

OXYGEN CONCENTRATORS

Market Research, Comparison of Available Appliances and Energy Efficiency

Oxygen plays a vital role in the breathing processes and in the metabolism of the living organisms.

In the human body, the oxygen is absorbed by the blood stream in the lungs, being then transported to the cells where an elaborated change process takes place.



SELCO Foundation

covid-19.selcofoundation.org

INTRODUCTION

An oxygen concentrator is a type of medical device used for delivering oxygen to individuals with breathing-related disorders. Individuals whose oxygen concentration in their blood is lower than normal often require an oxygen concentrator to replenish the oxygen.

These devices also come with an electronic user interface so you can adjust the levels of oxygen concentration and delivery settings. You then inhale the oxygen through the nasal cannula or special mask.

Oxygen concentrators filter surrounding air, compressing it to the required density and then deliver purified medical grade oxygen into a pulse-dose delivery system or continuous stream system to the patient. It's also equipped with special filters and sieve beds which help remove Nitrogen from the air to ensure delivery of completely purified oxygen to the patient.

Generally, the oxygen concentrator output is measured in LPM (liters per minute)¹.

What is the appliances implication for COVID-19?

According to WHO, data from China suggests that although the majority of people with COVID-19 have mild illness (40%) or moderate illness (40%), about 15% of them have severe illness requiring oxygen therapy, and 5% will be critically ill requiring intensive care unit treatment. In addition, most critically ill COVID-19 patients will require mechanical ventilation. For these reasons, COVID-19 treatment healthcare facilities should be equipped with pulse oximeters, functioning oxygen systems including single-use oxygen delivery interfaces.

Oxygen therapy is recommended for all severe and critical COVID-19 patients, with low doses ranging from 1-2 L/min in children and starting at 5 L/min in adults with nasal cannula, moderate flow rates for use with Venturi mask (6-10 L/min); or higher flow rates (10-15 L/min) using a mask with reservoir bag. In addition, oxygen can be delivered at higher flow rates and in higher concentrations, using high-flow nasal cannula (HFNC) devices, non-invasive ventilation (NIV) and invasive ventilation devices⁷.

The appropriate choice of oxygen source depends on many factors, including: the amount of oxygen needed at the treatment centre; the available infrastructure, cost, capacity and supply chain for local production of medicinal gases; the reliability of electrical supply; and access to maintenance services and spare parts, etc.

Oxygen Surge Plan

The ability to boost capacity to deliver oxygen therapy is the cornerstone of the overall approach to managing the COVID-19 outbreak and it has implications for the functioning of the entire system. The principles, set out here, of building surge capacity should be integrated into a health system's readiness and response capacities for all functions – either centrally, or at facility level.

Oxygen supply and delivery systems are limited in many resource-limited settings. Each supply option needs to be examined with attention to access and distribution.

The following document showcases the need to account for energy efficiency and improved consumption when planning for oxygen requirements at a facility. It also showcases technical design for solar energy systems to ensure availability of reliable and sustainable energy at the health facility.

Characteristics	Cylinders	Concentrators	Oxygen Generators
Description	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, electrically powered medical device designed to concentrate oxygen from ambient air, using PSA technology.	An onsite oxygen generating system using PSA technology, which supplies high-pressure oxygen throughout a facility via a central pipeline system, or via cylinders refilled by the plant.
Clinical Application and/or Use Case	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 the bedside or within close proximity to patient areas. A single concentrator can service several beds with the use of a flowmeter stand to split output flow.	Can be used for all oxygen needs, including high-pressure supply.
Distribution Mechanism	Connected to manifold of central/sub-central pipeline distribution system, or directly connected to patient with flowmeter and tubing.	Direct to patient with tubing or through a flowmeter stand.	Central/ sub-central pipeline distribution system, or can be used to refill cylinders that can be connected to manifold systems in the facility.
Electricity Supply	No	Yes	Yes
Power Consumption	n/a	5 LPM- 280 - 350 W per concentrator >5LPM - 400 - 600 W per concentrator	1.22 kWh \pm 5% of power is needed per m3 of total flow
Features	<ul style="list-style-type: none"> - Requires transport/ supply chain - Exhaustible supply - Highly reliant upon supplier - Risk of gas leakage - Risk of unwanted relocation 	<ul style="list-style-type: none"> - Continuous oxygen supply at low running cost - Requires continuous power supply - Output flow can be split among multiple patients - Low pressure output, usually not suitable for CPAP or ventilators - Requires maintenance 	<ul style="list-style-type: none"> - Cost-effective for large facilities - Continuous oxygen supply - Requires uninterrupted power. Needs adequate infrastructure - High maintenance for piping - risk of gas leakage

