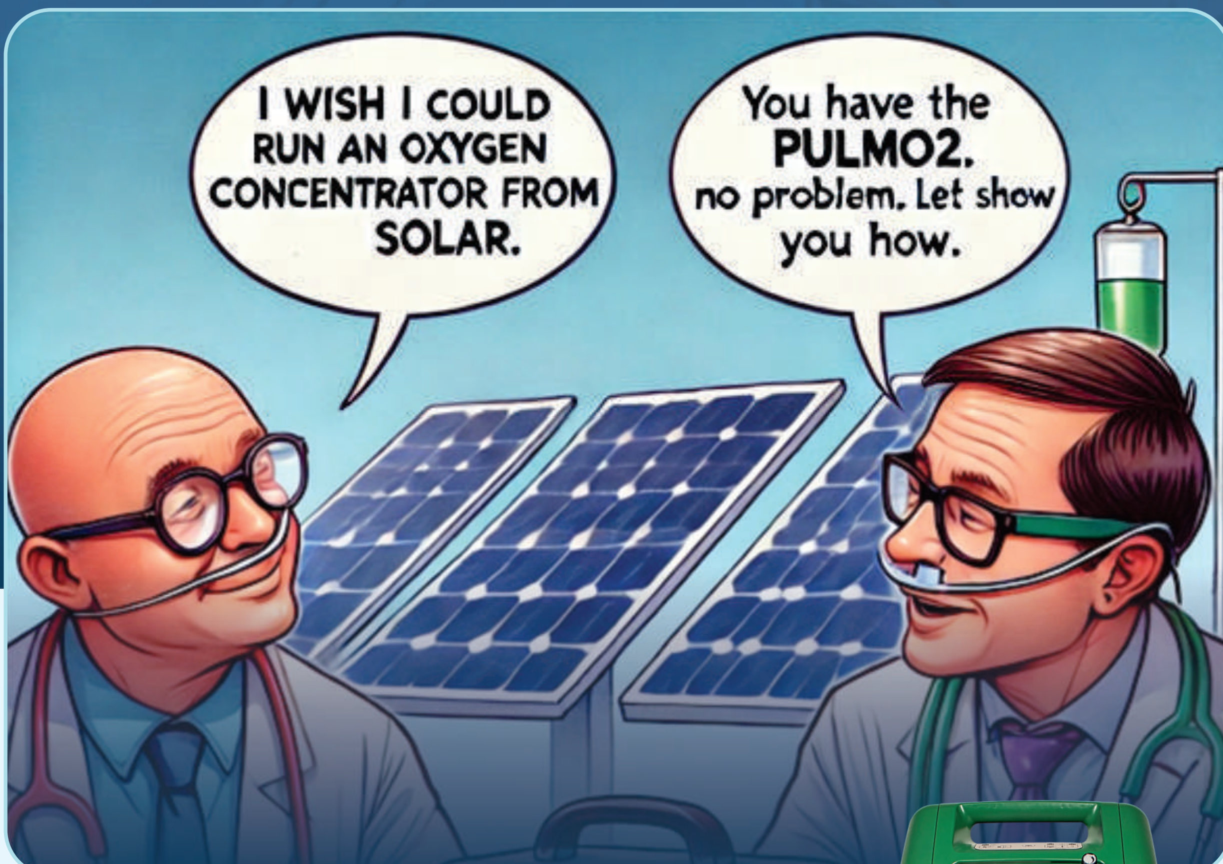
SANRAI INTERNATIONAL

PulmO2

INTRODUCTION

TO SOLAR FOR THE **DEVILBISS/SANRAI PULMO2**



The **PulmO2** has several features that make it highly suitable for powering from solar. We've put together a simple “primer” to help you understand the basics. We start off by explaining the main components that you would need for the most simple system. With that background, we help you understand how to go about sizing the components to meet your needs.

SOLAR FRIENDLY OXYGEN CONCENTRATOR

What we need is a solar-friendly oxygen concentrator, one that does not consume a lot of power and is efficient enough to be powered by solar energy. Traditional oxygen concentrators, while effective, are not optimized for solar use due to their reliance on certain design features. Older concentrators typically use an alternating current (AC) motor to power their air compressors. AC motors run from power taken directly from the wall socket and rotate at a fixed speed. These motors have significant drawbacks when paired with solar systems.

