

THE CARBON CONUNDRUM

With cars, going green typically means going electric. When it comes to boats, though, there are faster, easier, and more environmentally sustainable ways to reduce our carbon footprint



This Candela hydrofoil lifts the powerboat out of the water at speed, thereby substantially reducing drag and slashing fuel use. Candela, known for innovative hull designs, was founded in 2014 with the goal of creating electric-propelled boats with the range of those with internal combustion engines. It has a new investor: Groupe Beneteau, the world's second-largest builder of recreational boats.

COURTESY, CANDELA

How many hours do you use your boat each year? If the answer is more than 37, congratulations! You've beat the national average. By contrast, today's cars are used daily and travel on average more than 14,000 miles per year in a service life routinely topping 200,000 miles. They both get you from one place to another, but boats are obviously not like cars.

This boating-use statistic emerged during a keynote presentation called "The Carbon Conundrum," [REDACTED] with *Professional BoatBuilder* magazine editor Aaron Porter at the October 2023 International Boatbuilders Exhibition & Conference (IBEX) in Tampa, Florida. Our goal? To address the recreational marine industry's seem-

ingly disjointed stance toward environmental sustainability. Our panel included two cutting-edge yacht designers (one based in North America, one in Europe), a marine-propulsion manufacturer, a director of a marine-industry association, as well as a room full of hands-on experts who wrestle with these questions every day.

Sustainability or schizophrenia?

At its core, "corporate sustainability" means doing business while reducing adverse environmental, social, and economic impacts to ensure long-term viability for future generations, rather than a strictly growth-and-profit-maximization business model. There's a reason why "sustainability" is mentioned in every corporate annual report these days.

"Over the last decade, all major businesses, including Brunswick, have seen a tremendous increase in the focus on corporate sustainability," wrote CEO David Foulkes in Brunswick Corporation's "Sustainability Report 2023." He continued: "Today, comprehensive sustain-

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ability disclosures are an expectation among shareholders, and governments around the world are introducing regulations to mandate management and reporting of corporate sustainability. Brunswick acknowledges the responsibility we hold in continuously enhancing our sustainability programs and caring for our communities and the planet."

Brunswick, the parent company of familiar brands such as Mercury Marine, Boston Whaler, and Sea Ray, is North America's largest marine manufacturer, with net sales of \$6.4 billion in 2023. The company has made environmental responsibility a serious part of its business plan. In 2021 the company published its first sustainability report and appointed its first chief sustainability officer, who reports directly to the CEO. That same year, Brunswick's flagship engine manufacturer, Mercury Marine, introduced the world's first V-12 outboard engine, the gasoline-powered 600-hp Verado. The marketing brochure copy detailed how its "7.6-liter displacement and performance-inspired quad-cam design generates superior torque and acceleration to lift heavy boats on plane and conquer the water with confidence." The brochure shows four V-12 outboards on a center-console boat. ("Quint V-12s" is how Scout describes the five outboards offered on its 530 model; the boat is also available with six.) How big is a 7.6-liter engine? For comparison, the 2023 Dodge Charger, one of the most gas-guzzling cars on the road with its city rating of 12 miles per gallon, is powered by a single 6.2-liter engine.

Performance is a crucial factor in boat design with huge sales appeal. Performance is the thrust that gets a skier up quickly, the range that gets anglers out to the fish when they're biting, the speed that gets cruisers tucked in at their anchorage before sundown. But can an industry that's delivering new boats with 48 (or even 72!) cylinders sending hydrocarbons, carbon dioxide, and carbon monoxide into the atmosphere credibly model environmental sustainability? Are performance and sustainability an irreconcilable zero-sum set? Or can technical innovations crack



Neste claims its MY Renewable Diesel made from cooking oil, animal fat, and food industry waste (left) reduces CO₂ emissions by 75% compared to conventional fossil-based diesel fuel (right).