OXYGEN CONCENTRATOR

When is oxygen concentrator usage suggested?

Doctors can recommend their patients to undergo oxygen therapy with an oxygen concentrator for several medical conditions. Our lungs absorb oxygen from the air and transfer it into your bloodstream. In a blood test, if it indicates low blood oxygen levels, the doctor could recommend short or long term oxygen therapy².

In the context of Covid-19 and the estimated spread, there may be a shortfall of oxygen cylinders. In this context, an oxygen concentrator could play an essential role in treating mild to moderate cases of Acute Respiratory Infection associated with Covid-19, while saving oxygen cylinders to treat more severe cases^{3,4,5}.

How does an oxygen concentrator work?

An oxygen concentrator is a self-contained, electrically powered medical device designed to concentrate oxygen from ambient air. Utilising a process known as pressure swing adsorption, an oxygen concentrator produces up to 95.5% concentrated oxygen⁶.

1. Atmospheric air is drawn through a gross particle and intake filter before moving through a compressor.
2. The pressurised air passes through a heat exchanger to reduce the temperature before entering sieve beds that contain zeolite, a mineral material that preferentially adsorbs nitrogen gas (N₂) at high pressures.
3. As each sieve bed is depressurised, N₂ is released.
4. Valves open to deliver concentrated oxygen into a reservoir where it accumulates, and from which a flowmeter can be used for measured and continuous release of oxygen to the patient at a specified flow rate.

What are the types of Oxygen Concentrators?

In general, there are two types of oxygen concentrators: stationary and portable.

STATIONARY

Most stationary oxygen concentrators weigh less than 27 kg and have wheels so that they are easily movable by the user. They are self-contained devices that supply an economical, continuous stream of oxygen at flow rates up to 10 litres per minute (LPM). Very low flows, down to 0.1 LPM, may be delivered via the built-in flowmeter or with additional accessories. **Most concentrators that are appropriate for health facilities can deliver at least 5 LPM and operate on alternating current electricity, and consume approximately 280 - 600 watts (W), depending on the model (Refer below table). Separate models for 110 - 120 VAC (typically 60 Hz) and 220 - 240 VAC (typically 50 Hz) are generally available from the manufacturer to match the voltage and frequency of the local grid power⁷.**

PORTABLE

Portable oxygen concentrators have a lower output capacity (3 LPM or less), consume less power than their stationary counterparts (approximately 40 - 130 W) and are used by individual patients as ambulatory oxygen systems. They may contain batteries capable of operating on direct current (DC)⁷.

Advantages of an Oxygen Concentrator

Concentrators are designed for continuous operation and can produce oxygen 24 hours per day, 7 days per week, for up to 5 years or more. These devices can be used at any level of health facility. But not used in highly specialised care units such as ICUs,, where centralised oxygen supply is preferred. They are highly applicable in situations which require home based supplementation is indicated such as COPD, Sleep Apnea etc. For these there is a **need for continuous source of reliable power and a system for regular cleaning and maintenance** by users and technical personnel alike. While most oxygen concentrators operate by the same principles, spare parts are not interchangeable between different models⁷.

Drawbacks of an Oxygen Concentrator

Due to their low flow capacity, they are not suitable for simultaneous use by multiple patients. In addition, many portable devices contain a mechanism that allows oxygen delivery only during inspiration. This type of flow, known as pulsed-dose or intermittent flow, conserves oxygen and battery power. It is important to note that some infants and young children may not generate enough negative pressure during inspiration to reliably trigger oxygen flow⁷.