Some of these drawbacks include a high startup power demand. AC motors require a substantial power surge, up to seven times the operating power, to start. While this is manageable on a stable electrical grid, it creates challenges for solar systems, particularly when combined with inverters. Another drawback is the fixed speed operation. AC motors run at a constant speed, consuming the same amount of power regardless of the actual oxygen demand. This inefficiency means unnecessary power is wasted when lower oxygen flow rates are sufficient, such as for pediatric patients.

The PulmO2 addresses these inefficiencies by employing a brushless direct current (BLDC) motor, a key innovation that makes it exceptionally solar-friendly. Firstly, the BLDC allows for a soft start by use of an electronic speed control unit that gradually ramps up the motor speed, reducing the initial power surge required to start. Additionally, the BLDC motor is capable of operating at variable speeds. As such, the PulmO2 adjusts its speed to match oxygen demand. This means that when the need for oxygen is lower, such as during lower flow rates, the motor consumes significantly less power. It should be noted that regardless of whether the compressor utilizes an AC or a Brushless DC motor, when it comes to power consumption, the maximum power the device is expected to consume under normal operating conditions is indicated on a label on the back of the concentrator.

Another key feature of the PulmO2 is that its internal power supply converts AC to DC, enabling operation across a wide voltage range. This adaptability not only makes it compatible with various power standards (110-127V and 220-240V) but also helps maintain performance during undervoltage conditions also known as “brown-outs”.

All these features combine to make the PulmO2 an ideal candidate for solar-powered operation. Its low power consumption, flexibility, and ability to adapt to variable conditions make it a practical solution for regions with unreliable power grids or where solar is the primary power source.

DEEP CYCLE BATTERIES

Batteries used for starting cars deliver high current (up to 600 Amps) for very short periods of time. The process of starting the engine uses very little of the battery power, which is then quickly recharged by the alternator of the car once the engine is running. These batteries do not work well for solar applications as they can be easily damaged if they are deeply discharged and rarely last for 1,000 charge and discharge cycles before needing replacement.

Applications that require relatively small amounts of power over extended periods, such as running an oxygen concentrator, need a different battery design. These are called deep-cycle batteries and are commonly used in solar systems, boats, and recreational vehicles, for example. As batteries have evolved, different compositions of chemicals have resulted in improved performance. The latest battery chemistry is called Lithium Iron Phosphate (LiFePO4). This chemistry allows batteries to be charged and discharged more than 5,000 times.

The PulmO2 can be operated from a deep cycle battery with the addition of an inverter. The battery can be recharged using solar panels and a solar charge controller. Traditionally, the inverter and solar charge controller were separate devices. However, more recently they are commonly found integrated into a single device, which also allows for connection to the main power grid. Let's unpack these options

INVERTER

Inverters convert direct current (DC) from a battery into alternating current (AC), required to run an oxygen concentrator. There is always some loss of energy due to heat from the conversion, but they are typically around 90% efficient (you are losing 10% of the power to heat). Higher quality inverters tend to be more efficient, but this comes at a cost. The native input voltage of an inverter is commonly 12V. However, models exist with 24V, 48V and even 96V. In reality, the higher the input voltage, the more efficient the inverter will be. Output voltages are usually matched to power grid voltage. The PulmO2 can use either a 110V or 220V inverter, as it is compatible with various power standards (110-127V and 220-240V), as previously highlighted.

Inverters are rated based on the size of the load they can continuously power, measured in Watts. They can also handle short bursts of higher power, known as peak power, which is typically twice the continuous rating (e.g., 1,000 watts continuous / 2,000 watts peak power). Inverters come in three broad classes: Pure Sine Wave, Modified Sine Wave and, let's just call them “other”. Devices that utilize AC motors, such as the compressor used in most oxygen concentrators, perform best when using a Pure Sine Wave inverter. However, since the PulmO2 utilizes a BLDC motor with an internal power supply, it will work equally as well on all three types of inverter.

