

Sunsail: A Solar-Electric Vessel Feasibility Experiment

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This solar-electrically powered boat was designed and built to determine if a recreational vessel could be run exclusively on solar power, without any fuel or recharging connection to the power grid. I also wanted to build a boat that was quiet for fishing, stable in waves, unswampable, and straight tracking in the water. The boat was to require minimal maintenance, but did not have to go particularly fast. The primary uses were to be casual cruising and fishing.

Planing hulls, although well known for their speed when on plane, consume a large amount of energy. They are basically using lift and displacement principles to lift a boat out of the water to reduce drag and shed the speed-limiting wake behind the boat. Displacement hulls are limited in speed by the wake they produce (the harder you push a displacement hull, the taller the wake from which they must climb). When moving through water below their theoretical limiting speed, they operate quite efficiently. Most sailboats have displacement hulls, and are, of course, driven by the wind, another form of solar energy. Since a solar-electric boat has a limited immediate supply of energy, a displacement hull was chosen. The hulls selected are normally used on a SeaCycle, a pedal-powered, propeller-driven recreational vessel. The hulls are long enough for adequate speed and buoyant enough to carry some serious weight.

This project involved researching some hull choices, writing a mathematical computer simulation model of the boat, designing a deck and support system that was light but very strong and rugged, and ensuring that there were redundant control elements to enhance operator safety. And of course, a lot of construction time.

There are two separate methods of steering the boat. The rudder is the primary steering control, and the boat responds quickly to even small changes in the rudder position. The rudder is designed to swivel up out of the way in the event an underwater obstruction is accidentally hit, and gravity allows it to swing back into place once the obstruction is cleared. There is very little free play in the rudder control system. A one-millimeter (dime thickness) change in the rudder handle results in a noticeable course change. In the event of a total rudder failure, redundant steering is provided by swivelling the front-mounted drive motor to redirect the thrust.

There are two separate sources of power on the boat: the solar panels, and the deep-cycle battery. Normally, the solar panels charge the battery through a charge controller. During operation, if the motor is throttled to a low setting and the sun is shining, the solar panels provide all the electricity that the motor is using, and anything that is leftover is used to maintain the battery reserves. If a cloud passes overhead, the battery supplies the power to keep the boat running. On a bright sunny day with light winds, the solar panel can supply all the power the boat needs for normal trolling or casting fishing without borrowing any power from the battery. If any of the battery reserves are used during the day, the solar panels continue to recharge the battery when the boat is parked in a suitable, sunny location. A fully discharged battery can be fully recharged in two bright sunny days of idle storage. Thus, any use of the battery reserves is still using solar energy. A battery is just a

storage bank for energy, and all the energy in the battery originated from the solar panels. In the event of a total battery failure or discharge, the system can be reconfigured on the water to run the motor exclusively from the solar panels. The boat is not currently equipped to legally operate at night, however it is capable through the use of the energy stored in the battery.

The hulls are closed from the environment, rendering the boat unswampable. A large wave can safely break over the deck, and there is no place for the water to accumulate or swamp the boat. The hulls are spaced far apart to provide a large deck area and a very flat, stable ride. A seatbelt is provided for safety when crossing laterally through rough waters. The boat easily handles three-foot waves.

A center-off polarity reversing switch is attached to the port side of the seat and storage box. This switch allows the motor to be quickly turned off or reversed. Not all trolling motors allow reversing their polarity as the newer motors have throttle electronics that do not tolerate reversed polarity. The motor was deliberately mounted forward of the rider to provide superior tracking, redundant steering, and throttle control access. As any boat owner knows a trailer tracks straight when pulled by the tongue, but jackknifes when pushed backwards. Boats behave in the same manner. A front-pulled boat tracks straighter than a stern-pushed boat.

The charge controller is a *Flexcharge*® USA two-point switching relay-operated controller. When a somewhat discharged battery drops below 13.4 volts, the solar panels are connected to the battery. When the voltage rises up to 14.4 volts, the solar panels are disconnected from the battery. Once the battery becomes fully charged, and the panels are exposed to almost any level of light, the solar controller will occasionally briefly pulse the battery with a short burst of power to bring the battery up to 14.6 volts, then disconnect from the battery. This taper charges the batteries to full capacity, prevents overcharging, provides equalization to prolong battery life, and minimizes electrolysis loss of battery water.

The boat design provides a stable, comfortable, quiet ride, with excellent steering and control characteristics. The boat costs nothing to run, except for a new battery every 5 years or so (estimated), is environmentally friendly, and provides a shaded riding area for those hot summer days. The rider might not enjoy being in the sun on a hot summer day, but the boat loves it, and rewards the rider with a shady spot to sit and enjoy a free ride. You don't water ski behind this boat, but it sure is fun to use and doesn't drain your wallet.

Parameter	Specification
Maximum speed in No Wind	4 knots (4.6 mph, 7.4 km/h)
Solar panels	Two 100-Watt Siemens monocrystalline panels
Total solar wattage (rated)	200 Watts at 1 standard sol (sunpower)
Solar panel current total	11.8 Amps
Battery capacity	105 Ampere-hours
Motor	Minnkota Enduro 30 (30 pounds thrust maximum)
Motor current at throttle 1	6
Motor current at throttle 2	7
Motor current at throttle 3	9
Motor current at throttle 4	15
Motor current at throttle 5	25
Normal trolling throttle	position 3
Normal trolling speed	1.8 knots (2.07 mph, 3.33 km/h)
Maximum head wind capability	20 knots (23 mph, 37 km/h)
Cloudy day trolling duration	9 hours
Boat weight	342 lbs (155 kg)
Boat carrying capacity	550 lbs (249 kg)
Smallest turning diameter	50 feet (15 meters)
Materials cost including trailer	\$3400 U.S.
Construction time	100 hours
Mileage this season	330 miles (531 km)