Comparison of Oxygen Concentrators

MAX O2 Output - 5 LPM

Manufacture	AirSep		Caire Medical	De Vilbiss	Inova Labs Inc	Invacare	Krober		Nidek Medical	Philips Respironics	Precion Medical, Inc.
Model	Newlife Elite	VisionAire	Companion	525	Activox DUO2	PerfectO2	Aeroplus	Krober	Nuvo Lite	EverFlo	EasyFlow5
Power (W)	350	290	250-350	310	372	280-325	280-325	280-350	300-330	350	350
Power Efficiency (W/LPM)	70	58	53-117	67	75	65	65	56-58	60-660	70	70
Min O2 output (LPM)	0.125	0.125	0.5	0.5	-	0.5	0.5	1	0.125	0.5	0.5
Max O2 output (LPM)	5	2-5	5	5	5	5	5	5-6	5	5	5
Outlet pressure (kPa)	45-60	30	30	60	60	35	35	70	50	40	55
Power Input options (VAC/Hz)	120/60, 220-240/50, 220/60	115/60, 220-240/50, 230/60	120/60, 230/50	115/60, 230/50, 230/60	110/60, 230/50	120/60	230/50, 115/60	230/50, 115/60	115/60, 230/50, 230/60	115/60, 230/50, 230/60	115/60
Temperature	10-40 C	5-40 C	5-40 C	5-40 C	10-40 C	10-35 C	10-40 C	10-35 C	10-38 C	13-32 C	10-35 C
Relative Humidity	95%	95%	95%	95%	95%	20-60%		95%	95%	95%	95%

Comparison of Oxygen Concentrators

MAX O2 Output - Greater than 5 LPM

Manufacture	AirSep		Canta Medical Tech.co.Ltd	Invacare	Nidek Medical
Model	Newlife Intensity	Newlife Intensity	HG Series	Platinum™XL	Nuvo 8
Power (W)	410	590	350-530	585	490
Power Efficiency (W/LPM)	52	59	60-117	59	61
Min O2 output (LPM)	0.125	-	1	0.5	2
Max O2 output (LPM)	8	10	3-10	5	8
Outlet pressure (kPa)	135	135	40-80	35-60	115
Power Input options (VAC/Hz)	120/60, 220-240/50, 220-240/60	120/60, 220-240/50	220/50	120/60	115/60, 230/50-60
Temperature	5-40-C	5-40-C	10-40-C	10-35-C	10-38-C
Relative Humidity	10-95%	10-95%	30-85%	60%	95%

Solar System Designs

5 LPM

Taking into consideration varied grid power availability, the comparison below shows efficient and inefficient solar energy system designs for a complete off-grid scenario (24 Hours back-up), 12 Hours and 6 Hours of back-up.

EFFICIENT

1 x 280W Oxygen Concentrator

	System Voltage	Energy consumed per day (kWh)	Total Usage Hours	Cost of System
Option 1	96 V	6.72 units	24 hrs	Rs. 3,90,000/-
Option 2	48 V	3.36 units	12 hrs	Rs. 2,30,000/-
Option 3	24 V	1.68 units	6 hrs	Rs. 1,15,000/-

INEFFICIENT

1 x 350W Oxygen Concentrator

	System Voltage	Energy consumed per day (kWh)	Total Usage Hours	Cost of System
Option 1	96 V	8.4 units	24 hrs	Rs. 4,75,000/-
Option 2	48 V	4.2 units	12 hrs	Rs. 2,84,000/-
Option 3	24 V	2.1 units	6 hrs	Rs. 1,40,000/-