SOLAR PANELS

Solar panels can be used to keep the battery charged. Panels commonly come in native 12VDC and 24VDC configurations. Their output is rated in Watts of power that they can produce in direct sunlight. Multiple panels can be connected in both series to increase the voltage and/or in parallel to increase the current. To achieve the most output from a solar panel the panel needs to be correctly oriented, and kept out of shade. In the southern hemisphere panels are tilted towards the north and vice versa.

Note that Lithium-ion batteries are a different type of battery chemistry that have been around for some time. With the similarity in names, Lithium Iron Phosphate and Lithium-ion can be easily confused.

The angle of tilt depends on the latitude of the locations. Specifically, the further away from the equator you are the steeper the angle.

While we may have 12 hours of daylight on average, the amount of time that the intensity of the sun is sufficient for a solar panel to generate energy close to its rated power is limited to 4-5 hours, and can be less depending on the season and on climatic conditions that day. We can use this window of high sun intensity to charge batteries with energy from the solar power, allowing us to use the stored energy from the battery to run the concentrator at other times during the day.

While the 4-5 hours window gives us the most power from the panels, it is important to understand that the panels are still generating energy several hours before and after. The efficiency of the panel is shown for each hour of the day between 7 AM and 5 PM (varies between summer and winter).

TIME OF DAY	PANEL EFFICIENCY
7 AM - 8 AM	20%
8 AM - 9 AM	30%
9 AM - 10 AM	50%
10 AM - 11 AM	70%
11am - Noon	90%
Noon - 1 PM	100%
1 PM - 2 PM	90%
2 PM - 3 PM	80%
3 PM - 4 PM	60%
4 PM - 5 PM	40%

This is equivalent to about 6.3 hours at 100% efficiency, which can be used in calculating required capacity of solar panels for your system

SOLAR CHARGE CONTROLLER BASICS

The power produced by a solar panel varies depending on factors such as sun intensity, climatic conditions, and the angle of the sun related to the solar panel. Consequently, we cannot simply connect the solar panel to the battery. The solar charge controller optimizes the power from the solar panel to charge the battery as efficiently as possible. If you use a stand-alone solar charge controller you should select a model that is compatible with the battery chemistry you plan to use.

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HYBRID CHARGER/INVERTER

Life got somewhat simpler with the introduction of these devices. These devices integrate the solar charge controller and the inverter into a single unit. The term hybrid comes from the device's ability to manage power from multiple sources of energy. The most common configuration is to have a connection to the electrical grid as well as solar panels. While the unit can still work entirely from solar panels, an additional grid connection has several benefits. When grid power is available, even intermittently, it can supplement the energy stored in the batteries, prolonging the runtime of the oxygen concentrator. It can also charge the batteries at night when the solar panels are not producing energy. Smaller models in the 1,000 Watts range are available with 12 volts input from the battery and medium-sized models are available with 24 Volts input. These devices are highly configurable to accommodate for the many different types of solar panels and battery types. Configuration is done using a computer connected to the device via a USB cable.

LET'S GET STARTED SIZING YOUR SOLAR SOLUTION

STEP 1 Understanding the expected runtime on Battery Power

It's helpful to understand the expected runtime of the PulmO2 from batteries alone. This would represent the runtime during the evening and early morning when the solar panels are not in operation. For the purposes of this example, we selected Lithium Iron Phosphate batteries with a total capacity of 5,120 Watt-hours. This capacity can be achieved using two 2,560 Watt-hour (12.8 Volt @ 200 Ampere-hour(Ah)) batteries. These batteries are widely available. These are also available in a smaller 1,280 Watt-hour (12.8Volt @ 100Amp.hour) capacity.

As the PulmO2 incorporates a novel feature to reduce the power consumption when operating at lower flow rates, runtime has to be shown based on the flowrate of the concentrator. The table below shows the expected runtimes at specific flow rates based on a full charge with the batteries described above.

FLOW RATE (LPM)	EXPECTED RUN TIME (HOURS)
2-4	17.4
5	16.7
6	14.8
7	12.5
8	10.5
9	9.1
10	7.7

These times may vary slightly depending on the efficiency of the inverter you choose. Runtime can be easily extended by adding additional batteries. Doubling the battery capacity will double the runtime.

STEP 2 Choosing the inverter

For the ease of simplicity, we will focus on using a hybrid charger/inverter, as these are widely available and provide additional benefits over using a separate inverter and solar charge controller. The hybrid charger/inverter pictured above is manufactured by SNRE. This is a mid-range brand that is commonly available in most countries.

