ELAnalysts

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IDTechEx

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Electric Boats and Underwater Vehicles

BY PETER HARROP AND RAGHU DAS, IDTECHEX

Overview

IDTechEx expects global sales of marine electric vehicles, including hybrids and pure electrics, to rise from 73,000 in 2013 to 118,000 in 2024, and from $2.6 billion to $7.3 billion. This market includes leisure, light industrial and military craft, both for inland waterways and seagoing, as well as autonomous underwater vehicles (AUVs), non-military small submarines and underwater electric sea scooters for divers. Average ex-factory prices vary hugely from $25 million hybrid super yachts and $5 million for the most expensive submarine or AUV, to $50 for a diver's sea scooter.

In 2014, by far the largest share of revenue – 63 percent – is for military uses. But commercial applications play their part: the next largest share, 14 percent, is work boats such as tugboats and oil slick collectors, contributing about $370 million this year. About 3 percent is leisure and tourist surface boats, 2 percent is personal and tourist submarines, and 9 percent is attributable to autonomous underwater vehicles, excluding military. In civilian life, AUVs are used particularly by the oil and gas industry and in science research.

In 2024, workboats' share is set to increase to 25 percent, while military uses fall to 53 percent.

Benefits

In understanding EV markets and trends it is absolutely vital to realize that their adoption is not usually for the popularly understood reasons.

In fact, so far, marine electric vehicles are usually financially successful where are bought because they:

- Can be used under water;
- Replace human effort including much maintenance;
- Make new things possible, such as record-breaking acceleration or silence;
- Save costs; and
- Last longer.

Frequently, the successes combine many of these attributes. For example, tug boat companies will switch from diesel alone to hybrid electric because they will save 70 percent on fuel costs, which is expected to translate to a two-year return on investment. Another reason is a 60 percent reduction on emissions over diesel, which is something that tugboats will need to meet future emission regulations.

Voluntarily saving the planet is rarely the primary reason why someone buys an EV. The moral of the story is that those dedicated to reduction of pollution should design exciting, convenient, stylish and novel vehicles that replace human effort, make new things possible and save cost over alternative procedures.

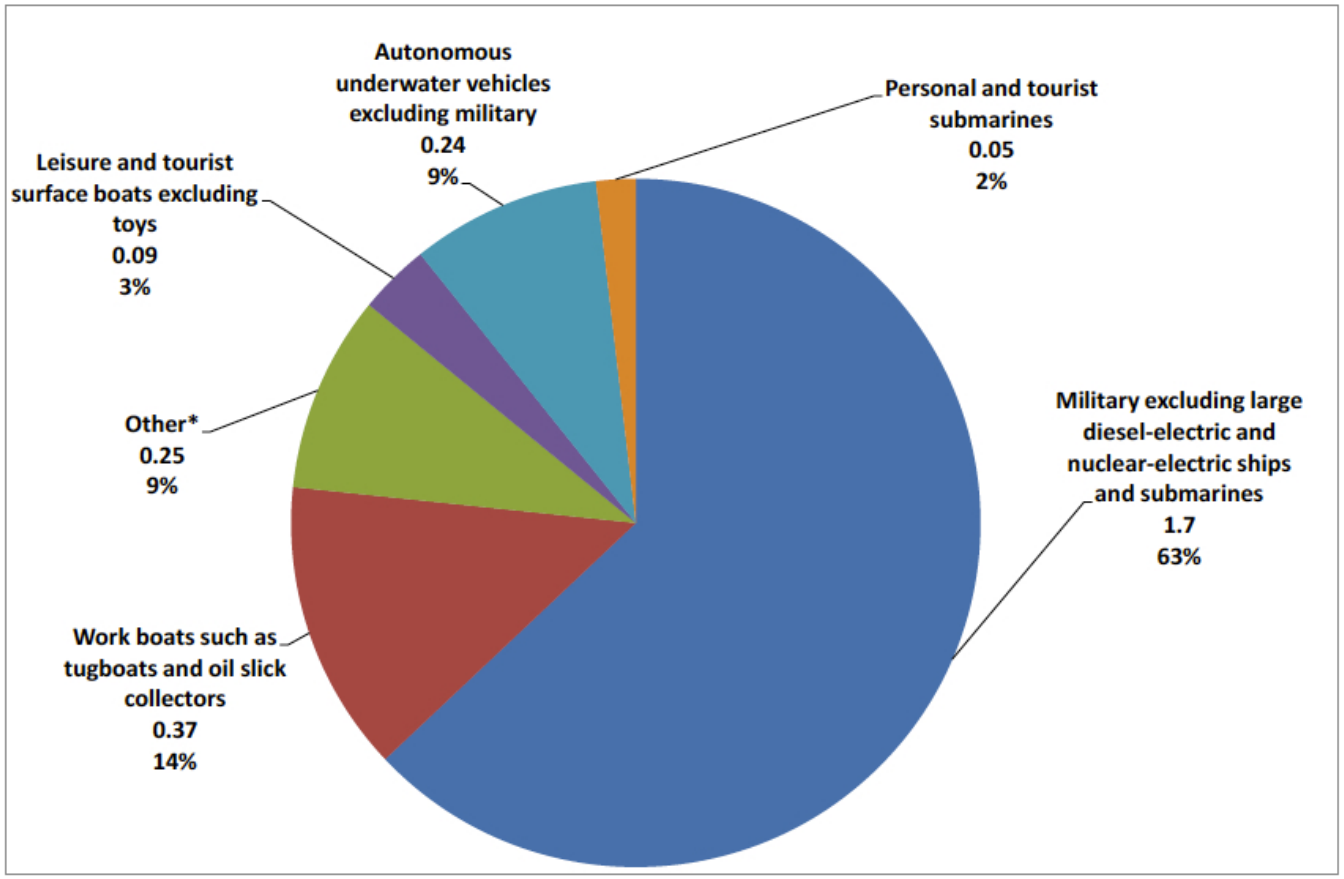
Examples of making new things possible are:

