ABB Witness Testimony

TESTIMONY OF:

PETER BRYN

TECHNICAL SOLUTIONS MANAGER, NORTH AMERICA

ABB MARINE AND PORTS

BEFORE THE:

UNITED STATES HOUSE OF REPRESENTATIVES

COMMITTEE ON TRANSPORTATION & INFRASTRUCTURE

SUBCOMMITTEE ON COAST GUARD AND MARITIME TRANSPORTATION

HEARING ON:

“THE PATH TO A CARBON-FREE MARITIME INDUSTRY: INVESTMENTS AND INNOVATION”

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Contents

Executive Summary

ABB has been an electrification and automation technology leader for over a century. With about 147,000 employees across the globe and 24,000 here in the US, we are a market leader in power grids, advanced manufacturing technology, and electric transportation. This includes electric vehicle charging infrastructure as well as marine and port electrification and automation solutions. The marine industry in the early stages of a transformation to low and zero emissions technologies. While there is no one-size fits all approach to reducing marine emissions, ABB believes the future of marine vessels will be electric, digital, and connected.

1. **With electric propulsion systems, marine vessels can get to zero emissions.** Most alternative propulsion system arrangements are centered around an electric powertrain, including diesel or LNG electric hybrids ships, full battery powered ships, and fuel cell powered ships. Electric propulsion not only cuts emissions but also improve safety and reliability while reducing lifecycle costs. An electric-based powertrain is also futureproof as new power sources are developed. Whether the power source is fuel cells, batteries, ammonia-fueled generators, or a wave energy harvesting system, electric powertrains can integrate them. This is especially important for Jones Act vessels which often undergo multiple repowers over their sometimes 50+ year lives.

2. **It's critical to fit the right solution to the vessel.** Vessel types are as varied as the missions they serve and cargoes they carry. Ferries, inland towboats, harbor tugs, offshore workboats, and oceangoing vessels all have different operational characteristics that require different low or zero emission technologies. Fortunately, there are a number of such technologies either available today or under development including diesel or LNG electric hybrids, biofuels, fuel cells, and batteries. Accordingly, policies should focus on setting emissions targets for the marine industry, allowing the industry to assemble the best technology solution for meeting emissions and operational goals, and providing support to the marine industry as they meet those targets.

3. **Lifecyle costs of electric powertrains are typically lower than conventional diesel powered vessels.** Vessels with electric powertrains and direct current (DC) electrical systems typically cost less to operate over their lifetime due to higher energy efficiency, lower maintenance, and reduced fuel costs. However, their upfront capital costs tend to be higher. This challenge is similar to other recent energy technology breakthroughs, like wind and solar power and electric vehicles. However, through a myriad of research, development, and deployment policies and incentives, those upfront costs have come down considerably and have reached or are approaching cost parity. With appropriate support, the same will happen with zero emission marine technologies.

4. **Low and zero emission marine vessel technologies are in the early stages of adoption and need government and policy support.** Today there are commercially available zero emission marine technologies for some segments, like ferries. However, they tend to be more expensive upfront to purchase, which is a big deterrent to ship owners and operators, even though they are cheaper to operate. For other segments like offshore workboats, and oceangoing vessels, cost-effective commercially available zero emission solutions are still in their very early stages of development. To lower costs and reach a fully zero emission vessel fleet, deployment of existing technology and development of new technology must be expedited. The industry would benefit from government investments in research, development, and deployment of zero emission marine technologies.

Introduction

Good morning Chairman DeFazio, Chairman Maloney, Ranking Member Graves, Ranking Member Gibbs, members of the Subcommittee and my fellow panelists. Thank you for the opportunity to testify today. My name is Peter Bryn and I am Technical Solutions Manager in ABB Inc.'s Marine and Ports Business Line.

ABB is an electrification and automation technology leader that is driving digital transformation of industries. With a history of innovation spanning more than 130 years, ABB has four customer-focused, globally leading businesses: Electrification, Industrial Automation, Motion, and Robotics & Discrete Automation, supported by ABB Ability™ digital platform. With about 147,000 employees across the globe, we are a market leader in power grids, advanced manufacturing technology, and electric transportation. This includes electric vehicle charging infrastructure and marine and port electrification and automation.