COURTESY, NESTE

the carbon conundrum for boats as electric propulsion may do for automobiles? Our panelists explored these questions.

Perhaps boats are getting a bad rap?

"One of the challenges the marine industry faces, honestly, is the perception that recreational boating contributes unnecessarily to global climate change," said Jeff Wasil, who oversees environment, health, and safety compliance issues for the National Marine Manufacturers Association. "A lot of this is derived from the conventional carbureted two-strokes of years past where you started up the engine and it was like a tire fire, with the sheen on the water and smoke. Nobody's

THE FACT THAT RECREATIONAL BOATING IS REALLY SMALL DOESN'T GIVE US AN EXCUSE TO STOP WORRYING ABOUT [CO₂ EMISSIONS]

building those products anymore. Today's engines run like sewing machines."

The U.S. transportation sector accounts for 29% of the nation's greenhouse gases emitted into the atmosphere. Of those 1,900 million metric tons of CO₂ discharged from that sector, Wasil said, "recreational boating accounts for 0.7%." This statistic comes from a landmark 2023 report called "Pathways to Propulsion Decarbonisation for the Recreational Marine Industry," sponsored by the International Council

of Marine Industry Associations (ICOMIA), which Wasil chairs.

ICOMIA commissioned global engineering consulting firm Ricardo PLC to conduct independent scientific research and third-party reviewed life-cycle assessments to identify and independently verify suitable propulsion technologies for decarbonizing recreational craft.

"It's the most comprehensive life-cycle assessment of recreational watercraft ever conducted," said Darren Vaux, ICOMIA's president.

"The fact that recreational boating is really small doesn't give us an excuse to stop worrying about this," said Wasil. "Everyone must do their part to minimize CO₂ emissions. But there are a few important differences between what's happening in the automotive industry and boating."

The crucial difference

Carbon footprint is a breezy shorthand for life-cycle assessments, a set of methodologies formally defined under the independent, nongovernmental International Organization for Standardization (ISO), that calculate the entire environmental cost of a given product. With cars, a life-cycle assessment tallies all the processes that go into producing a vehicle – the extraction and shipping of raw materials, the electricity consumed by the factory, the components, the fuel consumed by the car as it runs, the costs of recycling and disposal at the end of the car's life – based on 150,000 miles of use.

If boats are operated only a fraction of the time of cars, and the sustainability calculus focuses on the entire life cycle of the boat, then the actual usage

becomes a much smaller part of the product's total emissions.

"As part of our sustainability initiatives for 2023, Brunswick increased the usage of recycled aluminum in our boats and engines, resulting in a reduction of approximately 48 kilotons of carbon emissions," said Jennifer Koenig, Brunswick's chief sustainability officer.

The fact that Brunswick now accounts for its emissions alongside the other figures you'd expect to see in an annual report truly is a significant change for the better. For its initiatives across all operations, Brunswick was named to *Newsweek*'s inaugural list of "America's Greenest Companies 2024."

For any given boat, its carbon footprint includes how much greenhouse gas is emitted in the production, as well as how much during operation. At first glance, an all-electric boat seems like the greenest choice for reducing carbon emissions. But how green depends on how frequently the boat is used, even if there are zero emissions during operation, set against the cost of building and disposing of it. A complete life-cycle analysis of an electric boat would account for the mining and energy costs to produce lithium-ion batteries that, if your usage is anywhere near the national average, may be far costlier than the carbon emissions

saved from propulsion by a traditional internal-combustion engine. And then there's the physics of a boat underway.

BOAT USE ON THE WATER CONSTITUTES A SMALL FRACTION OF A BOAT'S CARBON FOOTPRINT. FOR ANY GIVEN BOAT, THAT FOOTPRINT MUST INCLUDE GREENHOUSE GAS EMITTED FROM THE PRODUCTION PROCESS ON THE BOAT, ALL GOODS USED, AND THE COST OF DISPOSAL AT ITS END OF USE

No braking, no coasting

A boat takes 10 times more power to move through the water than a car does to travel over pavement, said Jeff Bowles, director of DLBA Naval Architects, based in Chesapeake, Virginia. "That's because water is a thousand times denser than air."

