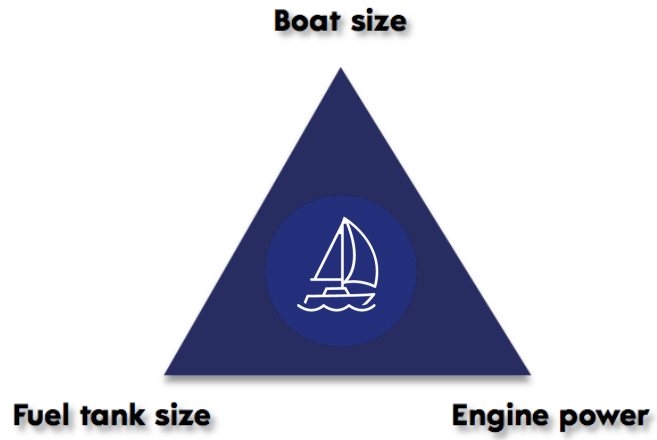
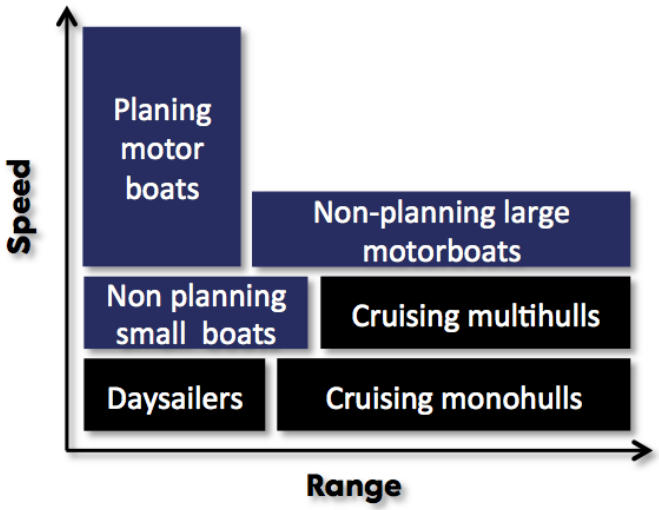
Range - The basics



The range of an electrical or hybrid powered boat is determined by the same rules and principles that apply to a boat that has a diesel engine. These are the size and weight of the boat, which governs the resistance or drag it creates in the water. Then the size of the motor, or more specifically the power, which dictates how fast the boat can move. And the fuel tank(s) or battery packs.

All of these affect each other and usually finding the right balance is the recipe for a boat with good motoring capabilities. It's a question of having the right size engine and fuel tank for a certain sized boat. If the engine is too big, it adds unnecessary weight and uses an un-economical amount of fuel, which leads to a shorter range or having to add more fuel that negates the effects of the larger engine.



Boating people have grown to be accustomed to expect and accept certain performance envelopes and limitations from boats. People await to be able to motor 60-100nm on a high power planing motorboat, four hours at high throttle. But would accept that on a daysailer with an outboard and a 15l portable fuel tank you would maybe be able to motor 30nm - six hours at five knots. The type of boat, its size, engine power and fuel tank capacity dictate all of this.

For a boat with electric propulsion the basic principles are exactly the same. The power of the motor is typically stated in kilowatts (kW) and the size of the fuel tank is expressed either in kilowatt-hours (kWh) or amps and ampere-hours instead of horsepower and liters.

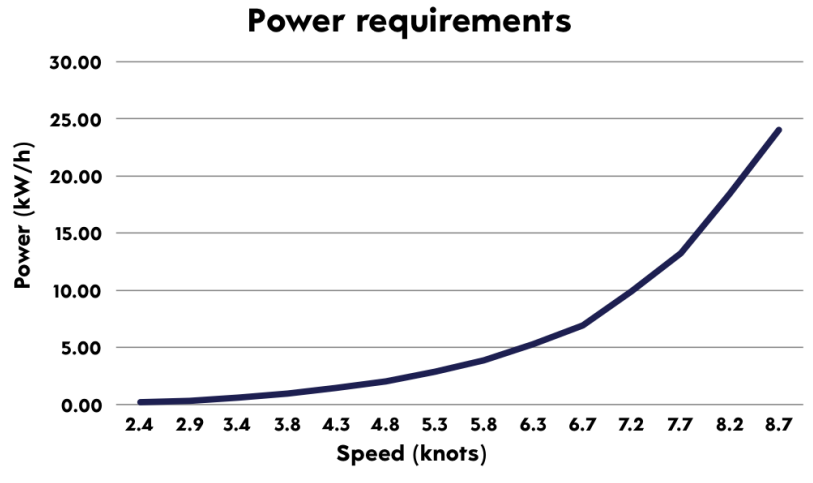
To be objective in this white paper, we first have to accept some facts. One fact is that a liquefied fossil fuel (gasoline, diesel or liquefied gas like propane or LNG) is an extremely efficient way to store energy in a compact form. The amount of energy stored in a kilogram of diesel fuel is 35800KJ compared to a standard marine lithium battery which would be able to house anywhere between 900 to 2630 KJ/kg. The drawback of this is that burning one kilogram of diesel fuel has a significant environmental effect, while you can charge the lithium battery thousands of times.