ABB is proud of our 24,000 US employees along with our 60 US manufacturing or assembly sites and significant operations in 32 states, including Arkansas, Missouri, Ohio, Oregon, Pennsylvania, Tennessee, Wisconsin, and North Carolina which is home to our U.S. headquarters. Our global headquarters is in Zurich, Switzerland. Over the past decade we have invested over $14 billion in the United States, more than tripling our workforce.

ABB Commitment to Reducing Emissions

Climate change is one of the biggest challenges of our time. ABB supports the Paris Agreement, which came into force in November 2016, and considers it the linchpin of efforts to limit global warming and avert the potential devastating consequences of climate change. ABB actively contributes to climate goals by encouraging the early and rapid adoption of clean technologies and by helping its customers improve energy efficiency and productivity while extending the lifecycles of their equipment and reducing waste.

Meeting the goals of the Paris Agreement will require significant investment in new and upgraded technologies, which will only be forthcoming with solid, reliable, and predictable policymaking. As a company with around 9,000 technologists that is set to invest around $23 billion in innovation between the signing of the Paris Agreement and 2030, ABB urges policymakers to adopt sound climate policies to encourage innovation and create secure investment conditions.

ABB understands that investments in developing and deploying technologies that reduce climate impacts, while incrementally higher cost at first, lead to significant intermediate and long-term cost savings. Such technologies are core to ABB, as nearly 60 percent of ABB's global revenues are derived from technologies that directly address the causes of climate change through energy efficiency, renewables integration, and resource conservation. The marine sector also holds a similar promise of reducing emissions and overall costs.

ABB's contributions to climate goals are widely acknowledged and were recognized in August 2018 by "Fortune" magazine, which named ABB as one of the top 10 companies that are changing the world. ABB has set its own target to reduce its GHG emissions by 40 percent by 2020 from a 2013 baseline.

Reducing Marine Emissions

We are in the very early stages of a transformation of the marine industry to low and zero emissions technologies. While ports have already begun their march toward electrification, which enables zero emission operations, the marine sector is just beginning. ABB provides ship and port electrification and automation technologies and solutions. From replacing diesel powered cranes at ports with electric solutions powered by microgrids, to fully electrifying marine vessel propulsion systems, and everything in between, we believe the future of the maritime industry will be electric, digital, and connected. These technologies are used in ports across the US, from Charleston, South Carolina to Long Beach, California. And the Coast Guard has deployed one of ABB's advanced diesel-electric hybrid propulsion systems on the Great Lakes Icebreaker, the USCGC Mackinaw.

Global Adoption of Zero Emissions Technology

Globally, the maritime industry remains dominated by diesel-power, but the beginnings of a significant shift in energy source is underway. The start of adoption of low to zero emission ship technology is shown in Figure 1. While conventional power plants still dominate, a significant jump in both battery powered and liquified natural gas (LNG) ships is evident in Figure 2.

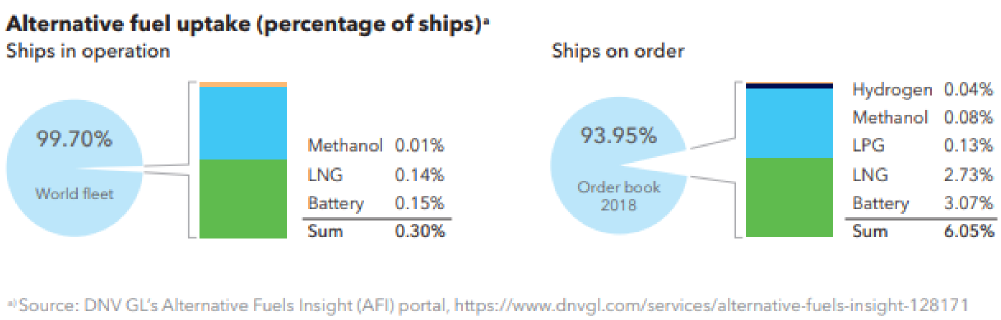


Figure 1. Alternative fuel by ship count (DNVGL, 2018)

By vessel type, certain technologies are emerging because they complement the vessel's operational profile. For example, ferries are great candidates for batteries because of their short distance operation and predictable port calls, which allow for installation of shore chargers. Conversely, container ships travel long distances and have incredibly high power demands. Because battery and fuel cell technologies need more research and development to be able to meet oceangoing vessels' needs cost-effectively, these ship owners and operators have begun adopting LNG.

