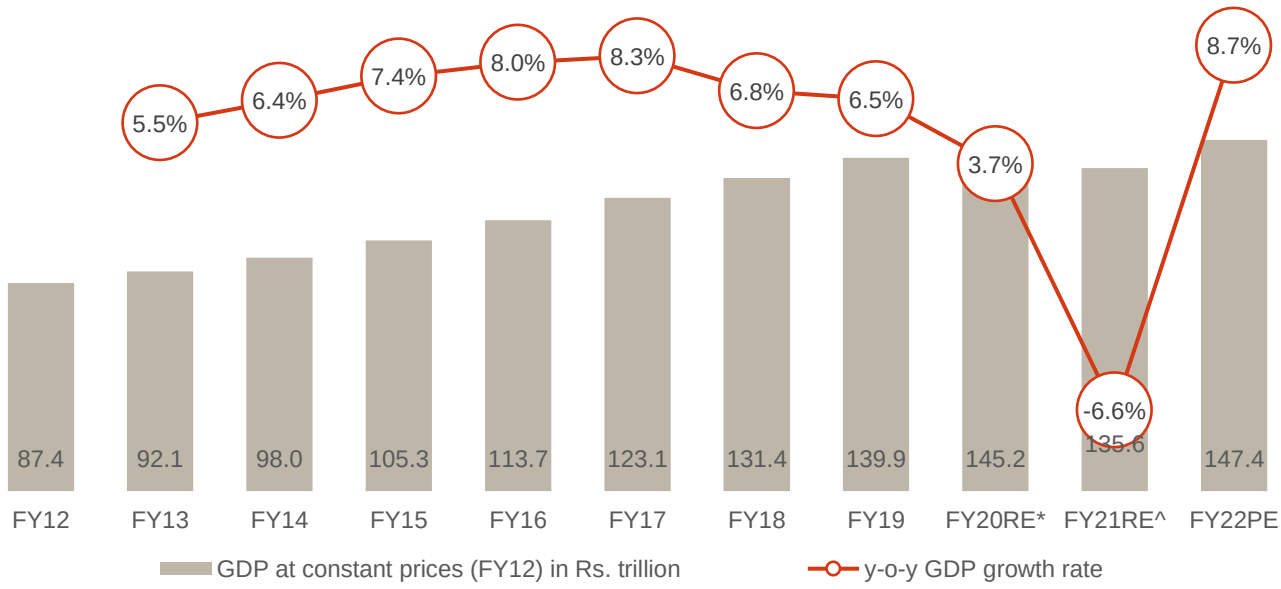
1.2 Review of India's GDP growth

GDP logged 6.6% CAGR between fiscals 2012 and 2020

In 2015, the Ministry of Statistics and Programme Implementation (MoSPI) changed the base year for calculating India's GDP between fiscals 2005 and 2012. Based on this, the country's GDP logged an ten-year CAGR of 5.4%, growing to Rs 147 trillion in fiscal 2022 from Rs 87 trillion in fiscal 2012.

Fiscal 2021 has been a challenging year for the Indian economy, which was already experiencing a slowdown before the pandemic struck. GDP contracted 6.6% (in real terms) after growing 3.7% in fiscal 2020. At Rs 136 trillion in fiscal 2021, India's GDP (in absolute terms) dipped even below the fiscal 2019 level of Rs 140 trillion. In fiscal 2022, the Indian economy revived at 8.7% y-o-y growth with GDP at Rs 147 trillion.

Real GDP growth in India (new GDP series, in Rs trillion)



PE: Provisional estimates RE: Revised estimates

**: second revised estimates*

^: First revised estimates

Source: Provisional estimates of national income 2021-22 and quarterly estimates of GDP for quarter four of 2021-22, 31st May 2022, Central Statistics Office (CSO), MoSPI, CRISIL Research

Fiscal 2023 GDP growth estimated at 7.3%

The on-going Russia-Ukraine war has caused turmoil in commodity markets. While freight costs have moderated of late, they are still elevated when compared with pre-war situation during the beginning of the year. For India, this translates to higher import bills and higher inflation. For the fiscal 2023, CRISIL Research estimates the GDP growth to be 7.3%. These estimates come at the back of major upside and downside factors discussed below

Downside factors:

1. **Higher Inflation**: The Consumer Price Index (CPI) based inflation print – 7.0% in May 2022 – remained a full percentage point above the upper limit of the Reserve Bank of India's (RBI's) 2-6% target. Rising inflation reduces purchasing power and would weigh on revival of consumption — the largest component of GDP.

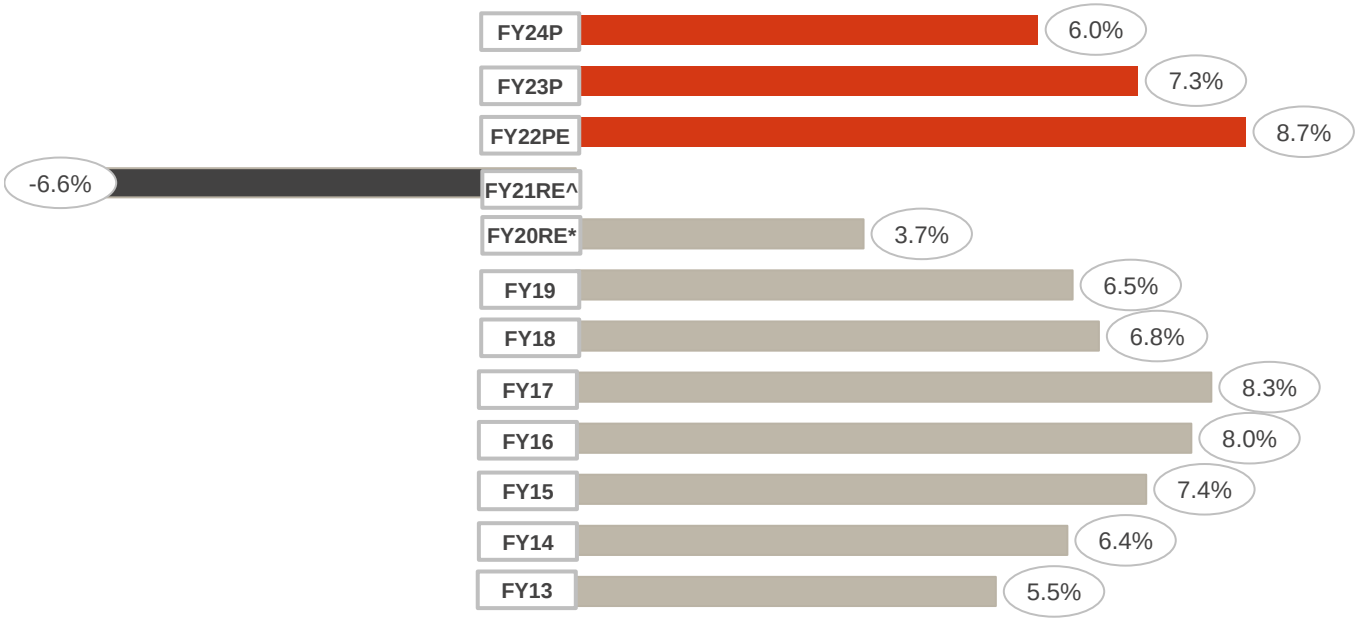
2. **Increasing crude oil prices**: India is one of the major importers of crude oil, prices for which are expected to average $105-110/bbl during fiscal 2023 as per CRISIL estimates, which is a 35% rise over last fiscal, and the highest since 2013. High commodity prices have a domino effect on Indian GDP

3. **PFCE:** Private final consumption expenditure (PFCE), the largest demand-side driver, remains weak. The recovery in PFCE has been the slower from the pandemic's impact — it was just 1.4% above its pre-pandemic (fiscal 2020) level in fiscal 2022, reflecting the mixed impact of the omicron-led third wave and higher inflation

Upside factors:

Forecast of normal monsoon: The India Meteorological Department (IMD) has forecast normal rains (103% of the long-period average) during the south-west monsoon this year. Though this augurs well for the agriculture sector and, thereby, rural demand, the spatial and temporal distribution of rainfall is a monitorable.

Real GDP growth (% on-year)



RE: Revised estimates PE: Provisional estimates; P: Projected by CRISIL Research; GDP calls updated as of June 2022

*: second revised estimates

^: First revised estimates

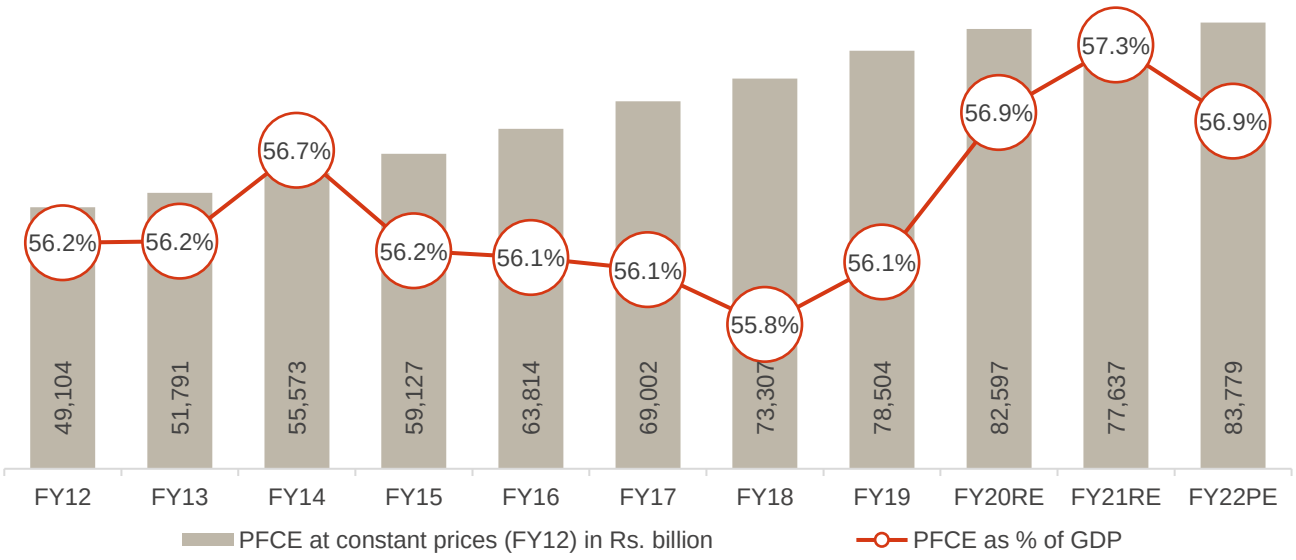
Source: Provisional estimates of national income 2021-22 and quarterly estimates of GDP for quarter four of 2021-22, 31st May 2022, Central Statistics Office (CSO), MoSPI, CRISIL Research

1.3 Review of private final consumption growth

Private final consumption expenditure to maintain dominant share in GDP

Private final consumption expenditure (PFCE) at constant prices clocked 6.7% CAGR between fiscals 2012 and 2020, maintaining its dominant share in the GDP pie, at ~57% or Rs 82,597 billion. PFCE, however, declined in fiscal 2021 to Rs 77,637 billion on account of the pandemic, when consumption demand was impacted on account of strict lockdowns, employment loss, limited discretionary spending, and disruption in demand-supply dynamics. PFCE increased by 7.9% to Rs. 83,779 billion in fiscal 2022, but as % of GDP remained low at 56.9% as personal expenditure had negative impact of COVID-19 pandemic and Government spending expenditure saw an increase for boosting the economy from COVID-19 slump.

PFCE (at constant prices, in Rs trillion)



Note: RE - revised estimates, PE: Provisional estimates

Source: Provisional estimates of national income 2021-22 and quarterly estimates of GDP for quarter four of 2021-22, 31st May 2022, MoSPI, CRISIL Research

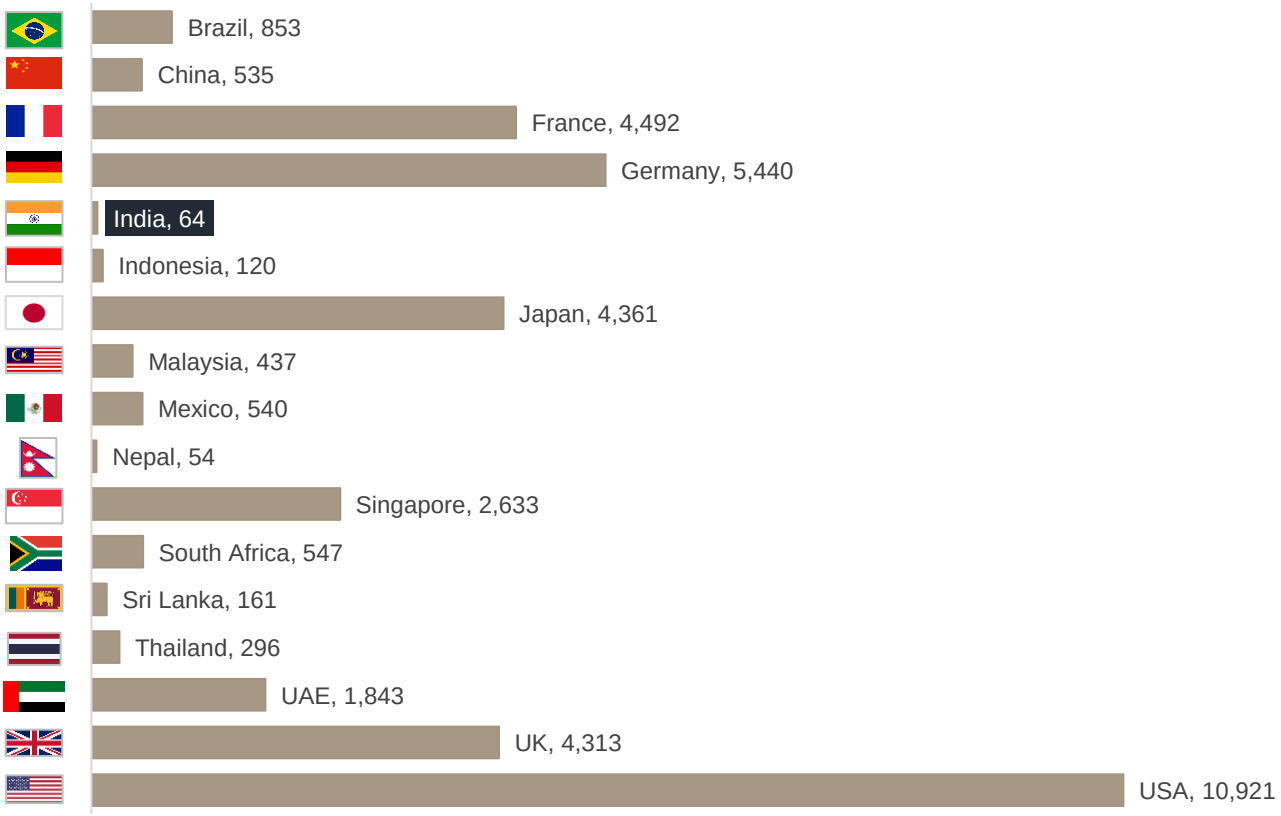
Consumption expenditure to be driven by discretionary items

CRISIL Research estimates that basic items accounted for 40.4% of the total consumption expenditure of Indians in fiscal 2020, with discretionary items accounting for the remainder 59.6%. It is worth noting that the share of discretionary items in consumption increased to 59.6% in fiscal 2020 from 53.4% in fiscal 2012. The increased spending on discretionary items suggests rising disposable income of households.

Indians spend too little on healthcare

Global healthcare spending has been rising, in keeping with economic growth. As the economy grows, public and private spending on health increases. Also, greater sedentary work gives rise to chronic diseases, which pushes up healthcare spending. Fast-growing economies with low spending on health are seeing chronic diseases increase dramatically as they move up the income ladder. India lags most of the emerging and developed counties in healthcare expenditure. Its per capita current health expenditure in 2019 was a paltry $64 compared with the major emerging and advanced economies.

Per capita current health expenditure (current US$, 2019)

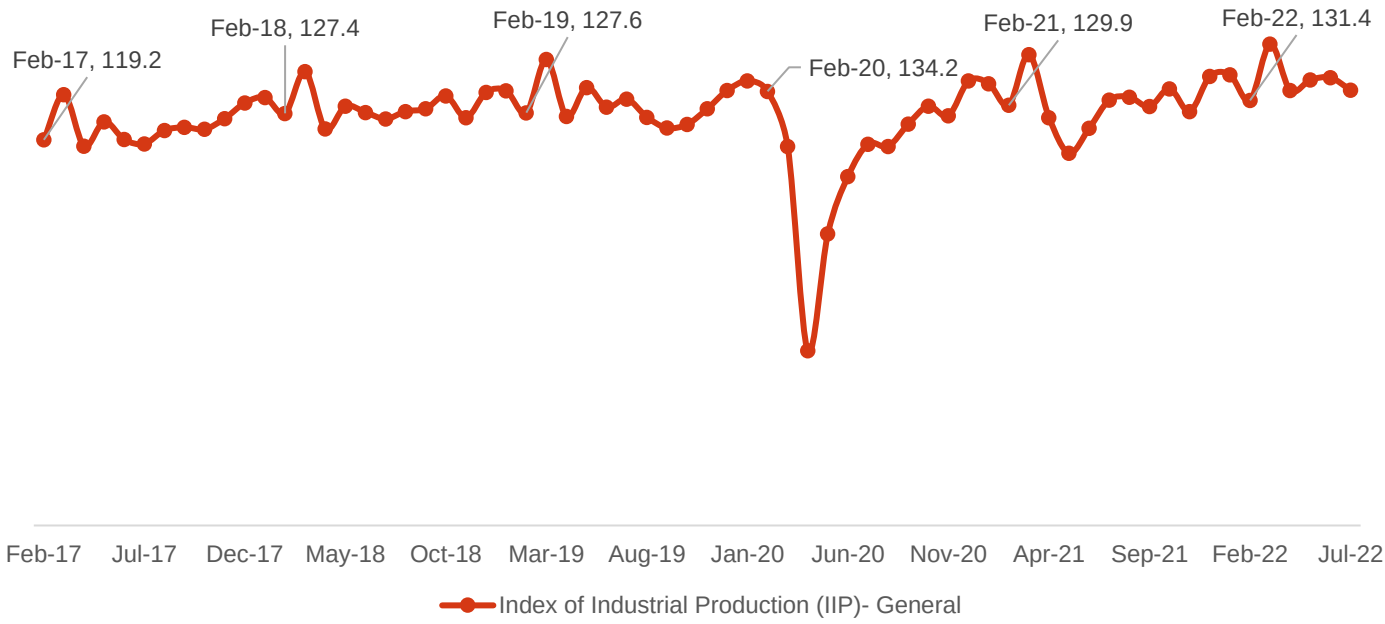


Source: Global Health Expenditure Database - World Health Organization, CRISIL Research

India's manufacturing sector has experienced various shifts in recent times

Manufacturing was affected in several ways by the pandemic, leading to low-scale operations, and eventually, a negative impact on production volumes. Over a period, this adversely affected turnover and revenue. The complete and partial lockdowns had both demand- and supply-side impacts on the sector. On the supply side, the limited movement of goods, services, and personnel affected the production network. The Index of Industrial Production (IIP) that tracks manufacturing activity in different sectors of an economy took a nosedive during the first lockdown period implemented towards end of fiscal 2020. The IIP again took a downturn during the second wave in the beginning of fiscal 2022. While the second wave did upset overall economic growth, the impact was moderate compared with the first wave, as businesses and states had adjusted to the Covid situation.