% Savings of using efficient system over inefficient system

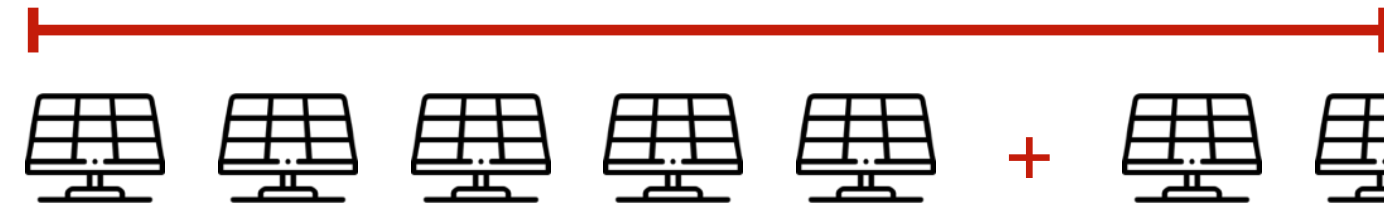
	Total Usage Hours	Total Energy Required (Efficient)	Total Energy Required (Inefficient)	% Savings
Option 1	24 hrs	6.72 units	8.4 units	20%
Option 2	12 hrs	3.36 units	4.2 units	20%
Option 3	6 hrs	1.68 units	2.1 units	20%

Note: All costings prescribed in the document are calculated for Indian market, and might differ region to region.

OPTION 1 24 Hours

Solar Module with Mounting Structure
with 5 hrs. of average effective sunshine hours
throughout an year

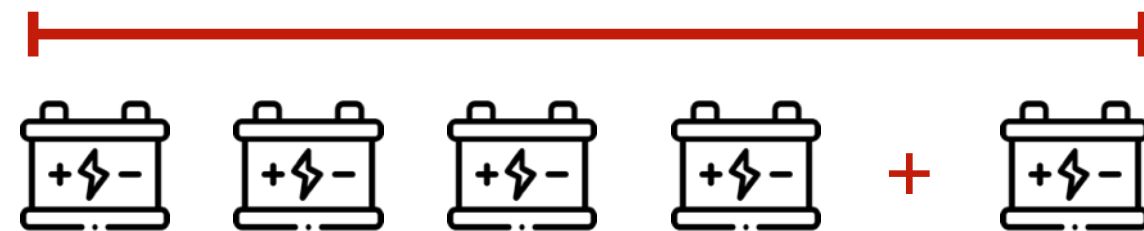
Inefficient
3.96 kWp (330 Wp panel X 12 Nos.)



Efficient
3 kWp (300 Wp panel X 10 Nos.)

Solar Battery
Considering 2 days of autonomy and 80%
depth of discharge with lead-acid battery

Inefficient
300 Ah @ 96 V (150 Ah X 16 Nos.)



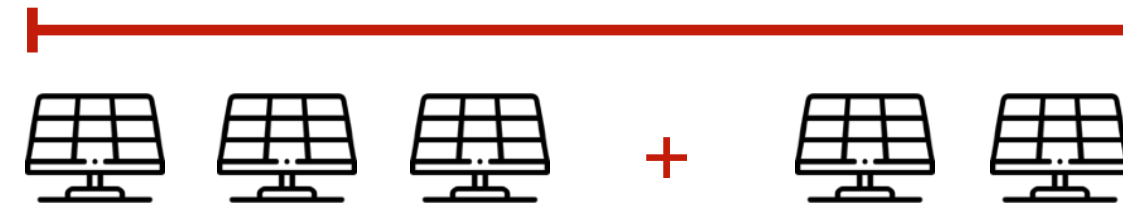
Efficient
240 Ah @ 96 V (120 Ah X 16 Nos.)

OPTION 2 12 Hours

*Excluding the No-load losses of the Power conditioning unit for the rest of the 12 hrs. However, we have added it in the total solar module capacity and storage need.

