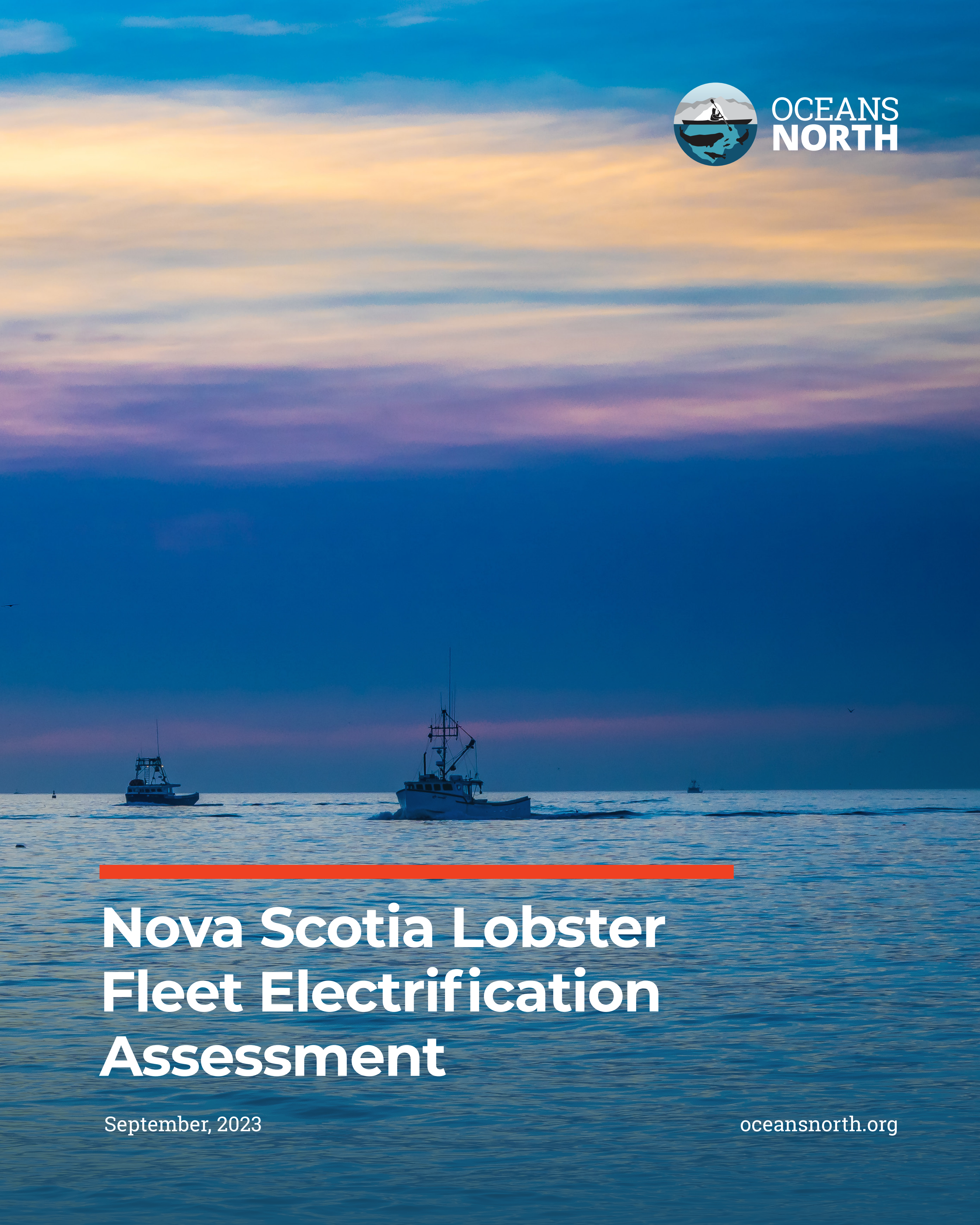

OCEANS NORTH

Nova Scotia Lobster Fleet Electrification Assessment

September, 2023

oceansnorth.org

Nova Scotia Lobster Fleet Electrification Assessment

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Acknowledgements

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The report builds off an extraordinary existing body of work beginning with the Review of All-Electric and Hybrid-Electric Propulsion Technology by the NSBA in 2015, and has been carried on by companies and non-governmental organization such as Glas Ocean Electric, the Centre for Ocean Ventures & Entrepreneurship, and the Island Institute in Maine, who are all working to advance marine electric propulsion and hybrid systems. Thank you to RBC Tech for Nature, Google, and ClimateWorks Foundation for making this work possible.

Further Information

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List of Acronyms

Acronym	Definition
ACOA	Atlantic Canada Opportunities Agency
CO_2e	Carbon Dioxide Equivalent
DC	Direct Current
DFO	Fisheries and Oceans Canada
GHG	Greenhouse Gas
hp	Horsepower
ICE	Internal Combustion Engine
IMO	International Maritime Organization
KW	Kilowatt
kWh	Kilowatt-hour
LFA	Lobster Fishing Area
LFP	Lithium-Iron-Phosphate
LOA	Length Overall (the maximum length of a vessel’s hull measured parallel to the waterline)
MW	Megawatt
TC	Transport Canada
TRL	Technology Readiness Levels
V	Volt
V2G	Vessel to Grid

Background

This report presents an overview of the opportunity to modernize Nova Scotia's lobster fishing fleet with zero-emission propulsion systems. The report is intended to serve as a complement to previous studies that have focused on the challenge of powering an individual boat by capturing a fleet-level perspective and examining the potential for zero-emission technologies across the entire Nova Scotia lobster fleet. The goal of this report is to provide lobster fishers, boatbuilders, and decision-makers with an overview of the technology's potential and begin to equip them with the information they need to make system-level plans to decarbonize at a scale and pace that fits with Canada's and Nova Scotia's commitments to achieve net-zero emissions by 2050.

The report was prepared through a collaborative process which brought together the specialized expertise of professionals from different sectors, including naval architects, energy system experts, academics, electrical engineers, boatbuilders, fishers and climate change and clean energy advocates. Together, this group reviewed the appropriateness of existing technologies, built the fleet energy profile, and assessed the cost-effectiveness of the technologies, as well as the broader economic and environmental benefits that will come from the creation of a zero-emission fishery. The group also began to identify the policies and enabling conditions that will need to be in place for such a transition to get started.

Information used in this report was gathered with the help of Fisheries and Oceans Canada (DFO), from previously published reports, as well as primary research, including sensor tracking on boats in different Lobster Fishing Areas (LFAs) and interviews and community meetings with fishers and boatbuilders.

Executive Summary

The Nova Scotia lobster fishery is both economically and culturally important to the province. The lobster fishery represents more than 80% of the province's fisheries sector value and is recognized across the world as a symbol of the province. Yet, to date, and despite a rapidly changing policy landscape calling for full marine decarbonization no later than 2050, no clear strategy is in place to transition the lobster fishery or other commercial fisheries in Canada to zero-emission technologies and fuels.

This report argues that the Nova Scotia lobster fishery is well suited to advance the development and commercialization of emission-free alternatives to diesel, as most vessels operate close to shore with relatively consistent operating patterns. Further, there is an opportunity to establish Nova Scotia as a leader in the adoption of zero-emission vessel technology, creating jobs and economic opportunities for the province.

This report assesses the potential for zero-emission vessels in the Nova Scotia lobster fishery and asks the question: "***Can battery propulsion power a fishing boat for a full day of work off the coast of Nova Scotia in a cost-effective way?"*** To get to the answer, the report first examines a series of related questions.

What type of zero-emission propulsion system is best suited for lobster vessels in Nova Scotia?

The answer is explored in Chapter One of this report, which looks at both battery-electric and hybrid fuel cell electric propulsion systems. These systems are the two most technically advanced zero-emission technologies available in the marine space for nearshore activities, with dozens of battery-electric ferries and work boats operating in commercial service around the world—including in Canada. Based on market research, vessel energy profile analyses, and direct experience with designing battery powered vessels, the project team reasoned that the typical size of many Nova Scotian inshore lobster boats could hold ~500 kWh of batteries and still have allowance for their catch weight.

How much energy is needed to power the majority of lobster vessels?

Chapter Two assesses the energy profile of the lobster fleet in Nova Scotia. This fleet energy profile is based on the characteristics of different lobster vessels (length and beam) and the operating patterns of different lobster boats fishing within specific LFAs (how long and how far they travel). The research team's analysis concluded that 70% of days fished by the entire fleet occur within 20 km of their home port, making almost 2300 lobster vessels good candidates for electrification. Our assessment finds that 60% of these vessels could fulfill a day of fishing with less than 400 kWh of energy and are a great fit for battery-electric propulsion systems. The remaining 40% of vessels fishing within 20 km of their home port, as well as those fishing further, are expected to be served by either larger battery-electric or fuel cell electric systems.

Are zero-emission technologies cost effective?