IIP at constant fiscal 2012 prices

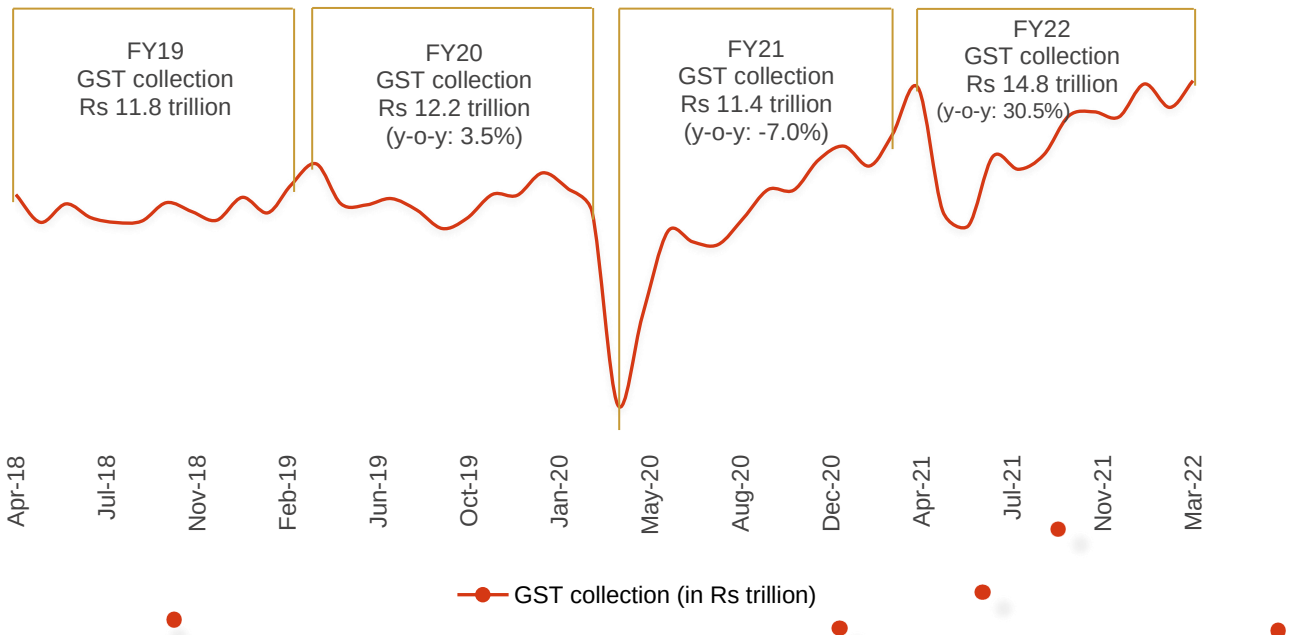


May'22, Jun'22 and July'22 numbers are provisional

Source: MoSPI, CRISIL Research

On similar lines, the impact of the second wave on Goods and Services Tax (GST) collection was much more muted than the impact of the first wave, which saw a nationwide lockdown. There was a quick recovery in monthly GST collection during the second wave.

GST collection (Rs trillion)



Source: GST Council, CRISIL Research

2. Overview of oxygen demand in India

Critical in supporting life, oxygen is the second-largest component in the atmosphere, comprising 20.8% by volume. It combines readily with many elements to form an oxide and is necessary to support combustion.

Oxygen is generally liquefied to transport it more efficiently and store it in large volumes. However, most applications use oxygen after it is vapourised to the gaseous form.

Liquid oxygen is cryogenic, i.e., it is a liquefied gas with a normal boiling point below –90°C. Liquid oxygen specifically has a boiling point of –183°C. Since the temperature difference between the product and the surrounding environment is substantial, keeping liquid oxygen insulated from the surrounding heat is essential, even in winter. The product also requires special equipment for handling and storage

Liquid storage is less bulky and costly than the equivalent capacity of high-pressure gaseous storage. A typical storage system consists of a cryogenic storage tank, one or more vapourisers and a pressure-control system. The cryogenic tank is constructed, in principle, like a vacuum bottle. There is an inner vessel surrounded by an outer vessel. Between the vessels is an annular space that contains an insulating medium from which all the air has been removed. This space keeps heat away from the liquid oxygen held in the inner vessel. Vapourisers convert the liquid oxygen into a gaseous state. A pressure control manifold then controls the gas pressure that is fed to the process or application.

Gaseous oxygen is shipped and stored in high-pressure cylinders, tubes or tube trailers, depending on the quantity required by the user. Cylinders are designed and manufactured according to applicable codes and specifications for the pressures and temperatures involved. The quantity of product a container can hold is determined by its pressure rating and internal volume.

Based on sample set considered by CRISIL, on an average 1.3-1.5 Kw/Hr power is required for generation of oxygen at a flow rate of 1 Nm3/Hr

Medical oxygen needs checks and certification, while industrial oxygen doesn't

	Medical oxygen	Industrial oxygen
Definition	The oxygen used to treat patients	The oxygen used for industrial purpose
Purpose	To maintain enough oxygen level in blood	Mainly for combustion and gasification processes in industries
Grade	Accepted purity: 93%±3% according the Indian Pharmacopoeia	Generally high purity oxygen is required for industrial purpose (~99.5%)
Handling	Generators or compressors usually are in oil-free or oil-less varieties	Can be generated by oil-lubricated, oil-less or oil-free compressors

Source: CRISIL Research

Medical oxygen is oxygen that is produced and used specifically for medical purposes. Medical oxygen can only be generated by medical air generators or compressors, which are usually oil-free or oil-less varieties. The entire supply chain of medical oxygen, including transport and storage cylinders, strictly controls the presence of water to prevent rusting inside the cylinders.

In contrast, industrial oxygen is oxygen used in industries and manufacturing plants for combustion, oxidation, cutting and various chemical reactions. Industrial oxygen is not intended to be inhaled like medical oxygen, and it can be generated by oil-lubricated, oil-less or oil-free compressors.

The basic difference between oxygen IP (Indian Pharmacopoeia, medical oxygen) and industrial oxygen is in assuring the control as per the specification demanded in the finished product to achieve ‘standard IP 2018’. This means that the process for manufacturing medical oxygen should be as per the requirements of Schedule M of the Drugs and Cosmetics Acts and Rules. Moreover, the testing protocol and process regulations as demanded by Indian Pharmacopoeia in its latest edition, IP 2018, should be stringently followed.

The purity levels of industrial oxygen are not on par with medical oxygen. Medical oxygen cylinders should be free of contaminants. Strict regulations and setting parameters pertaining to tank cleanliness are a must to eliminate the possibility of any potentially harmful contaminants and infections. While industrial cylinders should be thoroughly cleaned before use, there can be impurities from the containers. Knowing this, industrial oxygen should never be used for medical purposes unless strict parameters are applied vigilantly.

Over 80% of the of the hospitals in India procure medical oxygen through cylinders

Oxygen sources include oxygen generation plants, bulk liquid oxygen storage tanks and oxygen concentrators. The most common storage system used in health-care facilities is a cylinder. Factors that affect the choice of appropriate oxygen source at the treatment unit include amount of oxygen required, infrastructure available, local supply chain, reliability of electric power, and availability of spare parts and maintenance service.

Pressure swing adsorption (PSA) oxygen generators

Oxygen is generated from compressed air by a separation process that uses the principle of selective adsorption. PSA oxygen generators of required capacity can be located at the medical facility. The generated oxygen is then piped directly to patients and used through a booster compressor to refill cylinders. Oxygen generators require a reliable source of power and a back-up supply in the form of cylinders. When PSA oxygen generators are used for oxygen supply at hospitals, the facility must have a battery of pressurised oxygen cylinders as a back-up. The PSA oxygen generator must be supplied with emergency power to the feed air compressor.

Oxygen cylinders

Oxygen gas can be compressed and stored in cylinders. These cylinders are filled at a gas manufacturing plant, either via cryogenic distillation or a PSA oxygen generator, and then transported to health facilities. Cylinders can be used in one of two ways. One, by installing them directly within patient areas or similar to direct piping and two,

by connecting them to a sub-central manifold system (groups of cylinders linked in parallel) at the facility. Thus, oxygen can be piped to specific areas of the health facility, even at the ward level. When cylinders are the only source of oxygen in a health facility, a strong supply-chain is required to ensure ongoing availability. Once filled, cylinders themselves do not require electricity, but they do require several accessories and fittings to deliver oxygen, such as pressure gauges, regulators, flowmeters, and in some cases, humidifiers. Cylinders also require periodic maintenance, commonly provided by gas suppliers at the point of refilling. Cylinders can be used for all oxygen needs, including high-pressure supply and in facilities where power supply is intermittent or unreliable. They are also used for ambulatory service or patient transport.

Supply options and their comparison

	On-site production (PSA)	Bulk delivery (Liquid oxygen)	Cylinders	Concentrators
Description	An on-site oxygen generation system using PSA technology supplies high-pressure oxygen throughout the facility via a central pipeline system, or via cylinders refilled by the plant	Bulk liquid oxygen production off-site; Stored in a large tank and supplied throughout the health facility through pipeline system; Tank required refilling by liquid oxygen supplier	A refillable cylindrical storage vessel used to store, and transport oxygen in compressed gas form; Cylinders are refilled at a gas generating plant and thus require transportation to and from the plant	A self-contained electricity powered medical device designed to concentrate oxygen from ambient air
Clinical application	Can be used for all oxygen needs, including high-pressure supply	Can be used for all oxygen needs including high-pressure supply and in facilities where power supply is intermittent or unreliable	Can be used for all oxygen needs, including high-pressure supply and in facilities where power supply is intermittent or unreliable. Also used for ambulatory service or patient transport. Used as a backup for other systems.	Used to deliver oxygen at bed-side or within proximity to patients. A single concentrator can service several beds with the use of a flowmeter stand to split output flow
Distribution mechanism	Central, sub-central pipeline distribution system, or can be used to refil cylinders that can be connected to manifold system in the facility	Central pipeline distribution system	Connected to manifold central sub-central pipeline distribution system, or directly connected to patient bed with flowmeter and tubing	Direct supply to patient with tubing or through a flowmeter stand
Maintenance requirement	Significant maintenance of system and piping required by highly trained technicians and engineers; can be provided as part of contract	Significant maintenance of system and piping required by highly trained technicians and engineers, which can be provided as part of contract	Limited maintenance required by trained technicians	Moderate maintenance required by trained technicians
Recurring cost	Electricity cost	Cost of liquid oxygen and rent	Cost of procuring the cylinder	Electricity cost
Logistics management	One-time installation of plant	Issues might arise when a tanker needs access to bulk-storage tank to refill liquid oxygen	Issues might arise with the transporttion, storage and access to the cylinders.	One-time transpotation of concentrators

Source: CRISIL Research

Liquid oxygen

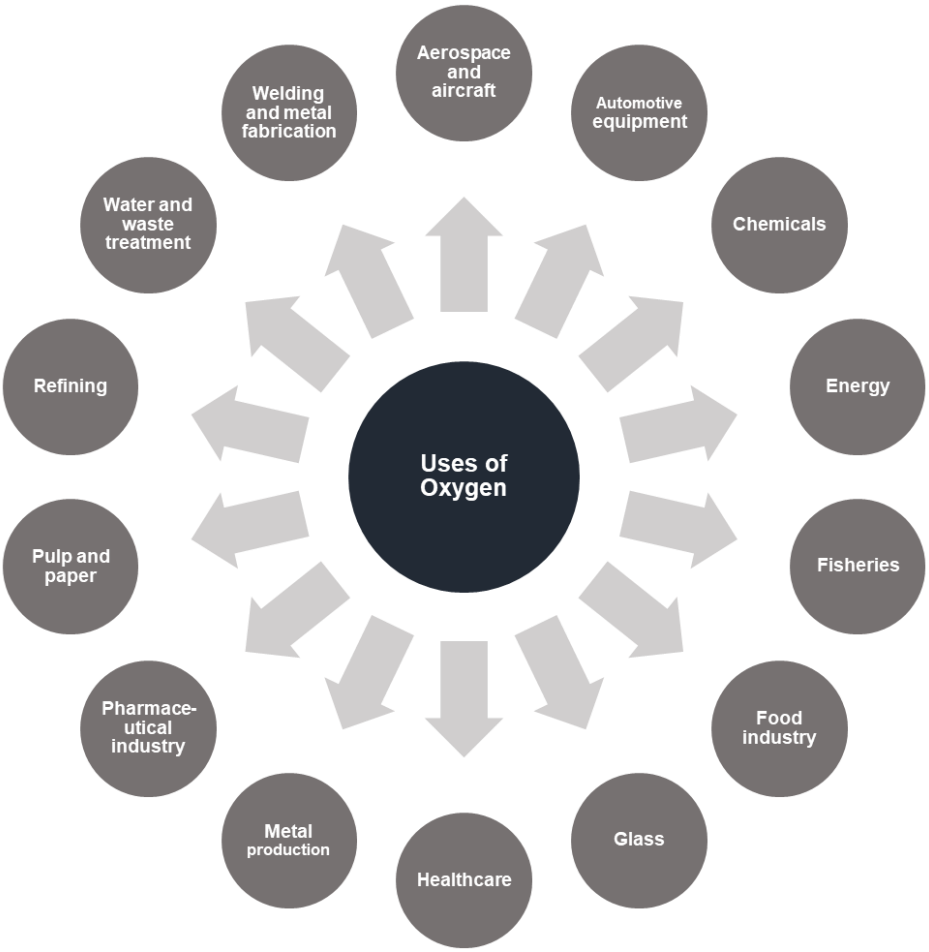
Liquid oxygen produced at the offsite cryogenic facility is stored in tanks at the hospital, periodically filled from a tanker. The oxygen supply in the healthcare facility is through a central piping system where the gas is self-vapourised without external power. The system is suitable for larger installations with assured supply chain

mechanisms and strong operating procedures for handling the high-pressure system. It is necessary to provide adequate insulation to avoid boil-off and evaporation loss. The inventory must be continuously monitored. The system needs to have back-up in the form of cylinders.

Oxygen concentrators

Oxygen concentrators are miniature PSA oxygen generators; and the technology used is also similar to that of PSA oxygen generators. It has been successfully used as primary source of oxygen supply. It is a safe, efficient and reliable means of supply when built, tested and maintained as per international standards. This is a portable unit running on electric power that is required to drive the air compressor of the PSA oxygen generators. Concentrators can provide a safe and cost-effective source of oxygen, but they do require a source of continuous and reliable power and regular preventive maintenance to ensure proper functioning. Having cylinders as a backup supply is a best practice.

Oxygen finds its usage in multiple industries, including healthcare



Source: CRISIL Research

Aerospace and aircraft

Depending upon the type and role of the aircraft concerned, oxygen system(s) may be used for normal operations, to provide supplemental oxygen for specific situations or for provision of emergency oxygen in the event of smoke, fire, fumes, or loss of pressurisation. Gaseous oxygen also supports rocket fuel combustion.

Automotive and transport equipment

Oxygen is used as a plasma-cutting gas, an assist gas for laser cutting, and is sometimes added in small quantities to shielding gases. Gases play an important role in several automotive glass and lighting processes. Industrial oxygen is used in the glass furnaces supplying the glass for the lighting components.

Chemicals

In its purest form, oxygen is used to alter the structure of feedstocks through oxidation, producing nitric acid, ethylene oxide, propylene oxide, vinyl chloride monomer and other building block chemicals. It is also used to increase the production capacity of oxidation processes and to increase capacity and destruction efficiency of waste incinerators.

Energy

Using oxygen in the place of air can increase performance and capital efficiency in many industries and can enable carbon capture processes. It is often used in boilers and process heaters, industrial fermenters and gasification processes to improve productivity.

Fisheries

As fish absorb oxygen through direct contact with water, dissolved oxygen is the most important factor in achieving good results in fish farming. Adequate oxygen levels in the water ensure growth, promote the health, appetite and general well-being of the fish. Oxygen also helps to reduce the effects of temperature-induced stress in fish.

Food industry

In the food and beverage industry, oxygen is used to extend the shelf life of various foods and beverages, and to stabilise their quality. Oxygen is used as a shielding gas for beef products and steaks, for example. In this regard, the oxygen in the packaging helps to prevent the growth of anaerobic microorganisms.

Glass

Oxygen in glass industry plays an important role and is commonly used to enhance combustion. The benefits are fuel saving due to improved furnace efficiency, increased flame temperature, reduced energy cost, reduced pollutants such as nitrogen oxide, and improved glass quality.

Healthcare

Oxygen is commonly relied upon in health and medical applications. Healthcare professionals use oxygen to treat respiratory illnesses such as Covid-19 and pneumonia. Oxygen is also essential for surgery and trauma. Vulnerable groups such as the elderly, pregnant women and new-borns need oxygen for care

Metal production

As an industrial gas, oxygen is used to replace or enrich air, ultimately increasing combustion efficiency in both ferrous and non-ferrous metal production. Oxygen is also used to raise steel temperatures to enhance recycling of scrap metal in electric arc furnaces. It is also used to replace coke as the combustible in steel making.

Pharmaceuticals

Oxygen with a purity of approx. 95% is required in many pharmaceutical and biotechnological applications. Certain process steps in the manufacture of medicines, antibiotics, additives, biopolymers or acids are carried out in fermentation reactors, for example. Cell cultures, bacterial strains, and microorganisms are cultivated in this manner. In addition to a special nutrient solution, oxygen is needed for the cultivation process.

Pulp and paper

Oxygen plays an important role in producing pulp and paper products. Oxygen can be added to the pulp in alkaline extraction to intensify the bleaching effect and decrease the volume of more expensive bleaching chemicals required. As an industrial gas, oxygen helps meet stringent environmental regulations through use in delignification, oxidative extraction and wastewater treatment.

Refining

Oxygen enrichment is a widely established technology in refining and is successfully used for sulphur processing in Claus units and in the regeneration section of fluid catalytic cracking units (FCCU). Oxygen enrichment can provide refinery operators with maximum flexibility as it can be implemented in different ways. Low- level oxygen enrichment solution can be tailored specifically to the needs of fired heaters.

Water and wastewater treatment

In wastewater treatment, aeration is the process used to dissolve air into water. It enables growth of aerobic bacteria on key pollutants such as biochemical oxygen demand and ammonia during treatment. Used as an industrial gas, oxygen can supplement or even replace air in the aeration basin to maximise treatment capacity, minimise volatile organic compound emissions, reduce odour and foam, and increase flexibility. It is also used as a feed gas to generate ozone for water disinfection.

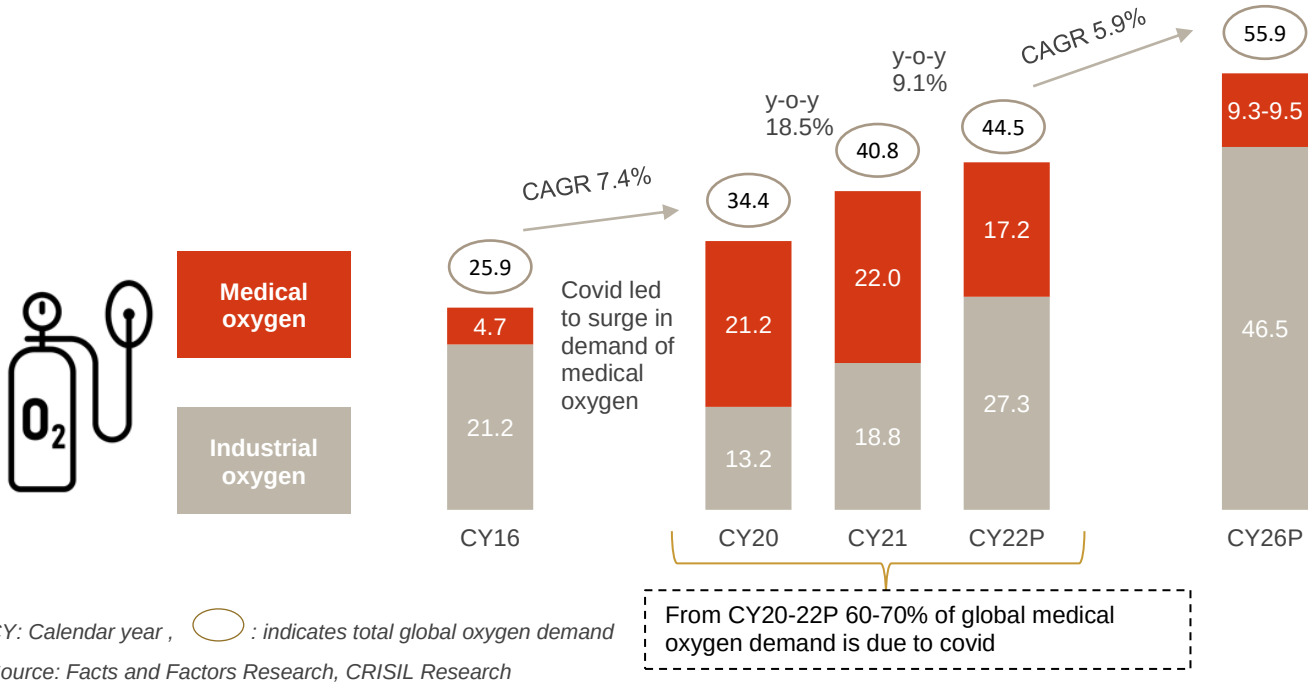
Welding and metal fabrication

Oxygen is used to create a hot flame in high-temperature welding torches used in cutting and welding and is used

as an assist gas for laser cutting. Oxygen is sometimes added in small quantities to shielding gases.