- Tugboats with maximum power from stationary;
- Record breaking acceleration, e.g. ski boats;
- Leisure submarines providing fun and independence. People who do not scuba dive can explore under water;
- Silent river boats permitting undisturbed study of wild life;
- Military seagoing craft with little or no heat or sound signature for missiles to home in on.

Regulations

Battery-driven surface craft help to meet pollution regulations from India and Taiwan to the US. Already, internal combustion engines (ICEs) have been banned from all lakes in Austria and certain lakes in Switzerland, Germany, Denmark, Holland and several fisheries in the UK. Taiwan has given notice of banning ICE boats on its largest lake. There are hundreds of solar boats operating in Europe and Australia. Tourist boats in India are frequently electric even today, with many inland waterways banning the ICE.

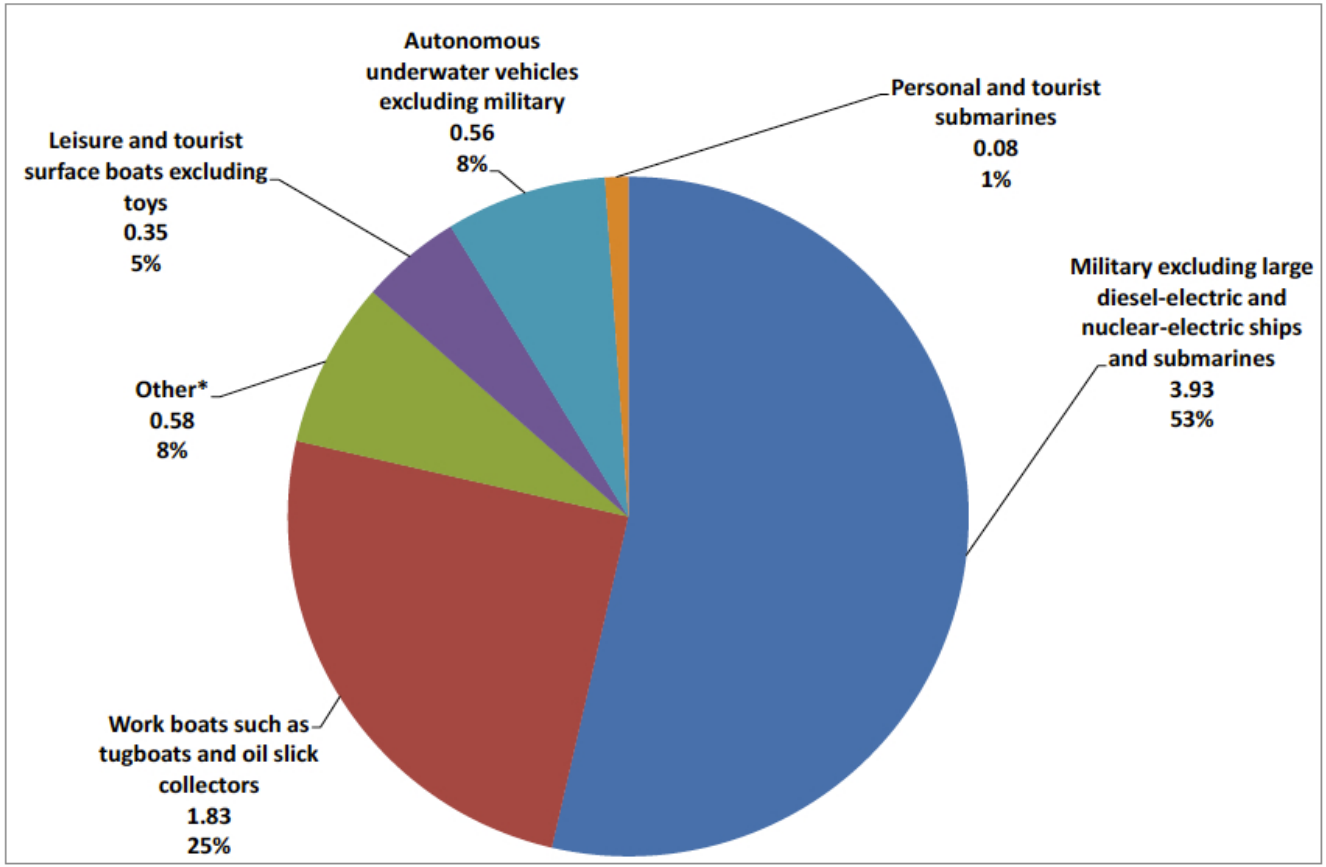
Fig. 1.2 **Marine electric vehicle market $ billion in 2014 by applicational sector**