While there are several unknown factors in this analysis, Chapter Three presents an overview of some of the cost considerations for zero-emission technologies and presents a simplified economic analysis comparing the total cost of acquiring and operating diesel, battery-electric and fuel cell electric propulsion systems based on an actual vessel operating in LFA 26A. The analysis shows that the total cost of a battery-electric system is competitive with diesel when looked at over a 20-year time horizon. The higher capital acquisition cost is quickly offset by much lower operating costs. Zero-emission systems for vessels that transit farther from port or

have fewer battery charging cycles per year will have longer pay back times. While the analysis completed is acknowledged to be high level, it shows that battery-electric propulsion is economically viable and that further in-depth analysis should be undertaken to develop a robust understanding of the economics of zero-emission technologies in commercial fishing applications.

What is needed to make the change?

While the federal and provincial governments have committed to lowering emissions, they have yet to include commercial fishing vessels in their plans. Chapter Four argues there are economic and environmental benefits to be achieved from decarbonizing the Nova Scotia lobster fleet. There is potential for more than $10 billion in economic activity in Nova Scotia related solely to the construction of new vessels and the installation and operation of shoreside infrastructure. Battery electric vessels will also eliminate air pollutants, improve the air quality and health of local communities, and will dramatically reduce underwater noise pollution. Based on fuel consumption estimates, the total GHG (greenhouse gas) emissions for the fishing fleet are calculated to be 82 million kg of C02e each year, roughly equivalent to up to 35,000 cars. The fleet-wide energy assessment identified that battery-electric vessels with 400 kWh of energy used could eliminate 40% of the lobster fleet's emissions, or 33 million kg of CO_2e annually.

Chapter Four further identifies incentives governments could offer to accelerate the transition to a zero-emission fleet. This includes clear Paris Agreement-aligned targets for marine emissions reductions (with both 2030 and 2050 targets) and ensuring that Canada's commercial fishing fleet is included in the forthcoming Marine Climate Action Plan. Other market acceleration strategies include incentivizing the adoption of new technologies through support for feasibility assessments, demonstration projects and incentives for boatbuilders to explore new hull designs. Additionally, support will be required to build the necessary long-term infrastructure. This could range from enhancing electricity grid capacity and including marine shore charging applications in existing electric charging infrastructure programs to tariff schemes for bidirectional charging. It could also include initiatives aimed at workforce and skills development programs and financing programs to help offset the capital costs of new systems.

This report represents a first attempt to carry out a fleet energy assessment of the Nova Scotia inshore lobster fishery, with the goal of identifying opportunities and next steps in building a pathway to zero emissions for this important sector. While there are areas where further research is warranted, this report provides clear evidence of the potential of electrification to decarbonize the fleet and makes a strong argument for continued investment in research and demonstration projects to help build the market for zero-emission propulsion systems.

There is an imperative to act quickly. Lobster vessels and propulsion systems have lifespans of over 20 years. For the lobster fleet to be net-zero by 2050, it is believed that 15% of the fleet will need to be powered by renewable energy and zero-emission fuels by 2030. This shift will not happen without a joint effort from the government, energy providers, boatbuilders, boat owners and fishers.

Introduction

Nova Scotia's lobster fleet lands more than $500 million worth of lobsters each year,[1] some 80% of the value of Nova Scotia's entire fisheries sector. Fishing, and especially lobster fishing, is not only essential to the well-being of coastal communities; it is a part of Nova Scotia's heritage. This important fishery is supported by a robust boatbuilding and marine services sector that contributes $378 million[2] to the Nova Scotia economy each year.

While the lobster fishery has a long history in Nova Scotia, change is ongoing and inevitable. The fishing fleet is currently powered almost exclusively by diesel-powered internal combustion engines. Fuel can account for as much as 30% of total fishing costs. With future fuel price volatility and the ongoing evolution of carbon pricing schemes, boat owners are eager to mitigate the impact of rising fuel costs. Fishers and coastal communities are also increasingly aware of the impacts of climate change. Fishers are observing changes in the fish they catch, with an influx of new species in their fishing grounds. Those living in coastal communities are experiencing storms and weather events that are more intense, frequent, and unpredictable.

The high-profile nature of the lobster fishery in Nova Scotia and its strong consumer connection makes it a logical target for demonstration projects that could eventually be scaled nationally and internationally. As fishing fleets around the world look for low- and zero-carbon alternatives to fossil fuels and consumers make more eco-conscious choices, proactively working towards solutions in this overlooked space could position Canada as a leader in providing both emissions-free seafood and technology solutions. Identifying a net-zero pathway for this important economic sector in Atlantic Canada could also provide a source of jobs and local economic activity as a new lobster fleet, specifically designed to be powered by zero-emission propulsion systems, is built.

The lobster fishery in Nova Scotia has a tradition of resilience and innovation that positions it well to play a role in advancing zero-emission technologies. However, the fishing industry and the boatbuilding industry that supports it have historically not factored as strongly as other sectors in government climate and innovation planning. Despite the industries' lack of inclusion in government planning, fishers and boatbuilders who are observing the evolving policy landscape in Canada with regard to reducing marine emissions are seeing a need to explore zero-emission solutions. Research undertaken for this report identified an opportunity to use the inshore lobster fishery as a commercialization test ground that will not only prove battery-electric systems are ready to perform the daily work, but will also demonstrate the economic opportunities for Nova Scotia to build a modern fishing fleet and provide cost savings and certainty for boat operators. To get started, fishers, boatbuilders, innovators, clean-energy providers, and governments will need to coalesce around a shared understanding of the challenge and work collaboratively to accelerate the development and uptake of zero-emission solutions.

Climate Risk and Policy

The ocean absorbs vast quantities of the excess energy in the atmosphere that is trapped by greenhouse gases. Over the past century water temperatures off the Maritimes have increased by 1.5˚C, with new record highs seemingly being set on an annual basis. Warmer oceans are also leading to the increasing intensity of tropical storms and storms that persist further north.

In response to these and other looming climate-related challenges, governments and industry leaders from around the world have agreed to develop plans to reduce GHG emissions so that global warming is limited to 1.5 degrees Celsius compared to pre-industrial levels. In December 2021, the federal government passed the *Canadian Net-Zero Emissions Accountability Act*, which legally enshrined Canada's emissions reduction target of 40-to-45% below 2005 levels by 2030 and net-zero emissions by 2050 for all sectors of the Canadian economy. The Province of Nova Scotia has made similar commitments: the *Environmental Goals and Climate Change Reduction Act* legislates that, by 2030, emissions must be reduced to at least 53% below 2005 levels, and it seeks to achieve net zero by 2050. Private sector companies, including banks, energy companies, and retailers, are also making commitments to decarbonize their operations by 2050.

Growing Global Momentum to Address Marine Emissions

Over the last several years, marine emissions have become a major focus for increased climate action. The shipping industry produces over 1 billion tonnes of GHG emissions every year—about 3% of global emissions, roughly the same as a major industrialized country like Japan or Germany. It is estimated that marine fishing vessels release more than 200 million tons of CO_2 into the atmosphere annually, equivalent to 51 coal-fired power plants.[3]

Canada recently began consultations to develop a Canadian Marine Climate Action Plan to reduce marine sector emissions in line with its legislated commitments. The focus on marine emissions is happening in other jurisdictions as well. In 2021, the California Air Resource Board introduced regulations requiring short-run ferries and excursion vessels to be zero-emissions by the end of 2025, as well as incentives for harbour craft to switch to zero-emission technology. The European Union is investing in clean fuel production and marine electrification. Norway has banned fossil fuel emissions in its fjords starting in 2026 and has developed a plan to reduce domestic fleet emissions by 50% by 2030, including emissions from its fishing fleet.

While Canada has not yet linked the commercial fishery with its marine decarbonization plan, the government is supporting the development of zero-emission solutions in the fishing and local boatbuilding sector in other ways. These include the Efficient Hull Design Contest that was run by the Atlantic Canada Opportunities Agency, Transport Canada (TC)'s recent adoption of classification standards for electric and hybrid electric propulsion systems, as well as funding through DFO and TC for the research and development ofv zero-emission solutions.