Global demand of medical oxygen surged in calendar years 2020-21 on account of rising Covid-19 cases

Global demand of oxygen bifurcated into industrial and medical oxygen (in million tonne)



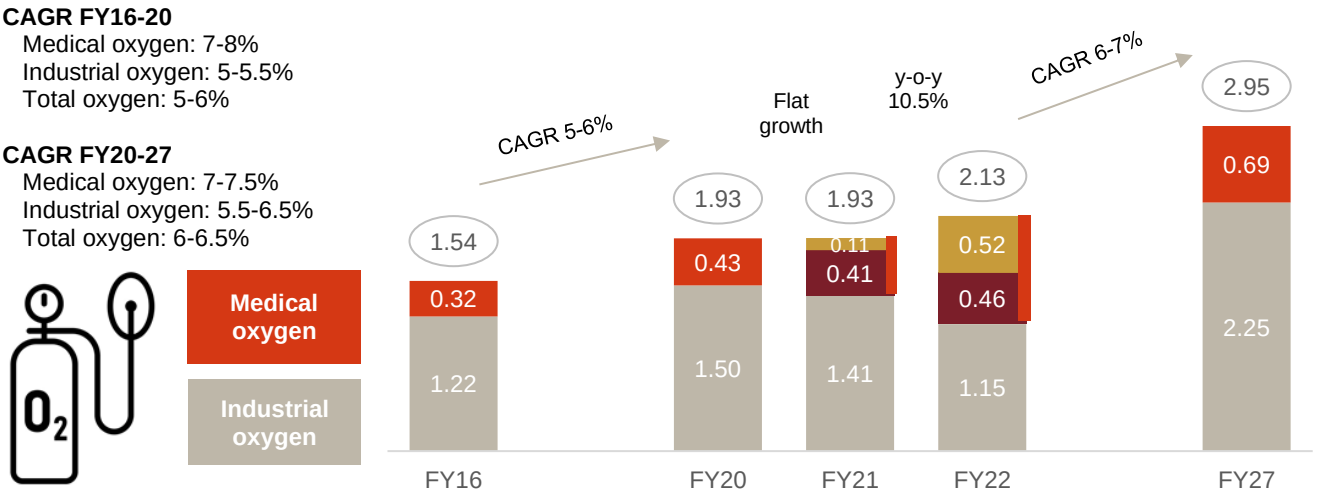
CY: Calendar year , : indicates total global oxygen demand

Source: Facts and Factors Research, CRISIL Research

According to CRISIL Research and industry estimates, the share of medical oxygen in total oxygen demand globally in the year 2016 was around 18% which rose over 50% when the pandemic outbreak was at its peak. With number of infected cases growing rapidly in different parts of the world, the demand for medical oxygen skyrocketed. Diminished economic activities reduced the demand of industrial oxygen. Further, as per CRISIL Research and industry estimates the demand of industrial oxygen in 2020, came down to ~60% level of 2016. In 2021, the on-year industrial oxygen demand is expected to have grown by 40% but still below 2016 level. With demand of medical oxygen slightly heading back to normally, the expected on-year demand of medical oxygen in 2022 is expected to de-grow by ~22% but the total oxygen demand is expected to grow by on-year 9.1%. Going forward, the combined medical and industrial oxygen demand globally is expected to grow at a CAGR 5.9% from 2022 to 2026. In addition, the medical oxygen demand globally is expected to grow from 5.5-5.7 million tonne in 2019 to 9.3-9.5 million tonne in 2026 at a CAGR of 7.0%.

Demand of medical oxygen shot up during the first and second waves in India

Indian oxygen demand bifurcated into industrial and medical oxygen (in million tonne)



Note: ⬭ : indicates total oxygen demand in India

- *For fiscal 2020 and fiscal 2021*

Source: CRISIL Research

In India, the share of medical oxygen in total oxygen production has remained in the range of 20-25% in last few fiscals. The demand of industrial oxygen in fiscal 2020 was supressed due to reduced economic activities in the year followed by further reduction in demand due to the outbreak of pandemic. As estimated by CRISIL Research, the combined medical and industrial oxygen demand grew by CAGR 5-6% between fiscal 2016 and 2020. India experienced its first Covid-19 wave in fiscal 2021 which led to incremental annual medical oxygen demand.by ~22% compared to previous fiscal. The annual medical oxygen consumption in fiscal 2022 is expected to be double of previous fiscal on account of deadly second Covid-19 wave. Part of the incremental demand in fiscal 2022 was catered by directing industrial oxygen production to medical usage. CRISIL Research projects the combined medical and industrial oxygen demand to grow by CAGR 6-7% from fiscal 2022 to 2027. The reduced industrial oxygen demand in fiscal 2022 is expected to revive and the heightened medical oxygen demand is expected to normalise going forward. In addition, the non-covid medical oxygen demand in India is expected to grow from 0.43 million tonne in fiscal 2020 to 0.69 million tonne in fiscal 2027 at a CAGR of ~7.0 – 7.5%.

- The demand of medical oxygen is expected to grow at a CAGR of 7-7.5% from fiscal 2020 to fiscal 2027 in volume terms
- Within medical oxygen market, the demand of medical oxygen in private hospitals in India is estimated to grow at a CAGR of 8-10% from fiscal 2020 to fiscal 2027 and the demand of medical oxygen in government hospitals is estimated to grow at a CAGR of 2-4% from fiscal 2020 to fiscal 2027
- In addition to above mentioned, CRISIL Research estimates, the healthcare delivery market comprising of hospitals in India, is expected to grow at a CAGR of ~13-15% from fiscal 2022 to fiscal 2026

Key global players in the oxygen market include Air Liquide S.A., Air Products and Chemicals, Inc., Airgas, Air Water Inc., Shanghai Boaster Gases Ltd, Guangdong Huate Gas Co., Ltd, Linde plc, Messer Group GmbH, Taiyo Nippon Sanso, Yingde Gases Group Company

Overview of the oxygen markets in select geographies

Bangladesh

The oxygen market in Bangladesh is dominated by Linde Bangladesh Ltd, followed by Spectra Oxygen Ltd and Islam Oxygen Ltd. According to Additional Director General (ADG), Directorate General of Health Services of (DGHS), the oxygen production capacity of the country increased from 150 tonne per day pre-pandemic to 250 tonne per day at present. Capacity was added after the country suffered a huge supply shortage of medical oxygen during April-May 2021 and June-September 2021, when the lethal waves of the pandemic lashed the country. Most hospitals get liquid medical oxygen in tanks and then store in the central oxygen system. The government has started focusing on installing liquid oxygen plants for the hospitals to reduce dependency on the suppliers. India extended its support to Bangladesh by transporting liquid medical oxygen (LMO) by the railways during the second half of the year.

The Philippines

The Philippines has four key local oxygen producers. According to the Department of Trade and Industry (DTI), the country has oxygen production capacity of over 600 tonne per day, out of which around one-third is for production of medical oxygen and the rest for industrial oxygen. In 2021, the country faced two pandemic waves, first peaking in March-May and then in July-October. Both the waves caused incremental demand of medical oxygen in the country. Most of the medical oxygen is supplied to hospitals in cylinders. According to the Philippine Confederation of Industrial Gases Inc. (PCIGI), the main reason for medical oxygen crunch in the hospitals was the slow turnaround in the return of empty cylinder tanks used in hospitals. Typically, oxygen production capacity in the country is in surplus during normal times and the oxygen producers usually maintain an inventory of 4-14 days.

Indonesia

Medical oxygen is available in health facilities in the more populated and developed regions of the country. In contrast, access to oxygen is unreliable in the undeveloped remote regions due to supply chain logistics challenges and inadequate electricity. The gas production industry, which provides oxygen for both medical and industrial use, prioritises distribution of oxygen to urban areas. Poor infrastructure coupled with smaller sales volume creates fewer incentives for oxygen supply companies to sell their products in remote regions. According to the Ministry of Health of Indonesia, it has a national oxygen production capacity of up to 866,000 tonne per year, with a utility rate of 640,000 tonne. The country experienced incremental medical oxygen demand when Covid-19 cases peaked during June-August 2021. The Indonesian government reached out to several countries (including China, Singapore, and Australia) to address oxygen shortage. To ensure ample supply of medical oxygen to the hospitals, the Indonesian government first allocated 90% of oxygen for medical needs, and later increased it to 100%. During April-May 2021, Indonesia supplied ~3,400 oxygen cylinders and concentrators to India to ease the shortage of medical oxygen.

African region

African region faced shortage of medical oxygen in the continent during the second wave of Covid which was at peak during the month of February 2021. At the beginning of the pandemic, Africa was house to 68 oxygen generating plants, which got increased to 119 across the continent by the time second wave arrived. The number of oxygen concentrators also increased from 2,600 to 6,100. The rapid number of increasing cases widened the demand supply gap of medical oxygen casing acute shortage. Medical oxygen in Africa is mostly stored in cylinders. Under normal scenario, the supply of medical oxygen was not a problem in the region as all the African countries have oxygen manufacturing plants or can source it from private sector providers The issue with oxygen supply in Africa during peak demand was with the delayed delivery and limited storage capabilities rather than issues with manufacturing. To address the issues and to take preventive measures, many African governments and non-governmental organisations have started building oxygen infrastructure, including piping into the ICUs.

Overview of Nitrogen gas generation

Some of the companies involved in oxygen generation are also involved in the manufacturing of other gases such nitrogen and hydrogen among others. Nitrogen gas is available in abundant amounts in nature and occupies a more than 3/4th share among the various gases by volume. It is also an inert gas which doesn't react very much with any other elements in the nature.

The generation of Nitrogen is majorly done through three different manufacturing methods, namely Fractional distillation, Pressure swing adsorption (PSA) and Membrane separation technology. Under fractional distillation, the air mixture is cooled until it turns into liquid form and selectively distilling various components of it at different boiling points. PSA uses the principle of differential separation where in it uses an absorbent material such as zeolites, activated carbon, molecular sieves to separate the required gases from the gaseous mixture. Membrane separation technology uses a permeable membrane that separates gases from the mixture depending upon the speed of the molecules of the required gas.

Due to the inert nature of nitrogen coupled with its physical and chemical properties it finds application across various industries. Few illustrations are discussed below

Food packaging: Nitrogen is used to create an unreactive atmosphere and remove oxygen from food packaging so that food can last longer

Light bulb industry: Light bulbs can't be filled with air as Tungsten inside the bulb combusts if it reacts with oxygen. Else if vacuum is maintained instead, the glass may break due to atmospheric pressure. Hence filling bulb with inert gas such as nitrogen acts as an alternative to prevent such incidents from occurring.

Fire extinguishers: Nitrogen is used in fire extinguishers to reduce the concentration of oxygen thus controlling further spread of fire and aiding to extinguish it quickly.

Electronics and Steel manufacturing: Nitrogen gas is commonly used in soldering of electronic components as it provides high quality finishes. Use of nitrogen in the steel manufacturing industry prevents oxidation of steel.

Chemical Industry: Nitrogen forms an important role in the chemical industry. It is used in the manufacturing of fertilisers, nylon, dyes and explosives. Common usage of nitrogen is during the sample preparation and also in volume reduction and concentration of chemical samples.

Pharmaceutical industry: Nitrogen is used in pharmaceutical industry for achieving better quality through blanketing. In this inerting of storage and production containers with nitrogen prevents the substances present inside from coming into contact with moisture or oxygen

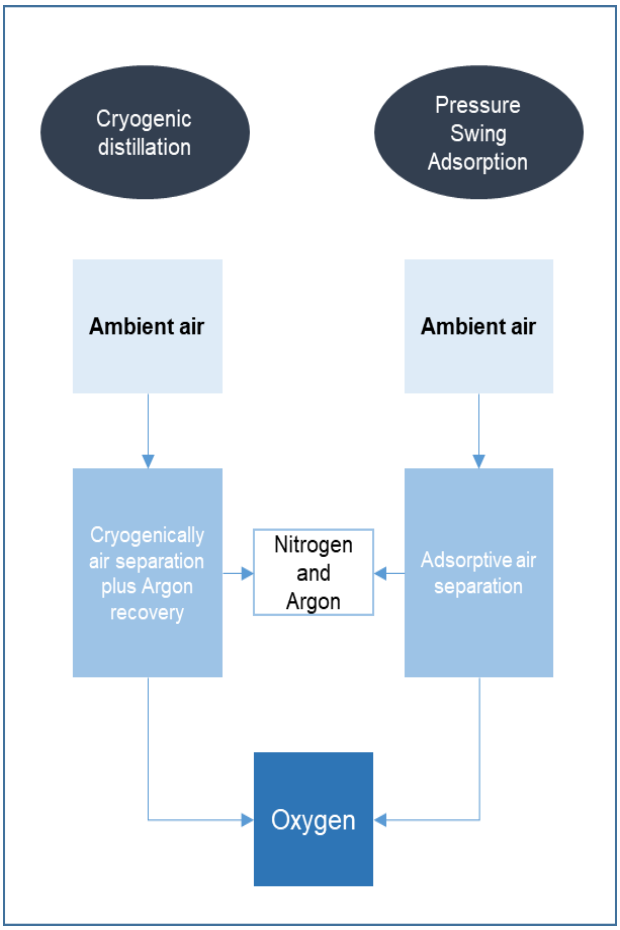
Oil and gas industry: Nitrogen is widely used in the oil and gas industry to prevent fire and explosion both on-shore and off-shore. Some of the common usages include nitrogen blanketing, nitrogen gas purging among others.

3. Overview of oxygen production in India

Cryogenic distillation is the most preferred production method in the country

Cryogenic distillation process

Cryogenic distillation is the most common production method by separation of oxygen in air separation units (ASUs), which are plants that separate large volumes of gases. The fractional distillation method is used to produce pure oxygen from atmospheric air, which consists mostly of nitrogen and oxygen – 78% nitrogen, 21% oxygen, and 1% other gases such as argon, carbon dioxide, neon, helium, and hydrogen.



In this method, gases from the air are separated into various components after cooling them into a liquid state and then liquid oxygen is extracted from it. Atmospheric air is first cooled to -181°C. Oxygen liquefies at this point. Since, the boiling point of nitrogen is -196°C, it remains in a gaseous state. But Argon has a boiling point like that of oxygen (-186°C) and, hence, a significant amount of argon liquefies along with oxygen.

The resultant mixture of oxygen and argon is drained, decompressed and passed through a second low-pressure distillation vessel for further purification. The final output of purified liquid oxygen is transported in cryogenic containers. Cryogenic liquid containers are specially designed for safe and economic transportation and storage of liquefied gases at cryogenic temperatures, lower than -90°C. These containers are highly insulated, in which liquid gases are stored at very low temperatures.

Pressure swing adsorption (PSA)

Oxygen can also be produced non-cryogenically, in gaseous form, using selective adsorption. This method leverages the property that under high pressure gases tend to be attracted to solid surfaces. The higher the pressure, the more the adsorption of gas.

PSA is one of the modern technologies used for separating oxygen from air. The PSA process utilises the ability of a synthetic zeolite molecular sieve to absorb mainly nitrogen and other gases. While nitrogen concentrates in the pore system of the zeolite, the clean dry air is then passed through the sieve beds on the oxygen generator, which produces an oxygen enriched gas as a product.

PSA oxygen generators have two vessels filled with zeolite molecular sieve as adsorbers. An air compressor is used to compress the air which passes up through one of the adsorbers, the molecular sieve selectively adsorbs the Nitrogen. This then allows the remaining oxygen to pass on up through the adsorber and exit as a product gas. When the adsorber becomes saturated with Nitrogen the inlet airflow is switched to the second adsorber. The first adsorber is regenerated by desorbing nitrogen through depressurisation and purging it with some of the product oxygen. The cycle is then repeated, and the pressure is continually swinging between a higher level at adsorption and a lower level at desorption. Out of the molecular sieve, the oxygen produced is sent through the buffer tank via a multifunction block. Nitrogen is released via a silent escape and forced back outside.

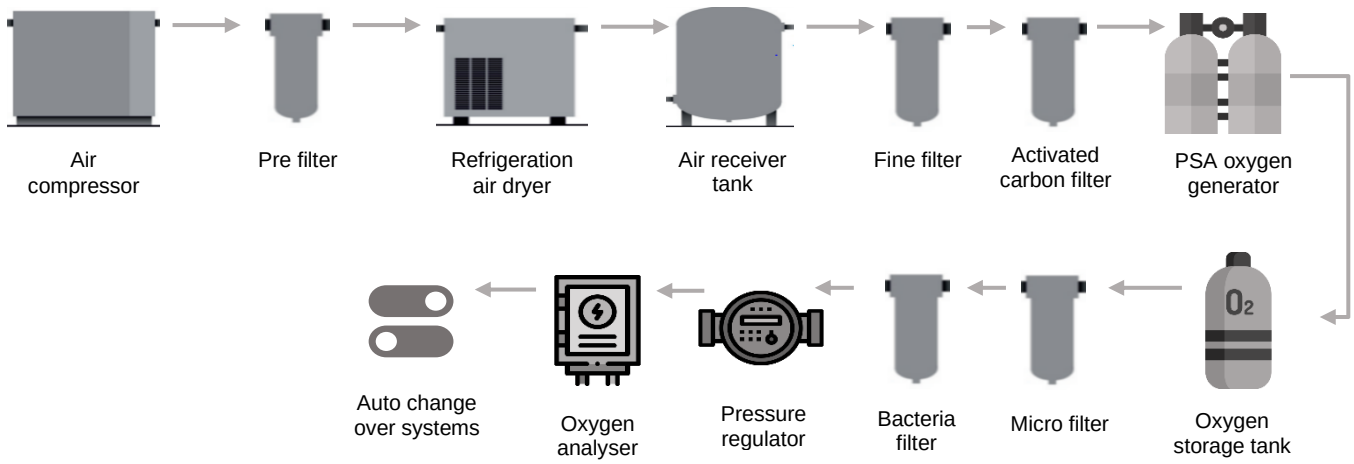
Hospitals can also opt for on-site generation of oxygen by this method, where oxygen is produced from ambient air by concentrating it. The design and instrumentation make the plant size very compact, can be comfortably set-up in the backyard or even at the terrace with covered shed. The production of oxygen near hospitals eliminates the need for transportation.

A PSA oxygen generator set-up typically consists of

- Air compressor
- Pre filter
- Refrigerated compressed air dryer
- Air receiver tank
- House pipe
- Fine filter and Activated carbon filter
- Oxygen generator
- Oxygen receiver tank
- Copper pipeline outlet
- Oxygen analyser
- Auto change over systems

Sieves is the main component which separates oxygen from air and accounts for 25% of total oxygen generator cost.

