

SOLAR POWERED VENTILATORS

In the Context of COVID 19



SELCO Foundation

covid-19.selcofoundation.org

INTRODUCTION

Covid19 pandemic is the major on going public health concern all over the world. This disease is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The outbreak was first noted in Wuhan, Hubei province, China, in December 2019. The World Health Organisation (WHO) declared the outbreak to be a Public Health Emergency of International Concern on 30 January 2020 and recognised it as a pandemic on 11 March 2020 (1).

As of 5 April 2020, more than 1.22 million cases of COVID-19 have been reported in over 200 countries and territories resulting in approximately 66,500 deaths. More than 252,000 people have recovered world (2). In India first case of COVID 19 was detected on 30th Jan 2020 and close to 3377 people infected with this virus, 275 were cured and there were 79 deaths reported (3). Most COVID -19 patients recover. For those who do not, the time of development of symptoms to death has been between 6 and 41 days with the most common being 14 days. It was observed that 80% of deaths were among persons who are above 60 years. Majority i.e.75% were suffered from pre-existing disease condition like heart disease and diabetes (4).

According to WHO's clinical management of COVID 19 guidelines, out of 100 people who are infected with this virus, 15% require hospital admission and 5% require intensive care unit.

For those who develop trouble breathing, medical care outside of the home is needed. This may be in the form of supplemental oxygen and/or breathing treatments. These may be given in an urgent care or emergency room setting, but as hospital beds become more and more scarce, more and more people are being sent home with oxygen therapy. These home oxygen machines come in various sizes and forms, and can administer various concentrations of oxygen as advised by the physician.(5)

Ventilators are required to treat to manage and treat individuals with severe lung infections, require highly trained professionals, typically intensive care physicians, anaesthesiologists, intensive care nurses, and respiratory therapists. As the individuals who are caring for the exponentially growing ill population become sick or worse, the level of care for critically ill patients will be compromised as exponentially as their numbers increase.

Due to rapid increasing number of COVID 19 cases, there is growing demand health facilities like isolation wards and ICU. Developed countries like US, ITALY and Spain where there are improved health systems also facing severing challenges in the treatment and management of COVID 19 cases. In the context of resource constraint countries where there are crippled health care systems it will be even pose if there is sudden rise of COVID infections and it will pose greater challenge if there is community transmission. Expert says in India if COVID 10 cases surges ahead we struggle because close to 3% of these cases would require ventilators. As per Brookings report, the country might need anywhere between 1.10 to 2.2 lakh ventilators by mid of May in the worst-case scenario. The number of ventilators available in the country is a maximum of 57000. Most of those ventilators cannot be put in use.

Government of India Specification on Ventilators for COVID 19:

It should be Turbine compressor based because the installation sites might not have central oxygen lines. The machine should have features like invasive, non-invasive and Continuous Positive Airway Pressure (CPAP) and makes them versatile. They also need to have 200-600 ml TIDAL volume, lung mechanics display, and continuous working capabilities of 4 to 5 days.

What is a Ventilator and when is it used?

A ventilator is a machine designed to provide mechanical ventilation by moving breathable air into and out of the lungs, to deliver breaths to a patient who is physically unable to breathe, or breathing insufficiently.

- Ventilators are chiefly used in Intensive care medicine
- Home care
- Emergency medicine (as standalone units)
- Anaesthesiology (as a component of an anaesthesia machine)

What is mechanical ventilation?

- Mechanical ventilation, or assisted ventilation, is the medical term for artificial ventilation where mechanical means are used to assist or replace spontaneous breathing.
- Mechanical ventilation is termed "invasive" if it involves any instrument inside the trachea through the mouth, such as an endotracheal tube or the skin, such as a tracheostomy tube.
- Non-invasive ventilation (NIV) is the use of breathing support administered through a face mask, nasal mask, or a helmet.
- Mechanical ventilators typically require power by a battery or a wall outlet (DC or AC) though some ventilators work on a pneumatic system not requiring power.

What are the different types of mechanical ventilation?

