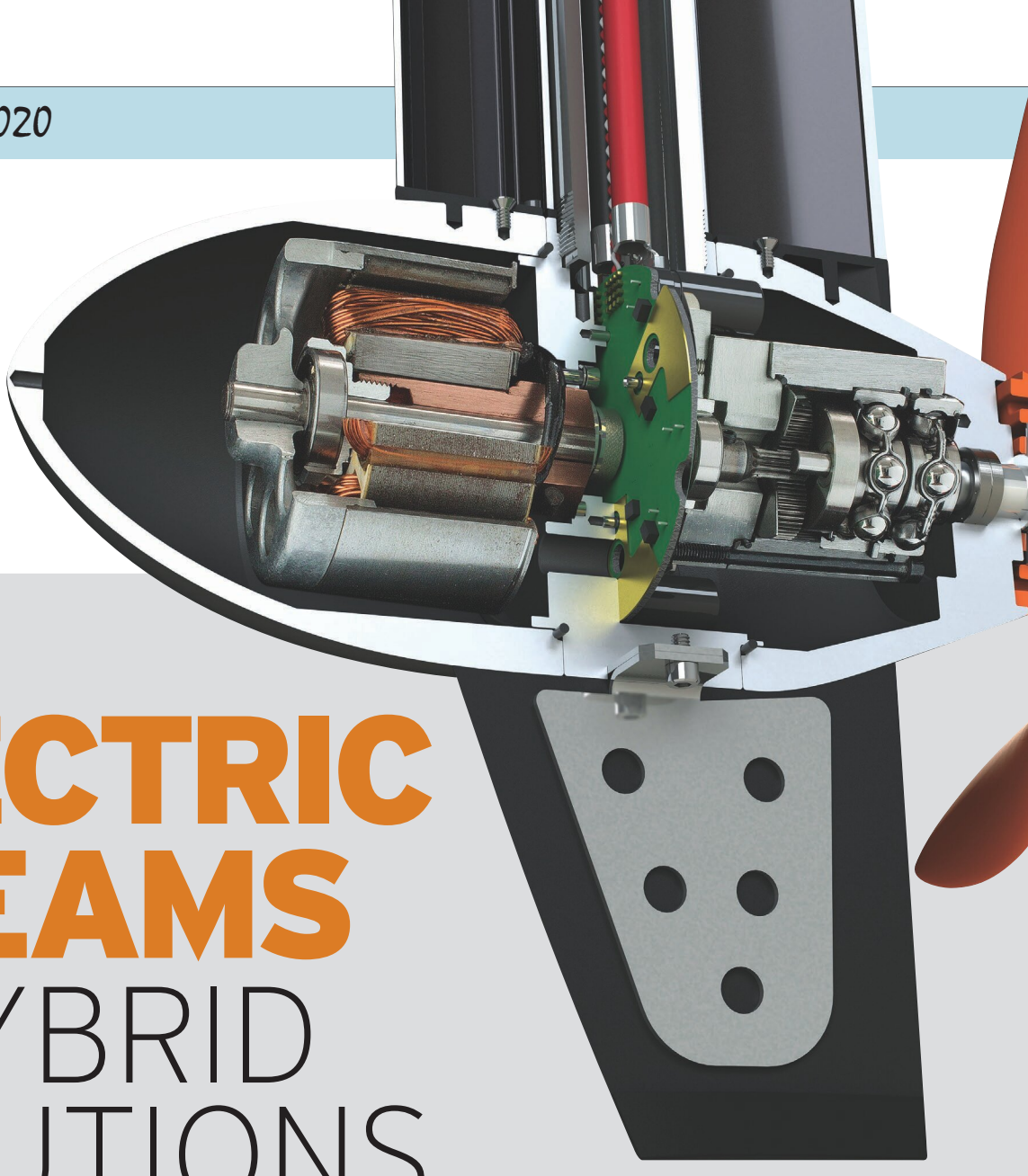
Interested in plugging into the growing world of electric and hybrid-powered boats? Here's how they work, their benefits, and limitations

BY [redacted]



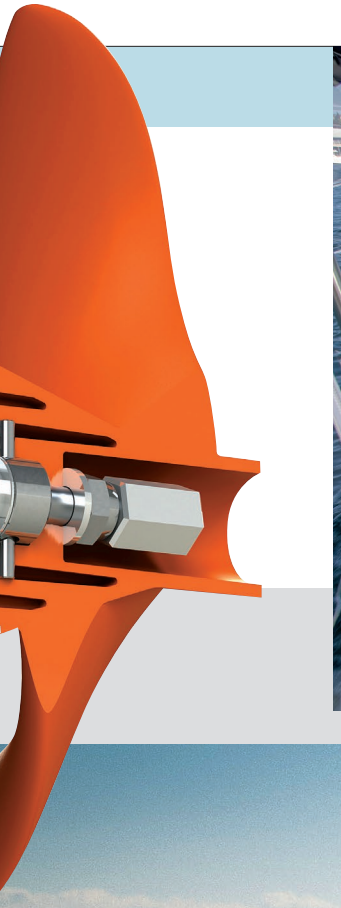
ELECTRIC DREAMS & HYBRID SOLUTIONS

Cross section of a Torqeedo electric outboard motor, which incorporates brushless external rotor motors with rare-earth magnets

Just as electric and hybrid cars are increasingly common on highways, electric and hybrid boats are beginning to make a ripple on cruising grounds across North America. Electric remains a small but growing niche in recreational boating. It's not for everyone, but for certain boaters on certain cruising grounds, electric provides a rewarding addition to their lifestyle.