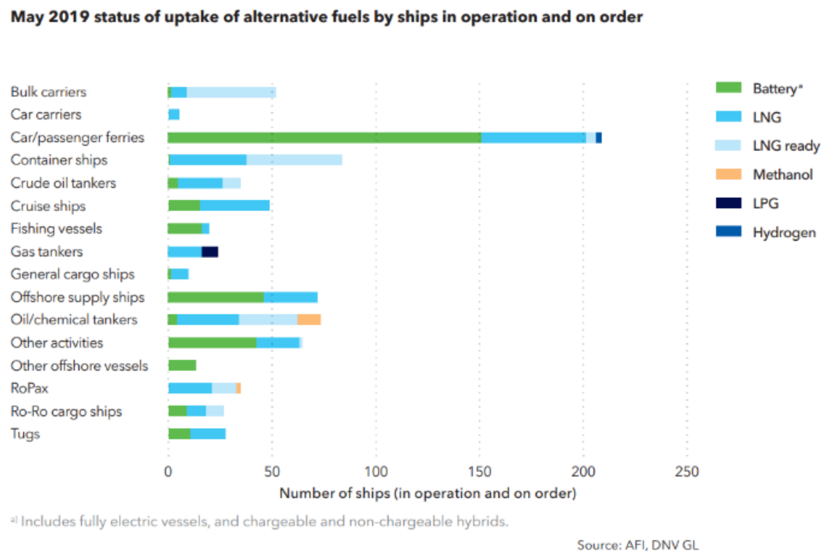


Figure 2. Alternative fuel by ship type (DNVGL, 2018)

An Electrified Propulsion System

Most alternative propulsion system arrangements are centered around an electrified powertrain. Whether diesel or LNG electric hybrids, full battery power, or fuel cell power, most low and zero emissions vessels will employ an electrified powertrain. Electric propulsion can not only cut emissions but also improves safety and reliability while reducing lifecycle costs. An electric-based powertrain is critical as it allows for easy integration of current and future power sources, which is important for Jones Act vessels that often undergo multiple repowers over their sometimes 50+ year lives.

Fitting the Right Solution

Vessel designs vary significantly, based on the vessel's application and purpose. The low and zero emission technologies that will be selected for a particular project will be dictated by the needs and operational profile of the vessel. These technologies may include:

Low Emissions	Net Zero Emissions
• Diesel-Electric • Diesel-Electric with Battery • Diesel-Electric with Battery and Shore Charging • Power Take In/Take Off (PTO/PTI) • LNG/dual-fueled engines • Biofuels (some) • Fuel Cell with Fossil-Derived Fuel	• Full Battery-Electric Propulsion and Shore Charging • Fuel Cell with Net-zero Fuel • Biofuels (some) • Ammonia

It is critical that ship owners and operators identify the proper solution for their vessel whether using a conventional diesel engine arrangement or some combination of low or zero emissions technologies. For example, a harbor tug which operates with a significant amount of idle time and short bursts of full power during operation has a very different operational profile than a Very Large Crude Carrier (VLCC) tanker which trades internationally on the spot market across oceans and can spend days at anchorage. Failing to consider the vessel's operation may lead to a propulsion system that is less efficient and cost effective than the diesel-mechanical baseline.

ABB is working with many Jones Act vessel owners, operators, and designers to seek the best solution for their operation. This ranges from ferries to fishing boats, harbor tugboats to dredgers, and passenger vessels to river towboats.

Across segments, some recurring challenges persist. First, while the total lifecycle cost of ownership of a vessel with electric propulsion is lower than a diesel-powered vessel, the upfront costs are often higher. Second, research, development, demonstration, and deployment investments are needed to bring down costs of these new systems and commercialize zero emissions solutions for more challenging applications like high speed catamarans and oceangoing cargo vessels.