Solar Module with Mounting Structure
with 5 hrs. of average effective sunshine hours
throughout an year

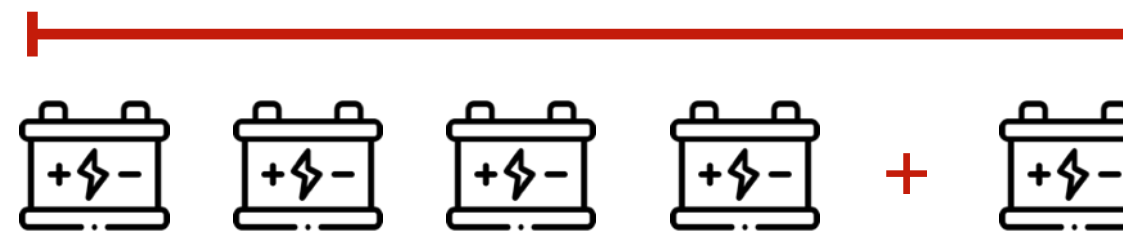
Inefficient
2.25 kWp (250 Wp panel X 12 Nos.)



Efficient
1.8 kWp (300 Wp panel X 6 Nos.)

Solar Battery
Considering 2 days of autonomy and 80%
depth of discharge with lead-acid battery

Inefficient
360 Ah @ 48 V (180 Ah X 8 Nos.)



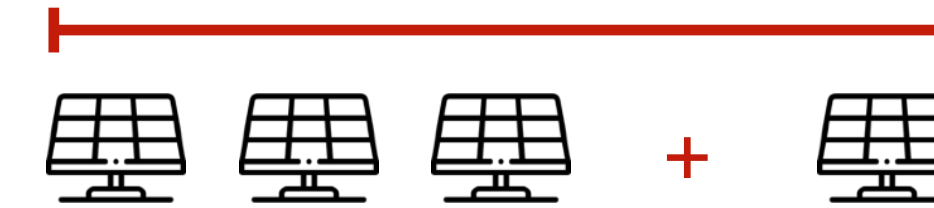
Efficient
300 Ah @ 48 V (150 Ah X 8 Nos.)

OPTION 3 6 Hours

*Excluding the No-load losses of the Power conditioning unit for the rest of the 12 hrs. However, we have added it in the total solar module capacity and storage need.

Solar Module with Mounting Structure
with 5 hrs. of average effective sunshine hours
throughout an year

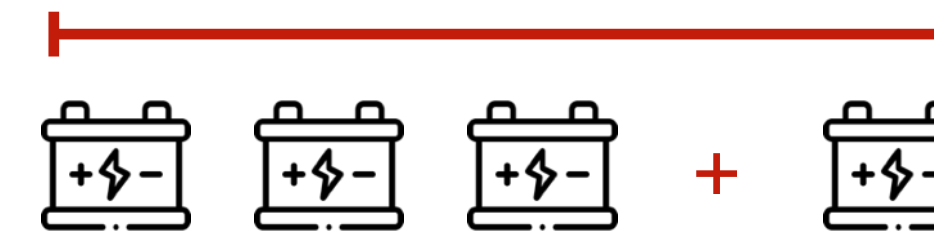
Inefficient
1.2 kWp (300 Wp panel X 4 Nos.)



Efficient
990 Wp (330 Wp panel X 3 Nos.)

Solar Battery
Considering 2 days of autonomy and 80%
depth of discharge with lead-acid battery

Inefficient
400 Ah @ 24 V (200 Ah X 4 Nos.)



Efficient
300 Ah @ 24 V (150 Ah X 4 Nos.)

Solar System Designs

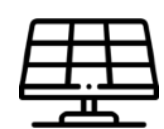
10 LPM

Taking into consideration varied grid power availability, the comparison below shows efficient and inefficient solar energy system designs for a complete off-grid scenario (24 Hours back-up), 12 Hours and 6 Hours of back-up.

600W Oxygen Concentrator

OPTION 1 24 Hours

Max units of energy (kWh) usage per day	System Voltage	Estimated System Cost
14.4 units	120 V	Rs. 750,000/-



Solar Module with Mounting Structure with 5 hrs. of average effective sunshine hours throughout an year

Efficient
6.6 kWp (330 Wp panel X 20 Nos.)



Solar Battery
Considering 2 days of autonomy and 80% depth of discharge with lead-acid battery

Efficient
400 Ah @ 120 V (200 Ah X 20 Nos.)