In this special section, our [redacted] takes a deep dive into the subjec o e ec r c oa s o earn w ere e technology stands and when we can expect electric boats to become more mainstream.

1. The sweet sound of silence – Who's going electric?
2. How does electric propulsion technology work aboard a boat?
3. Hybrids combine electric with traditional propulsion
4. Advancements in batteries



Top: The 100% electric Duffy 22-foot Sun Cruiser can cruise for 12.5 hours and accommodate 12 adults, plenty of time and space for sundowners. Left: From Germany, Frauscher Shipyard's all-electric 740 Mirage Air, powered by Torqeedo's Deep Blue 110 kW motor, will silently glide at 6 mph for more than 10 hours.

The sweet sound of silence

Meet the boaters across America who decided to switch to electric propulsion, and learn why they made the leap

Gregory Grande at the helm of his 1974 Penn Yan (above) after he removed its old gas engine system for 100% electric power.

When Gregory Grande plans to go boating on a Saturday, he plugs in his 1970s-era powerboat the night before. The next morning, he and his partner, Sue, launch at Bigelow Hollow, a state park in Union, Connecticut. Grande starts the motor. The only sound: the clicking of the key in the ignition. Cruising at just under 10 knots, they chat without having to shout over engine noise as they explore pristine islands and alcoves, seeking out the perfect picnic spot in the sun. Far from being fringe hobbyists, Gregory and Sue are part of an electric-boat movement gaining momentum across the country.

In California, Duffy Electric Boats devotees congregate in Newport Beach for rallies and on-the-water scavenger hunts. At the 2019 Lake of the Ozarks Shootout, a massive annual powerboat race in Missouri, a stock Canadian Electric Boat Volt 180 set an unofficial speed record by clocking 30 mph. Meanwhile in Florida, visiting boaters, hoping to spot a manatee, peacefully explore the wildlife of the Intracoastal Waterway in silence aboard rental electric boats.

What types of boats are going electric?

Christoph Ballin is co-founder and CEO of Torqeedo, a German manufacturer that debuted a small outboard in 2005 and now produces electric outboard, inboard, pod, sail, and hybrid drive systems, offered around the world.

Ballin estimates that close to 2% of recreational boats are electric, with the greatest adoption in tenders, daysailers, and boats on "green lakes," where combustion engines are forbidden. He also sees great potential for electric on larger sailboats, "My target is that in 10 to 15 years, [combustion engines] will be the exception on sailing yachts."

It's not just dinghies and sailboats that are going electric, though. Some luxury yachts now have hybrid propulsion. Greenline Hybrid Yachts, a Slovenian manufacturer, launched the first serial production hybrid boat in 2008 and has since produced 450 of them – a model line now ranging from 33 to 65 feet – making it the largest hybrid fleet in the world.

While there are several electric planing boats on the market, they all have less than an hour of range at planing speeds. "Generally, anything planing is comparatively more difficult because you need substantial power and very low weight," Ballin says.

More difficult still are water sport boats, bass boats, and offshore fishing center-consoles. These power-hungry applications demand 100s of horsepower, far surpassing the abilities of production electric engines on the market today – though there are signs this is about to

change, with an electric watersports boat introduced at the 2020 Miami Boat Show.

Correct Craft (parent company to Nautique, Centurion, and SeaArk Boats, among others) launched Watershed Innovation in 2018 as an innovation lab focused on identifying, researching, developing, and integrating rapidly developing technologies for the marine industry. One project coming to fruition is an electric watersports boat powered by Ingenity (a Watershed Innovation company). The electric Super Air Nautique GS22 debuted with a whopping 150 kW (201-hp equivalent claimed) motor and 124 kWh lithium-ion battery pack. According to Sean Marrero, president of Watershed Innovation and chief strategy officer at Correct Craft, the GS22 provides "two to three hours of normal water sports activity," which includes multiple rides and time spent transitioning between riders at the dock.

Repowering with electric

Across the country, some boaters are choosing to haul out their old diesels and replace them with soundless electric motors. For some, it's about the peaceful aesthetic. Steve Lamando, CEO of Elco Motor Yachts, which began building electric motors in the 1890s, says he's seen an increase in electric repowers on restored sail and power classics as well as club-racer sailboats. For cost-savvy DIYers, an electric repower might even make economic sense.