Positive pressure ventilation where air (or another gas mix) is pushed into the lungs through the airways

Negative pressure ventilation where air is, in essence, sucked into the lungs by stimulating movement of the chest.

What are the different types of mechanical ventilators?

Transport ventilators: These ventilators are small and more rugged, and can be powered pneumatically or via AC or DC power sources

Intensive-care ventilators: These ventilators are larger and usually run on AC power (though virtually all contain a battery to facilitate intra-facility transport and as a back-up in the event of a power failure). This style of ventilator often provides greater control of a wide variety of ventilation parameters (such as inspiratory rise time). Many ICU ventilators also incorporate graphics to provide visual feedback of each breath.

Neonatal ventilators: Designed with the preterm neonate in mind, these are a specialized subset of ICU ventilators that are designed to deliver the smaller, more precise volumes and pressures required to ventilate these patients.

Positive airway pressure ventilators: These ventilators are specifically designed for non-invasive ventilation. This includes ventilators for use at home for treatment of chronic conditions such as sleep apnoea or COPD. (11)

Power requirements for mechanical ventilators:

- Mechanical ventilators require electrical power and/or gas pressure
- Different permutations of ventilator power supply include:
 - Gas pressure to drive inspiratory flow and to supply mechanical power to operate valves and switches (example: "fluidic" valves). Ventilators which rely on gas pressure for inspiratory flow are highly energy-efficient but require a stable supply of compressed gas, making them ideal for in-hospital applications
 - Gas pressure to drive inspiratory flow, but electrically powered valves and switches (this is the norm)
 - Electrical power to drive turbines/compressors for inspiratory gas flow as well as to operate valves/switches (transport ventilators, home ventilators) Ventilators which use internal gas compressors to drive flow have reduced (or zero) reliance on compressed gas, and are ideally suited for transport and domiciliary purposes. (12)

Basic Requirement of Ventilators for COVID19

On the basis of the recommended features (stated below) for Ventilators for COVID19 by WHO, a market research was conducted to identify the current market benchmarks on efficiency.

- Tidal Volume up to 1000 ml
- Pressure (inspiratory) up to 80cm H₂O
- Volume (inspiratory) up to 120 L/minute
- Respiratory Rate: up to 60 breaths per minute
- SIMV Respiratory Rate: up to 40 breaths per minute
- CPAP / PEEP up to 20cm H₂O
- FiO₂ between 21 to 100%
- Inspiratory and expiratory times up to at least 2 seconds and 8 seconds respectively
- I:E Ratio at least from 1:1 to 1:3

Modes of Ventilation:

- Volume Control
- Pressure Control
- Pressure Support
- Synchronised intermittent mandatory Ventilation (SIMV) with pressure support
- Assist/ Control mode
- CPAP / PEEP Alarms are required: FiO₂, minute volume, pressure, PEEP, apnoea, occlusion, high respiration rate, disconnection

Other Features:

- System alarms required: power failure, gas disconnection, low battery, vent inoperative, self diagnostics
- If the alarm silencing feature is incorporated, it must be temporary and clearly displayed when activated
- Air and externally supplied oxygen mixture rations fully controllable. Inlet gas supply (O₂) pressure ranges from at least 35 to 65 psi. Medical air compressor integral to unit, with inlet filter