PSA oxygen generator process flow

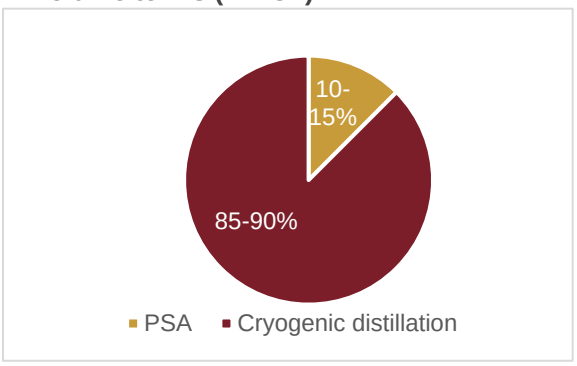


Advantages of PSA oxygen generators:

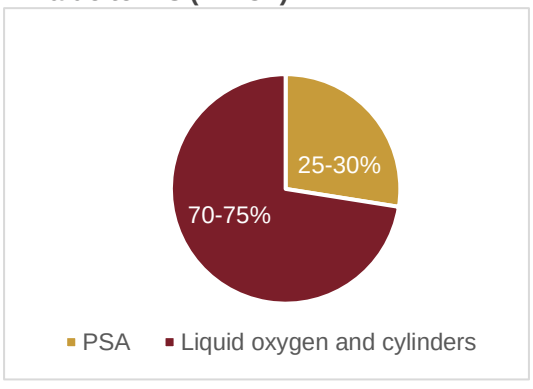
- With PSA oxygen generators having advantages such as continuous supply of desired grade of oxygen compared to other modes of oxygen generation and requirement of less manpower, it caters to multiple problems such as oxygen cylinder filling capacity, amount of oxygen wastage, extra staff need to manage oxygen cylinders
- Price fluctuation of oxygen is under control as the cost is directly related to actual consumption.
- Less prone to explosion or fire hazards compared to the filling of the cryogenic tanks or with the cylinders.
    - PSA oxygen generators operates at 4.5 bar pressure whereas oxygen cylinders are being filled at 150 bar pressure which makes PSA oxygen generator less combustive and safer to operate in hospitals. Actual oxygen pressure requirement is 4 to 4.2 bar to operate ventilator and anesthesia machine.
- Does not require large space.
    - Oxygen generators can be installed in smaller spaces such as terrace while adhering to the safety standards required

Current oxygen production method-wise share

In volume terms (FY23E)



In value terms (FY23E)



Source: CRISIL Research

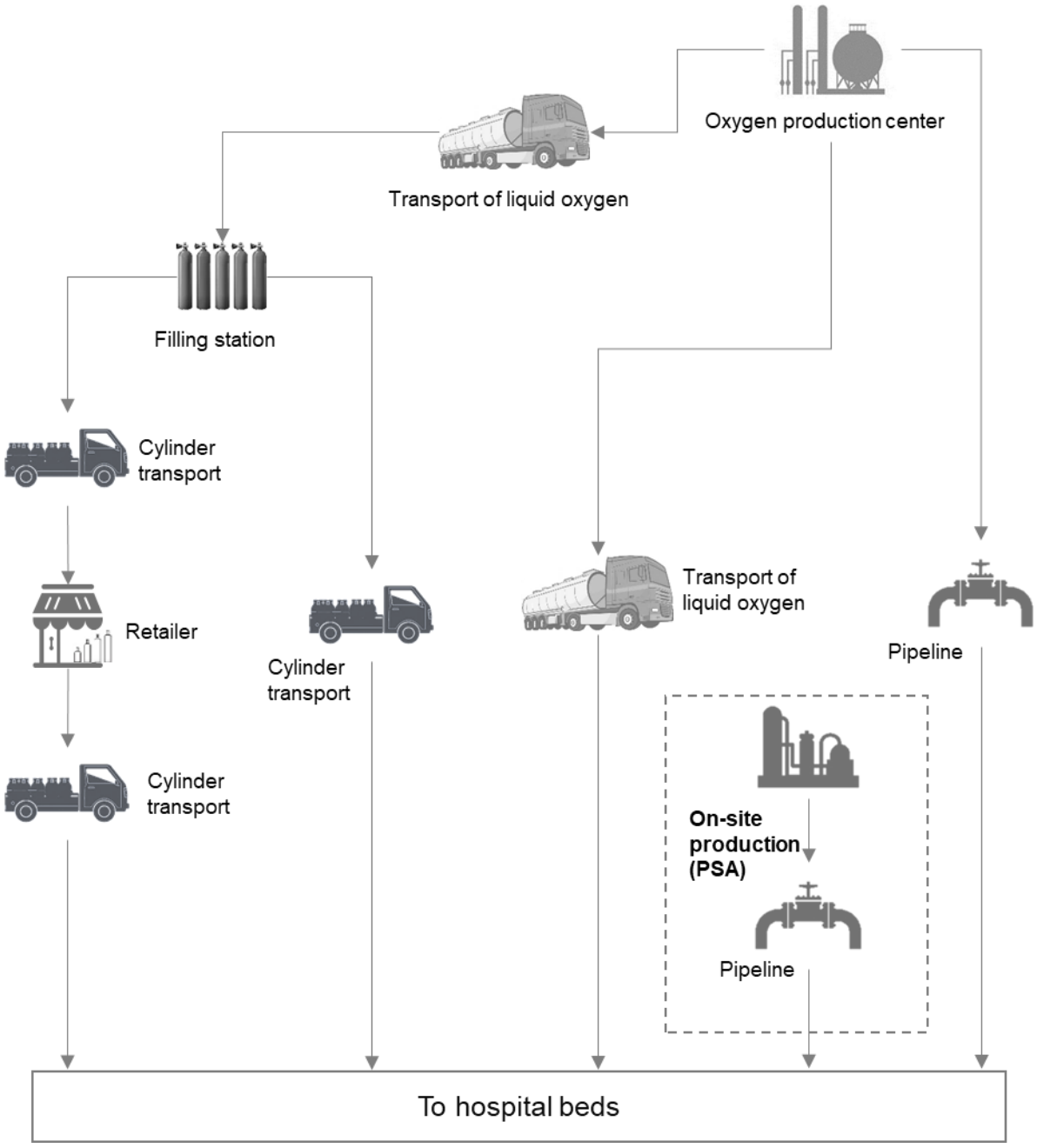
Oxygen produced through PSA is the cheapest

	On-site production (PSA)	Cylinders	Bulk delivery (Liquid oxygen)
Scale of operations	Depending on hospital requirement, PSA plant can be set up. Additional set-up cost and space will be required to meet incremental demand	Incremental demand can easily be met by procuring additional number of cylinders	Meeting incremental demand depends on currently installed handling capacity of vacuum insulated evaporator
Advantages	• Cost effective • Continuous supply of desired grade oxygen • Plant occupies limited space • Clean operation	• No power source • Relatively convenient form of storage without the need for insulation	• High oxygen output for small space requirement
Disadvantages	• High capital investment • Requires uninterrupted power • Requires backup cylinder supply	• Requires adequate reliable supply chain • Reliance on supplier • Exhaustible supply • Exposed to cylinder price fluctuation • Lack of assurance of oxygen quality and quantity inside the cylinder • 5-10% Leakage while changing the cylinders	• Requires adequate reliable supply chain • Needs adequate infrastructure and regular maintenance • Reliance on supplier • Cumbersome compliance due to hazardous nature of liquid oxygen
Capital investment	Substantial one-time capital investment required to set up the plant. For a 300 bedded hospital, capital cost (equipment cost + infrastructure) could be around Rs 10 million	No capital investment required	For a 300 bedded hospital, Rs 2-3 million initial investment is required to set-up liquid medical oxygen tank and vaporizer
Operating cost	To run a PSA plant in a 300 bedded hospital, 30-50 units of electricity is consumed per hour, Assuming Rs 8.5/unit cost of electricity, the annual electricity cost sums up to Rs 2.3-3.7 million	A 300-bedded hospital would require ~110 oxygen cylinders in a day; Assuming Rs 250/cylinder cost, the total annual expenditure would be ~Rs 10 million	A 300 bedded hospital would require 1,000 to 1,100 kg of liquid oxygen in form of container in a day; Total annual expenditure of Rs 8-9 million
Cost of oxygen	Rs 9 to 15 per cubic meter (includes maintenance cost and electricity cost)	Rs 33 to 50 per cubic meter`	Rs 22 to 40 per cubic meter`

Note: Capex expenditure for on-site is not included in cost of oxygen. Considering the capex cost investment in on-site PSA is recovered in 1.5 to 2 years for large to mid-size hospital

Source: CRISIL Research

On-site oxygen production through PSA avoids the hassle of transportation



Source: CRISIL Research

On-site oxygen production through PSA eliminates the possibility of logistical failure in case of adverse situations as the oxygen is generated at the hospital premises.

Liquid oxygen supply system

In the liquid oxygen system, cold liquid oxygen is stored in bulk in an insulated reservoir known as a vacuum insulated evaporator. The reservoir may be a permanent installation or a portable, lightweight container. In either

case it has a double-walled construction, with vacuum between the outer and inner shells. During normal operation, the liquid oxygen is made to flow out of the reservoir and pass through an ambient vaporizer. Heat from the surroundings warms the liquid oxygen in the vaporizer, causing it to turn into gas. Gaseous oxygen is heated further and delivered through a pressure regulator to the distribution line.

Cylinders

Oxygen may be stored and supplied as a compressed gas in cylinders. The oxygen from a cylinder is admitted to the distribution line through a pressure regulator. The regulator reduces the pressure of the oxygen to a level that can be used safely. Typically, a group of cylinders, known as a cylinder manifold, is used to supply oxygen through a pipeline to a hospital. Oxygen is drawn from all the cylinders of a manifold simultaneously. Often, the cylinders are arranged group-wise: primary and secondary. A pressure transducer switches to the secondary manifold once the pressure in the cylinders of the first manifold drops below a certain limit. The primary manifold is replenished when this happens.

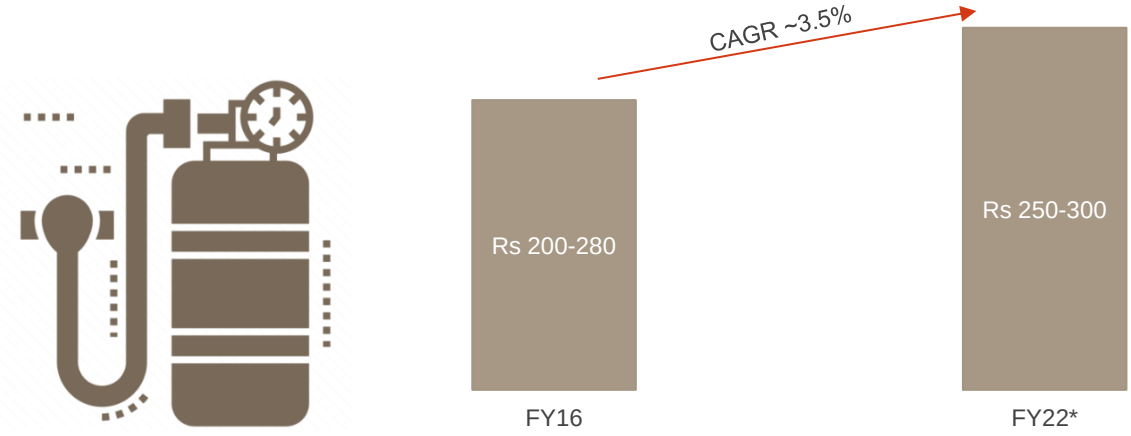
PSA oxygen generators

Medical oxygen can be generated on-site at any hospital, clinic, or health care centre using PSA oxygen generators. The main input in the production of oxygen using PSA process is air. In a PSA process, air is pressurised and passed through a bed of adsorbent. PSA processes rely on the fact that under such conditions gases tend to be adsorbed by solids. The adsorbent used in PSA-based oxygen production attracts nitrogen more strongly than it does oxygen. The generated oxygen can be piped directly to the patients and cylinders can be refilled through a booster compressor.

During fiscal 2021,due to the unavailability of medical oxygen during the COVID-19 crisis, few states such as Andhra Pradesh, Haryana and Maharashtra have made it mandatory for hospitals with certain number of beds to install oxygen generators. In addition, National Council for Clinical Establishments, under the Directorate General of Health Services, has recommended installation of mini oxygen/ PSA oxygen generators across India for the existing and new hospitals with a capacity of more than 50 beds.

Oxygen cylinder refilling price has steadily increased at ~3.5% CAGR over past 6 years

Refilling price of medical cylinder in India



Note: Assumed cylinder capacity is of 7 litres

**Oxygen cylinder refilling price shown in the figure does not incorporate refilling cost surge during the pandemic's second wave.*

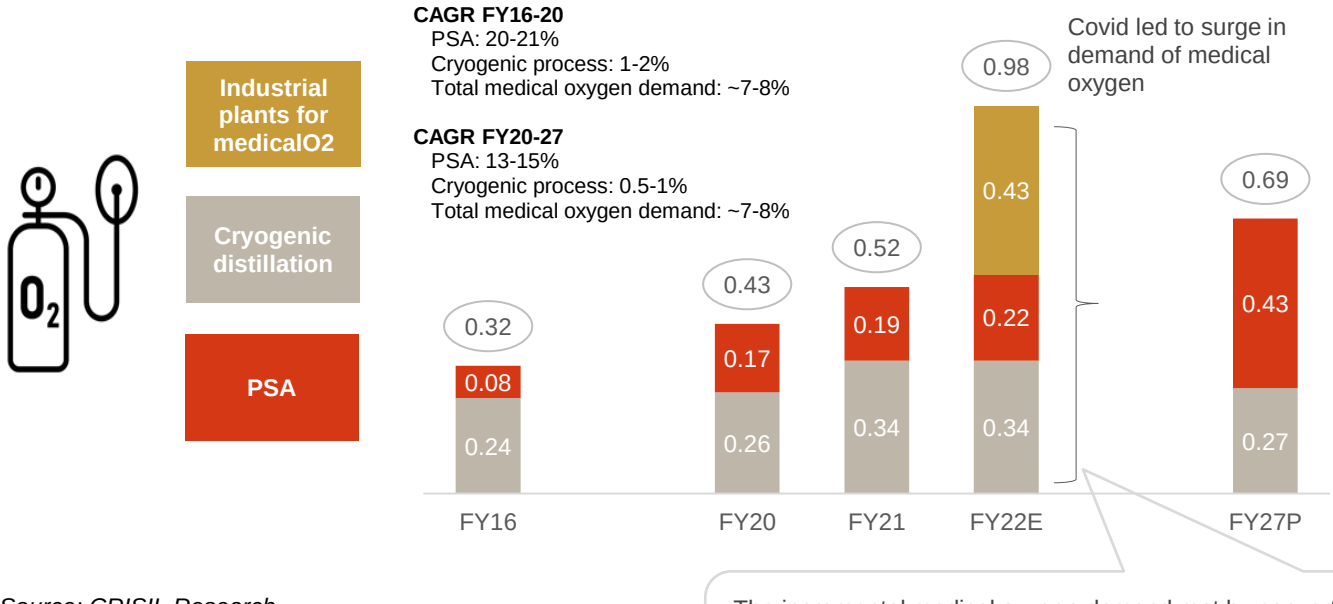
The refilling price is inclusive of taxes

Source: CRISIL Research

Depending on the location, the oxygen cylinder refilling price in India mostly range between Rs 250-300 per cylinder. During the second wave of Covid-19 when the country suffered shortage in supply of medical oxygen, many players increased the price of oxygen cylinder. Even with authorities' intervention in form of price caps, the refilling price in the market shot up to 2-4 times. The oxygen cylinder refilling price otherwise has grown by ~3.5% CAGR from fiscal 2016 to 2020.

Oxygen production through PSA method is expected to outgrow cryogenic distillation method

Medical oxygen demand in India segmented into production method-wise (million tonne)



Source: CRISIL Research

Historically, cryogenic distillation method has remained the most used method for supply of medical oxygen to healthcare facilities in India. With PSA technology being relatively new in India, the penetration of oxygen production through PSA technology has seen a rapid adoption. The total medical oxygen demand in India, as estimated by CRISIL Research, is assessed to have grown at a CAGR of 7-8% from fiscal 2016 to 2020 in volume terms and ~8% in value terms during the same period. The production of medical oxygen through PSA methods during the same period is estimated to have grown double compounding 20-21% annually while medical oxygen production through cryogenic distillation showing a milder growth of CAGR 1-2% during the same period.

During the unprecedented times created by Covid-19, the demand of medical oxygen shot up worldwide. India experienced its first Covid-19 wave in fiscal 2021 during the months of August and September. The overall annual demand is estimated to have grown by ~25% compared to previous fiscal. The incremental demand was partly catered by increased number of PSA oxygen generators and partly through cryogenic distillation production method. The second wave of Covid-19 early in fiscal 2022 proved to be deadlier which soared the medical oxygen demand by 10 times compared to pre-Covid times when the wave was at its peak. The country suffered the shortage of medical oxygen during April-May 2021. The incremental demand was fulfilled by converting industrial oxygen production units to medical oxygen plants and through import of liquid medical oxygen. The alarming situation led to increased number of PSA oxygen generators installations during the fiscal. During the same time, the country experienced spurt in manufacture and sale of oxygen concentrators. Besides multi-national brands, several Indian start-ups, funded under the CAWACH (Centre for Augmenting War with Covid 19 Health Crisis) programme of Department of Science & Technology, developed efficient and cost-effective oxygen concentrators to meet the surged demand.

CRISIL Research expects that going forward the medical oxygen supply through PSA method will outgrow cryogenic distillation method. The demand of medical oxygen is projected to grow by a steady CAGR 7-8% from fiscal 2020 to 2027. More than half of the medical oxygen demand is expected to be fulfilled by PSA method by fiscal 2027 with compounded production growth of 13-15% annually during the same period.

In India, over 80% of the hospitals procure medical oxygen through cylinders. Going forward, more than half of the demand of medical oxygen is expected to be met through PSA method by fiscal 2027

Operational PSA oxygen generators require annual maintenance and effective programming for smooth functioning of the system. The growth of medical oxygen production by PSA oxygen generators projected by CRISIL Research assumes that the vendors operating in Indian market will enhance technical expertise from current level during the projection period. Technology simplification in medical oxygen production may increase competition in the market which can poses a direct threat to expected growth of PSA oxygen generators.

Measures to be followed by players operating in domestic medical oxygen market

The manufacturing, distribution and import of medical oxygen in India is regulated by The Drugs and Cosmetic Act, 1940 and rules framed thereunder. Any person or organisation manufacturing medical gases (i.e. medical oxygen IP, nitrous oxide IP, and medical carbon dioxide IP) should have a valid manufacturing licence issued from the

respective state Drug Controller in accordance with the provisions of The Drugs and Cosmetic Act 1940 and rules thereunder.

The Indian Pharmacopoeia Commission (IPC), an autonomous institution under the Ministry of Health and Family Welfare, Government of India, prescribes the standards for the identity, purity and strength of all drugs that are manufactured, sold and consumed in India. These standards are published under the title Indian Pharmacopoeia. The Indian Pharmacopoeia has a legal status under Section 16 of The Drugs and Cosmetic Act 1940. Drugs specified in the second schedule under The Drugs and Cosmetic Act 1940 are required to comply with specified standards.

For setting up a medical oxygen facility, approvals are required from the following two government bodies:

1. Local Pollution Control Board

The applicant and operator of the medical oxygen facility must secure an Establishment Registration Licence from the labour department of the respective state government.

A brief project report must be submitted to the local pollution control board authorities for obtaining a licence for producing medical oxygen.

The project report shall include, but not limited to the raw materials used, quantity per day/month, name plate capacity, etc. Any kind of hazardous material/or any other chemical used in the process must be highlighted. The report shall contain process description and process brief of the manufacturing technology.

2. Petroleum and Explosives Safety Organisation (PESO)

Similar to any other chemical facility, engineering drawings such as plant layout, area classification, etc. have to be submitted to PESO for approval. No approvals are required for commissioning.

Any person or entity involved in the process of filling and storing a cylinder with a compressed gas has to abide by the Gas Cylinder Rules, 2016, which prescribes the appropriate procedures to be followed, standards to be adopted, restrictions and licences to be obtained. As per Section 43 (1) of the Gas Cylinder Rules, 2016, licence should be obtained for filling and storing compressed gas in cylinders. Furthermore, the said provision levies the responsibility on the licensee for all operations connected with filling and possession of cylinders in the licensed premises. Additionally, Gas Cylinder Rules, 2016 prescribes that a cylinder used for storage and transportation of a flammable or toxic gas cannot be used for other gases. Separate dedicated facilities are required to produce gases used in medical and pharmaceutical fields in order to avoid the risk of cross-contamination.

