

High-tech electric propulsion

A rigorous focus on cutting-edge technology, R&D and new production processes, as well as optimizing performance, comfort, safety and economic features, has made one German supplier a key player in electric and hybrid marine technology

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When Torqeedo's founders, Dr Christoph Ballin and Dr Friedrich Boebel, looked at solutions for electric propulsion systems for boats in 2004, they noted that existing products did not reflect the then state of technology, with the solutions coming from low-volume, high-price manufacturing starting points.

This gap in the market prompted the creation of Torqeedo, a new player in the marine industry, focusing only on high-tech propulsion, combined with industrial R&D and manufacturing, to realize competitive price points while also providing revolutionary benefits.

Despite being founded less than a decade ago, Torqeedo has already gathered critical global acclaim by being first to market with key innovations. For example, the company was the first to introduce brushless motors into marine propulsion. It was also the first to introduce lithium batteries to the marine industry on a broad scale and the first to integrate them into electric outboard designs. These critical breakthroughs, and many other high-tech innovations, have made Torqeedo one of the best-known brands in the field of marine electric propulsion.

Located in Starnberg, near Munich, with sales offices in the USA, the UK, France and Spain, Torqeedo offers propulsion systems from 0.5kW through to 110kW, all developed according to the same ethos – superior technology with revolutionary benefits.

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1 Torqeedo's headquarters is located in the Starnberg District, near Munich

Focus on propulsive power

When discussing the power rating of a boat drive, kilowatt and horsepower outputs are critical aspects that need to be taken into consideration. Yet from Torqeedo's perspective, providing horsepower or kilowatt ratings is only one way to describe, analyze and optimize boat drives. First and foremost for any power discussion, one needs to know where the power is being measured. For example, gasoline and diesel propulsion systems typically provide power ratings measured at the propeller shaft – called shaft power. Providers of electric propulsion systems sometimes provide shaft power as a power rating, but sometimes input power is also referred to within the industry, with the power being consumed by the electric motor.

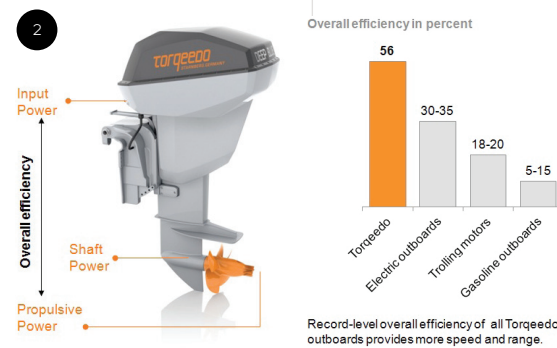
It is clear that shaft power says more about a propulsion system than input power. However, shaft power ratings do not express propeller losses. As propeller losses vary from 30% to 80% (depending on specific applications), the shaft power rating of a propulsion system is only a very rough indicator of the overall performance of a boat drive – and it is vitally important that this fact is not overlooked.

With this in mind, Torqeedo focuses on optimizing the propulsive power of a boat drive, such as the kinetic power exerted from the boat drive onto the boat after all losses, with propeller losses also being taken into account.

Input power, shaft power and propulsive power are all measured differently, however, each can all be expressed in kilowatts or horsepower. This includes input power

[watts] via current x voltage; shaft power [watts] via torque x angular velocity; and propulsive power [watts] via speed x thrust exerted onto the boat.

Besides propulsive power, overall efficiency is a key performance indicator for an electric propulsion system, mainly due to the fact that electric propulsion systems often operate with a limited power supply. Consequently, getting the most propulsive power (speed and range) out of a limited energy supply is paramount, and overall efficiency data provides exactly this performance criterion. This data is defined as propulsive power divided by input power and expressed in percent.