Chapter One

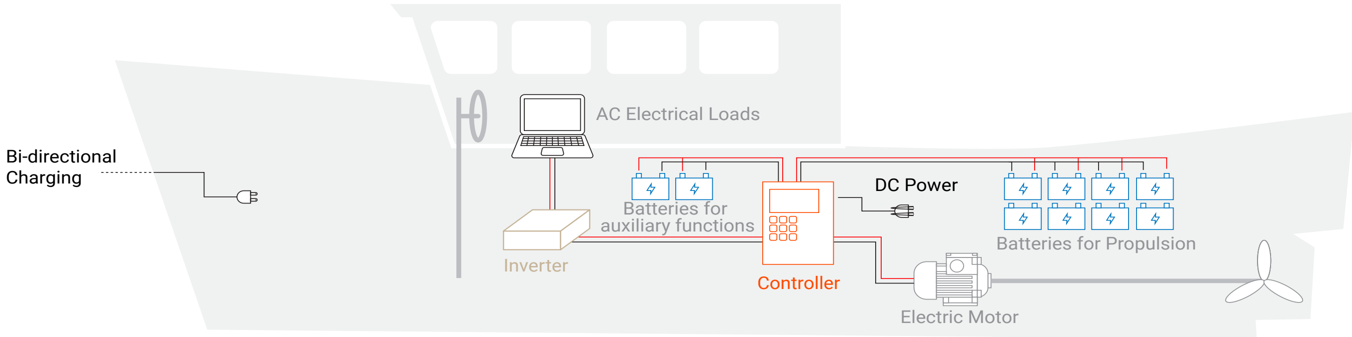
Zero-Emission Propulsion Systems

This chapter presents a technology overview and assessment of what are considered the top two zero-emission propulsion system technologies identified for meeting the needs of the Nova Scotia inshore lobster fleet: battery-electric, and hybrid hydrogen fuel cell electric. Battery-electric propulsion systems are already in commercial service in ferries and work boats around the world, whereas hybrid electric hydrogen fuel cell technology is operating primarily in precommercial deployment settings. Zero-emission fuels such as e-methanol, e-ammonia, and biofuel are also being developed for marine use for larger ocean-going vessels. The technologies considered for this report are those that have the greatest potential to be scaled over the next decade as emission-free alternatives to fossil fuels. In addition to the propulsion system technology itself, there are additional considerations that will impact the viability of a given technology, such as space, weight and storage considerations of the battery and/or fuel cell on board the vessel, hull efficiency, and shoreside infrastructure.

Box 1 – The Nova Scotia Electricity Grid

Since battery charging and hydrogen production both require electricity, the energy sources of Nova Scotia's grid will drive the lifecycle emissions of future zero-emission vessels. Coal accounted for 51% of electricity generation in Nova Scotia in 2019. The province also produces electricity from oil, natural gas, hydro, wind, and biomass.[8] Nova Scotia has been making strides to move to a cleaner grid. The current standard requires Nova Scotia Power to generate at least 40% of electricity from renewables. The Nova Scotia grid could soon be up to 60% renewable energy when the Maritime Link starts providing reliable, clean hydroelectric energy along with other renewable energy projects. The utility is looking for strategies to help them reach 70% renewable electricity by 2026 with new renewable energy projects. The long-term plan is to replace approximately 1200 MW of coal powered plants in Nova Scotia with clean energy sources by 2030 and to run a net-zero grid by 2035.

Figure 1 - Battery-electric Propulsion System



Battery-electric Vessels

Battery-electric powered vessels are considered to be the most efficient zero-emission systems, achieving up to 85% efficiency in the conversion of electrical energy to mechanical energy to propel themselves.[4] Battery-electric propulsion systems are also the simplest form of zero-emission systems as there are only three main components: battery, motor, and controller. Figure 1 shows a model of a typical battery-electric propulsion system that would be deployed on a commercial fishing vessel.

The feedback from those that have captained battery-electric boats is positive. The first is that there is much less noise. The second is that it eliminates exhaust fumes, which are customary in diesel engines. Both of these are benefits to crew working onboard fishing vessels.

Batteries are at the core of electric vessels. Lithium-based batteries have been identified as the most viable for electrification of the lobster fleet due to their high energy density (per volume), high specific energy (per mass), long cycle life (thousands of charge/discharge cycles), and high energy efficiency per cycle (>90%). No other battery technologies are positioned to overtake lithium-based batteries for marine propulsion applications over the near- to medium-term. Specifically, Lithium-Iron-Phosphate (LFP) batteries are commanding the greatest market share today due to their safety and cost. This report focuses exclusively on LFP batteries. LFP batteries typically perform for 3,000 to 5,000 cycles staying within 80% of their rated charge capacity. For a lobster vessel making 60 or even 100 voyages per year, LFP batteries should far outlive the vessel.

The cells that make up a marine battery pack vs. non-marine battery packs (e.g., those used for land-based vehicles) are the same. The differences come in the casing that houses the battery pack and the procedures for how to install and maintain those battery packs. The primary challenge for placing batteries onboard a vessel is their weight and the position of that weight onboard the vessel.

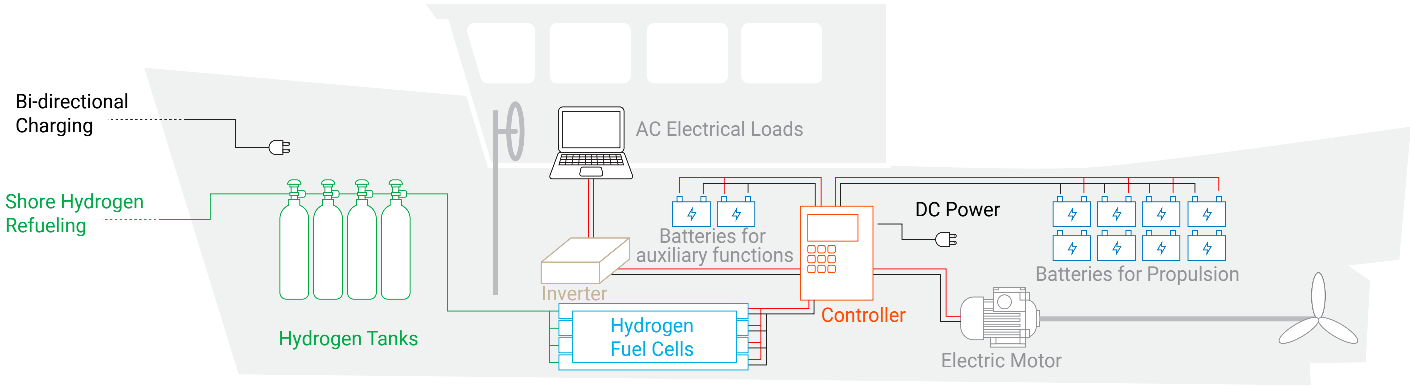
The approximate weight of a 100 kWh battery pack is 600 kg. This means that a 500 kWh battery pack would weigh 3000 kg, which is 3.0 tonnes. This weight is partially offset by the removal of the diesel engines, engine systems, as well as the weight of the diesel and tanks. New designs for battery-electric vessels will need to consider proper location and weight impact for mounting, as well as the fact that new batteries are becoming more energy dense and lighter.

Promising data and developments are emerging on the safety and reliability of battery-electric vehicles in the automotive industry and becoming more frequent in the marine industry. Governments can fund and drive more research in this area. A recent study by AutoInsurance EZ found that fires, an oft-cited safety concern with battery-electric vehicles, are much less common in electric vehicles than in internal combustion engine (ICE) vehicles.[5] Electric power systems have fewer moving parts compared with ICE systems, which suggests that they will be more reliable than diesel systems. The OceanVolt electric propulsion system, for example, requires one hour of annual maintenance and will last for 50,000 hours, about ten times longer than an internal combustion engine. In the vehicle market, we see that electric cars are targeting one million miles of operation compared to the ICE historic average of 124,000 miles,[6] which is a strong argument for increased performance.

Cold temperature reduces battery capacity and range; however, it is important to recognize that less capacity and range impact can be expected in marine applications given that water temperatures are higher than air temperatures. In addition, scientists are working to perfect improved battery chemistries for cold weather versus the current LFP batteries.[7]

For battery-electric propulsion systems to be truly zero emission, the work being done to clean the grid in Nova Scotia must continue (see Box 1) in parallel to market development for zero-emission modes of transportation. Battery-electric vessels for the inshore fleet are expected to have a working range of ~20 kms from shore, which encompasses most fishers in the province. While batteries are intended to fulfill a normal day of fishing with some margin of comfort, a range extender (small electrical generator) will likely be required equipment onboard for safety in the rare cases that the battery is depleted early. This generator would not normally run except in emergencies or for trips extended beyond normal distances.

Figure 2 - Fuel Cell Battery-electric Propulsion System



Hybrid Hydrogen Fuel Cell Electric

In a hybrid hydrogen fuel cell electric system, electricity produced from a hydrogen fuel cell is coupled with a battery so that the fuel cell can operate at its peak power and charge the battery. The rest of the system works the exact same as the battery-electric, with the battery controller powering the electric motor (see Figure 2).

Hydrogen fuel cells generate direct current (DC) electricity through an electrochemical reaction that combines hydrogen and oxygen and exhausts water vapor. Hydrogen fuel cells are 40-60% energy efficient. Alternatively, hydrogen can be used as a fuel for internal combustion engines, but that approach results in a lower energy efficiency than fuel cells.

In comparison to battery power, hydrogen offers a higher energy density but a lower efficiency and higher cost per kW of power available. To minimize cost, the fuel cell will be sized to run continuously at its rated power and the battery will provide power during high load times, such as while the vessel is in transit. The fuel cell will recharge the battery during low-load times, such as while hauling pots. The storage tanks would be sized based on the amount of hydrogen needed to complete the vessel's journey. As a result, fuel cell electric systems are expected to be most favourable in applications with long voyages where battery-electric alone would not be able to provide sufficient energy. Examples of this are the vessels in LFA 33 and 34, which go for multi-day fishing trips and fish 50 km offshore. Numerous fuel cell electric marine vessels are being piloted around the world[9] and more are expected to be launched in the immediate future, including the ferry vessel ***Sea Change***[10] in California and the Norwegian ferry ***Hydra***.[11] Hydrogen fuel cells are also being used in commercial service for buses and are receiving increased interest in the heavy equipment and long-haul trucking sectors. Using hydrogen in a fuel cell is less costly and energy-intensive than converting it to e-ammonia or e-methanol, making it a front-runner for coastal and nearshore applications where regular refuelling is an option.