Source IDTechEx

EPRI is optimistic that increased restrictions on pollution in US inland lakes could lead to a significant percentage of the million or more inland surface boats in the US being switched to electric ones. They felt this could grow the market by tens to hundreds of thousands of boats yearly.

Fig. 1.3 **Marine electric vehicle market $ billion in 2024 by applicational sector**



Source IDTechEx

Applications and Technologies

Although about 60 percent of manufacturers of electric craft concentrate on underwater vehicles, most make very small numbers. We believe that about 50 percent of the expenditure on electric watercraft concerns underwater versions and 50 percent concerns on-water versions. Military expenditure on

electric water craft is mainly directed at underwater craft, whereas civil expenditure is mainly directed at electric surface craft.

Underwater EVs mainly use brushless motors and lithium-ion batteries and are built to purpose – born electric. For balance, the batteries of an AUV are near the front and for simplicity, space-saving and reliability, the motor and propeller are together at the back. Manned underwater craft and surface craft tend to have the battery and motor amidships but this will change as legacy power trains will be employed less frequently.

Often with more limited funds to deploy, the surface electric craft is more likely to have electrics shoehorned into a boat not originally intended for such a drive train. Lead acid batteries often suffice because there is usually no attempt to push the limits of speed.

The trend is for more and more lithium-ion batteries to be used on and under the water and almost invariably these have combined solid/gel polymer electrolytes to reduce the chance of leakage and increase safety. Such batteries are called lithium polymer but within that category there are many different chemistries, lithium iron phosphate cathodes being particularly favored for safety and independence from high material costs. Lithium titanate and other later generation anodes are of interest so the battery can tolerate the fast charging that is usually preferred.

Underwater EVs are invariably pure electric, a few having a fuel cell in addition to the traction battery to increase speed and range. Pure electric small surface craft are commonplace and hybrid battery-sail and battery-conventional engine is increasingly used to extend EV use to boats and ships with more onerous performance requirements. As lithium-ion batteries improve, hybrids are evolving to have longer electric-only range. This is in line with what is happening with land and air EVs.

Range extenders

As hybrid vehicles, in the form of surface craft, evolve towards being pure electric vehicles, they will increasingly be series hybrids and employ larger batteries and smaller engines called range extenders, the idea being that the vehicle may be used in all-electric mode most of the time. The legacy thinking that has meant that the conventional engine in a hybrid is an internal combustion engine, not optimized for the purpose, will give way to use of such things as mini jet engines that burn a variety of fuels and

are much smaller, lighter weight and reliable. In this, the marine industry will follow what some buses already have and some planned supercars will have.

Market

Thanks to high average unit price, marine EVs are 5 percent of the value total global market for all EVs - land, water and air. Notably, huge growth in the marine electric vehicle market is outpaced by the faster growth of the large bus and car markets for electric vehicles.

Some of the presumed driving forces behind our forecasts are as follows: Some effects of global recession remain in the early years. Further green laws being introduced will help most marine sectors to grow. For example, pure electric craft benefit from laws that increasingly ban polluting alternatives on inland waterways. Plug-in hybrids will be favored for the larger seagoing boats to save cost and improve reliability over ones with conventional engines. Many new forms of expensive underwater craft will appear. The seagoing vehicle market will be increased particularly by military build-up and a trend to understand the influence of the oceans on weather and to harvest the oceans, including minerals and livestock.