Bowles described the physics of a car accelerating on the freeway, how the driver maximizes the torque by pressing on the accelerator up through the gears.

Today's bottom line

Technological developments in engine efficiencies, hull design, battery storage, and biofuels are now being achieved at impressive speeds. However, at this point, when hydrogen and all-electric power propulsion offerings are compared to boats propelled by traditional internal combustion engines (ICE) running fossil fuels, there are still too many trade-offs to make these options tenable in the recreational boating market. Here are some takeaways distilled from the ICOMIA "Pathways to Propulsion Decarbonisation" report:

Battery electric versus internal combustion engines

► To achieve 14 hours of range (166 nautical miles) with a pure battery system, the boat requires a 360% increase in volume to house the batteries and motor, which will increase vessel displacement by 133%.

► Scaling down the number of batteries proportionally reduces required storage, but also range. For a boat only out for two or three hours, this might be an acceptable trade-off to achieve quiet running.

Hydrogen versus fossil fuel

► To achieve 14 hours of range (166 nautical miles), a hydrogen-powered internal combustion engine would require 430% more volume and increase displacement 56%.

► While the R&D on this technology is impressive, it's not a practical solution for boating in the near term. Among other issues, in its gas form, hydrogen takes up enormous volume requiring special tanks and extra space, it needs to be kept at an extremely low temperature to remain a liquid, and it can be very dangerous. The extra weight of the tanks require structural reinforcements; there is no retrofit option for existing boats.

There's already a leader in the alternative fuels race

► Biofuel is the current hands-down winner in the recreational boat market. Clean, renewable, and around a quarter of the emissions of fossil fuels, it's been tested and determined by the National Marine Manufacturers Association to be safe as a drop-in alternative for existing marine engines. – THE EDITORS

"Once you achieve highway speed, you lift up on the accelerator because a lot less power is required to maintain that speed."

If the car is hybrid-powered, all the better; it has brakes that engage the electric motors, which recharges the battery bank as it slows the vehicle.

"The electric motors become generators. We call that 'energy harvest,'" said Bowles. Powerboats don't have that scenario.

"On a boat, you push the throttle down and slowly accelerate. Sometimes it's questionable whether you'll get over the hump and on plane. When you finally achieve cruising speed, you leave the throttle at 85%, sucking down fuel. The engine never unloads and can't go through the hybrid cycle, where a bit of electric boost will help. So, except for some uses like tugboats, electric or hybrid propulsion on boats has limited application, in my mind."

Certainly, boat designers can and do improve the efficiency of hull forms and the accessories that make up our house loads (lights, refrigeration, air-conditioning, and so on). Many companies are demonstrating what can be done now and at scale. Earlier this year, for example, Groupe Beneteau invested in Candela, the Swedish builder of hydrofoiling boats for commercial and recre-

ational use. Navan by Quicksilver, a new brand Brunswick introduced last fall, arrived with a twin-stepped hull, promising 15% improvement in efficiency compared to similar boats.

There's no getting past the fact that boats require lots of power to move through and over the water. Here, again, physics describes the fundamental problem.

"Batteries simply do not yet have the energy density necessary to create the kind of range that boaters expect, nor the performance for the amount of time they've come to expect," said Martin Peters, Yamaha's director of external affairs.

Yamaha has committed to carbon neutrality for its operations by 2035 and its products by 2050. Sustainable fuels, which promise up to 30% less CO₂ emissions relative to conventional fossil-based gasoline, "actually could get us to carbon neutrality quicker than electrification," he said.

No charge required

"The annual replacement rate of boats is about 2% per year, compared to 20% for cars," Peters said. "At this rate it would take 40 years to turn every boat into an electrified boat, simply because the replacement rate is so low." The widespread introduction of sustainable drop-in fuels could immediately reduce carbon emissions from the nation's 12 million registered recreational boats.