Comparison of ICU Ventilators

Manufacture	Cardio Labs	Air Liquide Healthcare	Draeger-Evita	Analytical Technology	Air Liquide Medical Systems	Life Line Biz Pvt	Meditec England	GE Healthcare	Philips Respironics
Model	Cvent-1200T	Orlon-G	Evita V300	ICU Ventilator-3110	Extend XT	Brio-09	Meditec 1700	CARESCAPE R860	V680
Power (W)	100 VA	120 VA	322 VA	900 VA (with compressor) 250 VA (without compressor)	120 VA	100 W	150 W	0-200 VA	300 VA
Power Supply	100-26 V AC 10/60 Hz	100 V to 240V 50/60 Hz	100 V to 240V 50/60 Hz	220V 50 Hz	100 V to 240V 50/60 Hz	100 V to 240V 50/60 Hz	100 V to 240V 50/60 Hz	85 to 132 VAC; 190 to 264 VAC 47/63 Hz	100 to 240 VAC 50/60 Hz
Tidal Volume	10 to 2000 ml	50 to 2000 ml	2 to 3000 ml	0.2 to 2000 ml	20 to 2000 ml	100 to 2000 ml	50 to 2500 ml	5 to 2500 ml	50 to 2500 ml
Respiratory Rate	1 - 200 bpm	1 - 60 bpm	0 - 300 bpm	1 - 100 bpm	5 - 100 bpm	1 - 80 bpm	2 - 120 bpm	3 - 150 bpm	1 - 80 bpm
CPAP / PEEP	0-50 cm H2O	0-25 cm H2O	0-50 cm H2O	0-40 cm H2O	0-40 cm H2O	5-60 cm H2O	0-45 cm H2O	1-50 cm H2O	1-50 cm H2O
Pressure Support	0-120 cm H2O	3-35 cm H2O35	0-50 cm H2O	0-80 cm H2O	90 cm H2O	0-80 cm H2O	5-80 cm H2O	0-60 cm H2O	0-74 cm H2O
FiO2	21% - 100% 100% O2 (0-5 mins)	21% - 100%	21% - 100%	21% - 100%	21% - 100%	21% - 100%	21% - 100%	10% - 100%	18% - 100%
Insipratory and Expiratory Times	0.1 to 12s (Increment 0.1s)	0.3 to 5s	0.1 to 30s	0 to 5s	0.2 to 5s	0.2 to 10s	0.1 to 9.9s	0.25 to 15s	0.3 to 3s
I:E Ratio	1:9.9 - 9.9:1	25% to 50%	1:150 to 150:1	4:1 to 1:8	1:0.3 to 1:50	1:10 to 4:1	1:9.9 to 2.5:1	1:79 to 60:1	9.9:1 to 1:9.9

Solar System Designs

ICU VENTILATORS

Taking into consideration varied grid power availability, the comparison below shows efficient and inefficient solar energy system designs for a complete off-grid scenario with 24 hours back-up

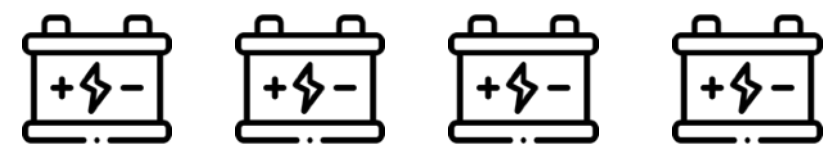
EFFICIENT 100W Ventilator

System Voltage	Energy consumed per day (kWh)	Total Usage Hours	Cost of System
24 V	2.4 units	24 hrs	Rs. 150,000/-



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

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



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

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

INEFFICIENT 322W Ventilator

System Voltage	Energy consumed per day (kWh)	Total Usage Hours	Cost of System
96 V	7.7 units	24 hrs	Rs. 460,000/-