The key benefit of the battery pack is that it can be charged with a renewable energy source onboard like solar panels, a wind generator or if a modern electric motor is used then by using the motor as a generator while sailing. This enables an energy autonomous operation of the boat in suitable conditions. And when the boat is in a harbour the batteries can be charged from the shore power rapidly.

Again, to be objective we must accept that a pure electric boat has range limitations. This is determined by the size of the battery pack, which is economical to carry onboard in two senses: weight and cost. Typical battery packs installed in today's monohulls are in the range of 6-16kWh. This enables the boat to motor 4-10h at an average speed of 4-7kts. Meaning that a boat will have a practical range of 30-40 nautical miles with battery power alone. The attached graphs explain this in more detail.

You have probably at some time in your life rode a bicycle. Notice how after a certain speed pushing even a little bit more requires significantly more energy than the relative speed gain? That's because the resistance of the bike to airflow builds at a square of the speed. The exact same principle applies to a boat in the water. The graphs represent a typical sailboat that is 10m long, 3.3m wide and weighs 5000kg. The equations are standard marine engineering calculations and have nothing to do with electric or hybrid power; they will also apply for a diesel engine or an outboard.

As the "Power requirements" chart shows, when the hull speed is around 7 knots, it requires 8 kW of power to move the boat and a very economic speed is somewhere around 5 knots where you need 2 kW to move the boat in flat water. The increase of power from 5 kW to 10 kW only yields a knot of more boat speed and the next 5 kW increment only 0,5 knots.



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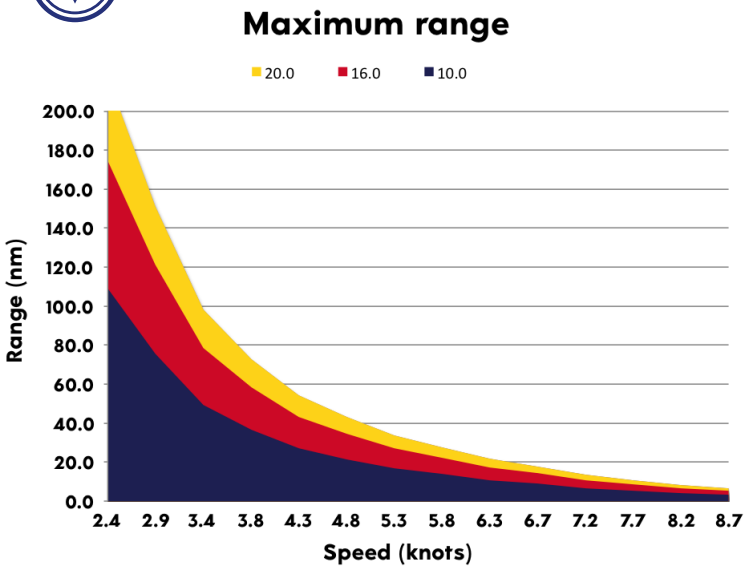
This brings us to the discussion of range. On the "Range" chart you will see range calculations with three different battery pack sizes for the same boat. You witness the same effect of resistance building up when speed grows, this of course means that with less speed you have less resistance and you have longer range.



There are two ways to gain more range in a boat. You must stop and charge the batteries. Or you must go for a hybrid solution. Meaning that you must have an alternative source of generating power onboard.

Today, the only real alternative source of generating enough power (for example 2 kW) to enable you to motor 400 nautical miles if you are stuck in middle of a massive high-pressure system is to have a generator onboard. You might rightfully ask, doesn't this defeat the whole purpose of going electric in the first place? The answer however is not that simple. First we must take into account the usual usage profile of a boat. Most boat owners motor in and out of the marina using the engines maybe 0.5-1 hour before setting sail. If the wind calms they might motor 4h back to a marina. This is not an issue for an electric motor and any size battery pack. They use the engines for extended periods only in calm seas when sailing is impossible. Or in some special circumstance where sailing for some reason is not a practical solution to get to the direction they're heading. In these circumstances using the generator is the only solution. The second thing to understand is that a modern marine generator is not some horrible noisy, large bulky thing. They are engineered to be lightweight, compact and very silent. A typical marine DC generator will produce about 60dB (equal to the noise level of a normal conversation) at a 1 meter distance without any sound insulation.

Small portable 2kW Honda EU 20i generator

A fully automatic 10kW DC generator

A key driver for hybrid yachts is the fact that the generator is much more fuel efficient than a diesel engine. Fuel efficiency comes from the fact that the generator is built to operate at an optimum 2800-3200 RPM range. A diesel engine in a boat usually runs at 1500-1800 RPM, which is a very inefficient operating speed for a diesel motor. In a typical real-life scenario, owners notice that they are able to motor roughly three times further with the same amount of fuel, when using the generator and electric engines, compared to only diesels. This is exactly the same principle that is applied in today's shipping industry – all modern ships have diesel generators powering electric engines due to this efficiency gain.