4. Assessment of oxygen generation systems for medical applications

Pressure swing adsorption (PSA) method for oxygen production is a cost-effective technique

Case study:

- Considering a 300 bedded hospital with ~35-40 installed ICUs and half of them equipped with ventilators
- The daily average oxygen requirement of such a hospital is expected to be 750-850 cubic meter

Oxygen through cylinders	Oxygen through PSA system
Capital expenditure: • For procurement of oxygen through cylinders, hospitals don't require any additional capital expenditure	**Capital expenditure:** • To supply medical oxygen to the assumed case, capital investment would be approximately Rs 10 million • The investment would cover equipment cost and ancillary infrastructure setup required to run the PSA plant
Operating expenditure: • Average requirement would be ~110 oxygen cylinders in a day • Assuming Rs 250/cylinder cost, the total annual expenditure would be ~Rs 10 million	**Operating expenditure:** • 30-50 units of electricity would be consumed per hour, depending on power efficiency of the installed equipment • Assuming Rs 8.5/unit cost of electricity, the annual electricity cost sums up to Rs 2.3-3.7 million
	Saving per year: 10 million – 3 million = 7 million
	Payback period: Approximately ~1.4 to 1.6 years
	Life-cycle: Largely dependent on quality of equipment used. The highest plant life in Indian market is claimed to be ~18 years

Note: Kindly note that, 300 bedded hospital considered above is for illustration purpose. However, oxygen generators can also used for smaller hospitals with a bed capacity of 30.

Source: CRISIL Research

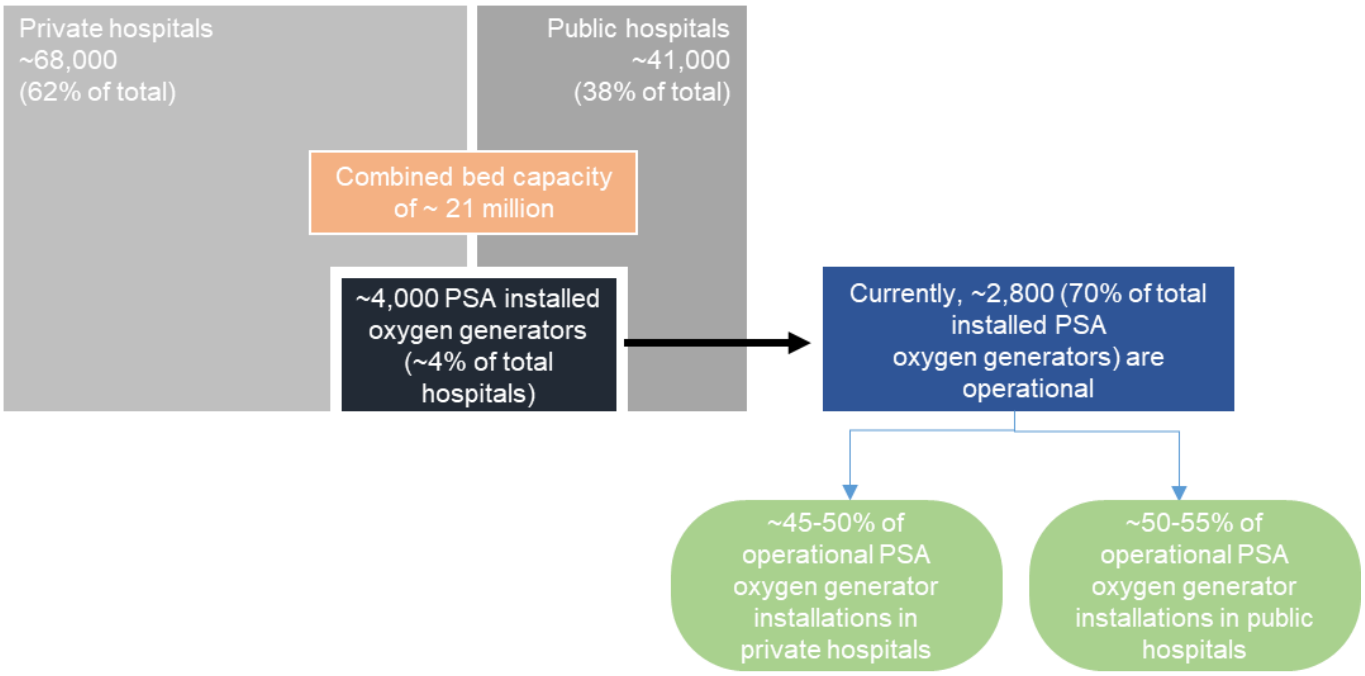
Advantages of PSA method

PSA is a cost-effective method for oxygen production. As shown above, the payback period for a PSA oxygen generator ranges from ~1.4 to 1.6 years

- Captive PSA oxygen generators are installed in hospitals to generate oxygen, thus their reducing reliance on external vendors for supply of cylinders or liquid oxygen
- PSA is a clean technology
- Ambient air is the only raw material required
- The PSA process can be continuously repeated to produce an uninterrupted supply of oxygen
- The process meets the standards set by the Indian Pharmacopoeia Commission for medical usage of oxygen
- PSA process contribute in reduction of carbon footprint while supplying Oxygen. Transportation of oxygen produced through cryogenic process, be it liquid oxygen or the gaseous oxygen filled in cylinders, happens by consumption of fuel. As PSA method is an in-house oxygen production set-up, it does not require additional transportation system of oxygen for end-use, reducing fuel consumption.

Low penetration of PSA – An opportunity for PSA oxygen generator manufacturers and vendors

According to the National Health Profile (NHP) of India - 2021, National Sample Survey (NSS) 75th round report, and CRISIL Research, India has approximately 1,09,000 hospitals, with the share of private and public hospitals at around 62% and 38%, respectively. CRISIL Research estimates around 4,000 hospitals to have installed on-site oxygen production facilities in the form of PSA oxygen generators by the end of fiscal 2022. Given the cost-effective nature of PSA technique and other advantages compared with traditional medical oxygen procurement methods, the penetration level of PSA oxygen generators is low. This offers an opportunity for PSA oxygen generator manufacturers and vendors offering services in the medical oxygen market in India.



Note: Number of PSA oxygen generators is estimated based on industry interactions and is not a reported figure
Source: NHP 2021, NSS 75th round report, CRISIL Research

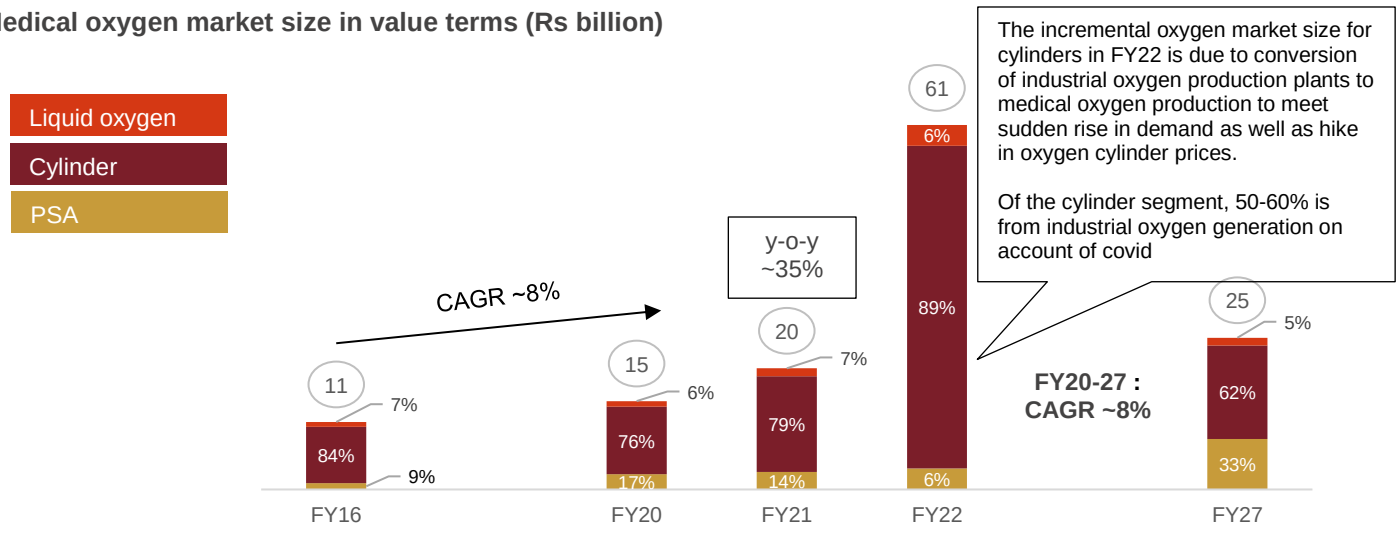
A PSA oxygen generator is an assembly of multiple equipment producing oxygen of the required grade. PSA oxygen generators themselves can be turnkey units complete with all the necessary equipment and supplies; however, the staff operating and maintaining them require specialised training. Strict maintenance schedules are needed to prevent malfunctions. Adequate supplies and spare parts are needed to allow operations for a few years in resource-limited settings. A reliable supply chain is needed to meet any additional needs. Due to lack of expertise in successful operation and maintenance of PSA oxygen generators, many players could not service the equipment, resulting in defunct PSA oxygen generators.

Sensing the incremental demand due to the pandemic, multiple manufacturers and vendors have started supplying PSA oxygen generators to hospitals. CRISIL Research estimates that approximately 2,800 PSA oxygen generators (~70% of the total installed PSA oxygen generators) are currently operational. Out of these 2,800 operational units, CRISIL Research estimates that ~45-50% of the installations are in private hospitals and the remaining ~50-55% in public hospitals as of fiscal 2022. Few key players in private hospital market are Airox Technologies, Absstem Technologies, Oxymat India, Oxair Gases, Trident Pneumatics etc.

ICU beds equipped with ventilators consumes major chunk of medical oxygen stock in the hospital. A 300 bedded hospital with around 35-40 installed ICU beds, half of them equipped with ventilators on an average consumes 750-850 cubic meter of medical oxygen or 1,000 to 1,100 kg of medical oxygen. Thus, per ICU bed utilisation turn out to be around 25-30kg of oxygen per day.

Second wave of Covid saw increased medical oxygen cylinder prices

Medical oxygen market size in value terms (Rs billion)



Source: CRISIL Research

In value terms, the medical oxygen market size has increased by a CAGR of ~8% from fiscal 2016 to fiscal 2020 in value terms. To arrive at the value of medical oxygen through PSA process, CRISIL Research has used operational costs such as electricity cost and annual operation and maintenance cost as the cost parameters and has excluded the capital expenditure required to set-up the PSA oxygen generator. In fiscal 2021, the demand of medical oxygen increased due to first wave of Covid. The sudden increase in demand led to increase in prices of oxygen cylinders. The on-year growth in medical oxygen market size is estimated to be ~35%. Second wave was at its peak in fiscal 2022. The heightened demand of medical oxygen led to exorbitant pricing of the commodity. The demand for medical oxygen in India peaked to nearly 9,000 tonne/day during the second wave of covid as compared to the peak requirement of 3,000 tonne/day during the first wave of covid. The medical oxygen market in fiscal 2022, in value terms, is expected to be ~3 times of fiscal 2021 and ~6 times of fiscal 2016. Going forward,

CRISIL Research expects the medical oxygen market in value terms is expected to grow by CAGR ~8% from fiscal 2020-27.

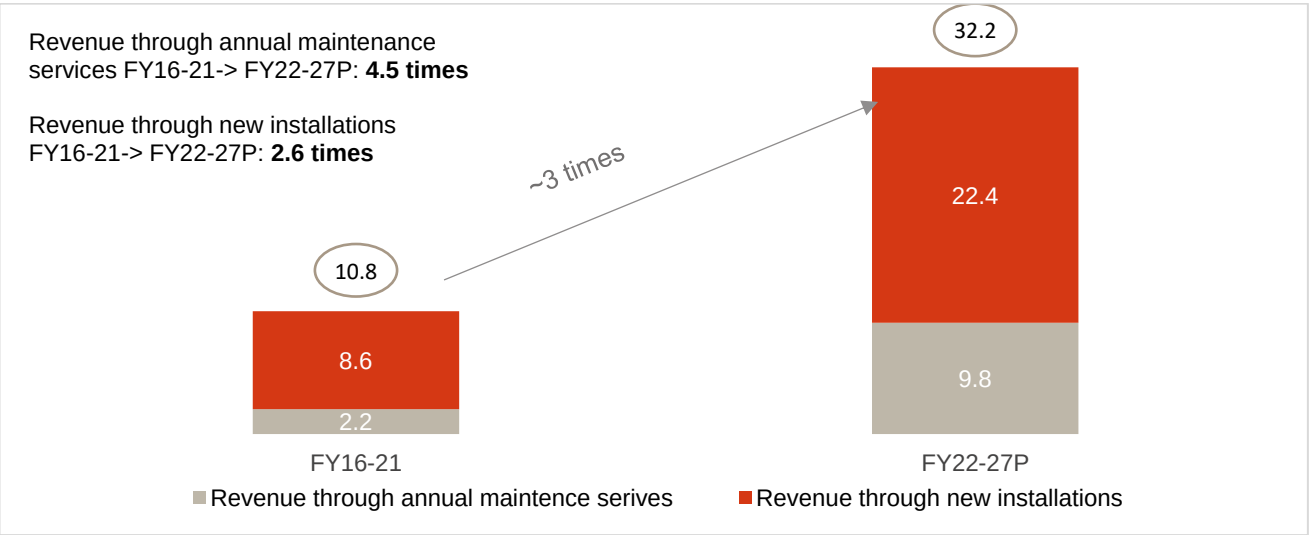
Market for PSA oxygen generator operators expected to grow by 3 times in next 6 fiscals compared to last 6 fiscals

To estimate the market for PSA operators, CRISIL Research has assumed the revenue earned through installing new PSA oxygen generators and revenue earned through providing annual maintenance services. With focus shifting towards installing new PSA oxygen generators in the country, the capital expenditure to set-up these is expected to be ~22.4 billion from fiscal 2022 to 2027.

Revenue through annual maintenance services form a stream of regular income for the PSA operators. Revenue through annual maintenance services is expected to see increasing contribution to total PSA market in the coming years. On the cumulative basis, revenue from annual maintenance is expected grow by 4.5 times from fiscal 2016-21 to fiscal 2022-27.

Demand for PSA oxygen generators is expected to grow during the next few years, providing an opportunity to PSA oxygen generator operators for revenue generation from the new installations. CRISIL Research estimates revenue generation from new installation on a cumulative basis to grow by 2.6 times from fiscal 2016-21 to fiscal 2022-27.

Market for PSA oxygen generator operators in India (Rs billion)



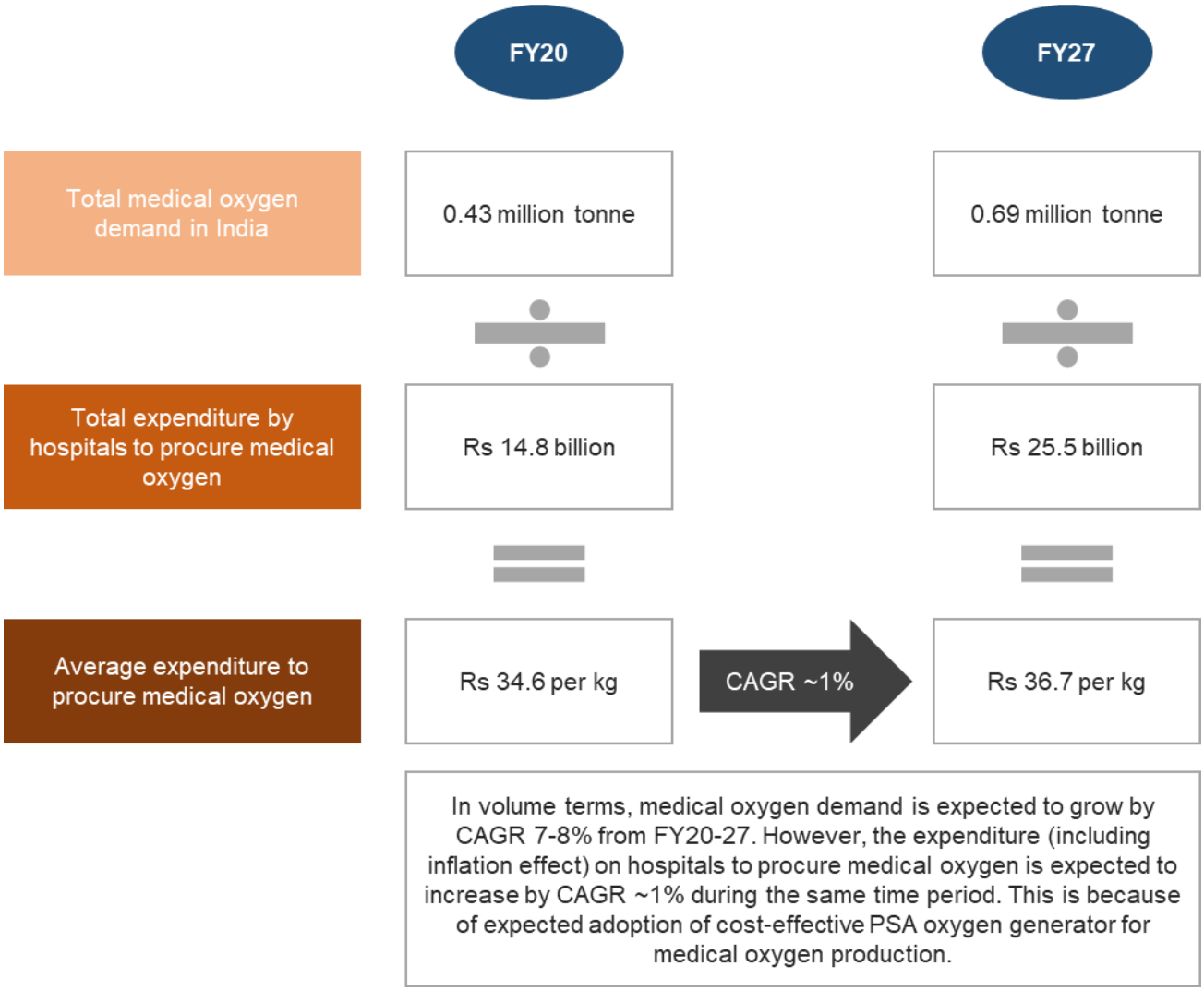
Note: The data mentioned for FY16-21 and FY22-27P is on cumulative basis respectively
Source: CRISIL Research

Apart from the opportunity, a new entrant into the PSA oxygen generator industry should also consider the following technical barriers that persist in the industry which are listed below

- In a PSA oxygen generator, the regeneration process consists of a sequence of steps where-in the compressed air is moved from one vessel to another vessel when a molecular sieve is saturated. This movement of compressed air is made possible through the usage of PLC (programmable logic controller) which is programmed to operate the values on an alternate basis keeping the flow and purity of oxygen at constant even during peak demand. This PLC requires programming expertise which makes it critical for new entrants establish robust PLC system to capture the market as improper functioning of programming would alter the purity levels making the oxygen non-compatible for medical purpose.

- The sieves are also most critical component in the PSA oxygen generators utilised for separation of oxygen from other gases during the generation process. This makes it mandatory for players to use high-quality sieves to avoid any reduction in their oxygen purity levels. However, limitation of access to such high-quality sieves creates a technical barrier to new entrants entering the market. Some Indian companies have collaboration with international players such as Airox Technologies Ltd and Airsep Corporation, Pec Therm Private Ltd and INMATEC Gas Technologies Gmbh & Co.