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



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

Comparison of Portable Ventilators

Manufacture	Drager	Oxvient	Philips Respironics	NIDEK	AEOMOD	Siare
Model	Oxylog 3000 plus	OXI2Plus	BiPAPA A40	Saliva Sonata	Shangrila 510S	ALCO 202 Evo
Power (W)	96 W	60W	100W	100W	65VA	150 W
AC Power Supply	100 - 240 V 50 to 60 Hz	220 V 50 Hz	220 V 50 Hz	115/230 V	100 - 240 V 50 to 60 Hz	100 - 240 V 46 - 63 Hz
DC Power Supply	12/24/28 VDC 5/2.5/2.1 A	12 VDC 5 A	24 VDC 4.2 A	12 VDC	12 VDC	12 VDC 7A
Tidal Volume	50 to 2000 ml	50 to 2500 ml	200 to 1500 ml	20 to 2000 ml	0 to 2000 ml	20 to 3000 ml
Respiratory Rate	2 - 60 bpm	1 - 120 bpm	0 - 40 bpm	4 - 80 bpm	1 - 120 bpm	4 - 150 bpm
CPAP / PEEP	0-20 cm H2O	0-20 cm H2O	4-40 cm H2O	1-35 cm H2O	0-30 cm H2O	1-50 cm H2O
Pressure Support	0-35 cm H2O	0-60 cm H2O	4-40 cm H2O	0-59 cm H2O	0-50 cm H2O	2-80 cm H2O
FiO2	40% - 100%	-	-	21% - 100%	40% - 100%	0% - 100%
Insipratory and Expiratory Times	0.2 to 10s	0.1 to 10s	0.5 to 3s	-	0.5s	0.036 to 9.6s
I:E Ratio	1:100 to 50:1	1:9 to 4:1	9.9:1 to 1:9.9	1:9.9 to 4:1	4:1 to 1:10	1:10 to 4:1

Solar System Designs

PORTABLE VENTILATORS

Case 1: Portable Ventilators used during Transportation of Patients

Portable ventilators are usually reserved for intra- and inter-facility transfer of patients. Generally a portable ventilator needs a 4-6 hrs charging time and can provide back up to 5-8 hrs.

EFFICIENT 60W Ventilator

System Voltage	Energy consumed per day (kWh)	Total Usage Hours	Cost of System
24 V	0.36 units	6 hrs	Rs. 50,000/-

INEFFICIENT 150W Ventilator

System Voltage	Energy consumed per day (kWh)	Total Usage Hours	Cost of System
24 V	0.9 units	6 hrs	Rs. 75,000/-



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



Efficient
200 Wp (200 Wp panel X 1 Nos.)



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



Efficient
60 Ah @ 24 V (60 Ah X 2 Nos.)



Inefficient
500 Wp (250 Wp panel X 2 Nos.)



Inefficient
135 Ah @ 24 V (135 Ah X 2 Nos.)

Solar System Designs

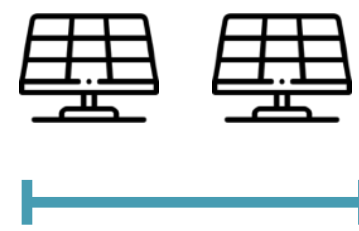
PORTABLE VENTILATORS

Case 2: Portable Ventilators as an Alternative to ITU/ICU Ventilators

In the case of Covid, a patient requires mechanical ventilation and only portable ventilators are available, one would have no choice but use them. However, portable ventilators are usually reserved for intra- and inter-facility transfer of patients. Portable ventilators are not as effective as intensive therapy unit (ITU) ventilators. In this scenario, IF portable ventilators will have to be used to treat severe cases of Covid 19 due to acute shortage of ITU/ICU/Anaesthesia ventilators, below is the system design with a backup of 24 hours. The reserve on-board battery will be used only as a back-up.

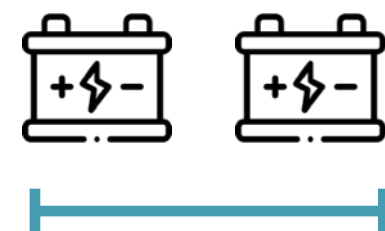
EFFICIENT 60W Ventilator	System Voltage	Energy consumed per day (kWh)	Total Usage Hours	Cost of System
	24 V	1.44 units	24 hrs	Rs. 95,000/-

INEFFICIENT 150W Ventilator	System Voltage	Energy consumed per day (kWh)	Total Usage Hours	Cost of System
	48 V	3.6 units	24 hrs	Rs. 210,000/-