US Newbuild Market

In the private sector, newbuild construction in the US is largely dominated by Short Distance Shipping (SDS) vessels, particularly tugs, towboats, and passenger vessels. By comparison, there is a small number of Oceangoing Vessels (OGV), as per Figure 3.

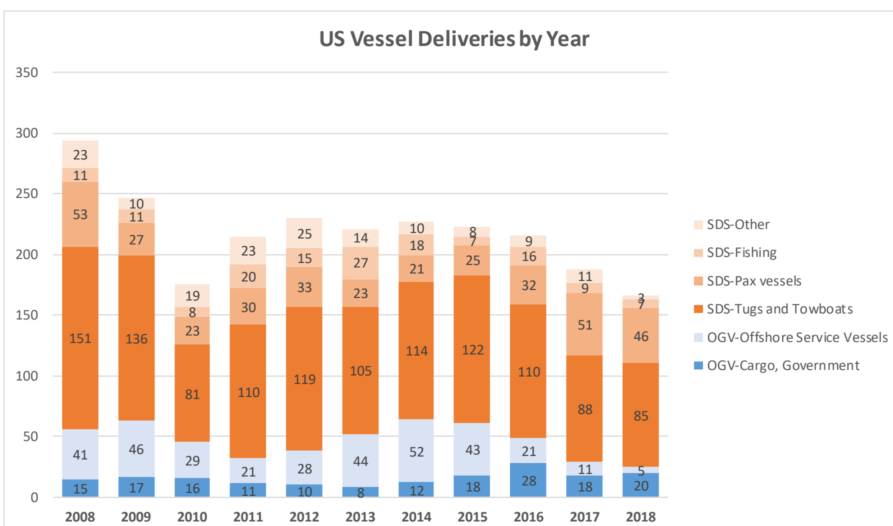


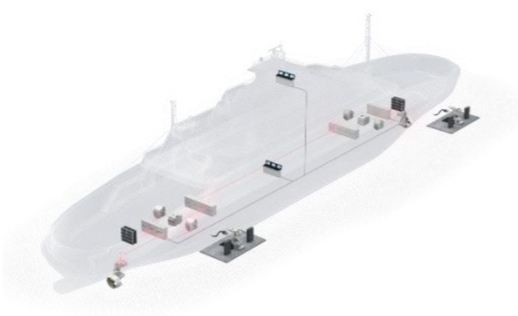
Figure 3. Recent US newbuild construction (Colton, 2019)

There are some exciting opportunities for Jones Act oceangoing vessels in the burgeoning offshore wind market, government fleet, offshore oil/gas activity, and larger cargo vessel markets. However, the bulk of this testimony will focus on the coastal and inland vessel markets, where most US newbuild construction is occurring.

Common US Vessel Types and Solutions

Road and Passenger Ferries

Ferries have become one of the pioneering vessel types for zero-emission battery deployment because they combine generally shorter routes with regular port visits. The shorter routes allow installation of battery packs that can fully power the vessels on their journeys while the predictable routes and turnaround times enable efficient deployment of shoreside charging infrastructure.



Operational profile	Fixed route, limited distance, not overly weight sensitive, volume limited
Conventional solution	Diesel mechanical to propeller
Reduced emission solution	Diesel electric with battery with propulsion motor to propeller
Zero emissions solution	Battery-electric with propulsion motor to propeller
Common challenges	Charging infrastructure, utility demand charges

For these reasons, its unsurprising that the ferry industry is among the first marine segments to adopt full battery-electric solutions. The first fully electric, battery-powered vessels to be built in the US are the two new Maid of the Mist ferries being powered by ABB. These Niagara Falls tour boats will be powered by a pair of battery packs with a total capacity of 316 kWh, split evenly between two catamaran hulls creating two independent power systems providing full redundancy.

Figure 4. New Maid of the Mist Ferry

The vessels will charge between every trip while passengers disembark and board. Shoreside charging will only take seven minutes, allowing the batteries to power the electric propulsion motors capable of a total 400 kW (563 HP) output. This will all be controlled by ABB's integrated Power and Energy Management System (PEMS), which will optimize the energy use on board.