Ted Wohlsen, who sails in Great Kills National Park on New York's Staten Island, refit his 1986 Catalina 30 with a 10 kW motor he bought from Thunderstruck-EV, an electric-drive technology research, development, and manufacturing company in Santa Rosa, California. "The install was super easy, and I spent about $8,000 including solar panels," he says. "The hardest part was getting the old diesel out!"

Bob Jennings, a New-Hampshire based sailor, repowered his 1980 Sabre 28 with a motor he, too, bought from Thunderstruck-EV. "In my opinion this has nothing to do with being green," he says. "It just has to do with trying not to use fossil fuels." He estimates that his install, including batteries and solar panels, cost him the same as a conventional install, "I could have bought a 14-horse engine for what I've invested in it."

When Grande, of Connecticut, discovered his 1974 Penn Yan had a cracked head gasket, he opted to repower the boat with electric for $4,000, a fraction of the cost of a conventional installation. After months of hard restoration work in the barn, he launched his beautiful electric picnic boat in September.

"We have cocktails, sit and talk, go out with a kid or two, whoever wants to come. We just enjoy it." At the end of the evening, if it isn't going to rain, Grande will bring an extension cord out from the barn and plug in. The next morning, he's ready for another day of electric boating.

THE INSTALL WAS SUPER EASY, AND I SPENT ABOUT $8,000 INCLUDING SOLAR PANELS. THE HARDEST PART WAS GETTING THE OLD DIESEL OUT!

– Ted Wohlsen, 1986 Catalina 30

Ted Wohlsen (left) of New York glides silently through the water aboard his 1986 Catalina 30 (above), which he repowered himself with a 10 kW motor.

How does the technology work?

An electric motor may seem like complex technology, but it's actually mechanically simpler than a combustion engine

Far from being futuristic, electric propulsion is in fact 19th century news. In 1893, Elco provided dozens of 34-foot electric boats to carry more than a million passengers at the Chicago World's Fair. This was revolutionary technology that enthralled fair-goers and set off a mini boom that counted inventors Henry Ford and Thomas Edison as owners of Elco electric motor launches.

How it works

As anyone who's spent time in an engine room can attest, combustion engines generate a lot of heat and noise. "The overall efficiency of a gas outboard is in the ballpark of 5% to 15%," says Christoph Ballin, Torqeedo CEO and co-founder. "So 85% to 95% of the fuel you put in is lost in the process, and only 5% to 15% drives your boat." Torqeedo's electric outboards, by comparison, using Ballin's estimates, would be about 44% to 56% efficient.

The "magic" behind electric motors, is magnetism. Inside an electric motor, magnets attract and repel, creating a rotation to turn the drive shaft. This relatively frictionless rotation means less energy loss to heat and noise. In addition, electric drive trains are highly efficient. High-torque and low-rotational speeds make it possible to use large-diameter, high-pitched propellers, which lessen losses to cavitation.

In practice

Today, most electric motors are available in the 5- to 100 kW (6.5- to 135-hp equivalent) range. It's not just about increasing power, though; these motors are smarter. Electric trolling motors, a staple among shallow-water anglers who don't want to spook the fish, have begun to look more like computers than outboards, offering features like chartplotter connectivity, sonar, and GPS anchoring. Examples include the new Garmin Force and Lowrance Ghost.

U.S. SALES OF ELECTRIC OUTBOARDS WILL GROW FROM $63 MILLION IN 2019 TO $120 MILLION IN 2024

Let's look at some pros and cons:

PROS

>> **The sound of silence** Described as similar to the experience of sailing, e-propulsion is completely silent.

>> **Instant torque** Electric motors can provide instant torque, meaning more maneuverability and more consistent speeds in heavy seas and headwinds.

>> **Low weight** An installation of an electric motor, batteries, and generator can weigh 20% to 30% less than the diesel it replaces.

>> **Low fuel costs** Plugging in an electric boat may cost only a couple of dollars per charge, while alternative energy sources like solar, wind, and hydro regeneration make it possible to charge even more inexpensively (once you've made the initial investment in solar panels or a windvane).

>> **Waterproof** Torqeedo's outboards and batteries can be immersed at a depth of 1 meter (3.3 feet) for up to 30 minutes without suffering damage.

>> **Maintenance-free** The simplicity of electric motors makes them more reliable, longer-lasting, and lower maintenance. Producing little heat, there's no need for complex cooling systems or fluid changes.

>> **Regenerative power** Electric systems make it possible to harvest propulsion power from renewable sources such as wind, solar, and hydro regeneration.

>> **Lower emissions** Electric motors

eliminate carbon dioxide (CO2), nitrogen oxides (NOx), and hydrocarbon (HC) emissions. They also eliminate carbon monoxide (CO) emissions, a safety concern that spurred boater Joe Grez of Washington to convert his family's 13-foot sailboat to electric and invent the EP Carry, a compact, ultralight electric dinghy outboard.