Hydrogen is normally stored as a high-pressure gas. Since hydrogen can be produced by renewable energy and stored on shore, it could offer the potential benefit of minimizing demand charges and electricity grid impacts in comparison to battery systems that may require larger loads to recharge vessels. Another advantage lies in the fact that hydrogen tanks can be refuelled in a few minutes, while charging batteries often requires at least 30 minutes and in some cases much longer, depending on the capacity of the charging system and the grid connection.

One of the major barriers to advancing fuel cell technology in the marine space is availability of clean hydrogen. Until hydrogen is readily available and cost competitive, it will be challenging to trial fuel cell electric technologies in near-shore marine applications. While there have been several hydrogen projects announced in Nova Scotia recently, they are not expected to produce hydrogen until at least 2025. Hydrogen-based systems also face a similar problem to electric systems in that there is a lack of necessary shore infrastructure.

Allswater First Electric Lobster Boat Design

Space, Weight, and Storage Considerations

Current vessel designs have been optimized around the most efficient placement of diesel engines and fuel tanks. When designing zero-emission vessels it will be critically important to account for the weight and volume of the batteries. The battery pack is estimated to take up approximately one-tenth of the available space on a vessel, but it is very heavy compared to the equivalent diesel storage tanks. Hydrogen tanks will also take up available space on the vessel. The exact amount of space is dependent on the volume of compressed gas that will be stored. Space restrictions for smaller boats will have to be addressed through design changes and retrofitting. Space, weight, and storage considerations suggest that new vessel designs could provide a greater opportunity to house new propulsion systems.

Based on market research, vessel energy profile analyses, and direct experience with designing battery-powered vessels, the project team reasons that the typical size of many Nova Scotian inshore lobster boats could hold ~500 kWh of batteries and still have allowance for their catch weight. In fact, there are several projects underway in Nova Scotia in which all-electric systems between 250 and 500 kWh are being integrated into workboats and lobster vessels. Vessel owners and boatbuilders will have to work together to conduct their own analyses based on the mission profile and operating patterns of the vessel they are replacing, and whether it's a new build or a retrofit.

Hull Efficiency

While there may be opportunities to refit existing hulls with battery-electric systems, significant engineering and design will be needed to ensure that the vessel has favourable weight distribution, stability and carrying capacity. Not all existing vessels and designs will be suitable for electrification, depending on the size of batteries needed for the boat. The most efficient zero-emission fishing vessels will likely be built from the ground up to accommodate batteries and propulsion with higher-efficiency hulls.

The efficiency of the hull significantly affects vessel range. Highly efficient hull designs can achieve a 20% reduction in drag, thereby reducing the battery need by 20% to achieve the same range. Having fewer batteries will reduce the capital and operating costs.

The key challenge at this pre-commercial stage of technology adoption is that there is limited access to demonstration vessels similar to those being used in the Nova Scotia fishery that have been built and tested in an operational environment. Boatbuilders will need assistance and incentives to develop new designs and hull moulds in order to improve vessel efficiency and accelerate the adoption of new vessels.

Additional Considerations

Shoreside Infrastructure

Battery Charging Infrastructure

The lowest-cost energy to use remains energy that is available through a connection to the electricity grid. Both battery-electric and plug-in fuel cell electric vessels will have batteries that will require or benefit from shore charging.

The shoreside infrastructure needed to charge the batteries onboard the fishing vessels is similar to that used for other electric vehicles. As an example, Level 3 chargers using combined charging system standards can charge up to 350 kW of power at up to 920V DC.[12] For large marine and vehicle applications, there are charging standards, such as megawatt (MW) charging standards with CharIN,[13] which are evolving to meet the demands of higher charge capacities. This means that a Level 3 charger could charge up to 80% of the energy in a 500 kWh battery system in about an hour. As marine charging standards evolve, the next generation of marine chargers are expected to provide up to a MW of power to the vessel battery, which would mean that a 500 kWh system could be charged to 80% in less than 30 minutes.

It is expected that grid infrastructure upgrades will need to be considered to accommodate the growth of electric vessels due to their energy demand on the electricity grid.

Bi-Directional Charging / Vessel-to-Grid (V2G)

An additional benefit of the batteries on board the battery-electric vessels is that while they are not in use and are connected to bi-directional charging infrastructure, they can serve as energy storage through vessel-to-grid (V2G) services. The V2G may include firm capacity, operating reserves, transmission, and distribution deferral.[14] With this model, vessel owners could receive financial benefits for providing electricity grid V2G services, which would offset some of the vessel's operating costs. In a recent Massachusetts pilot project, a single electric school bus with 220 kWh of battery capacity generated $23,500 USD of V2G revenue over a two-year period. Exactly what incentives will look like remains to be fully understood, as grid operators are only now starting to introduce commercial structures that support V2G.

The majority of the leading manufacturers of battery-electric systems globally recognize the advantages of bi-directional charging. The federal government already subsidizes bi-directional infrastructure in the automotive sector, so it would make sense for this support to extend to marine applications as well. For boatbuilders or system integrators, it will be important to ensure that any equipment that is put into the vessel supports bi-directional capabilities. For operators, financial incentives from V2G services could be a consideration in evaluating the economics of the propulsion system.

Hydrogen Shoreside Infrastructure

Hydrogen storage would be needed as part of the wharf infrastructure for the vessels that use hybrid fuel cell electric systems. Hydrogen would be bunkered in stationary tanks or portable storage trailers close to the wharf and then pumped into the vessel when it is alongside for refuelling. The type of hydrogen fuel transport infrastructure depends on the hydrogen storage mechanism for the vessels. Commercial demonstration projects show that hydrogen can be utilized from the wharf on smaller scales and that the technology is feasible for scaling.

Summary of Technologies

Battery-electric and hybrid fuel cell electric systems are the two zero-emission technologies that are most ready to replace current ICE technologies. Electricity is at the heart of both solutions, as charging batteries and producing hydrogen both require electricity. Fortunately, electricity is widely available and can be efficiently converted into propulsion energy at a lower cost per kWh of work than diesel fuel and hydrogen. Battery-electric fishing vessels are expected to be trialed in Atlantic Canada in the near-term, demonstrating that both the vessel technology and the shore infrastructure is available and ready to use today. Fuel cell electric vessels could be expected to have a role in powering fishing vessels for longer distances and for multiday trips. It will be several years before actual fuel cell electric fishing vessel demonstration projects are ready to be deployed in Nova Scotia because more time is needed to develop a hydrogen supply chain that can be utilized at fishing ports across the province.

Chapter Two

Fleet Energy Profile

Before exploring the potential for new energy systems in lobster vessels, we must understand how the fleet operates today. The fleet profile characterizes the size and age of vessels harvesting lobster in Nova Scotia, the typical operating profiles in various Lobster Fishing Areas (LFAs), the amount of fuel consumed per vessel, the amount of propulsion energy required per trip to sea, and the estimated greenhouse gas (GHG) emissions.

The fleet profile relies on government data, previously published research and new data collected for this study. While most vessels harvest lobster close to shore and return to port daily, some vessels spend days at sea. The optimal energy system depends on the operating profile and physical characteristics of the vessel. The profile can also determine which LFAs are best suited for early decarbonization and primed for investments in retrofits or new vessels.

Calculating the Fleet Energy Profile

The calculated Fleet Energy Profile shows the overall energy and associated fuel consumption used by the entire lobster fleet. This also shows the modelled amount of energy storage required to power vessels through their entire voyages. While previous reports have focused on creating an energy profile for specific fishing vessels, this report attempts for the first time in Canada to assess the energy needs for an entire fishing fleet.

The energy calculations were estimated based on some key input parameters:

- Vessel Locations and Characteristics (LFA vessel counts, beam)
- Distances Travelled within the LFA (fishing intensity within sub-grids within the LFA)
- Vessel Operating Patterns (transit, setting/retrieving traps, travel between traps)

The research team collected data inputs from several sources, including previously published reports and data from Fisheries and Oceans Canada (DFO) reporting vessels' size (length and beam) and fishing intensity within the LFAs. Because specific vessel energy data was limited, the project team instrumented a subset of five fishing vessels in various LFAs with sensors in order to capture vessel energy data as part of this study (see Figure 3 for detail on data inputs and calculations used in the Fleet Energy Profile); additionally, six fishers from LFA 34 were interviewed.

The overall energy for the fleet was calculated through the following steps:

1. Energy profiles for specific vessels were calculated using data recorded on the vessels.
2. Energy profile distributions were extrapolated for other vessels based on their beam (approximating tonnage).
3. Fleet energy usage was calculated for different LFAs based on fishing intensity, distance, and speed within the specific LFA using the energy profile distributions. This was done using a Monte Carlo method for simulating many types of trips over time by various types of vessels within subregions of all of the LFAs.