From small to large, most ferry boats and routes can be electrified. In 2018, two ForSea Ferries, operating between Denmark and Sweden, became the largest battery powered ferries, following an ABB-led conversion.

Figure 5. ForSea Ferries

Economics play a large part in the push toward electrification. While zero emission boats tend to have higher capital costs, operational costs are much lower than diesel powered ships, making them more cost-effective over the lifetime of the vessel. Figure 6 is an example for an existing ferry opportunity where the battery electric option (Case E) is more expensive up front, but because it costs less to operate, the ship owner or operator ends up saving $800,000 over the life the vessel. Just like with electric vehicles, increased deployments, financing support, as well as research and development can help lower the upfront capital cost of zero emission options.

2.0 Results - Lifecycle Cost Calculation

	(A) Diesel Mechanical (DM)	(B) Diesel Electric (DE)	(C) DE w/Battery for Peak Shave	(D) DE w/Battery & Shore Charge	(E) Battery Electric Vessel	(F) Shaft Generator Vessel	
CAPEX	$0.66	$1.33	$1.46	$1.61	$1.50	$1.62	$M
AVG OPEX	$0.31	$0.26	$0.24	$0.20	$0.17	$0.24	$M/yr
ANALYSIS 1: Payback Years							
Payback Years	--	11	12	9	6	13	yrs
ANALYSIS 2: Internal Rate of Return							
Internal Rate of Return	--	8%	7%	11%	19%	6%	
ANALYSIS 3: Lifecycle Total Cost of Ownership							
Lifecycle Cost*	$4.5	$4.5	$4.5	$4.2	$3.7	$4.6	$M
Lifecyle Savings	--	$0.0	$0.0	$0.3	$0.8	-$0.1	$M

*25 year life, 7% discount rate

Figure 6. Example of Project Economics for ABB Ferry Project

In addition to the cost savings of choosing a zero emission solution, the CO_2 emissions reductions are stark, as shown in Figure 7. A significant reduction of CO_2 is shown in the battery electric option, which assumes an emissions profile in line with the energy generation mix of the power grid in California.

3.4 CO2 Emissions Summary

FUEL AND RUNNING HOURS	(A) Diesel Mechanical (DM)	(B) Diesel Electric (DE)	(C) DE w/Battery for Peak Shave	(D) DE w/Battery & Shore Charge	(E) Battery Electric Vessel	(F) Shaft Generator Vessel	
Diesel Fuel consumed	79,213	69,100	67,098	34,097	0	65,606	gallons/yr
Electricity consumed	0	0	0	497,636	1,039,034	0	kWhe/yr
EMISSIONS TOTALS*							
Diesel Fuel CO_2 emissions	806,391	703,439	683,058	347,111	0	667,870	kg CO_2/yr
Electricity CO_2 emissions	0	0	0	107,261	223,954	0	kg CO_2/yr
TOTAL EMISSIONS	806,391	703,439	683,058	454,372	223,954	667,870	kg CO_2/yr

diesel emissions intensity per EPA; electric emissions intensity based on average for California

TOTAL REDUCTION	--	**102,953**	**123,333**	**352,020**	**582,437**	**138,522**	**kg CO_2/yr**