Shift to cost-effective PSA technology is expected to reduce medical oxygen procurement burden on hospitals



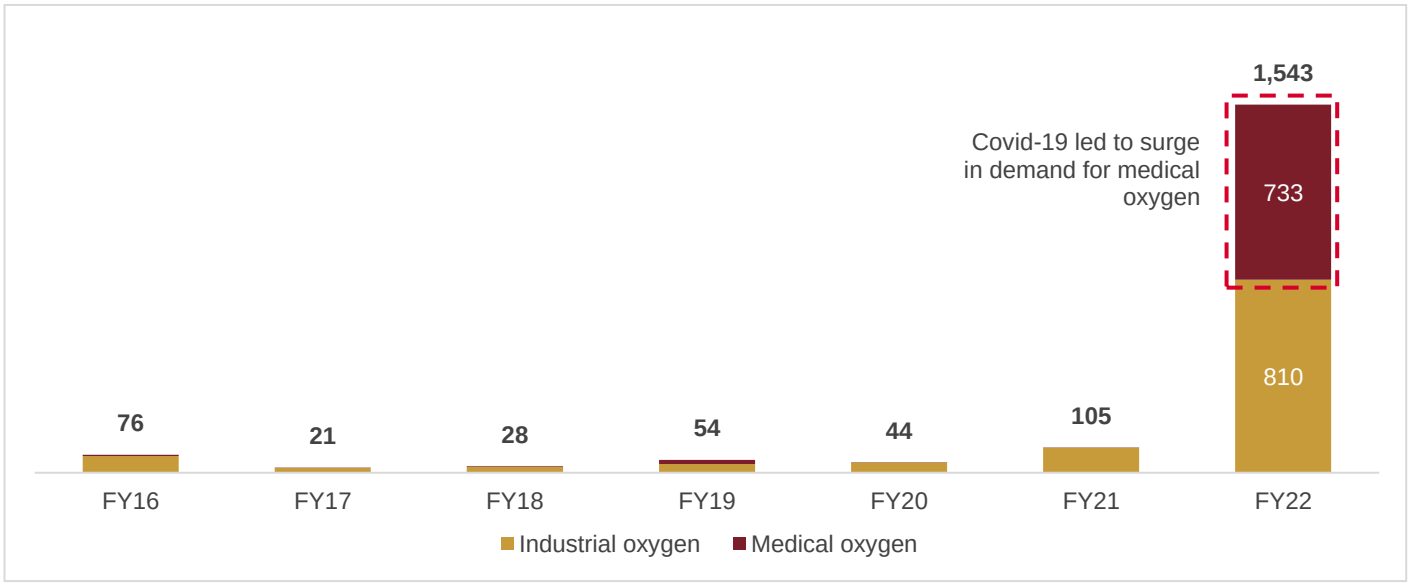
Source: CRISIL Research

Trade of medical oxygen shot up in fiscal 2022

India has largely been self-reliant in meeting its oxygen supply requirement – be it for industrial purpose or medical consumption. The country experienced a surge in demand for medical oxygen during the deadly second wave of Covid-19 (April-May 2021). Domestic oxygen production wasn't sufficient to match the incremental demand, which led to a spike in medical oxygen imports. More than half of the requirement for medical oxygen in fiscal 2022 was met through imports from Saudi Arab. The United Arab Emirates, North Korea and Indonesia were the other top

countries from which India imported medical oxygen. To increase the supply of medical oxygen during the second wave, government had directed partial supply of industrial oxygen for medical use. This led to increased import of industrial oxygen too.

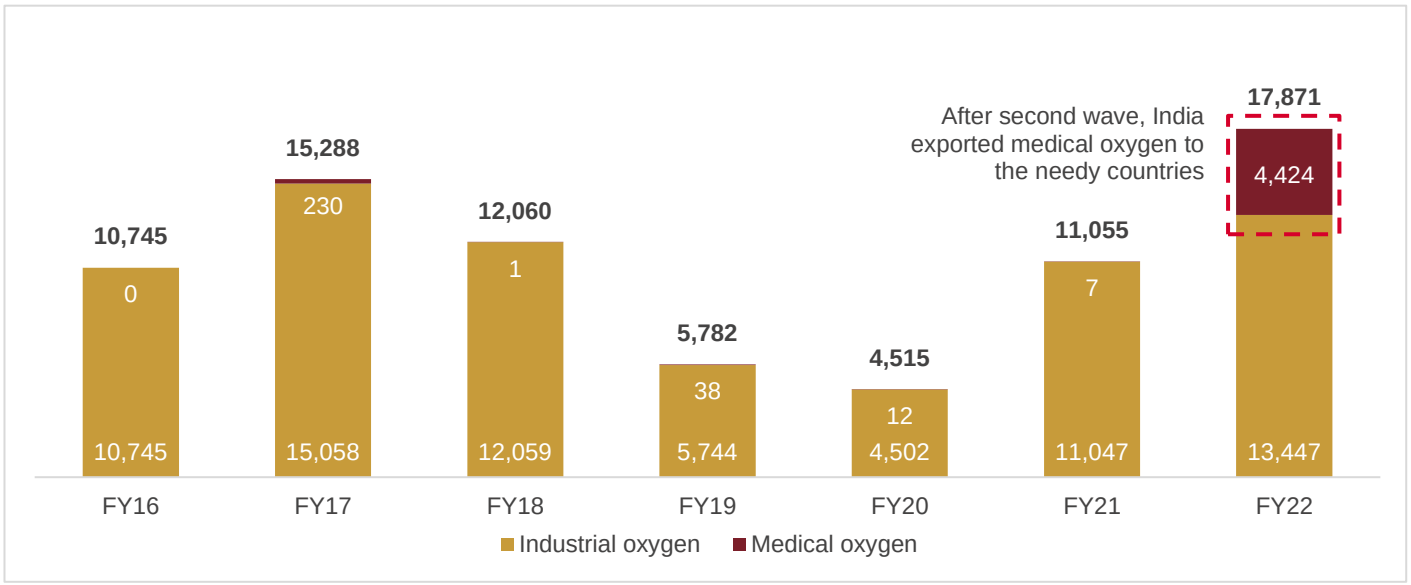
Import of oxygen (tonne)



Source: Ministry of Commerce and Industry, CRISIL Research

Post second wave of Covid-19 in the country, India exported medical and industrial oxygen predominantly to Bangladesh in fiscal 2022. Nepal and Sri Lanka were the other neighbouring countries to which India exported its oxygen production.

Export of oxygen (tonne)



Source: Ministry of Commerce and Industry, CRISIL Research

List of key oxygen producers in India

Name of oxygen producing company	
Airox Technologies Limited	Universal Air Products
National Oxygen	Asian Gases Industries
Bhagawati Oxygen	Air Liquide India Holding
Linde India	Air-n-gas Process Tech
Inox Air Products	Universal Boschi
Malabar Oxygen Company	AtlasCopco
MSPL Gases Ltd	Bellary Oxygen
Praxair India Pvt	BOC India
Indiana Oxygen Company	Sam Gas projects
Sri Balaji Oxygen	Trident Pneumatics
Grasim Industrial	Oxair Gases
Absstem Technologies	Oxymat India
Summits Hygronics	Inmatech

Note: The list includes industrial and medical oxygen producers irrespective of production method followed. The list of players is in no order. Set of producers shown in the list are indicative and the list per se is not exhaustive.

Source: CRISIL Research

Second pandemic wave showed the importance of an effective oxygen supply chain system

Governments across the world faced challenges due to medical emergencies triggered by the pandemic. Like several other countries, India too battled to ensure optimal usage of medical infrastructure such as hospital beds, medical oxygen, and others. Medical oxygen proved to be a critical ingredient in treating acute respiratory distress associated with Covid-19. High-flow nasal oxygen has been found to be a safe and efficient treatment for Covid-19 patients who are not in an ICU.

The Covid-19 pandemic has exposed the challenges in medical oxygen production and delivery in India, thereby highlighting the importance of producing oxygen on-site with the PSA oxygen generators compared to procurement of oxygen though cylinders. In May 2021, India’s hospitals were at a breaking point. The country found itself at the epicentre of the global pandemic, and one of the biggest challenges was providing enough medical oxygen to critical patients, who were unable to breathe unaided, as demand rose ten-fold. Just a few months earlier, in September 2020, the country had found itself in a similar situation: as case numbers soared, medical oxygen production failed to keep pace, amid an exponential growth in demand. Despite administrations trying to do their best to supply medical oxygen, demand overtook supply, making its availability a serious issue during the pandemic times. In such a scenario, central and state governments took multiple measures to meet the surge in demand for oxygen.

Centre and state governments have started adopting measures to develop a sustainable solution for adequate oxygen production

For a long-term solution towards sufficient production of oxygen, central and state governments expedited the establishment of PSA oxygen generator. Approximately 1,600 PSA oxygen generators were planned to be established in fiscal 2021 and 2022 near demand clusters to supply oxygen. It includes 162 PSA oxygen generators under PM CARES through the Ministry of Health and Family Welfare (MoHFW) sanctioned in 2020, for which over Rs 200 billion was warranted, 551 under PM CARES through MoHFW sanctioned in March 2021, 500 under PM CARES through the Defence Research and Development Organisation sanctioned on April 27, 2021, about 100 by oil and gas companies under the Ministry of Petroleum and Natural Gas, and rest by states themselves.

In April 2021, the central government floated a tender for the procurement of 1 lakh oxygen concentrators to further augment capacity. Multiple interventions have been used to improve oxygen tanker availability. During the second wave when oxygen demand surged, nitrogen and argon tankers were converted to oxygen tankers by following regulated norms, to meet the demand. In March 2020, the capacity of tankers stood at 12,480 metric tonne per day and their number was 1,040. In May 2021, capacity went up to 23,056 metric tonne per day and their number to 1,681, which included 408 converted tankers and 101 imported tankers. Number of cryogenic tanks for storing oxygen at hospitals increased to 901 in May 2021, from 609 in March 2020.

In April 2020, with the intention of ensuring uninterrupted supply of materials required for the treatment of patients with severe symptoms of Covid-19, the government allowed manufacturers of industrial oxygen to produce the gas for medical use too. The government announced that industrial gas manufacturers will be given the licence to produce medical-grade oxygen within 24 hours of applying, if they undertake to produce it as per the prescribed standards.

In May 2021, the government came up with the order that spending by corporates towards setting up of oxygen plants and other medical infrastructure for combating Covid-19 will be eligible to be counted as corporate social responsibility (CSR) activity. According to the order, funds earmarked for CSR could be spent on setting up medical facilities towards Covid-19 care, medical oxygen generation and storage plants as well as production and supply of oxygen concentrators, cylinders and other medical equipment.

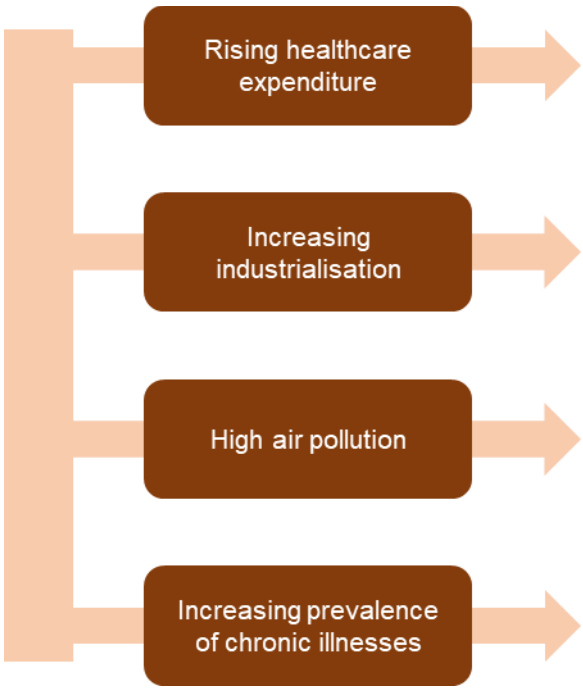
The central government, in June 2021, launched ‘Project O2 for India’ under the direct command of the office of Principal Scientific Adviser. The National Consortium of Oxygen consisting of corporations, Indian Institutes of Technology and various non-profit organisations, was established to help build the supply chain of critical materials and parts of oxygen plants. Funding for plants is being arranged through the PM CARES Fund, as well as corporate sponsorships via CSR funding. The consortium aims to supply critical raw materials such as zeolites, set up small oxygen plants, manufacture compressors and ventilators, among others using the accumulated fund. The consortium also aims to strengthen the manufacturing ecosystem of medical oxygen for long-term preparedness. A committee of experts has also been set up to evaluate critical equipment such as oxygen plants, concentrators and ventilators from a pool of India-based manufacturers, start-ups, and Micro, small and medium enterprises (MSMEs).

Several state governments too came forward to deal with the oxygen shortage during the second wave. For instance, Tamil Nadu state government announced incentives for companies willing to manufacture medical oxygen in the state. The state government announced that companies that invest in Tamil Nadu to produce oxygen concentrators, oxygen cylinders and medical oxygen will get 30% capital subsidy over a two-year period. Maharashtra state government set a target of manufacturing 3,000 metric tonne of oxygen per day. The state government decided to give special financial incentives to industrial units manufacturing liquid medical oxygen and for the manufacturing of oxygen cylinders and cryogenic tankers. Bihar state government launched the Oxygen Production Policy 2021, to make Bihar self-dependent in oxygen production. The policy provides for 30% capital

subsidy to entrepreneurs for establishing plant and machinery, with the maximum assistance pegged at Rs 25 crore for cryogenic oxygen plants producing liquid medical oxygen. Plants for oxygen cylinder manufacturing attract assistance up to Rs 75 crore. The Karnataka state cabinet decided to provide incentives, including 25% capital subsidy, to companies to set up medical oxygen plants in the state. Following the demand for incentives from oxygen manufacturing associated enterprises in Karnataka, it was decided to give 100% exemption on electricity duty for three years after commencement of oxygen production, and additional power tariff subsidy of Rs 1,000 per tonne of oxygen supplied to government medical hospitals.

With increased efforts from government and private entities in the direction of increasing medical oxygen production capacity, CRISIL Research expects the current medical oxygen production capacity in India is around 2,800-3,000 tonne per day considering the operational cryogenic distillation and PSA oxygen generators installed in the country.

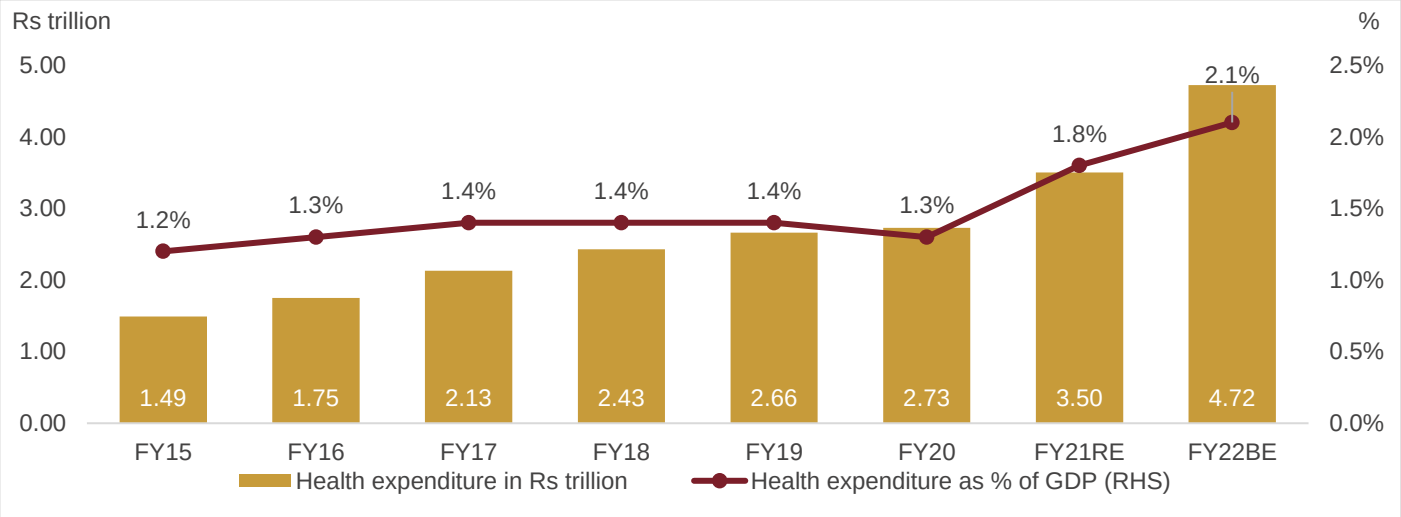
Factors that lead to growth of oxygen demand



India's health expenditure pushed to 2.1% of GDP in fiscal 2022

A significant budgetary increase for the healthcare sector in the wake of the pandemic pushed India’s healthcare expenditure to 2.1% of GDP for the first time, bringing it close to government’s policy aspiration of reaching a health expenditure of 2.5% of GDP by 2025 as envisaged in the National Health Policy, 2017. The government’s flagship policy in healthcare segment – National Health Mission – envisages achievement of universal access to equitable, affordable and quality healthcare services. As oxygen is an essential medicine, increased penetration and expenditure in the healthcare segment adds to the demand of medical oxygen.

Health expenditure by general government (combined Centre and states)



RE: Revised estimate; BE: Budget estimate

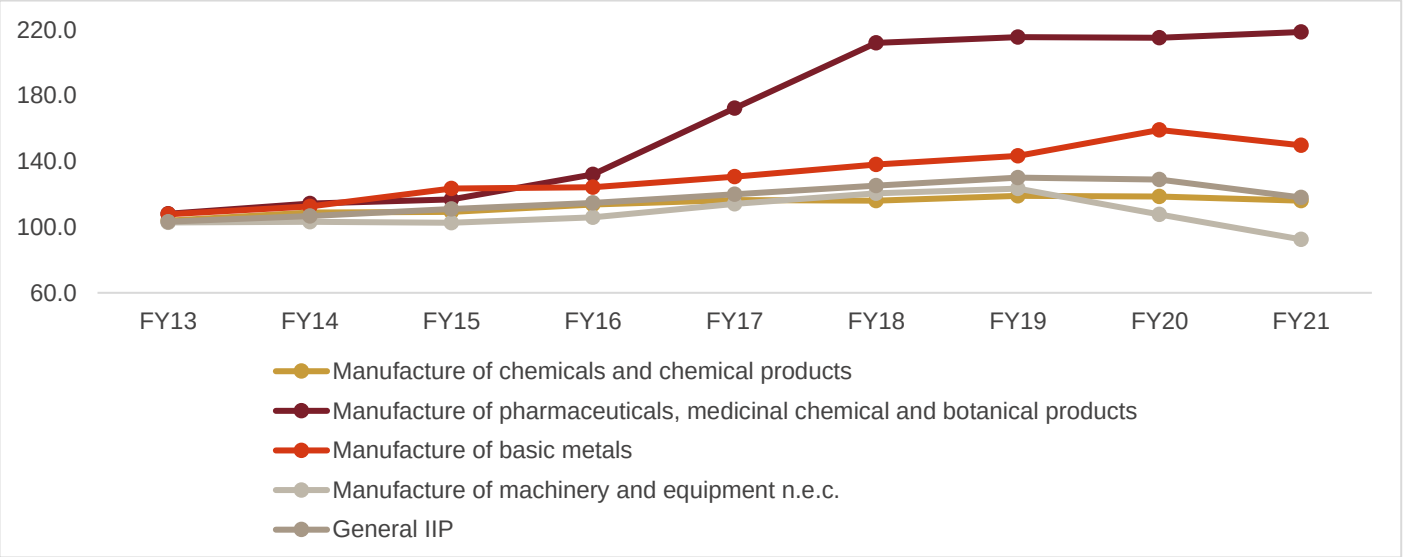
Source: Economic Survey of India 2021-22, CRISIL Research

The manufacturing sector was affected in several ways by the pandemic, leading to low-scale operations, and eventually, a negative impact on production volumes. Over a period, this adversely affected turnover and revenue. The lockdowns had both demand- and supply-side impacts on the sector. On the supply side, limited movement of goods, services and personnel affected the production network. The Index of Industrial Production (IIP) that tracks manufacturing activity in different sectors of the economy, nosedived during the first lockdown implemented towards the end of fiscal 2020. The IIP again took a downturn during the second wave in the beginning of fiscal 2022. While the second wave did upset overall economic growth, the impact was moderate compared with the first wave, as businesses and states had adjusted to the Covid-19 situation.

Increasing industrialisation to increase demand for industrial oxygen

Industrial oxygen finds application in multiple industries ranging from pharmaceutical product manufacturing to machinery and equipment manufacturing. As highlighted in the figure below, manufacturing activities have seen a positive on-year growth since fiscal 2013, except for fiscals 2020 and 2021, due to the slump in the economy caused by the pandemic. Correction in manufacturing activities is expected to supplement the demand for industrial oxygen.