To make the best use of the energy being produced by the solar panels, it is important to select a device that allows for fast charging, as this feature is supported by the LiFePO4 batteries. This means that even during the narrow window of time where the panels are producing energy the batteries can be recharged to full capacity.

Since the device contains both the charger and the inverter, getting a powerful charger means that you will also get an inverter that is balanced in capacity. Since the PulmO2 is very energy efficient, the larger inverter is not necessary. However, having a little extra capacity in the inverter would allow for other electrical devices to be run concurrently with the concentrator for short periods, without significantly reducing the runtime of the concentrator. We suggest that you select an inverter with a capacity of at least 1,000 Watts.

Smaller inverters in the range of 1,200 Watts to 2,000 Watts typically have 12 Volts DC, while medium sized inverters in the range 2,000 Watts to 5,000 Watts commonly have 24 Volts DC input. Two 12 Volts batteries can be connected in parallel to match with 12 Volts inverters, or connected in series to match with 24 Volt inverters.

STEP 3 Selecting solar panels

Now it comes down to selecting solar panels. Simply put, the more panels the greater the capacity and the faster the batteries will recharge. During the 4-5 hours of peak solar charging you want the the concentrator to be running entirely from the solar panels, and the excess energy from the panels to charge the batteries, so when the panels are no longer producing energy the batteries are fully charged.

Let's consider an extreme scenario where the concentrator is expected to run continuously. If we assume that we have peak sun from 10am to 3pm then the batteries need to keep the concentrator running for 3pm until 10am the next day, or a total of 19 hours

It is important to note that the window of usage is critical. For example, if the concentrator were to be turned on at 5pm after the solar panels had stopped providing energy, then the run time would be entirely determined by the flow rate and the capacity of the batteries, assuming they had been fully charged by the solar panels earlier in the day. However, if the concentrator were to be turned on at 10am when the energy from the solar panels was able to run the concentrator without any contribution from the batteries, then the expected run time would be extended by an additional 7 hours (the 10am to 5pm window).

In the table below we show estimated run times based on three different configurations of solar panels and batteries. We assume a scenario where the concentrator is switched on at 7 AM and the batteries are at 50% charge. We turn the concentrator off when the battery drops to 50% charge leaving adequate capacity to start again at 7am the following day. As the capacity of the solar system grows, the runtime exceeds 24 hours.

7 AM START - EXPECTED RUN TIME (HOURS)

FLOW RATE (LPM)	CONFIGURATION 1 TWO 560 WATT PANELS 5,120 WATT-HOUR BATTERY	CONFIGURATION 2 THREE 560 WATT PANELS 5,120 WATT-HOUR BATTERY	CONFIGURATION 3 FOUR 560 WATT PANELS 7,680 WATT-HOUR BATTERY
2-4	20.6	20.6	25.1
5	20.3	20.3	24.5
6	19.5	19.2	23.1
7	18.3	18.2	21.3
8	15.5	17.3	20.9
9	13.3	16.5	18.8
10	11.2	15.9	17.8

We can see from Configuration 3 that it's possible to run the PulmO2 continuously at flow rates in the range of 2 - 5 lpm. This can be achieved at higher flow rates by adding additional solar and battery capacity. However, it is important to note that as the performance is highly dependent on the season and climatic conditions during the day, it is not possible to give a definitive runtime.

STEP 4 Final Considerations for your Solar Installation

While we have covered the three main components required to get your PulmO2 operating using solar energy, there will be other costs.

For best performance, panels should be installed in areas that remain unshaded through the day. This can be a designated area next to the building where the solar panels can be mounted on the ground or can be on the roof of the building. When located on the ground they are more susceptible to theft and may need to be enclosed within a fence. Either way, mounting brackets will be required and must be budgeted for.

To maximize the efficiency of energy transfer between the solar panels, batteries and inverter, heavy duty wires must be used. The gauge of the wire can be calculated based on the capacity of the solar system and the distance between the system components. Additionally, fuses are essential to provide a safe installation.

Finally, while we hope that this guide has given you a deeper understanding of how all the pieces fit together, for safety reasons we recommend that installation should be done by an experienced professional.