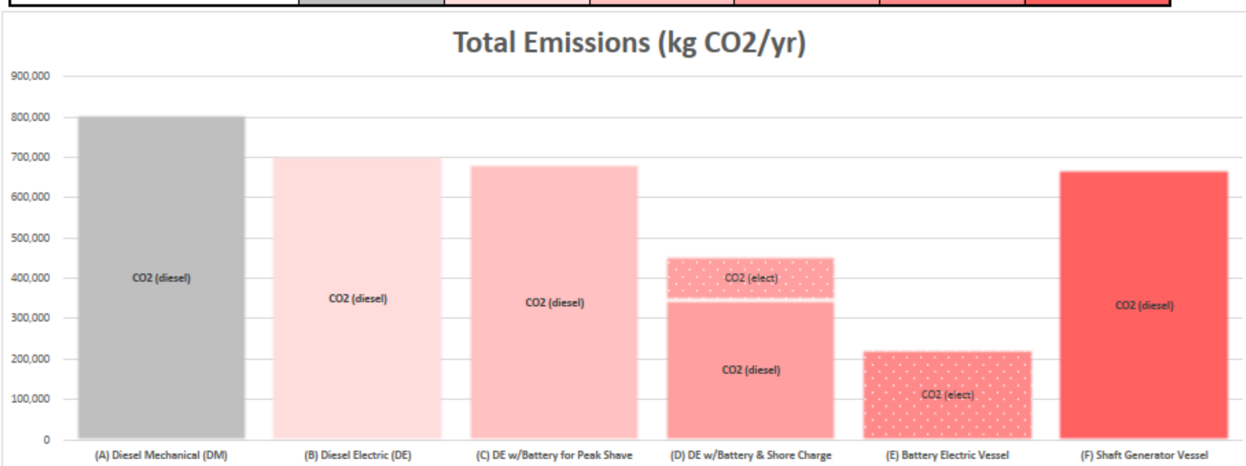


Figure 7. Example of Project Emissions Estimate for ABB Ferry Project

Harbor Tugs

Like ferries, harbor tugboats operate on short routes and typically return to the same port every evening. However, unlike ferries, they have significant idling time and higher power demands. To reduce emissions, a diesel-electric system with a smaller diesel generator and a battery bank can satisfy onboard power requirements when stationary while being ready to provide maneuvering power in an instant.

Operational profile	~60% idle time, ~35% at <40% power, <5% at full power
Conventional solution	Diesel mechanical to propeller
Reduced emission solution	Diesel electric with peak shaving battery, possibly plug-in, propulsion motor to propeller
Zero emissions solution	Battery-electric or fuel cell-electric, propulsion motor to propeller
Common challenges	Space for battery room, sometimes unpredictable periods away from dock

Figure 8 is an example of a typical tugboat use-case where a smaller diesel-electric powertrain paired with smaller battery for peak shaving (Cases C) or a larger battery for propulsion to be charged at port (Case D) were recommended by ABB. Like the ferry example above, despite higher upfront capital costs, the lower operating costs of an electric propulsion system can save the ship owner operator over $6m over the life of the vessel. Programs that address upfront capital costs will help increase deployments of low emission technologies and enable price reductions that come with scale and experience. For example, a low-interest loan program to cover the difference in capital cost could increase adoption.

2.0 Results - Lifecycle Cost Calculation

	(A) Diesel Mechanical (DM)	(B) Diesel Electric (DE)	(C) DE w/Battery for Peak Shave	(D) DE w/Battery & Shore Charge	(E) Battery Electric Vessel	(F) Shaft Generator Vessel	
CAPEX	$2.20	$5.53	$6.68	$7.88	$10.16	$6.48	$M
AVG OPEX	$1.85	$1.58	$1.30	$0.82	$0.52	$1.36	$M/yr
ANALYSIS 1: Payback Years							
Payback Years	--	12	8	5	6	9	yrs
ANALYSIS 2: Internal Rate of Return							
Internal Rate of Return	--	7%	11%	20%	17%	11%	
ANALYSIS 3: Lifecycle Total Cost of Ownership							
Lifecycle Cost*	$25.3	$25.3	$23.8	$19.2	$18.6	$24.0	$M
Lifecycle Savings	--	$0.0	$1.5	$6.1	$6.7	$1.3	$M

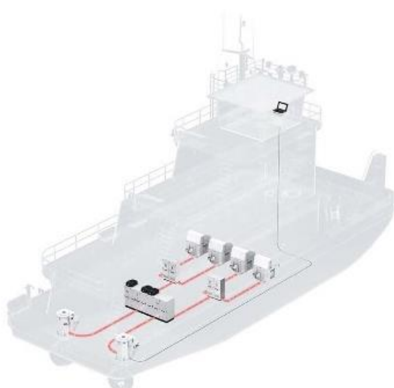
*25 year life, 7% discount rate

Figure 8. Example of Project Economics for ABB Tugboat Project

Inland Towboats

Inland towboats operate under a wide range of profiles. Factors like voyage length and consistency of docking schedule will drive either a battery-electric or fuel cell-electric solution. Less ambitious emission reductions can be achieved using a diesel-electric hybrid system with a battery.