IIP at constant fiscal 2012 prices

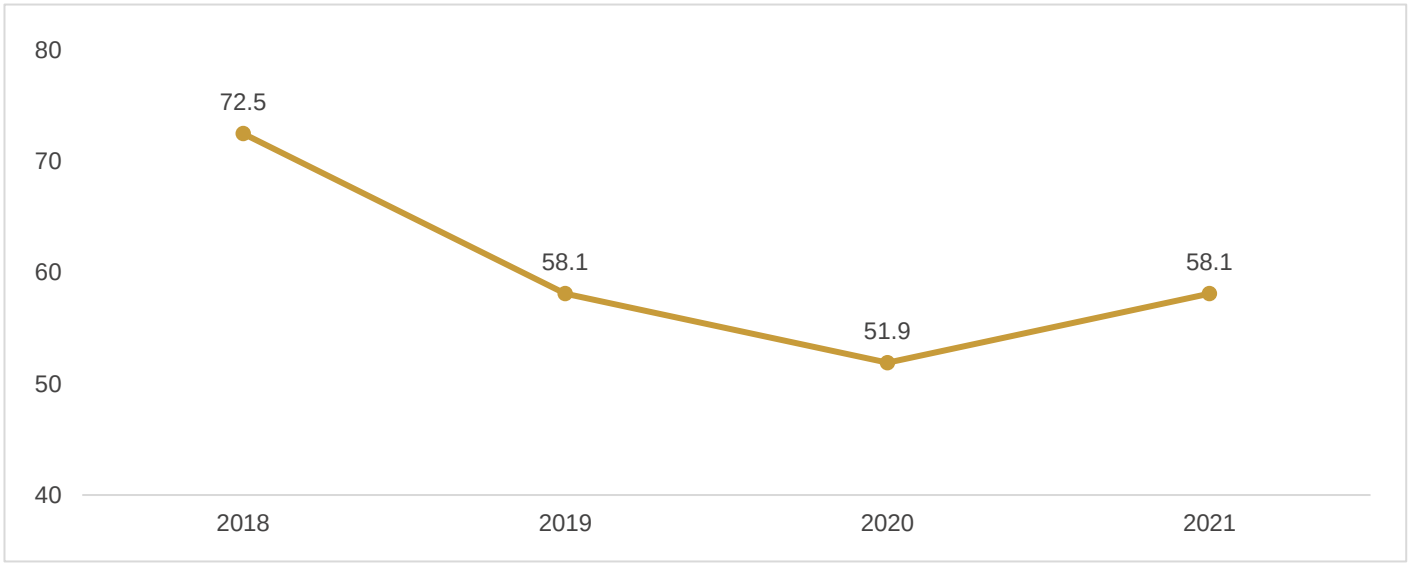


Source: MoSPI, CRISIL Research

Growing problem of air pollution further adds up to the oxygen demand

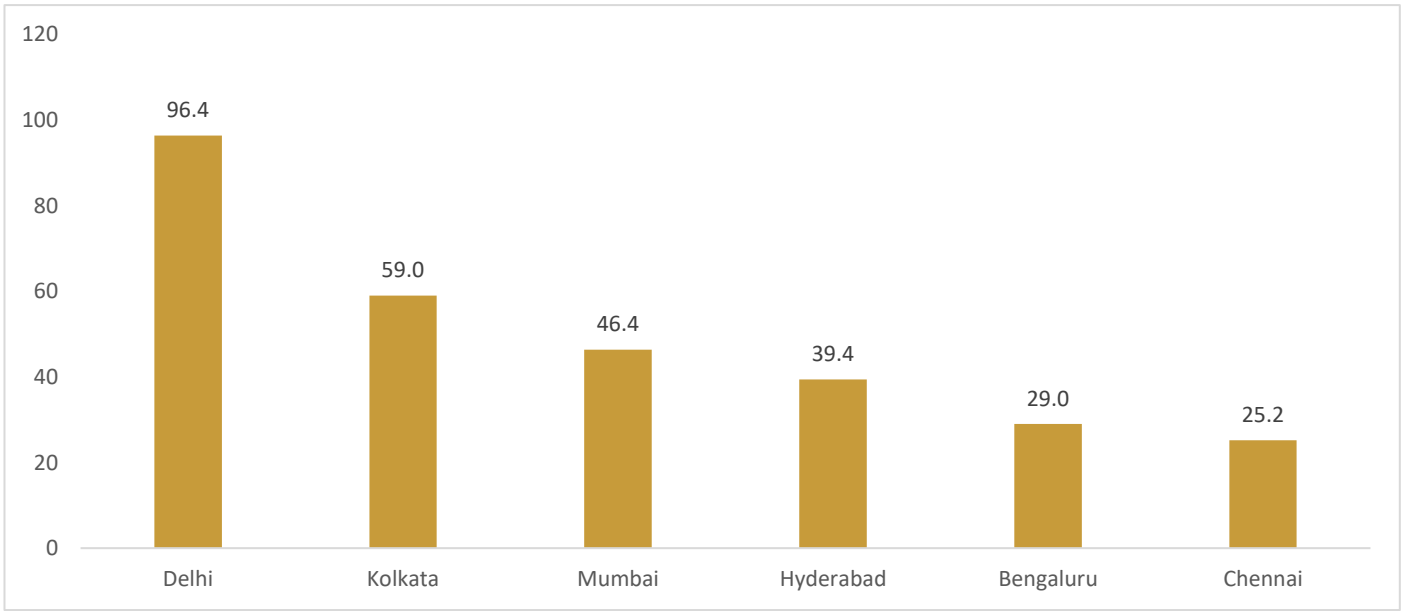
Air pollution has a massive impact on human health. In 2019, India's Ministry of Environment, Forest and Climate Change enacted the National Clean Air Programme. that seeks to reduce particulate matter (PM) concentration by 20-30% by 2024 in all identified non-attainment cities, increase air quality monitoring, and implement city-, region-, and state-specific clean air action plans. PM2.5 is defined as ambient airborne particulates that measure up to 2.5 micron in size. These particles include a range of chemical makeups and come from a range of sources. According to the World Air Quality Report 2021 by IQAir, India was home to 11 of the 15 most polluted cities in Central and South Asia in 2021. India's annual average PM2.5 levels reached 58.1 µg/m3 in 2021, ending a three-year trend of improving air quality. India's annual PM2.5 averages have now returned to pre-Covid concentrations measured in 2019. The growing problem of air pollution has increased the risk of ailments such as cardiovascular, respiratory diseases, as well as lung cancer. Growing air pollution has given rise to the concept of artificially oxygenated environments, to keep the ambient oxygen at natural optimum levels.

Air quality in India (PM2.5, µg/m3)



Source: World Air Quality Report by IQAir, CRISIL Research

Air quality across major cities in India (PM2.5, µg/m3) -- 2021

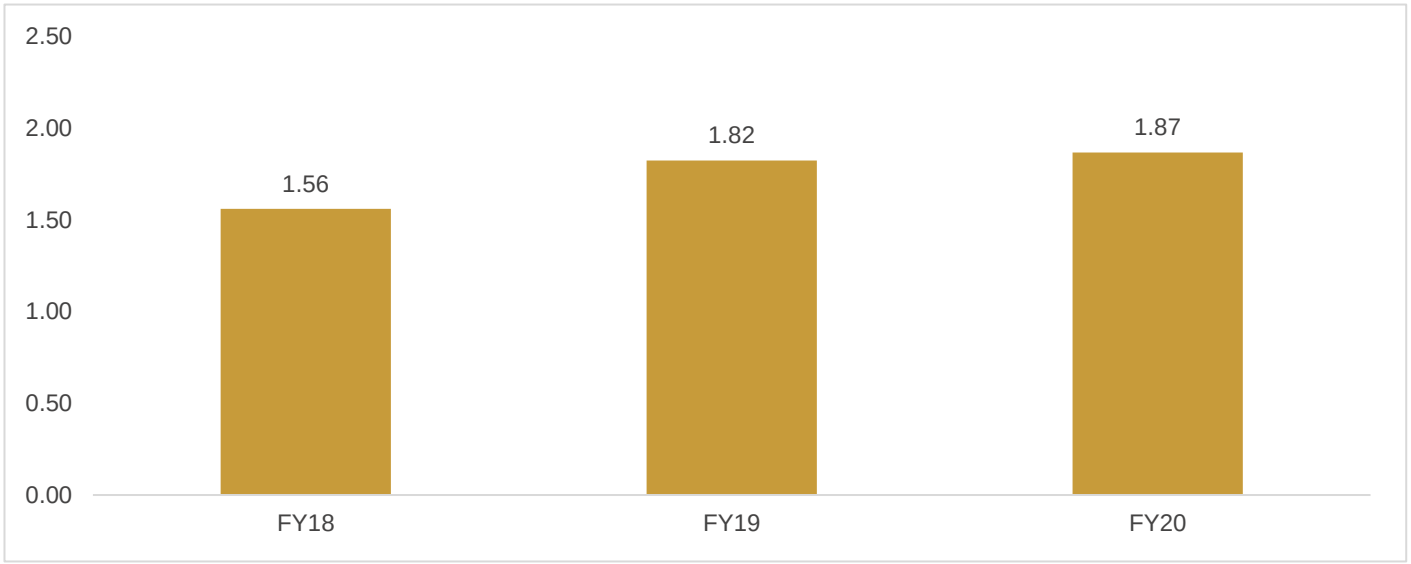


Source: World Air Quality Report by IQAir, CRISIL Research

Rising prevalence of chronic medical illnesses that necessitate oxygen treatment

India has experienced a rise in some common chronic medical illnesses such as chronic obstructive pulmonary disease, asthma, and other respiratory infections that necessitate oxygen treatment or supplemental oxygen. Additionally, medical oxygen is used for other clinical therapies too. Growth in the number of patients infected with such illnesses drives the demand for medical oxygen.

Inpatient count of asthma, chronic obstructive pulmonary disease, respiratory infections in India (million)



Source: Health Management Information System, CRISIL Research

Challenges faced by hospitals in operating PSA oxygen generators

A PSA oxygen generator is an assembly of multiple equipment -- compressor stabiliser, air dryer, PSA vessels, filters, surge vessels, auto changeover, flow meter, purity monitor, alarms, valves, and generators in many cases as power backup. It is important for all the equipment to perform accurately to get the desired purity of medical oxygen.

PSA oxygen generators installed in hospitals located in remote areas face delays in visits of technicians in case of some technical glitch. If the issue cannot be resolved over video/audio calls, hospitals have to temporarily shut the operation of such PSA oxygen generators until the technician visits. The setup of PSA oxygen generators starts with an inlet for ambient air and ends with a pipeline till hospital beds. On-site production facilities also face leakage issues at various points of the setup. Some hospitals with PSA oxygen generators lack power backup. As PSA oxygen generators require uninterrupted supply of electricity, their operation halts when no alternative power source is available.

The auto changeover system helps to automatically switch oxygen supply from one source to another under low input pressure to ensure continuity of oxygen supply. Facilities facing issue with auto changeover face issue with exploring the back-up oxygen supply to maintain the uninterrupted oxygen flow. PSA-specific technical issues faced by hospitals include problem with the zeolite, which leads to failure in separation of nitrogen from the air, and saturation of white dust in oxygen tanks. Other common technical issues are related to pressure, ignition, compressor, stabiliser, alarm, suction jar and valve.

Operational challenges faced with PSA as the oxygen generation method

- Efficiency of the system is directly affected by poorly sized and configured oxygen generators (including inadequate size compressor and refrigerant dryer, lack of in-built redundancy and inappropriately designed plant housing). This results in unnecessary operational overheads or complete abandonment of oxygen generators.

- Certain operating environments can cause premature damage to the system. Hot and/or humid climates

and dust can have an impact on production capacity by either damaging or rapidly ageing the filtration system and sieve beds.

- There is a lack of publicly available technical guidance for system operations. For example, a drop in either output capacity or product purity during daily operations requires immediate troubleshooting by trained operations and maintenance personnel.
- There is lack of generic technical guidance for preventive and curative maintenance. Clear routines for planned preventive maintenance can be perceived as complicated as there are product-specific nuances. Consideration of this aspect needs to be made during the planning and procurement phases to ensure adequate budget for requisite spares, and adequate contact time and a support structure for knowledge transfer. This training of staff is key to improving access and availability of the PSA oxygen generator
- There is lack of comprehensive quality standards for the system post-installation: no post-commissioning third-party testing guidelines, no indication of frequency of testing, and no homologized standards on oxygen purity and remaining impurities.

Overview of products related to oxygen market

Air dryers

In an air dryer, warm compressed air enters the air-to-air heat exchanger, where it is precooled by outgoing cold refrigeration air. Then the pre-cooled air enters the freon heat exchanger, where it is cooled down. At this cooled temperature, moisture condenses into liquid droplets, which are removed from air stream by a very efficient demister and automatically drained by an automatic drain valve. The cold dry compressed air passes back through the secondary side of the air-to-air heat exchanger, where it is re-heated by the incoming warm air. Reheating the outgoing compressed air increases temperature by heat with incoming warm air. The dry air coming out from the air dryer is ready to use for instrumentation and process air applications. Refrigerating air dryer is widely used in automobile, chemical and pharmaceutical industries.

Hyperbaric chambers

Hyperbaric chamber is a sealed medical device used to deliver oxygen at pressure higher than the normal atmospheric pressure, defined as 1 atmospheric pressure (ATM). Such a treatment is called Hyperbaric Oxygen Therapy (HBOT). In a hyperbaric oxygen therapy chamber, air pressure is increased to 2-3 ATM, producing strong hyperoxia for medical therapies. This process causes oxygen to be absorbed by all body fluids, cells and tissues, even those with blocked or reduced blood flow. The increased flow of oxygen stimulates and restores the function of damaged cells and organs, including liver and brain. Some therapeutic applications of hyperbaric chambers include treating decompression sickness, skin injuries, burns and carbon monoxide poisoning as well as post-radiotherapy treatment.

Oxygen analysers

Oxygen analysers are used to measure the level of oxygen in a given environment. Oxygen analysers are extremely important for various applications. Their industrial applications range from aerospace to electronics for continuous monitoring of oxygen levels, detection of presence of oxygen in gas plant gathering systems and tracking oxygen levels during handling of cryogenically liquefied gas or pressurised gas cylinders. Medical applications range from tracking oxygen levels at production to storage stages.

In an oxygen analyser, the ultrasonic gas flow and oxygen sensor implements the ultrasonic velocity difference between upstream and downstream to detect the gas flow and also to measure the oxygen purity. It is a reliable and low-cost sensor for integration into PSA oxygen generators, medical oxygen generators, personal respirator, oxygen concentrator, anaesthetic apparatus and high pressure oxygen storage.

Major types of oxygen analysers are:

Trace oxygen analyser offers rapid, reliable and highly accurate measurements of oxygen even at trace levels and suitable for many medical and industrial applications

Portable oxygen analyser: used for measuring oxygen levels at locations where oxygen analysers are not installed; small size makes it an ideal solution

Continuous oxygen analyser: often installed at individual sample points in facilities; designed for ongoing, permanent exposure to the sample gas

Oxygen deficiency analyser: designed to monitor the oxygen level in confined spaces such as tunnels, labs and control rooms

Vacuum pressure swing adsorption (VPSA)

VPSA oxygen gas generators are based on zeolite molecular sieves (ZMS) and vacuum system for regeneration. When ZMS is used in the VPSA process, nitrogen molecules, with diameter larger than oxygen molecules, pass through the pores and are adsorbed. Therefore, oxygen is recovered, while nitrogen is adsorbed. Adsorption of nitrogen happens at low pressure, which make it efficient and suitable for higher flow rates. In VPSA-based oxygen gas plants, vacuum pumps ensure complete regeneration of ZMS. Adsorptive air separation is a cyclic process in which the adsorbent material is alternately fed with pressurised air to produce the required product and regenerated by vacuum to remove waste gases from the adsorbent. The stages involved are:

Purification: Ambient air is filtered before being compressed moderately by a blower system.

Adsorption: The pre-treated air is sent to a vessel containing zeolites to remove any moisture and carbon dioxide. Nitrogen is adsorbed, while oxygen passes through the vessel outlet. Before the adsorption capability of zeolites is exhausted, the adsorption process is interrupted.

Desorption: The saturated zeolites are regenerated through pressure reduction below the adsorption pressure. This is achieved by using a dry running vacuum pump. The resulting off gas is vented to atmosphere. To maintain a continuous flow of oxygen supply, a surge tank is installed and so the cycle continues.

Oxygen gas booster

Oxygen gas boosters are used for compressing oxygen and are ideal for aircraft and bottle filling applications. The device features a cylinder and a piston. The cylinder is designed to withstand different operating pressures. Pressure is usually controlled with the piston, which is driven back and forth inside the cylinder. The cylinder head features discharge and supply ports, which are again connected to pipes or discharge hoses, and non-return valves. These valves help direct the flow of gas in one direction. The device is cooled with external fins or water jackets. Oxygen gas boosters are made from oxygen compatible materials to avoid fire hazards caused by compressed oxygen.

Container-based oxygen generator

Container-based oxygen generator is a mobile oxygen generator wherein oxygen generator is installed in a 20- or 40-feet container. The container is transported by truck to places where oxygen in required. Cylinders can be

refiled using the oxygen produced by the mobile container. Electric supply is required to make the container operational.

Auto changeover system

Auto changeover system helps to automatically switch oxygen supply from one source to another under low input pressure to ensure continuity of oxygen supply. Typically, two oxygen supply sources are used: oxygen produced through PSA oxygen generators and oxygen bank. The system ensures instant response to supply cut, switching from one source to another without disturbing the oxygen flow.

Advantages of using Auto Change Over system

- Doesn’t require additional air compressor and associated machinery
- High efficiency can be achieved as leakages are reduced
- Instantaneous response
- Doesn’t affect any atmosphere and temperature variations
- Reduces unscheduled service
- Helps in anticipating future requirements of oxygen

5. Competitor Analysis

Data in this section is obtained from publicly available sources, including annual reports of players, regulatory filings, and/or company websites. The financials used in the competitive section are re-classified by CRISIL based on the annual report and financial fillings by the players.

CRISIL Research has considered the following companies as competitors for Airox Technologies Limited. These lists of companies either operate in same line of business or offer same product portfolio as that of Airox Technologies Limited and available in public domain. Please note the peers set considered below is an indicative list and not an exhaustive list of players present in the oxygen generation industry.

Kindly note that the following abbreviations are used in this section

- *Atlas Capco (India) Ltd: Atlas*
- *Absstem Technologies LLP: Absstem*
- *Airox Technologies Ltd: Airox Technologies*
- *Med Freshe Pvt Ltd: Med Freshe*
- *MVS Engineering Pvt Ltd: MVS*
- *Oxair Gas Systems India Pvt Ltd: Oxair*
- *Pec Therm Private Ltd: Pec Therm*
- *Sam Gas Projects Pvt Ltd: Sam Gas*
- *Summits Hygronics Pvt Ltd: Summits*
- *Trident Pneumatics Pvt Ltd: Trident Pneumatics*
- *Uttam Air Products Pvt Ltd: Uttam Air*

Some of the major medical oxygen PSA players in India market are Airox Technologies Ltd, Uttam Air Products Pvt Ltd, Absstem Technologies. The industry also has players who derive their larger share of business revenue from other gases related segments such as air compressors, nitrogen gas generation, hydrogen gas generation, air dryers among others and have lower to moderate contribution from PSA medical oxygen generation segment. But CRISIL has considered all the players as competitive peers. Some of the players have also entered the market over the last few years, and especially during the COVID pandemic. But smaller players are unable to keep the PSA oxygen generators operational.

Some Indian companies have collaboration with international players such as Airox Technologies Ltd and Airsep Corporation, Pec Therm Private Ltd and INMATEC Gas Technologies Gmbh & Co. Airox Technologies uses sieves for oxygen separation from Airsep Corporation. Sieves of Airsep Corporation are approved by US FDA and the sieves have CE Medical Devices Class II Certification.