CONS

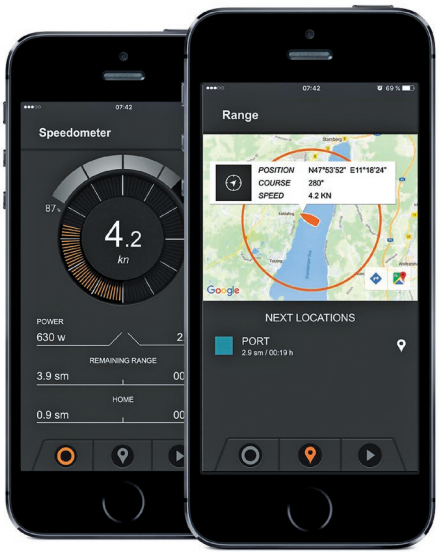
>> Range anxiety The ranges of electric propulsion systems today are being measured in 10s of miles, not 100s of miles. To ease range anxiety, Torqeedo's propulsion systems calculate and display the remaining range in real time on the motor display or smartphone app TorqTrac.

>> Cost Currently, small electric outboards (not including batteries) sell for up to two-and-a-half times the cost of equivalent gas outboards. "Electric is still in its growth stage and hasn't reached scale," says Elco CEO Steve Lamando. "Over time, those prices will come down."

The future

According to the firm Industry Research, a company that tracks emerging technologies, U.S. sales of electric outboard motors will grow from $63 million in 2019 to $120 million in 2024. But predictions for the future are just that – predictions. Just ask Thomas Edison, who declared in 1910, "In 15 years, more electricity will be sold for electric vehicles than for light." That didn't pan out for Edison, who moored his Elco electric boat at his estate in Florida. What he knew was that his innovations were subject to market demand, famously saying, "Anything that won't sell, I don't want to invent."

The same market realities apply today. "While we can develop anything," says Ballin of Torqeedo, "we need to see where the combination of power, speed, range, cost, weight, and volume is feasible in a way that makes electric a proper alternative."



Left: Torqeedo 40 kWh Deep Blue lithium-ion battery (with technology from BMW) offers a 30% increase in energy storage capacity over its predecessor with no increase in size. Above: Torqeedo's TorqTrac app displays the remaining range in real time.

What does that equal in horsepower?

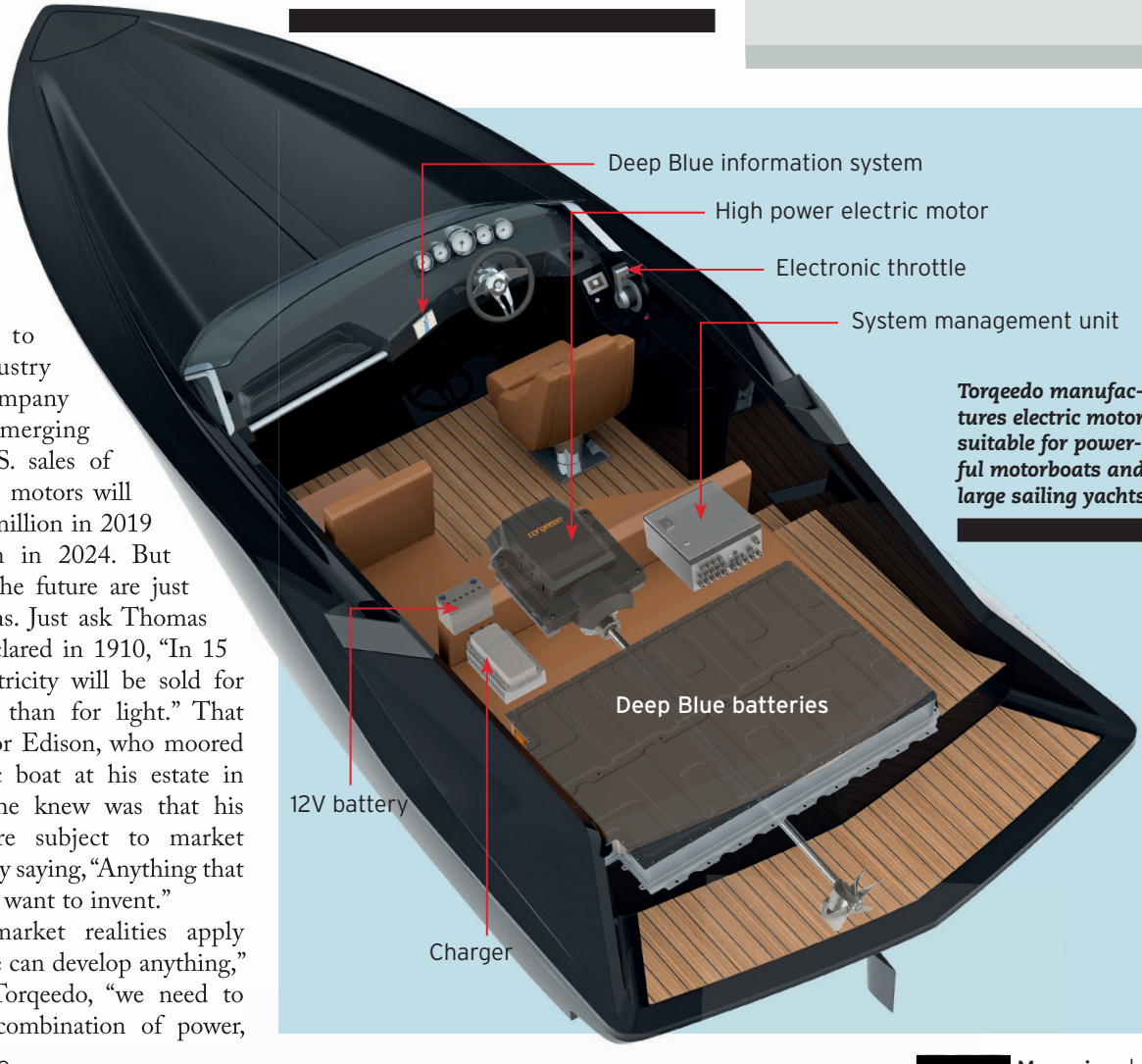
You probably know there is no horsepower to be found in the specs of electric propulsion. But you can calculate a close equation from kilowatts with a basic math formula:

1 kilowatt is equal to 1.3404825737 horsepower
(but 1.34 is close enough)

kW x 1.34 = horsepower equivalent

Example:
Convert 100 kW to horsepower
100 kW x 1.34 = 134 hp

– RICH ARMSTRONG



Torqeedo manufactures electric motors suitable for powerful motorboats and large sailing yachts.

Range anxiety? Hybrid may be the answer

If you can't fully commit to pure electric propulsion, consider the best of both worlds with a hybrid

Combustion engine skippers take comfort in their fuel gauge, watching the little red needle slowly tick down over a hundred or more miles. Electric boats have much shorter ranges, often in the tens of miles. For the electric skipper, this may mean an earlier return to port when a boating day doesn't go quite to plan. They've even coined a term for this unease – "range anxiety," which is the fear that an electric vehicle has insufficient range to reach its destination. This affliction has undoubtedly dampened the enthusiasm of some would-be electric boaters.

And, it's not purely psychological. One [redacted] member described calling Tow[redacted] after his electric boat ran out o[redacted] power. The most promising tonic for range-related malaise? A good dose of hybrid power.

How it works

A hybrid combines an electric motor and combustion engine to propel a boat through the water, so you can quietly cruise knowing you've got fuel to get home if you drain the batteries. As with cars, there are two common types: parallel and serial.

A serial hybrid uses a generator to power a large electric motor connected to the drive shaft. Once the batteries have drawn down, range can be extended by using an electric generator to power propulsion. In the automotive world, the Chevy Volt is one of the few examples of a serial hybrid.

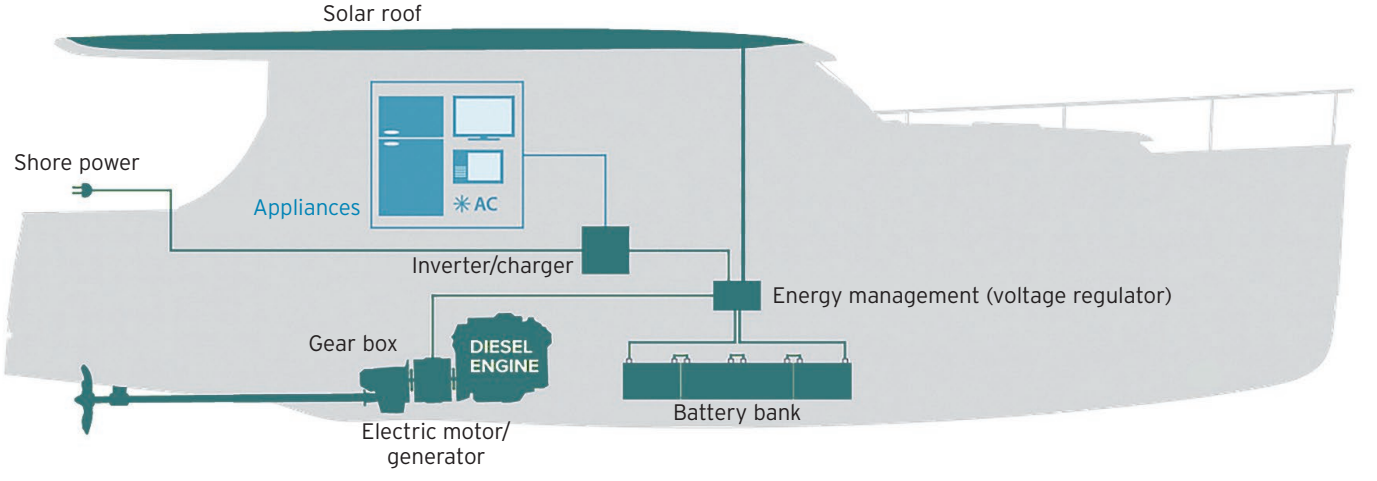
A parallel hybrid has both a conventional combustion engine and an additional small electric motor operating in parallel on the same drive shaft. A clutch enables switching between the electric motor and combustion engine for propulsion. Parallel hybrids have seen great uptake with auto manufacturers; the best-known example is the Toyota Prius.