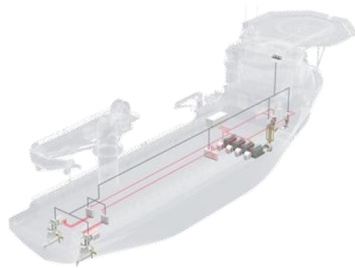
ABB is proud to be providing a complete fuel cell-electric power system for what will become one of the world's first fuel cell powered towboats, which will be operated by Compagnie Fluviale de Transport (CFT) of France.



Operational profile	Unit tows: varying length voyages Shuttle boat: short distance transits, long idle time Fleeting boat: stays local to fleet moving barges in and out Linehaul boat: regular long-distance hauls
Conventional solution	Diesel mechanical to propeller
Reduced emission solution	Unit tows, shuttle boat: Diesel electric with battery Fleeting boat: Battery-electric Linehaul boat: PTO/PTI
Zero emissions solution	Unit tows, shuttle boat, linehaul boat: Fuel cell-electric Fleeting boat: Battery-electric
Common challenges	Highly capex-focused market, cautious about new technology

Offshore Workboats

Offshore workboats have yet a different operational profile. Many have long dwell-times when servicing offshore assets like a wind farm or oil and gas rig, while also needing onboard power for ancillary service-related systems. A first step to reduce emissions for these workboats is to add batteries to a diesel-electric system. The batteries can be used to optimize diesel performance by assuming the very transient loads arising from the podded thrusters as they start and stop while in dynamic positioning mode. The diesel may shut off completely, or if running can operate at an optimal, steady point and avoid constantly ramping up and down. A movement to zero emissions will likely entail a fuel cell-electric propulsion system with battery.



Operational profile	Varied, but often have high dwell times and significant non-propulsive loads
Conventional solution	Varies, but often diesel-electric with podded propulsors
Reduced emission solution	Diesel-electric with battery storage for optimized operation
Zero emissions solution	Fuel cell-electric with battery storage

ABB is proud to have powered the NKT Victoria, a specialized offshore cable-laying workboat, with ABB's Onboard DC Grid system and achieved a remarkable 60% CO_2 reduction versus a comparable vessel. This was achieved both because of greater efficiency in the propulsion system, but also due to operational changes that the electrified system permitted.

Figure 9. NKT Victoria

Oceangoing Cargo Vessels

Oceangoing cargo vessels often have predictable operational characteristics, however their long distance routes, coupled with very short port stays, make full battery-electric propulsion systems challenging. The first step toward reducing emissions is to use an alternative fuel like LNG or biofuel, and potentially adding battery storage. A move toward zero emissions would likely incorporate a fuel cell-electric propulsion system, which ABB is developing for this need.

	At Sea	In Port
Operational profile	Most spend long periods of time at sea with limited port turnaround time	

Conventional solution	Slow speed diesel to propeller	Operate diesel-powered generators and steam boiler
Reduced emission solution	Alternative fueled (e.g. LNG, dual fuel), possibly with battery	Cold ironing (vessel plugs into local shore power) or battery
Zero emissions solution	Fuel cell-electric with propulsion motor to propeller, or engine with net-zero fuel (e.g. ammonia, biofuel) direct to propeller	

While in port, achieving zero emissions is possible for some vessels today by connecting to a shoreside power source, often called “shore power,” “ship to shore,” or “cold ironing”. ABB has provided a number of cold ironing installations across the globe involving both the onboard and shoreside equipment. There are challenges to cold ironing as most older vessels are not outfitted to accept shore power and not all ports are currently equipped to support it. Cold ironing can be of limited value if there are substantial non-electric loads (e.g. crude oil tanker steam-powered cargo pumps) or if the in-port power demands are not overly significant (e.g. a bulker with only hotel loads). In light of the unique demands of oceangoing vessels, more investment in research, development, and demonstration projects is needed to deliver cost-effective and commercially scalable zero emission solutions for these vessels.