2 The overall efficiency of Torqeedo's electric propulsion system is determined by dividing propulsive power by input power (left) and is expressed as a percentage (right)

Unique powertrain and battery engineering

For Torqeedo, superior propulsive power and overall efficiency comes from extensive in-house development that works uncompromisingly toward optimizing propulsive power and overall efficiency, with

engineers using the very latest technologies for every component. This includes the latest brushless motor designs with state-of-the-art electronic commutation; propeller calculation based on the highest standards, which are mostly used in commercial shipping; and careful design matching of the motor, electronics, gear and propeller in an effort to realize superior performance.

3 Torqeedo powertrain components feature the very latest technologies, carefully matched to one another

With tens of thousands of lithium batteries in the field since 2006, Torqeedo has become a pioneer in developing lithium battery technology for electric propulsion. Improving

marine lithium batteries year after year since 2006, Torqeedo has created a very comprehensive protection and safety process for marine lithium batteries on the market – bringing together performance, safety and comfort – three fundamental R&D aspects.

With regard to safety, Torqeedo follows an extensive process that has five significant focus areas, with the first being on safe battery chemistry, especially as lithium

battery chemistries vary in the way that they can react. In the early years of lithium batteries, highly reactive materials like lithium-cobalt were offered on the market. Nowadays, safer battery chemistries like LiFePo or LiNMC are commonplace. As such, it's important to choose appropriate battery chemistry in order to ensure maximum lithium battery safety.

The second focus to Torqeedo's five-step process centers upon the safe packaging of individual cells. As a company, Torqeedo uses only so-called safety cells, which are welded steel cylinders equipped with multiple hardware safety mechanisms. Alternative packaging, such as foil-welded cells, offer a reduced safety standard because they don't provide effective protection against internal short circuits of the cells (exceptions are foil-welded cells with ceramic separators, which provide safe packaging but are extremely rare on the market).

The third focus area for Torqeedo is precise and clean production processes at cell manufacturer level. Cells with proper battery chemistry that are packed into the battery system correctly will ultimately not be safe if the production processes of the cell manufacturer are not extremely clean and precise. As a result, Torqeedo recognizes this critical fact and only uses cells produced by renowned Japanese, Korean or USA manufacturers.

The next focus area with regards to battery safety is incorporating an advanced battery management system (BMS) with additional safety features. Unlike lead-based batteries, lithium batteries generally need a BMS to

waterproofing, with all of the company's batteries being fully waterproof according to IP67, to prevent short circuits, and corrosion of plugs or safety relevant electronics.

4 Torqeedo lithium battery with safety cells, BMS, data ports, water sensor, breathing valve and terminals

Systems engineering

As a company, Torqeedo believes that performance is best enjoyed when it's combined with convenience. As such, Torqeedo's systems allow for motors and batteries to be switched on and off, simply at the push of a button. Products and components can be designed to connect via an electronic button, enhancing user friendliness. Motor information can be married with battery data and GPS receiver information to provide the user with meaningful range forecasts. What's more, waypoints can be integrated into the onboard-computer and audible alarms warn the driver when the battery gets low. These examples are just some of the noteworthy convenience system features embedded into Torqeedo's propulsion systems.

5 GPS-based range calculation, also for electric outboards in the low power classes, features waterproof connectors and electronic communication between components

As mentioned earlier, Torqeedo's products range from 0.5kW to 55kW, and the latest addition to the company's product line is the 55kW Deep Blue propulsion system. This technology is the world's first production electric outboard product for the high power classes and since its introduction, it has received prestigious innovation awards from

propulsion system that defines state-of-the-art technology, convenience and safety, along with competitive industrial price points.