Another potential alternative fuel source with much promise is hydrogen, Peters said. While hydrogen energy density is less than that of gasoline, diesel, or biofuel, it's much higher than that of electricity stored in batteries.

"There are many states and regions, particularly in U.S. East Coast commercial ports, vying to become hydrogen hubs," he said. "This is interesting from the perspective of public policy, as it could increase the availability and practicality of hydrogen."

Last year, Yamaha introduced a prototype hydrogen-powered outboard engine in partnership with the boatbuilders at Regulator and Roush fuel-systems engineers. For its 2025 model year, Honda will introduce a hydrogen-propelled



Jeff Wasil of NMMA (left) and Gus Blakely from Suzuki Marine USA on the fuel docks at St. Andrews Marina in Panama City, Florida, where sustainable Hy-perfuels PurFuels is available for sale to recreational boaters. The fuel is 93 octane and ethanol-free.

COURTESY SUZUKI MARINE

CR-V automobile with a 270-mile range; experimental models are already on the road. It's a sign that fueling infrastructure is likely to follow; this is a technology that could move into the marine space on Honda's outboard engines.

For now, with no fuel delivery system yet in place, hydrogen at fuel docks is a ways off. Because of the diversity of recreational boats, both in size and how they move through the water, there's no "one-size-fits-all" approach to green power for boats. That's why the marine industry is simultaneously promoting electric, hydrogen, and biofuel alternatives.

Like other marine companies, Yamaha has committed to multiple technological solutions to reduce its greenhouse gas emissions based on boat types and how each boat will be used. In January 2024, Yamaha acquired the German-based electric propulsion manufacturer Torqeedo, instantly adding electric outboards to its model line.

Best bang for the buck

Despite current enthusiasm for electric propulsion in automobiles, this power source still has drawbacks for boats.

"Pure battery electric-propulsion craft will require a significant reduction in range and potentially also power to mitigate impacts on vessel mass, onboard volume, and purchase price," the ICOMIA "Pathways" report said. "It is impractical to match the range and performance system, as batteries take up too much space within the craft or are too heavy to be practical."

come from nonfood plants like agricultural waste, wood chips, and grasses. Third-generation biofuels derive from algae, which has a distinct advantage in that it can be grown in controlled environments that require neither land nor fresh water, creating a much smaller environmental footprint. It's with those "gen-3" fuels that some engineers see the most promise today.

At the 2024 Miami International Boat Show, the boating industry's premiere consumer event, Yamaha displayed a boat powered by gen-3 biofuels that significantly reduced CO₂ emissions. Here are more names that boaters may start seeing at their fuel docks:

» PurFuels is a gasoline/isobutanol blend that reduces CO₂ emissions by up to 30% relative to conventional fossil-based gasoline.

» Neste MY Renewable Diesel reduces CO₂ emissions by up to 75% relative to conventional fossil-based diesel fuel.

» EcoGen, from VP Racing, is a partially renewable gasoline that reduces CO₂ emissions by up to 30% more than E10 gasoline and does not contain ethanol.

Last July, the biofuel option arrived in Panama City, Florida, when St. Andrews Marina added a pump specifically for the gas/isobutanol blend of PurFuels, according to manufacturers.

There are currently 12 million existing boats in the market," said Ben Speciale, president of Yamaha U.S. Marine Business Unit. "The option of using biofuel within these vessels paves a path to carbon neutrality with boats and engines already on the waters."

My takeaways from all this? First, we should all be using our boats more than we do; let's get out there on the water! And second, electric motors have a place on some boats where range and speed aren't the primary concern. But for the most sustainable solution on most boats, keep an eye out for gen-3 biofuels at your local fuel dock. ▲

personal sustainability report includes the emissions from 11 cylinders on three boats.

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