Choosing a system is what Nigel Calder, one of the world's leading experts on marine hybrid technology, calls a "complex calculation."

FOR THE RANGE ANXIOUS, HYBRIDS [redacted] OFFER THE BEST OF BOTH WORLDS – EXTENDED RANGE, LOWER EMISSIONS, AND LOWER FUEL COSTS

"In a serial system, energy takes a less direct route than in a conventional diesel system, and as it flows from the generator to the motor controller to the electric motor to the propeller, energy is lost through heat dissipation," Calder says. He explains the core problem with serial hybrids is that if you run out of battery power while at cruising speeds and have to crank the generator, the system will be less efficient than a well-optimized inboard engine.

HOW HYBRID WORKS



Greenline Yachts are built with either E-Drive (all electric) or this hybrid H-Drive system. Depending on the operations mode – shore power charging, diesel drive charging, solar panel charging, or electric drive propulsion – various components will draw or deliver power to the systems in use. Shore power charges the batteries at the dock, while the diesel engine charges them while underway. Solar roof panels continuously charge the system. In electric drive mode, propulsion is provided by the electric motor powered by the battery. At 4 to 5 knots a fully charged battery pack typically provides a range up to 20 miles. All it takes is a flip of a switch to turn a diesel-driven boat into full electric and back.

Calder says that a serial system is good for boats that can "get most of [their] propulsion energy from non-fossil fuel sources." A sailing catamaran is a good example. But what if you regularly want to motor for more than two hours or can't generate power on the go?

"The moment you get into an application where you have to run the generator for long hours, frankly [a serial hybrid] doesn't make a lot of sense," says Calder. "The analogy here is a Chevy Volt, which has a range under battery power of maybe 40 miles. If your daily commute is less than this, all driving can be done under electric power (with recharging at work or at home). If you decide to drive across country, after the first hour or two when the generator has to kick in, you are less efficient than a conventional Chevy, diluting the benefits of the electric propulsion."

For that scenario he suggests a parallel hybrid, which at cruising speeds under fuel power, will deliver the same efficiency as a conventional system. "The bottom line is for any boat that requires sustained propulsion on a regular basis, a parallel system makes more sense than a serial system."

In a parallel system, he explains, the electric "machine" (which also doubles as a generator) is an adjunct to the propulsion engine, so it only needs to be powerful enough to handle light propulsion loads. When the engine is running, the motor switches to generator mode, so in sizing the system, the designer also has to make sure it is powerful enough to meet the "house" generating needs.

In practice

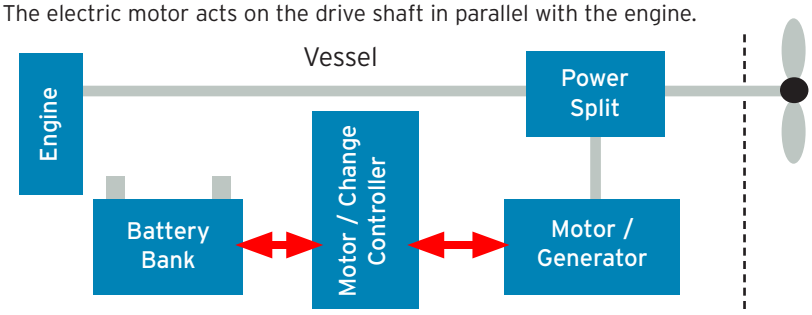
Are hybrids ready for prime time? In a word, "Yes," says Calder, who receives e-mails from boaters asking for recommendations.

For a parallel system, he suggests Hybrid Marine Ltd. systems (Beta, John Deere, and Yanmar all have hybrids that incorporate Hybrid Marine Ltd. technology). Leaders in serial systems include Torqeedo and Oceanvolt.

Hybrid boats can also be bought right off the production line. Greenline Yachts offers a hybrid-drive option in its range of 33- to 65-foot yachts.