Energy demand and propeller efficiency were used to determine the amount of energy storage required to power a vessel for its entire voyage.

Figure 3 - Data Inputs and Calculations for Fleet Energy Profile

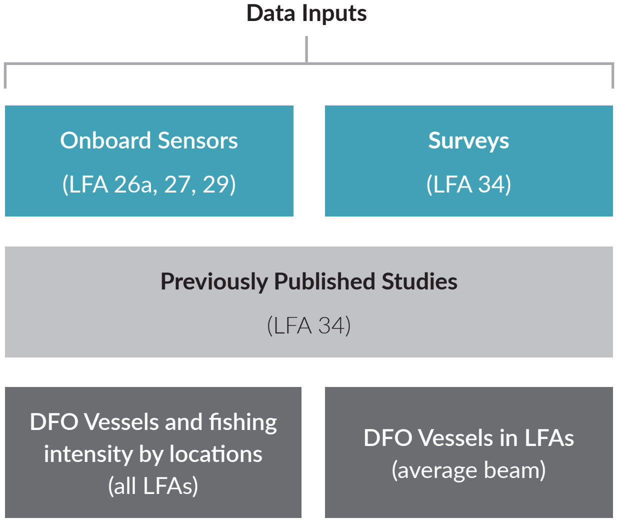
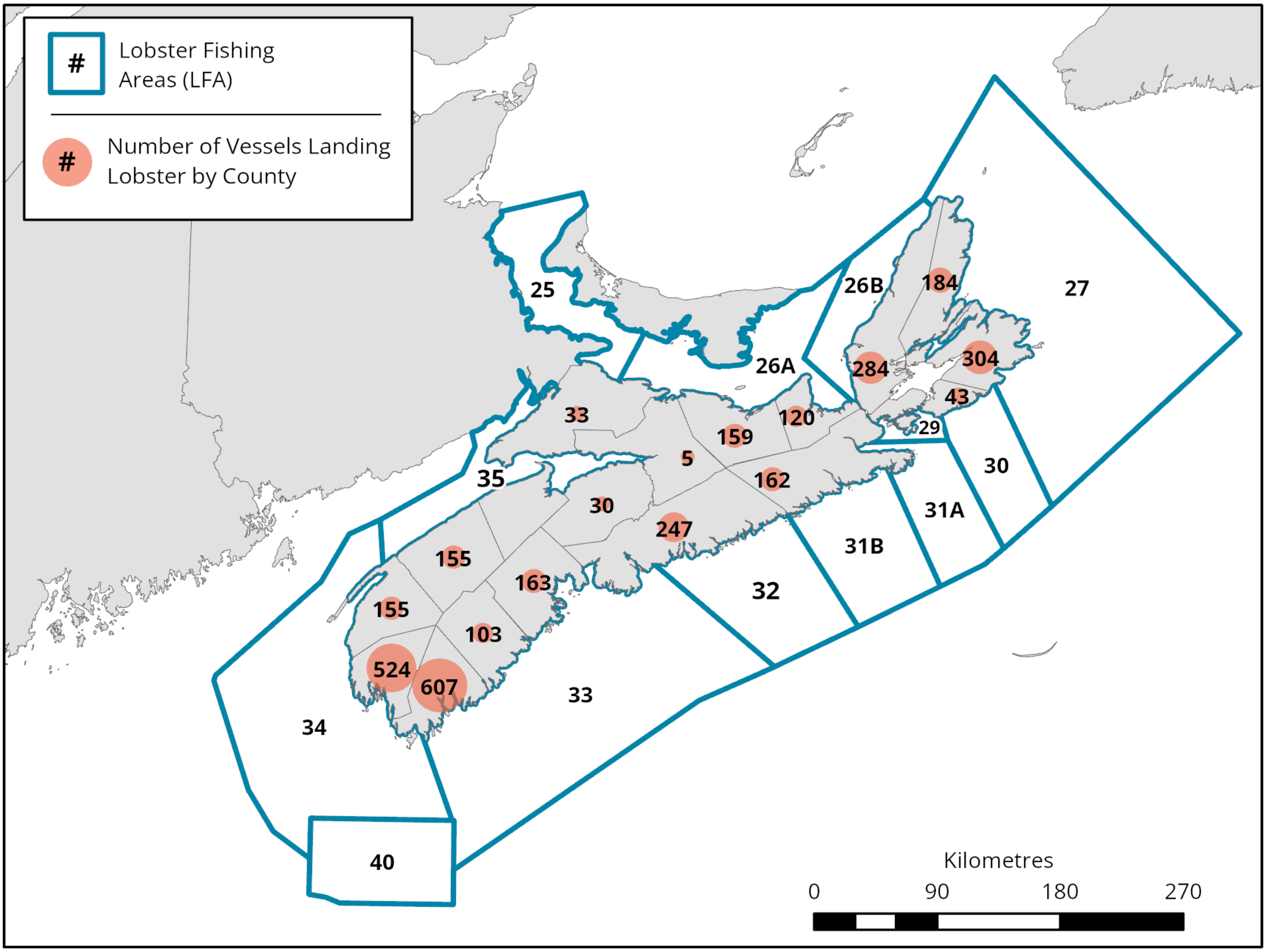


Figure 3 shows the data inputs and calculations used to complete the Fleet Energy Profile. Blue represents data or calculations that were captured during the study, light gray represents data that was sourced from existing published studies, and dark gray represents publicly available data accessed through DFO.

Figure 4 - Map of LFAs with lobster vessel counts



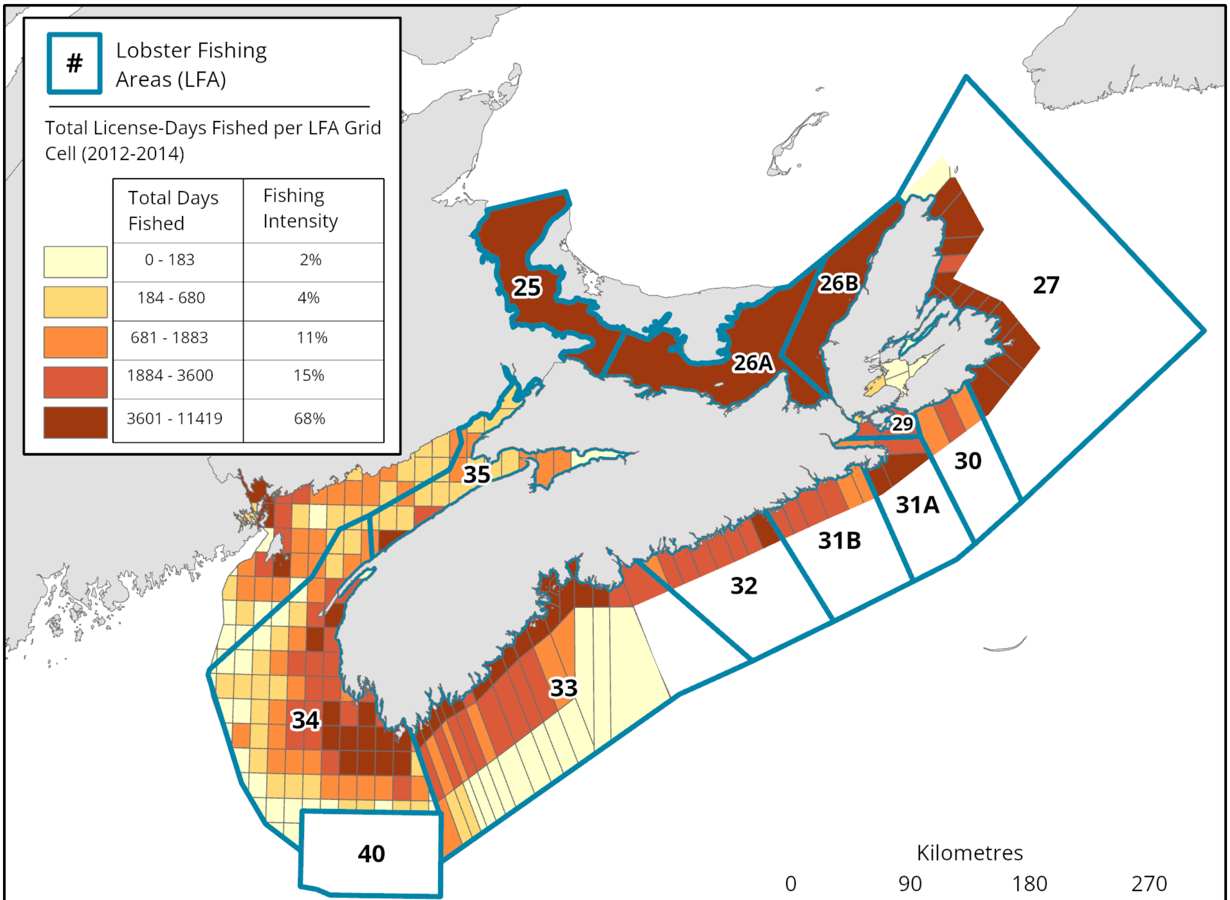
Input - Vessel Locations and Characteristics

There are 3,278 lobster vessels operating in Nova Scotia. DFO, which regulates the lobster harvest in the province, has established 13 LFAs (see Figure 4). LFAs 25-35 are situated along the coast of Nova Scotia, while LFA 40 is further offshore. Over one-third of the lobster vessels in Nova Scotia are in the southwest area of the province, in LFAs 33 and 34.