Summary and Recommendations

The marine industry is just beginning its march toward zero emissions with commercially ready cost effective solutions available today to meet the needs of multiple vessel segments. There are, however, some segments, like oceangoing vessels, that require significant additional technology research and development in order to reach a zero emission target. One commonality across all segments, which is also true across many new technologies, is that with scale and experience, costs trend downward. This has been the case with solar and wind power, and also electric vehicles. To same will hold true for marine vessels.

There are a number of actions that the Federal Government and this Committee can take to increase deployment of existing zero emission technologies, invest in the zero emissions technologies of the future, and grow US leadership in the marine sector for decades to come

1. **Green the Federal Fleet**. The US government is a globally leading shipowner, and as such it can become a pacesetter in deploying cost-effective, advanced technologies. In addition to Department of Defense ships, the US owned fleet includes Coast Guard, MARAD, and National Park Service vessels.

   ABB encourages the Committee to set an ambitious, long-term national plan to achieve zero emissions for all vessels under its operation. Doing so would have a meaningful impact directly on vessel emissions and establish the private US maritime industry as a global technology leader. This would also help the US do its part toward meeting the International Maritime Organization’s (IMO) Sustainability Goals. ABB is prepared to support the Committee in developing such a strategy to seek realistic, cost-effective solutions.

2. **Limit Tier 4 Engine waivers to where true hardships exist.** After a thorough rulemaking process and cost justification, EPA requirements for reduced emission engines have arrived. Engine manufacturers have provided proven, cost-effective engine solutions to meet these requirements. While EPA is not under the jurisdiction of this Committee, waivers for vessels under this Committee's jurisdiction should be issued judiciously and only after thorough demonstration of hardship to meet the requirement.
3. **Support financing mechanisms and direct funding for private sector, zero-emission vessels, projects, and equipment providers.** Zero emission vessels often have higher up front capital costs, but lower operating costs and therefore lower total cost of ownership than conventional diesel systems. Government investment in research and development can help lower those costs. As such, we recommend supporting and expanding programs like the Maritime Education and Technical Assistance (META) Program. The Federal Transit Administration's Ferry Grant Program should be expanded and could include a focus on zero emission technologies, just like the Transit Bus "No/Lo" program. We also suggest exploring establishing a low-interest loan program to cover the incremental capital cost of choosing a zero emissions technology.
4. **USCG Marine Safety Center**. The Coast Guard's Marine Safety Center (MSC) is faced with the challenge of ensuring the safety of vessels, regardless of propulsion technology. As lithium ion batteries, fuel cells, hydrogen, and other new technologies become commercially available, the MSC is tasked with updating the Code of Federal Regulations (CFR) to address these new technologies. This will require time and resources. ABB is prepared to support MSC in this role and asks the Committee to do the same.
5. **Invest in Research and Development**. While there are commercially available zero emission solutions available today for some marine segments, others still require significant research and development, particularly in the area of fuel-cells, advanced battery chemistries, and advanced net-zero fuels. Through the US Coast Guard's Research Development Test and Evaluation Program, the Department of Energy, and MARAD's META Program, the Committee could encourage development of a zero emissions ship research and development program.
6. **Help solve shore charging**. As vessels like ferries electrify, electric utilities are faced with high power loads during recharge. This can often trigger demand charges which can significantly challenge the otherwise favorable economics to move to electric. Solutions like shoreside energy storage systems are available to mitigate this cost, though they can add cost and complexity to the project. The Committee could also direct MARAD to invest in shoreside power through funding mechanisms like the Port Infrastructure Development Grants.
7. **Training**. Support Maritime Academies and ensure labs and curriculum include the latest technology. While alternating current (AC) electrical systems remains a common standard on vessels, ships powered by electric propulsion will be built using direct current (DC) architecture. Training curriculum should be updated to address these changes to how ships are powered.

To Learn More

Please visit new.abb.com/marine or ABB's SNAME webinar about marine electrification.

About Peter

Peter is the **Technical Solutions Manager for** ABB Marine & Ports, designing pure-electric and hybrid diesel-electric systems for ships and boats. He recently relocated to Seattle.

Prior to that, Peter **began his career** and spent **eight years with ExxonMobil's** marine company.

Peter has a BS in Naval Architecture/Marine Engineering from **Webb Institute** and an MS in Transportation from **MIT**.

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