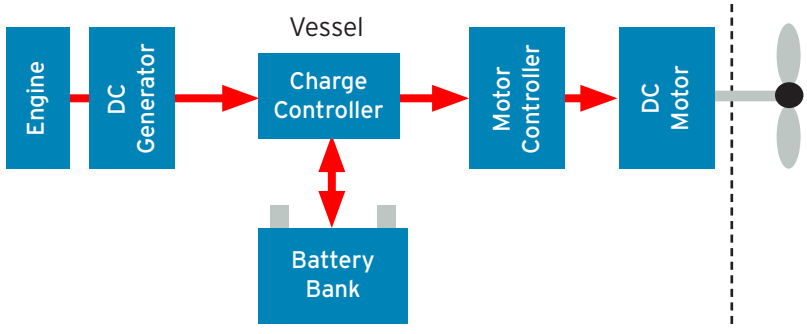
Parallel Hybrid

A parallel hybrid maintains the mechanical connection between engine and prop shaft. The electric motor acts on the drive shaft in parallel with the engine.



Serial Hybrid

The serial hybrid breaks the mechanical connection between the engine and propeller shaft. The only thing attached to the propeller shaft is the electric motor.



PROS

>> **All the benefits of electric, but with range** For the range-anxious, hybrids may offer the best of both worlds – extended range and lower emissions and fuel costs.

>> **Additional onboard luxuries** Fancy overnight air-conditioning? Hybrids offer huge efficiencies in supplying house power. "On many boats, you can improve the [house load] fuel efficiency by as much as 500%," Calder says.

CONS

>> **Added complexity** "To fully optimize a parallel hybrid, you need some pretty sophisticated software to switch backward and forward between the diesel and electric motor, like a Toyota Prius," Calder says, "and that's a really complex system."

The cost

The economics of a hybrid system depend on how you use your boat. "If you want to run air conditioning all night, you're going to have to buy large battery banks, in which case the cost of a conventional fossil-fuel system is going to approach that of some hybrids," says Calder. On the other hand, "If you are just looking at propulsion, it's simply not feasible to get more than an hour or two under battery power on most boat hulls. Then you crank an engine and the system doesn't look any better than a standard conventional installation – it just costs you a whole lot more."

The future

Hybrid Marine Ltd. is in the process of expanding its parallel systems to a broader range of engines (10- to 230 hp) in addition to working on a "Multimode Hybrid," a system that combines the advantages of series and parallel hybrids. Torqeedo currently makes hybrid systems for yachts in the 50- to 100-foot range, and will be increasing its hybrid offerings for 30- to 50-footers.

Hybrid development is expected to deliver increasingly sophisticated and efficient systems over the years and become available and practical for a wider range of applications. For some, hybrid technology may prove to be the panacea for all range-related worries.

Charging ahead

Speed into the future by swapping those familiar heavy lead-acid batteries for lightweight and efficient lithium-ion

Candela Speed Boat in Sweden recently launched the first production electric foiling powerboat that uses about 75% less energy than other electric boats and can cover four times the range of an equivalent e-boat. Right: This J/88 is powered by Oceanvolt's SEA system that generates power from both solar panels integrated into the mainsail and "hydro regeneration capabilities," meaning that you can create energy back to the batteries while sailing using the folding propeller mounted on the saildrive.

If there's one thing that the electric boating revolution hinges upon, it's battery energy density. There's currently no battery pack that can provide the same amount of energy as an equivalently sized and weighted tank of gas. This is why electric boats have shorter ranges. Christoph Ballin, Torqeedo co-founder and CEO, explains that the available energy in a pound of gasoline is approximately 100 times the available energy in a pound of lithium-ion battery. But, fortunately, a small electric outboard might be "10 times more efficient," says Ballin, "which shrinks the comparative disadvantage of electric down to 10:1." Though Ballin noted these numbers can differ depending on the type of motor.

Until batteries can provide similar amounts of power per pound as gas, electric boats will have more limited run times.

How it works

A lithium-ion battery has a positive electrode made from a lithium chemical compound and a negative electrode made from carbon. When charging, the positive electrode gives up its lithium ions through the electrolyte to the negative electrode. When discharging, the process is reversed. A lithium-ion battery has positive and negative electrodes which function in a similar fashion during charges and discharges as in a lead-acid battery. What is different is the materials from which these are made and the resulting performance. There are two common chemistries in marine applications: lithium iron phosphate (LFP) and lithium nickel manganese cobalt (NMC). Each chemistry offers different characteristics that impact their lifespan, performance, and thermal stability.

In practice

To those eager DIYers hoping to swap out lead-acid for lithium-ion, Nigel Calder, the noted marine author and a leading expert in onboard systems, says, "You can't just pull out a lead-acid battery and expect to drop in a lithium-ion battery in its place. You have to look at a lithium-ion battery as part of an energy storage system." He continues, "It needs to be integrated with the charging devices, and you need more sensors in the system and more control over it than you do with lead-acid." (See "Is lithium-ion safe on a boat?" on page 63.)

Calder has two criteria for lithium-ion on his boat. "The first is that the battery has passed really abusive and aggressive third-party testing," with his preferred standard being UL1973. Alternately, he'd look for a battery that "comes from a brand with extensive experience in the marine world such as Victron, MasterVolt, or Torqeedo."