Operational overview of the companies under review

Companies	Year of incorporation	Products		Compliance for medical oxygen generators
		Oxygen generators	Others (Indicative list)	
Experience in PSA oxygen for more than a decade				
Absstem	2017	✓	cylinder filling system and medical gas pipeline	US pharmacopeia, European pharmacopeia, Indian pharmacopeia
Atlas	1960	✓	PSA nitrogen generator, membrane nitrogen generator, air compressors, air dryers, gas compressors, construction equipment, and industrial tools among others	NA
Airox Technologies	2012	✓	hyperbaric chambers, auto change over systems, oxygen analyser, air dryers	US pharmacopeia, European pharmacopeia, Indian pharmacopeia
Pec Therm	1999	✓	Nitrogen generators, air compressors, air dryers	European pharmacopeia
Med Freshe	1980	✓	waste management solutions, healthcare solutions, consultation & planning for hospitals, turnkey solutions for healthcare institutions	US Pharmacopeia, European Pharmacopeia, Indian Pharmacopeia
MVS	1986	✓	PSA nitrogen generators, membrane nitrogen generator, Liquid Nitrogen Generators, hydrogen generators, ammonia crackers, air dryers, Gas purifiers, endo and exo gas generators among others	Indian pharmacopeia
Uttam Air	1972	✓	Filling solutions	US Pharmacopeia, European Pharmacopeia, Indian Pharmacopeia
Sam Gas	2004	✓	PSA nitrogen generators, membrane nitrogen generator, lab scale nitrogen generators, hydrogen generators, ammonia cracker, air dryers, gas purifiers, endo and exo gas generators	NA
Experience in PSA oxygen for less than a decade				
Summits	2001	✓	Air dryers, PSA Nitrogen Generator, Membrane nitrogen generator, Air dryers, zero Drain Valves, due point meters, filter element, air filters	NA
Trident Pnuematics	1999	✓	Compressed air dryers, compressed air filters and drains, values, PSA nitrogen generator	European pharmacopeia
Oxair*	2018	✓	PSA nitrogen generators, nitrogen membranes, air dryers, carbon absorpotion towers, pressure vessels, mist eliminators, pressure vessel filters and water seperators	European pharmacopeia

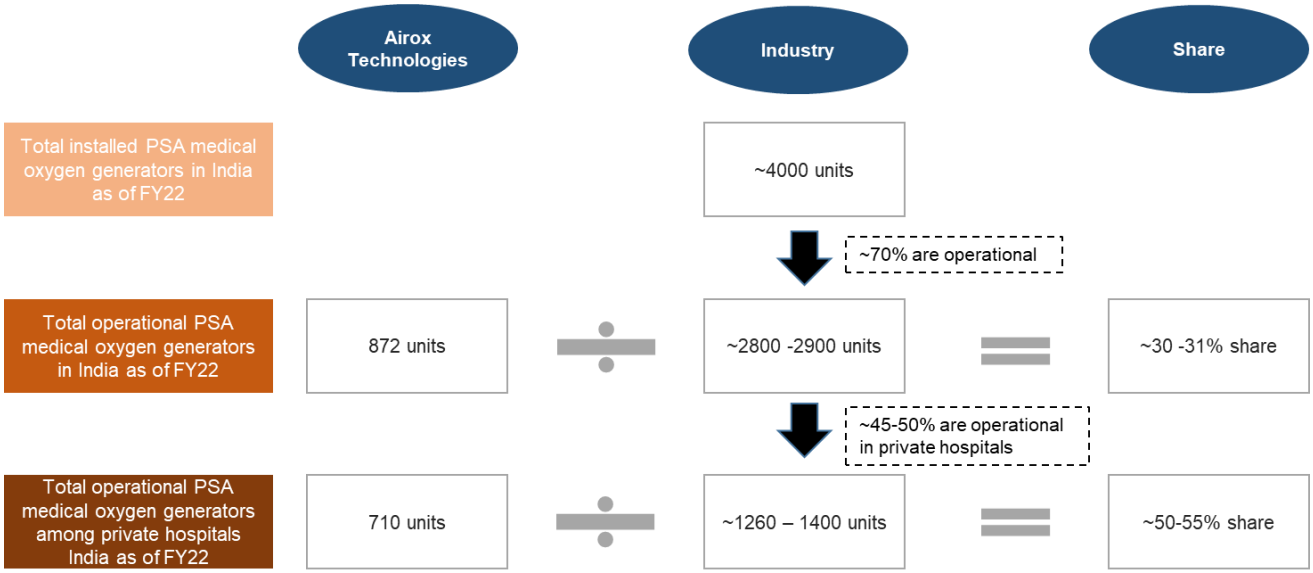
Note:

- *Oxair Gas Systems India Pvt Ltd (Oxair) is an Indian subsidiary of Oxair Gas Systems Pty Ltd an Australian company*
- **: Oxair products include products of Oxair Gas Systems Pty Ltd (an Australian company)*
- *NA: Not Available*

Source: Company websites, Credit ratings, Company filings, CRISIL Research

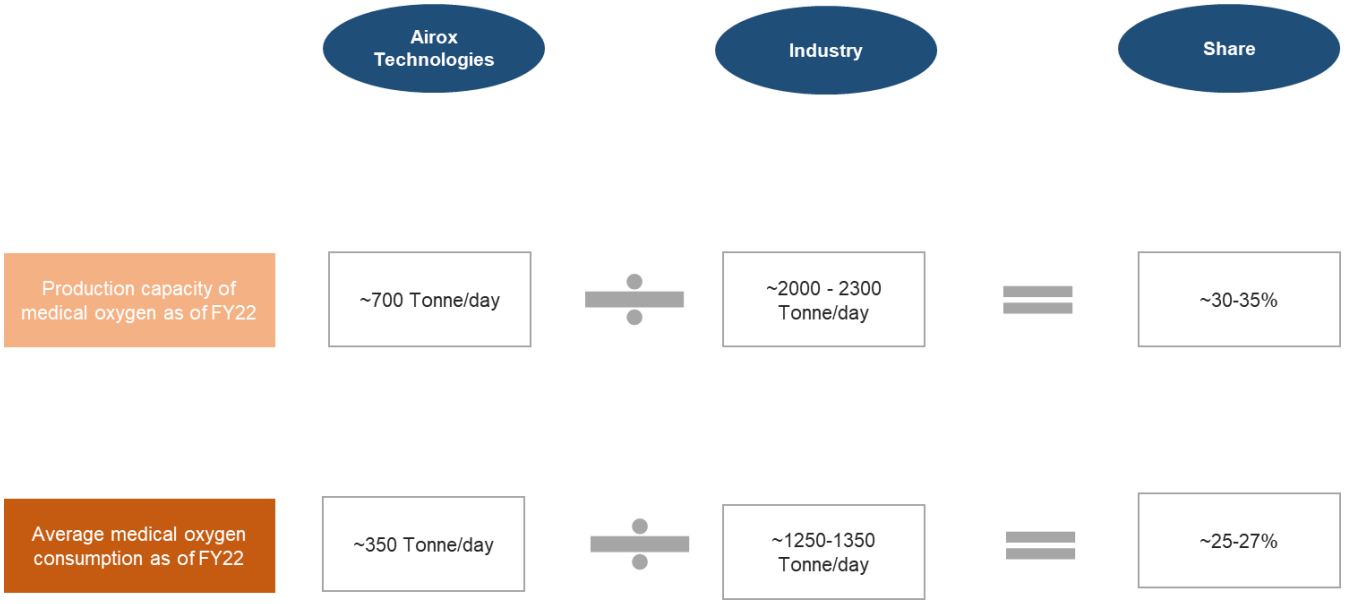
Market share Analysis

In terms of operational PSA oxygen generators installed



Source: CRISIL Research

In terms of production capacity and consumption

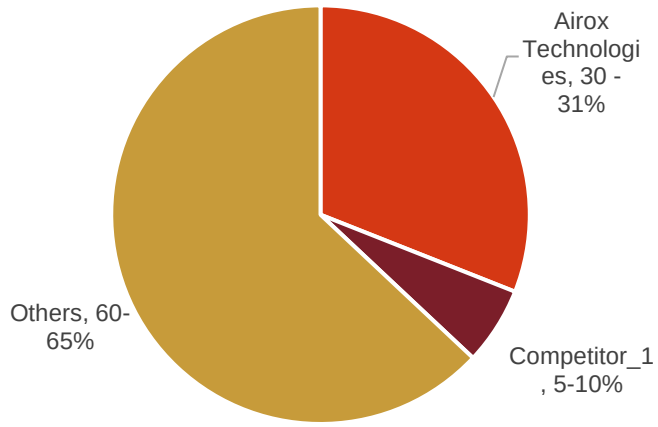


Note: The above-mentioned values are non-covid and don't include oxygen produced from industrial plants during the period mentioned

Source: CRISIL Research

Airox Technologies is a leading player in PSA medical oxygen market with a market share of ~30-31% in terms of installed oxygen generation capacities as of 31st March 2022.

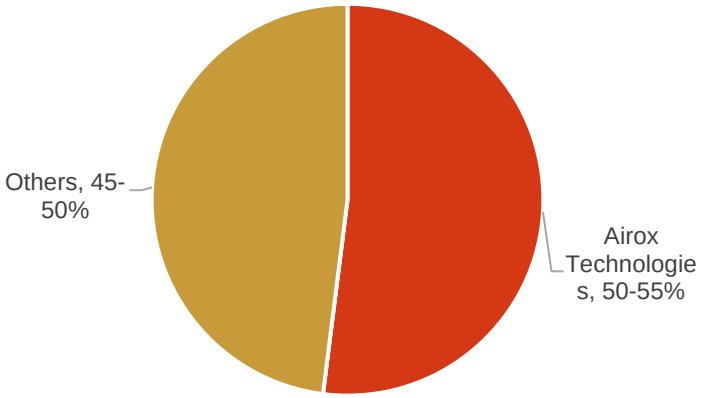
Airox Technologies Ltd market share in operational PSA medical oxygen market as of 31st March 2022



Note: Based on industry interactions CRISIL estimates nearly 70% of the installed PSA oxygen generators to be operational in India
Source: CRISIL Research

Airox Technologies Ltd is market leader, commanding a market share of 50-55% in operational private hospital PSA medical oxygen market

Airox Technologies Ltd market share in operational private PSA medical oxygen market as of 31st March 2022



Source: CRISIL Research

Financial overview of the companies under review

Across PSA oxygen generator segment, CRISIL Research has considered consolidated balance sheet for available players as of FY21. For the below section, CRISIL Research has considered players with operating income, as of FY21, less than Rs. 2,000 million.

Total operating income across all business segments

Rs. Million	Type	FY19	FY20	FY21	CAGR (%) FY19-21
Absstem	Standalone	NA	14.0	196.8	N.Ap
Airox Technologies	Standalone	127.4	171.3	730.3	139%
MVS	Consolidated	530.9	610.1	709.7	16%
Pec Therm	Standalone	52.4	84.7	249.6	118%
Oxair	Standalone	22.2	34.5	54.0	56%
Sam Gas	Standalone	259.3	241.1	237.7	(4)%
Summits	Standalone	408.3	353.8	422.8	2%
Trident Pneumatics	Standalone	526.0	637.6	690.2	15%
Uttam Air	Standalone	49.1	91.2	258.6	130%

Note:

- *Atlas Capco (India) Limited has operating income of Rs 29,284.6 million from all the operating segments which include compressed air equipment, vacuum solutions, industrial tools, power equipment and rental solutions as of FY21, hence has not been considered for further analysis.*
- *Med Freshe Private Limited having an operating income of Rs. 697.7 million as of fiscal 2021, has not been considered for further analysis as the company derives majority of revenue from other operating segments such as waste management solutions, healthcare solutions, consultation and planning for hospitals, turnkey solutions for healthcare institutions.*
- *NA: Not Available*
  - *Though Absstem Technologies LLP (Absstem) was incorporated in 2017, financial data till FY19 isn't available on MCA and the latest available data is FY20 and FY21*
- *N.Ap: Not Applicable*

Source: Company filings, CRISIL Research

Earnings Before Interest Tax Depreciation and Amortisation (EBITDA)

Rs. Million	Type	FY20	FY21	EBITDA margin (FY21)
Absstem	Standalone	0.6	35.0	18%
Airox Technologies	Standalone	21.2	234.9	32%
MVS	Consolidated	140.0	315.0	38%
Pec Therm	Standalone	6.3	23.3	9%
Oxair	Standalone	0.7	1.8	3%
Sam Gas	Standalone	14.0	16.8	7%
Summits	Standalone	26.2	58.2	14%

Rs. Million	Type	FY20	FY21	EBITDA margin (FY21)
Trident Pneumatics	Standalone	148.4	223.9	32%
Uttam Air	Standalone	4.6	17.2	7%

Note:

- *Atlas Capco (India) Limited and Med Freshe Private Limited are not considered for financial analysis. Please refer to footnote under the table named "Total operating income across all business segments" for further information*

Source: Company filings, CRISIL Research

Net profit

Rs. Million	Type	FY20	FY21	Net profit margin (FY21)
Absstem	Standalone	0.4	21.6	11%
Airox Technologies	Standalone	7.6	158.7	22%
MVS	Consolidated	81.9	218.0	31%
Pec Therm	Standalone	1.5	7.3	3%
Oxair	Standalone	0.7	1.5	3%
Sam Gas	Standalone	4.6	5.2	2%
Summits	Standalone	6.9	31.2	7%
Trident Pneumatics	Standalone	105.1	163.4	24%
Uttam Air	Standalone	0.3	1.6	1%

Note:

- *Atlas Capco (India) Limited and Med Freshe Private Limited are not considered for financial analysis. Please refer to footnote under the table named "Total operating income across all business segments" for further information*

Source: Company filings, CRISIL Research

Financial snapshot of key players considered (FY21)

	Type	Operating income	CAGR FY19-21	EBITDA	Net profit	EBITDA margin	Net profit margin	ROCE	ROE
		Rs Mn	%	Rs Mn	Rs Mn	%	%	%	%
Absstem	Standalone	196.8	N.Ap	35.0	21.6	18%	11%	159%	244%
Airox Technologies	Standalone	730.3	139%	234.9	158.7	32%	22%	158%	164%
MVS	Consolidated	709.7	16%	315.0	218.0	38%	31%	18%	16%
Pec Therm	Standalone	249.6	118%	23.3	7.3	9%	3%	57%	65%
Oxair	Standalone	54.0	56%	1.8	1.5	3%	3%	13%	74%
Sam Gas	Standalone	237.7	(4)%	16.8	5.2	7%	2%	11%	12%
Summits	Standalone	422.8	2%	58.2	31.2	14%	7%	35%	31%
Trident Pneumatics	Standalone	690.2	15%	223.9	163.4	32%	24%	37%	28%
Uttam Air	Standalone	258.6	130%	17.2	1.6	7%	1%	10%	4%

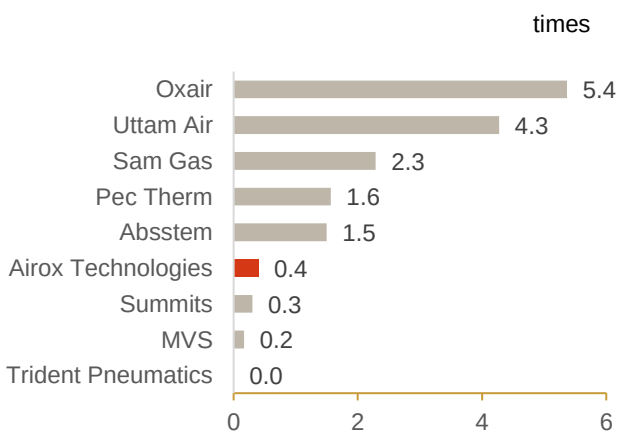
Note:

- *Atlas Capco (India) Limited and Med Freshe Private Limited are not considered for financial analysis. Please refer to footnote under the table named "Total operating income across all business segments" for further information*
- *N.Ap: Not Applicable*
  - *Though Absstem Technologies LLP (Absstem) was incorporated in 2017, financial data till FY19 isn't available on MCA and the latest available data is FY20 and FY21*

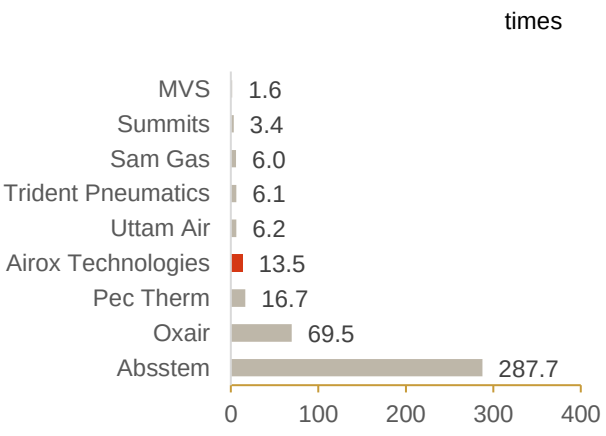
Source: Company filings, CRISIL Research

Other key financial ratios for players considered

Gearing (times) – FY21



Asset turnover (times) – FY21



Note:

- *Atlas Capco (India) Limited and Med Freshe Private Limited are not considered for financial analysis. Please refer to footnote under the table named "Total operating income across all business segments" for further information*

Source: Company filings, CRISIL Research

Airox Technologies financials for the FY22 period

Parameter (Rs. Million)	FY20	FY21	FY22
Operating income*	171.3	730.3	2266.4
Net profit	7.6	158.7	900.4

Note:

- **: includes operating income generated across all business segments of the company*
- *FY22 financials for the other players considered above are not available on MCA hence are not included*
- *Atlas Capco (India) Limited and Med Freshe Private Limited are not considered for financial analysis. Please refer to footnote under the table named "Total operating income across all business segments" for further information*

Source: Company filings, CRISIL Research

Key observations

- As per Government sources and CRISIL estimates, the medical oxygen consumption (non-covid and non-industrial) in India during fiscal 2021 and fiscal 2022 is 1100-1300 tonne/day.
- As per Government sources and CRISIL estimates, the medical oxygen consumption (non-covid and non-industrial) in India during fiscal 2022 is 1250-1350 tonne/day and Airox Technologies Limited with a consumption of 350 tonne/day through the 872 installed and operational PSA oxygen generators as of 31st March 2022 occupies a market share of 25-27%. The medical oxygen consumption stood at roughly 2,700 tonne/day in fiscal 2022 on account of covid pandemic, of which nearly 45% was catered by industrial plants.
- Taking into account the industrial oxygen consumption the total oxygen consumption in India is 6,050-6,100 tonne/day during fiscal 2023.
- In terms of production capacity, the total installed capacity of PSA medical oxygen generators is ~2,000 - 2,300 tonne/day as of 31st March 2022 and Airox Technologies Limited occupies a share of 30-35% during the same period.
- Airox Technologies Ltd is among the pioneers to facilitate penetration of on-premise PSA oxygen generators in Indian hospitals markets and is also one of the leading providers in PSA medical oxygen generation systems in India with nearly 872 installed operational PSA oxygen generators as of 31st March 2022
- Airox Technologies Ltd is an established player with an experience of more than one decade in the PSA oxygen generation market and has been able to capture and penetrate the Indian medical oxygen generation market to become a market leader with ~30-31% of market share as of fiscal 2022, in terms of total installed operational PSA oxygen generators in India - which includes both government and public sector hospital PSA medical oxygen market.
- As of 31st March 2022, of the total operational PSA oxygen generators installed by Airox Technologies Ltd ~80% are in private hospitals and ~20% are in government hospitals
- Further, as of 31st March 2022, Airox Technologies Ltd is market leader, commanding a market share of

50-55% in operational private hospital PSA medical oxygen market

- Over the past three years from calendar year 2020-2022 (till march) Airox Technologies Ltd has added a total production capacity of ~333 tonnes/day or 178,165 LPM.
- As of 31st March 2021, Airox Technologies Ltd is a leading player among the PSA oxygen generator providers considered above in terms of operating income.
- According to sample set considered by CRISIL, oxygen purity for PSA oxygen generators of Airox Technologies Ltd stands at an average of 94.3%, whereas the limit as per IP 2018 standards is of 90-96%
- In CY20 and CY21, the average capacity of PSA oxygen generator installed by Airox Technologies Ltd is nearly 0.9 tonnes/day as against 0.5-0.6 tonnes/day industry average of PSA oxygen generator.

About CRISIL Limited

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