Price sensitivity

As yet, few manufacturers of non-marine EVs make EVs, military suppliers such as Lockheed Martin being an exception. Like other EVs, marine EVs are not usually bought on price, but cost reduction in future years can only help. Here the batteries are the main determinant of price, as is true of most other EVs.

Importance of East Asia and China

East Asia has 56 percent of the value market for electric vehicles worldwide and it will remain at that share for the next decade. Within that, 66 percent of the manufacturers of electric vehicles in the world

are in China, which controls 95 percent of the rare earth reserves used in hybrid car batteries, motors and other key components of today's electric vehicles.

Currently east Asia, including China, is showing relatively little interest in marine electric vehicles, something which makes it easier to make good profits in that sector. However, East Asia and particularly China could flood global markets with very low-cost electric leisure boats at some stage. Until there is more evidence of this happening, we exclude it from our forecasts. Nonetheless, the effect of such a development would be to increase the market size while reducing average price, thus leaving our market value forecast largely intact.

Manufacturers

Manufacturers of marine electric vehicles are only 3.5 percent of all manufacturers of electric vehicles and this percentage will change little over the coming decade.

Organizations making AUVs include:

a.r.s. Technologies (Germany)
Atlas Elektronik (Germany)
Autonomous Undersea Systems Institute (USA)
BAE Systems (UK)
Bowtech Products (UK)
C&C Technologies (USA)
Deep Ocean Engineering (USA)
Defence R&D Organisation (India)
Falmouth Scientific (USA)
Florida Atlantic University (USA)
FMC Technologies (USA)
Hydroid (USA)
International Submarine Engineering (Canada)
JAMSTEC (Japan)

Kongsberg Simrad (Norway)
Lockheed Martin (USA)
MBARI (USA)
National Oceanographic Center, Southampton (UK)
OceanServer Technology (USA)
SAAB Underwater Systems (Sweden)
Teledyne Technologies (USA, Iceland)
Thales (France)
University of South Florida (USA)
Woods Hole Oceanography Institute (USA)

Organizations making surface craft include:

ALU Marine (France): Large surface craft
Beckman Electric Boats (USA): Open boats
Bobcat Boats (USA): Open boats
Bratt Tug (Canada): Tugboats
Budsin Wood Craft (USA): Open boats
Curtis Marine (USA): Open boats
Electric Boats (Thailand): Inland open boats
Electric Marine Industries (USA): Launches
Foss Maritime (USA): Tugboats
Kopf Solarschiff (Germany): Private and commercial inland solar boats
MW Line (Switzerland): Ocean-going solar boats
Senseable City Lab (USA): Oil-lifting surface robots

About IDTechEx

IDTechEx has published over 60 reports on Printed Electronics, Photovoltaics, Energy Harvesting, Electric Vehicles and RFID. IDTechEx gives strictly independent marketing, technical and business advice and services in three forms – consulting, research and events – covering areas such as: printed, organic and flexible electronics; RFID and wireless sensors; electric vehicles; energy harvesting and storage; photovoltaics; and smart packaging. Their work includes technology and market benchmarking, analysis of companies, due diligence, in-company master-classes and global research.

For more information read the IDTechEx report, "Electric Boats, Small Submarines and Autonomous Underwater Vehicles (AUV), 2014-2024," available at: http://www.idtechex.com/research/reports/electric-boats-small-submarines-and-autonomous-underwater-vehicles-auv-2014-2024-000371.asp

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Peter Harrop, PhD, FIEE is Chairman of IDTechEx Ltd. He was previously Chief Executive of Mars Electronics, the $260 million electronics company, and Chairman of Pinacl plc, the $100m fiber optic company. He has been chairman of over 15 high tech companies. He has written 14 books on technical subjects, these being published by the Financial Times, John Wiley and others. He lectures and consults internationally on RFID, smart labels, printed/organic electronics, smart packaging, and electric vehicles.

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Raghu Das MA (Cantab) is CEO of IDTechEx. He has an MA Natural Sciences degree from Cambridge University, where he studied physics. He has been closely involved with the development of RFID, printed electronics, energy harvesting and electric vehicles for over twelve years, carrying out consultancy in Europe, USA, Asia and the Middle East. He has lectured on these topics at over 300 events and conferences around the world and is author of several IDTechEx publications.

He leads IDTechEx's consulting effort and research programs. His analyses of the industry and market forecasts have been cited globally, in publications such as Wall Street Journal and the Financial Times.

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