The average lobster vessel length by county ranges from 10 to 13 metres, largely due to DFO regulations that require most vessels to be under 13.7 metres in length overall (LOA).[15] LFA 40 is unique in that it is much further offshore and therefore requires a larger vessel. Lobster fishing vessels in LFA 40 are not regulated by size and can exceed 40 metres.[16] For these reasons, LFA 40 has not been included in the Fleet Energy Profile for this report (currently, only one lobster vessel operates in LFA 40).

In the Nova Scotia lobster fishery, the beam of the vessel varies much more than the length, making beam a key indicator in understanding energy requirements. DFO data shows that vessels operating in northern and eastern Nova Scotia are much less beamy (<4 metres) versus vessels operating in southwestern Nova Scotia. Here, lobster fishers favour much wider vessels, with beams ranging up to 10 to 12 metres. Vessels that have more beam generally need much more energy for propulsion due to their reduced hull efficiency. Efficient hull design is a key factor in reducing energy consumption (see the conversation on hull efficiency on page 14), a key point to keep in mind when designing electric-powered vessels.

Figure 5 - Total Days Fished by LFA



Data Source: Fisheries and Oceans; Oceans and Coastal Management Division

Input - Distances Travelled within the LFA

DFO captured data from 2012 to 2014 in each LFA by requiring lobster fishers to report their fishing days in small statistical grid cells of approximately 19 km square (with some larger grid cells in Eastern Nova Scotia). These data show the fishing intensity within the LFA, and how many vessels fish at different locations within an LFA. The data is used to understand how far offshore fishers go and its impact on the energy systems.

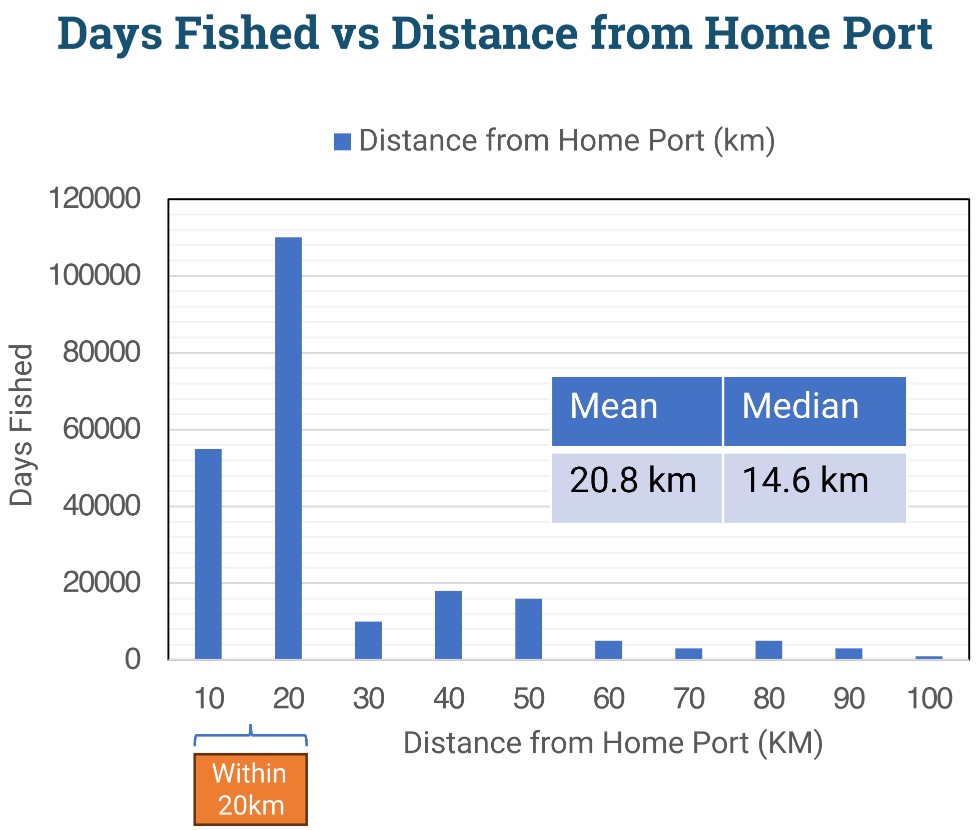
The key findings from the DFO data are depicted in Figure 5, which highlights fishing intensity within each LFA grid cell and are used as an input to the fleet energy calculation.

Three key assumptions enabled the project team to do the energy assessment at the fleet level:

- Fishing vessels only fish within their LFA. This allowed the project team to determine the percentage of fishing intensity within each LFA based on location.
- Fishing boats that fish within 20 km from their home port typically only do day trips. This is important because it allowed the project team to count one-to-one trips per licence day.
- Each LFA has unique opening dates and duration of the season. This was considered in any of the calculations on the LFA.

Based on this understanding, the research team was able to determine how many licence holders are fishing close versus far from shore. This is key to understanding the amount of energy that is being used to fish in each of the areas. Figure 6 adds all the licence days fished per year throughout Nova Scotia between 2012–2014 and groups them based on the distance from shore. The results show that more than **70% of the days fished by all the boats occurred within 20 km of their home port**. The majority of the boats fishing within 20 km of their home port would be the best initial candidates for electrification options as this comprised the majority of the fleet based on the distribution of days fished versus distance from home port.

Figure 6 - Days Fished by Distance from Home Port



Input - Vessel Operating Patterns

Calculating the Fleet Energy Profile requires building an understanding of vessels' daily operating patterns. Vessels have three distinct operation patterns which require different energy needs within a typical day of fishing:

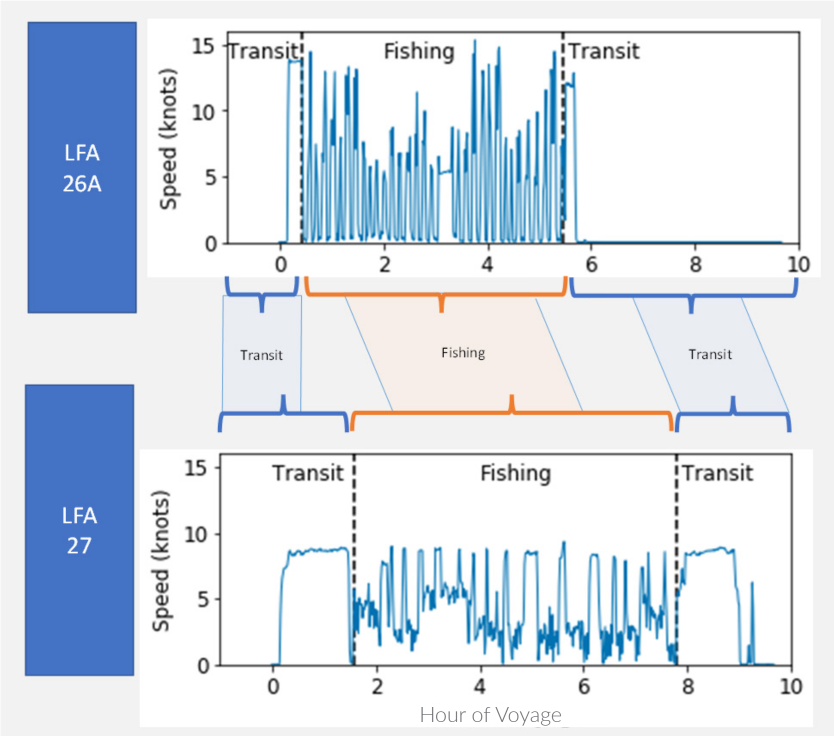
1. Transiting from the wharf to get to and from the fishing grounds,
2. Setting and retrieving traps,
3. Travelling between lobster pots/lines.

There is also a need to understand variability between voyages by the same vessel due to inclement weather, setting day (see Box 2), or other situations where more energy would be required. Variability in voyages is important so that energy storage systems are designed to support a range of energy needs from the least to the most energy-intensive days.

Once we know the individual vessel operational variability, this is used to model the operational patterns of all the vessels within the fleet. Rather than rely simply on the existing data, new primary research was conducted using sensors aboard actual fishing vessels which gathered location and speed (via Global Positioning System (GPS)) and fuel consumption and thrust (using onboard engine Controller Area Network (CANBUS / J1939) data) to determine the energy needs and operating variability of voyages.