OPTION 2 12 Hours

*Excluding the No-load losses of the Power conditioning unit for the rest of the 12 hrs. However, we have added it in the total solar module capacity and storage need.

Max units of energy (kWh) usage per day	System Voltage	Estimated System Cost
7.2 units*	96 V	Rs. 460,000/-



Solar Module with Mounting Structure with 5 hrs. of average effective sunshine hours throughout an year

Efficient
3.6 kWp (300 Wp panel X 12 Nos.)



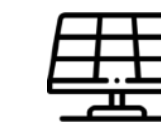
Solar Battery
Considering 2 days of autonomy and 80% depth of discharge with lead-acid battery

Efficient
300 Ah @ 96 V (150 Ah X 16 Nos.)

OPTION 3 6 Hours

*Excluding the No-load losses of the Power conditioning unit for the rest of the 12 hrs. However, we have added it in the total solar module capacity and storage need.

Max units of energy (kWh) usage per day	System Voltage	Estimated System Cost
3.6 units*	48 V	Rs. 280,000/-



Solar Module with Mounting Structure with 5 hrs. of average effective sunshine hours throughout an year

Efficient
2.25 kWp (250 Wp panel X 9 Nos.)



Solar Battery
Considering 2 days of autonomy and 80% depth of discharge with lead-acid battery

Efficient
360 Ah @ 48 V (180 Ah X 8 Nos.)

Note: All costings prescribed in the document are calculated for Indian market, and might differ region to region.

Using Flowmeters to Split Output Flow

When used with a flowmeter stand for splitting flow, concentrators can provide a continuous supply of oxygen to multiple patients at the same time. Concentrators can provide a safe and cost-effective source of oxygen. However, it is critical that there is a source of continuous and reliable power and regular preventive maintenance to ensure proper functioning.

Flowmeters have a dial that controls oxygen flow, flow markers to read the flow rate, and a ball that rises with higher flow. Flowmeters are important for the safe delivery of the right amount of oxygen (typically the lowest flow required to maintain adequate blood oxygen level). Flowmeter stands enables oxygen delivery from a single oxygen concentrator to multiple patient, with individual flowmeter control. This helps provide oxygen more efficiently, also reducing energy consumption per patient oxygen delivery.

For more details on flowmeter for oxygen concentrators, visit Azimut360.

Flowmeter stands can ensure delivery of oxygen to 4 patients from a single source of oxygen, thus, reducing energy consumption.



Source: Azimut360 : Illustration of ward oxygen system setup

Oxygen Generators

Hypothetical 10 bed COVID-19 ICU Facility

Disease Severity	Average O2 Flow Rate		Size of Solution of Scale
	Per Patient	Total	PSA Plant
Severe 7 Patients	10 L/min	$7 * 10 * 60 = 4,200$ L/min	42 m3/hr
Critical 3 Patients	30 L/min	$3 * 30 * 60 = 5,400$ L/min	54 m3/hr
		9600 L/hr	96 m3/hr (100 m3/hr)

Comparison of Oxygen Storage (Cylinder versus Generator in high use, low resource area)

	Oxygen Cylinder	Oxygen Generator		
Total Oxygen Requirement per day (ltrs)	2,30,400	2,30,400		
Capital Investment	15,40,000	25,00,000		
Cost of Solar Energy	-	4 hrs backup	8 hrs backup	24 hrs backup
		30,00,000	50,00,000	1,35,00,000
Recurring Cost (Refilling per day for cylinders)	1,23,200			
Recurring Cost (Refilling per month for one cylinder/electricity bill)	36,96,000	51,225	40,980	
TOTAL COSTS FOR THREE MONTHS (CAPITAL EXPENDITURE + RECURRING COSTS)	1,26,28,000	56,53,675	76,22,940	1,60,00,000

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Thank You!

Do get in touch for further information and assistance.

Write to us at:

covid19@selcofoundation.org

SELCO Foundation COVID-19 Response Website:

covid-19.selcofoundation.org



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