6 The Zodiac Milpro SRMN 600 rigid inflatable boat can be fitted with the Deep Blue propulsion system. These boats were originally built for military use so their hulls are reinforced to take the maximum G forces that are applied when fully laden and powered at maximum speed



A full Deep Blue system consists of the following components: Deep Blue outboard, with 98% motor-efficiency, housed in its own waterproof housing and suitable for saltwater cooling, with optimized gear and optimized propeller with hub-vortex-vane; and high-voltage batteries, which are the fruit of a cooperation between Torqeedo and Johnson Controls. The Deep Blue batteries' roots come from the automotive industry, but for this development, they have been adapted for marine use and are waterproof according to IP67. The batteries are fully integrated into Deep Blue's data and safety subsystems, with the pack coming with a nine-year-capacity warranty, even if they are used on a daily basis. Furthermore, detailed analysis has shown that after nine years of continuous use, the battery pack will still retain 80% of original capacity – a leading figure in the marine sector. The Deep Blue charger, which also derives from the automotive industry, is fully waterproof. The charging capacity can be controlled via the display.

Deep Blue also features an onboard-computer and touchscreen 5.7in display with 14 different screens. Information provided includes: power consumption, speed over ground, GPS-based range, distance and travel time to up to four individual waypoints, battery health, motor run-time and much more detailed data. Finally, Deep Blue also has a connection box that allows for waterproof connection of all Deep Blue electrical and signal cables.

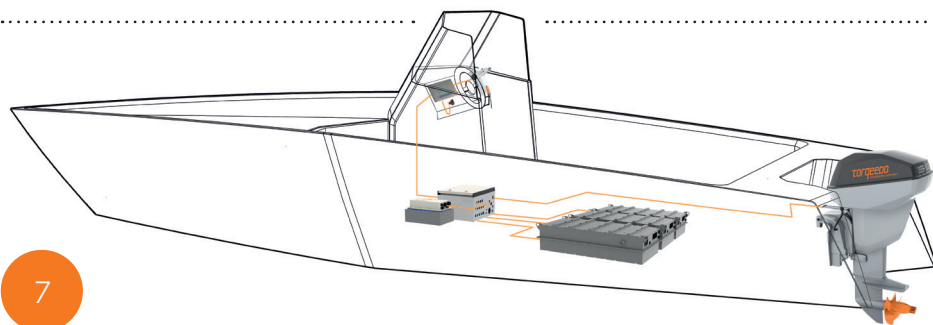


significant g-force shock levels. This feature ensures that cells and cell holders remain intact and prevents damage to electronic components.

The Deep Blue technology has also been designed to continuously monitor all connections in the system, with the system being able to shut down all components if one connection is disconnected or if the killswitch is pulled. Another key subsystem of Deep Blue is the Venting-Breathing-Seal-Combination (VBSC) function, where one

Torqeedo products in the smaller horsepower classes start with the Ultralight, which is the lightest outboard available. The 1hp equivalent outboard with integrated lithium battery weighs a mere 7kg, including the battery, but yet it propels lightweight boats, such as kayaks or canoes, up to 6kts. At slow speed, it provides a range for more than 20 nautical miles. Other Torqeedo products include the Travel series with integrated lithium batteries (1-3hp equivalents) and the Cruise series (5-8hp equivalents, up to 16hp equivalent in twin-installations) with external batteries. What's more, Torqeedo's lithium batteries of the Power series technology provide the energy supply for Cruise outboards. Solar and generator charging is also available for various product groups. +

9 The Torqeedo Travel series with integrated lithium battery (1-3hp equivalent) with electric outboard



7 The Deep Blue electric propulsion system has undergone extensive development and considerable investment with regard to using bespoke components and subsystems

Aside from the superior performance and efficiency levels, Deep Blue also boasts several state-of-the-art safety mechanisms, as found in electric cars, including constant insulation monitoring of the high-voltage batteries, which ensures the batteries only provide high voltage as long as the insulation of the system is intact. Deep Blue also benefits from battery damping, which is required if electric boats go at high speeds or if they are exposed to

component permits slow exchange of air through a membrane to compensate for changes in temperature and prevent the formation of moisture internally within the battery. This system also allows for a second component to permits rapid removal of gases in the unlikely event that the hardware protection trips and a cell discharges. In this case, the gases produced are channeled out of the boat via a tube into the air so there is no danger for the occupants.

8 The Deep Blue onboard computer and touch screen provides information such as power consumption, speed over ground, GPS-based range, and much more