Box 2 - Setting Day

Setting Day is when lobster fishers traditionally bring their pots to sea at the beginning of the season, the most energy-intensive day of fishing all season. Depending on the size of the vessel and transit distance to the lobster grounds, fishers may make three trips back and forth to port to deploy their pots on that day. For these vessels, their energy consumption on setting day will be three times higher than on any other day. Additionally, some captains may push their vessels faster than normal to ensure there is time to deploy all their pots in one day. Higher speeds will contribute to unusually high energy consumption as well as power demand.



Box 3 - Findings of Previous LFA 26 Studies

Previous studies[17,18] had captured engine speed, vessel speed, and engine power for one day from two East Coast lobster vessels as representative of typical operations in LFA 26A. Example vessels had transit periods of approximately 15 minutes at the beginning and end of the day, with approximately 5 hours of fishing in between. During transit, the vessels used 70-100 kW (94-134 hp) of power. While fishing, the propulsion load was very dynamic, ranging up to 76 kW (102 hp) as the vessels moved between pots, but averaging much less power due to the duty cycle of the pot hauling operation (estimated to be approximately 10 kW, or 13 hp, based on data extracted from the published figures).

Any battery or fuel solution for lobster vessels must accommodate the extra loads on setting days. Potential solutions include one already employed in Newfoundland where fishers are permitted to begin setting traps one or two days in advance of open day to avoid accidents caused by overloading vessels with traps.

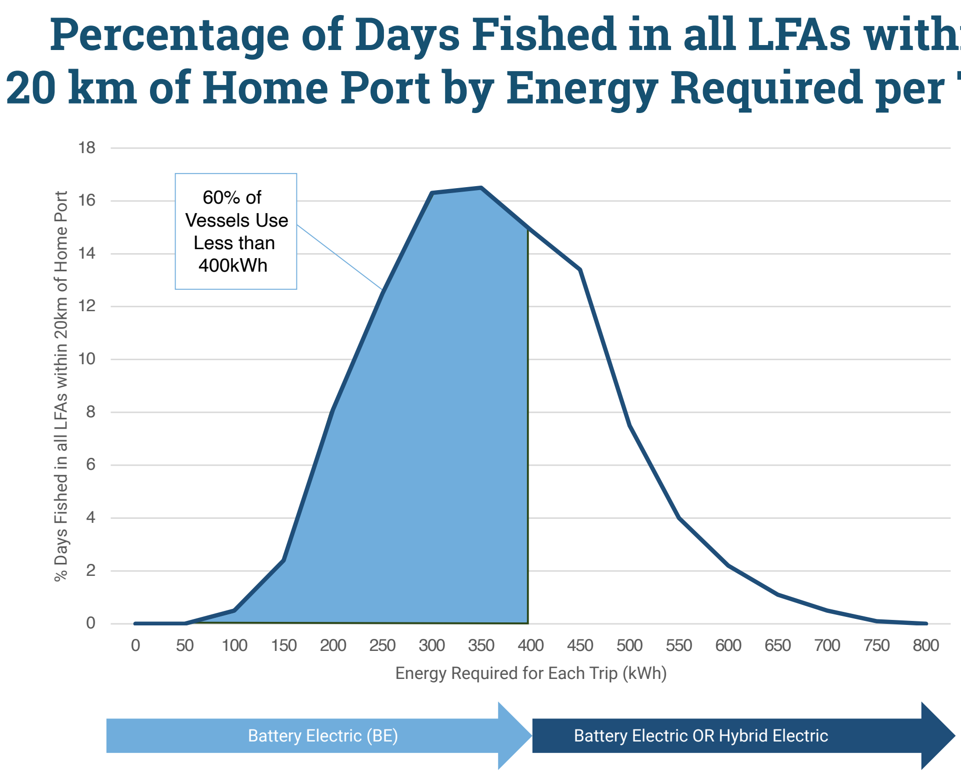
Navigation data was collected between May 1 and July 31, 2022 from vessels in LFAs 27, 29, 30 and 26A. The data from these four vessels show similar patterns to the LFA 26 vessels reported in previous studies (see Box 3) but provides additional context around the variability in energy demand between voyages by the same vessel, vessels within the same lobster fishing area, and between lobster fishing areas. The data was supplemented by interviews with lobster fishers conducted for this study as well as previously published survey data.

The data collected show that there is significant variation in the operating patterns of different vessels and between different fishing areas. Figure 7 depicts how operating patterns can differ by comparing a vessel in LFA 26A with a vessel in LFA 27. Both vessels are considered day fishers. While the characteristic transit and fishing modes can be seen in both instances, the speed and duration of transit as well as the range and variability of speeds are different between the two vessels. Specifically, the vessel operating in LFA 26A has much more variability in its energy needs. The vessel speed varies from near zero to over 5 knots six times in a single hour and often exceeds 10 knots. In comparison, the vessel fishing in LFA 27 maintains a speed above 1 knot and only accelerates to near-transit speeds about twice per hour.

For LFA 34, two data sources were used to build the operating profile: a survey of Yarmouth lobster fishers conducted in 2022 as part of this research report and a 2006 survey of lobster fishers that harvest in LFA 34.[19]

The information provided by Yarmouth fishers demonstrated some key differences between LFA 34 lobster fishing operations and those in northern Nova Scotia. While recorded lobster voyages in northern Nova Scotia showed voyages of 4–9 hours, voyages reported in LFA 34 ranged from 9–96 hours, as some fishers reported travelling 80 km or more offshore on multi-day trips. The survey responses show that lobster fishing in LFA 34 requires more energy per voyage than lobster fishing in northern Nova Scotia. The results from the 2022 survey were consistent with the 2006 survey.

Figure 8 – Percentage of Days Fished in all LFAs within 20 km of Home Port by Energy Required per Trip



Fleet Energy Profile Interpretation

The fleet energy was calculated as shown in the previous section for each of the LFAs. This let us focus on the fleet energy used within 20 km and allowed us to provide estimates for the overall fleet fuel usage and emissions.

Figure 8 shows the distribution of estimated energy use for trips that are 20 km from their home port across the inshore lobster fleet. 2295 vessels typically make trips of that distance or less. Figure 8 shows that most trips (approximately 60%) that transit 20 km from their home port use less than 400 kWh of energy. Vessels making shorter voyages will require less energy per trip.

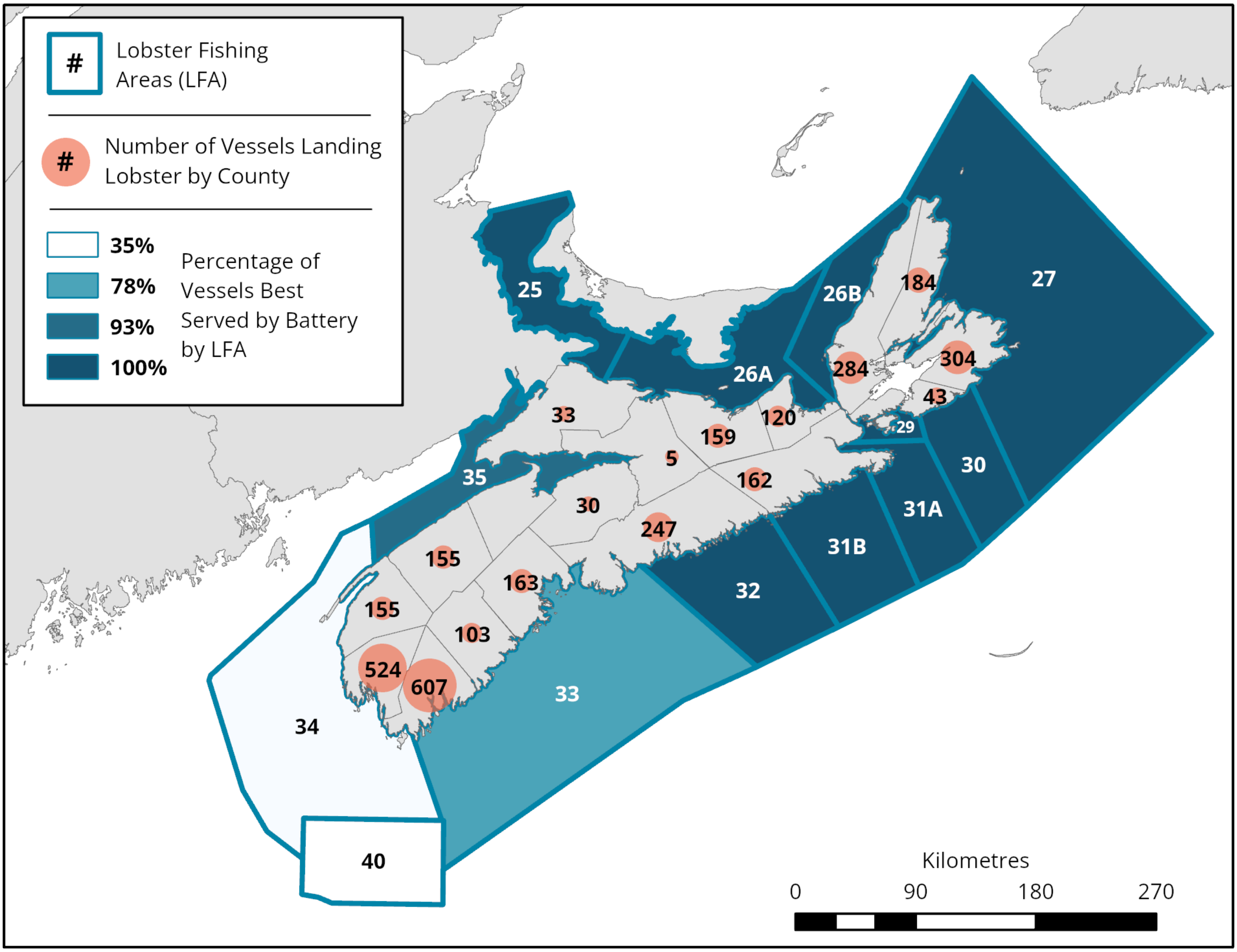
Put simply, a 400-kWh battery will support most inshore lobster fishing voyages. Vessels that transit distances near 20 km and demand greater-than-normal energy due to high transit speeds or inefficient hull forms could be served by larger battery-electric or hybrid propulsion systems.