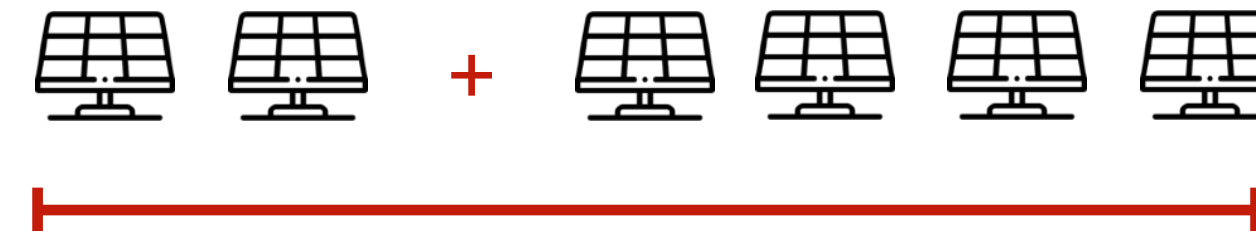
Solar Module with Mounting Structure with 5 hrs. of average effective sunshine hours throughout an year

Efficient
660 Wp (330 Wp panel X 2 Nos.)

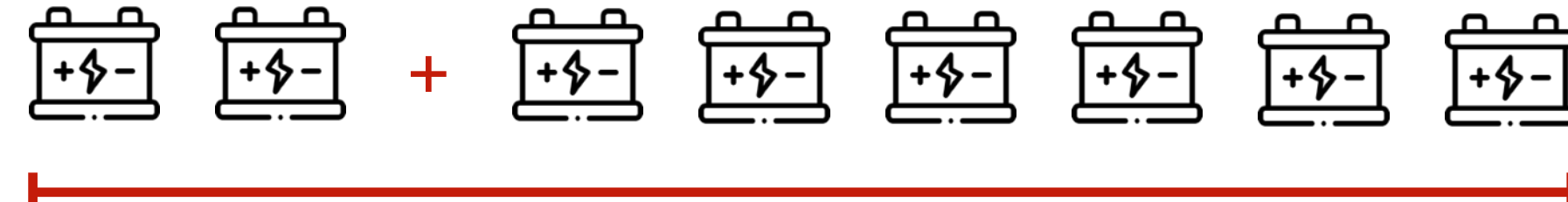


Solar Battery considering 2 days of autonomy and 80% depth of discharge with lead-acid battery

Efficient
200 Ah @ 24 V (2000 Ah X 2 Nos.)



Inefficient
1.5 kWp (250 Wp panel X 6 Nos.)



Inefficient
270 Ah @ 48 V (135 Ah X 8 Nos.)

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

TRAINING RESOURCES FOR USAGE OF VENTILATORS

<https://www.youtube.com/watch?v=mXEAqRaqafY>
Webinar on ICU Care and Ventilation Strategy AIIMS

https://www.youtube.com/watch?v=k_9EcM9Pjd8
Online Training on the Management of COVID 19

<https://www.youtube.com/watch?v=OckTydfGB-k>
Edited Covid 19 Webnair Epidemiology Diagnosis and Infection Prevention

<https://www.youtube.com/watch?v=cjJG5Q-C7Yk>
COVID 19 Guideline Based Ventilation Strategies

https://www.iephysicians.com/wp-content/uploads/2020/03/APIC_DosDonts_GOWNS.pdf
Dos and Don'ts for wearing Gowns in non-surgical health care settings

https://www.iephysicians.com/wp-content/uploads/2020/03/APIC_DosDontsofMasks_hiq.pdf
Dos and Don'ts for wearing Masks in non-surgical health care settings

https://www.iephysicians.com/wp-content/uploads/2020/03/APIC_DosDonts_Respirators_hiq.pdf
Dos and Don'ts for wearing Respirator in non-surgical health care settings

<https://www.iephysicians.com/wp-content/uploads/2020/03/COVID-19-infection-prevention-and-control-healthcare-settings-march-2020.pdf>
Dos and Don'ts For infection Control Measures

<https://www.iephysicians.com/wp-content/uploads/2020/03/2019-nCoV-Identify-Assess-Flowchart-002.pdf>

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Thank You!

Do get in touch for further information and assistance.

Write to us at:

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SELCO Foundation COVID-19 Response Website:

covid19.selcofoundation.org



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