Pros and cons

While it's possible to run an electric motor on a lead-acid battery the arguments for lithium-ion are its energy capacity, flexible recharging, and long life expectancy.

PROS

>> Increased capacity "In practice, the usable capacity [of lithium-ion] is about 70%, which is double what you can get out of a lead-acid battery," says Calder. It's possible to have half as many batteries (and a quarter of the weight) and get the same amount of energy per cycle.

>> Flexible recharging "You can recharge a lithium-ion battery rapidly to close to 100% state of charge, whereas the charge rate of lead-acid tapers off dramatically above 60%," says Calder.

>> Improved life span Some lithium-ion batteries are rated from 2,500 to 5,000 cycles, giving them a longer life expectancy than conventional lead-acid batteries.

>> No maintenance Unlike flooded lead-acid batteries, lithium-ion batteries don't need to be watered and are virtually maintenance-free.

CONS

>> Temperature sensitive "They are very temperature sensitive," says Calder, "You can't charge them much above 45 C (113 F), and they don't like to be charged at much below 0 C (32 F)."

>> Manufacturing and disposal envi-

ronmental impacts Manufacturing lithium-ion batteries is more energy intensive than lead-acid, and almost none of the materials are currently economically recycled.

The cost

Lithium-ion batteries cost two to four times more up front than an equivalently sized lead-acid battery. While prices are predicted to fall 50% by 2030 in the automotive industry, Calder cautioned that prices might not decline as quickly in boating. "The automotive world is soaking up all the capacity for lithium-ion batteries so [recreational boating] gets what's left over. Then we have to assemble the batteries and put a fairly complicated battery management system on it to make it safe on a boat," he says, adding, "I don't think the cost is likely to fall dramatically anytime in the next few years."

The future

Despite all of its merits, a lithium-ion battery remains effectively 10 times less energy dense than fuel. That's not to say there's no potential for breakthroughs, however. Every few weeks new discoveries and groundbreaking advances are announced.

"In 2019, Elon Musk promised that Tesla would soon have a million-mile battery, more than double the lifespan of Tesla's current battery packs; IBM announced that it had developed a "seawater" battery eliminating the use of heavy metals and reducing flammability; and Trevor Milton told *Forbes* that his company, Nikola, had developed a new type of battery with double the energy density, 40% of the weight, and at half the cost of current lithium-ion batteries.

Only time will tell which of these promising technologies will gain traction, but it's clear the rapid development in the automotive world will spill over into boating. For example, Torqeedo has worked closely with BMW to leverage BMW i8 powers in its propulsion systems. Another auto manufacturer, GM, recently unveiled First, a 200-hp prototype electric pontoon boat at the 2019 Miami International Boat Show.

Some boat manufacturers are tackling the energy density problem by leveraging composite and foiling technology. Think of foils as airplane wings mounted on the hull under water. As water flows over and under the "wings" (also called hydrofoils), it creates lift. Once a boat is going fast enough, the lift created allows the hull to raise above the water – at which point friction only acts on the small foils, not on the whole hull, dramatically increasing speed and energy efficiency.

"With e-foiling boats we can remove the energy density disadvantage." says Ballin. Candela Speed Boat in Sweden recently launched the first production electric foiling powerboat. Gustav Hasselskog, Candela founder and CEO, says that the Candela Seven, "uses somewhere between 75% and 80% less energy than other electric boats." Approximately half of these gains come from weight reduction and half from foils. "So for the same amount of batteries, we get four times the range," says Gustav.

While the energy density disparity looms large, innovations in electric and hybrid propulsion, battery technology, composite, and hull design are incrementally filling the gap. "Right now it's not easy to see, in fact it's impossible, to see how electric will work for many of our boating duty cycles," says Calder, "But when the pressure's on, it will unleash a whole lot of mental energy and we will find ways to do it."

Journalist and [redacted] w er us an , sa e a – oo er rom Canada to Australia.

ELECTRIC BOATING RESOURCES

Learn more about electric boats at PlugBoats.com and the Electric Boats and Electric Ships group on Facebook.

Is lithium-ion safe on a boat?

When lithium-ion batteries fail, the results can be catastrophic. Thermal runaway, a self-heating process that is difficult to stop, can cause the battery to catch fire – a scary prospect, especially on a boat. Fortunately, this risk can be mitigated by using products designed for the marine environment by companies with experience in the marine industry.

Craig Scholten, tech VP, and Brian Goodwin, tech director at ABYC, emphasized that lithium-ion batteries are not a drop-in substitute for lead-acid batteries, "The battery packs available today are being built with automotive parts," says Scholten, "but the confines of a boat's engine compartment are very different from under the hood of a car."

ABYC plans to release guidance on lithium-ion batteries in a technical information report this summer. In the meantime, "there are manufacturers that provide complete solutions, with very robust battery management systems, that can be safely used in the marine environment," says Goodwin. –