The following table was calculated based on the energy profile of the entire fleet, which shows the overall litres of fuel and millions of kg of CO_2e annually by segments of the fleet and overall fleet. Key figures show that the fleet accounts for 31 million litres of diesel annually, with 82 million kg CO_2e emissions annually.

Figure 9 – Table showing annual fuel consumption and CO_2e emissions by the lobster fleet

Segment	Million Liters of fuel	Million kg of CO_2e Annually	Percentage of kg of CO_2e Annually
Fleet Operating within 20km w under 400 kWh	12	33	40%
Fleet Operating within 20km using more than 400 kWh	6	17	21%
Remainder of Fleet Operating outside 20 km	13	32	39%
Total Fleet	**31**	**82**	**100%**

Figure 10 - Percentage of vessels that can be served by battery by LFA



Fleet Energy Profile Summary

The fishing intensity data from DFO show that most vessels (70%) operate exclusively within 20 km of their home port. Considering a wide range of operating patterns, vessel characteristics and distances travelled, it was determined that approximately 60% of lobster vessels with transit distances of 20 km of their home port would use 400 kWh of energy or less to complete a day of fishing, an energy load that is well within the constraints of current battery technology.

Figure 10 shows the percentage of vessels within each LFA which could be served through battery-electric vessels and be able to fully support their operational fishing requirements. The majority of the LFAs could be fully served with battery-only fishing vessels, as shown in the dark blue. LFAs 33 and 34 have a smaller percentage of overall vessels which can be served by battery-electric propulsion, but due to the total number of vessels operating in the LFA, still have a significant number of vessels which can be battery-electric; the remaining vessels in these LFAs will need to explore hybrid options.

Chapter Three

The Economics of Battery Electric and Fuel Cell Electric Lobster Vessels

The primary cost considerations for a battery-electric-powered vessel or fuel cell electric vessel are (a) the cost of the hull, (b) the cost of the propulsion system and energy to power it, (c) the cost of the onshore charging or fueling infrastructure, and (d) the cost of any necessary electricity grid upgrades. For this report, a simplified cost analysis was conducted focusing solely on the propulsion system, with the understanding that it would provide a more straightforward comparison of propulsion systems with lower capital costs but higher operating costs (diesel) versus a system with higher capital costs but lower operating costs (battery-electric).

The price points used in the cost comparison for the diesel and battery-electric systems were provided by local vendors in 2022. The pricing for the fuel cell electric system is an estimate based on other jurisdictions, primarily California and British Columbia, as in-market values for Nova Scotia are limited. Additionally, it should be noted that costs and particularly operating costs are very specific to individual fishers and will vary based on the specific voyage energy requirements for fishers and their vessels. [20]

As will be demonstrated in this chapter, when looking exclusively at the propulsion system and energy required to power it, battery-electric systems could be a cost-effective option and merit further exploration through commercial scale demonstration projects and a more thorough analysis of electricity grid infrastructure.

Simplified Cost Analysis of Propulsion Systems for an LFA 26A Vessel

The simplified economic analysis considers the initial capital cost of the propulsion and energy storage equipment on the vessel and estimates the operating costs over a 20-year time period as its useful lifespan. The specific vessel used for the analysis is an actual 12-metre (43-foot) lobster boat currently operating in LFA 26A with a 500hp diesel engine. The boat and engine are relatively new (2017). The energy analysis and voyage profile showed that the vessel uses 262 kWh daily for its fishing operations.

The fisher who owns the vessel wants a battery-electric system and wanted to see the comparable cost for a fuel cell electric system. It is important to note that energy requirements and system sizing will vary for each vessel within this LFA and across other LFAs in the province; this is a specific use case conducted as an example. Individual fishers and vessel owners will need to conduct their own analyses based on their unique circumstances and operating patterns.

This fisher is also planning to get a new, high-efficiency hull. As mentioned in the introduction to this chapter, the cost of the hull and other non-propulsion components of a vessel have been excluded from this analysis so that the different energy options can more easily be compared. However, hull efficiency could play a big role in decreasing upfront battery costs by reducing energy requirements, decreasing seasonal operating costs, and extending the range of the vessel.

Diesel Propulsion System

For the diesel configuration, the initial capital cost is estimated to be $70,000 for the engine and powertrain. The model assumes a daily fuel cost of $201 based on 2022 fuel prices, which is $10,452 per season or $209,040 over 20 years. Annual maintenance costs are estimated at $3,500, which is 5% of the capital cost; this is $70,000 over 20 years. This brings the total operating and maintenance costs over the 20-year period to $279,040. A more detailed Total Cost of Ownership analysizs would need to consider escalating fuel costs and the potential for a carbon tax on marine diesel. Historically, diesel propulsion systems have required a major overhaul every 10 years; this has not been included in this report because of evolving technology in diesel engines as well. **The total cost for a diesel propulsion system over a 20-year period is $349,040:** $70,000 purchase cost + $279,040 operating and maintenance costs.

Battery-Electric Propulsion System

The battery-electric configuration includes batteries, an electric powertrain, and a range extender for an initial capital cost of $169,550. The battery size needed for this vessel is estimated to be 262-288 kWh based upon daily energy usage, with a battery module cost of $472-525/kWh based on 2022 prices. This results in a total battery module cost of approximately $137,550. The 90 kW powertrain is estimated at $12,000, while a range extender is estimated to be $20,000. The model assumes a monthly blended demand and energy cost of $2,573 for running the vessel during the fishing season, based on 2023 energy rates for a commercial entity; over 20 years, the energy to power the vessel is $51,452. Annual maintenance costs are expected to be significantly less than diesel and estimated at $1,696, which is 1% of purchase cost ($33,910 over 20 years). Total operating and maintenance costs over the 20-year period are $85,362. This analysis does not include the cost of the shoreside infrastructure for charging the battery electric vessel, as this cost is expected to be shared across a broader group of users. **The total cost for the battery-electric propulsion system over a 20-year period is $254,912:** $169,550 purchase cost + $85,362 operating and maintenance costs.

Hybrid Fuel Cell Electric Propulsion System

The hybrid fuel cell electric configuration includes batteries, an electric powertrain, a hydrogen fuel cell, a hydrogen storage tank, and a range extender, for an initial capital cost of $192,860. The fuel cell is sized at 25kW for a 90kW drive system, costing $35,000. The battery is 100-110 kWh at $472-525/kWh, for a total battery cost of $52,500. The hydrogen storage tank is approximately $73,360, the powertrain is $12,000, and the range extender is $20,000. The seasonal fuel cost is estimated at $17,576 based on a hydrogen price of $12.50/kg; this would be $351,520 over 20 years. There is currently no hydrogen distribution for vehicles in Nova Scotia; this number is based on market prices in British Columbia. Annual maintenance costs are assumed to be 3% of capital or $5,786 annually, which is $115,716 over the 20-year comparison period. This analysis does not cover the cost of the shoreside hydrogen fueling infrastructure nor the charging infrastructure necessary for charging the battery-electric vessel. **The total cost for a hybrid electric hydrogen fuel cell propulsion system over a 20-year period is $660,096:** $192,860 purchase cost + $467,236 operating and maintenance costs.

Figure 11 - Summary Simplified Economic Analysis for LFA 26A Vessel

	Diesel Propulsion System	Battery-electric Propulsion System	Hybrid (Fuel Cell) Electric Propulsion System
Capital Costs	$70,000	$169,550	$192,860
Operating Costs	$209,000	$51,452	$351,520
Maintenance Costs	$70,000	$33,910	$115,716
Total Costs	**$349,040**	**$254,912**	**$660,096**

The simplified economic analysis shows that electric propulsion is the least costly configuration for this specific vessel in LFA 26A. The costs of each system over a 20-year time period are summarized in Figure 11.

Based on conservative estimates, the higher up-front costs of battery electric propulsion systems (more than double the capital cost of diesel propulsion systems) are offset in the medium term by much lower operating costs. Figure 12 shows that total cumulative lifetime costs for this example vessel become cheaper for a battery-electric system around year 11 relative to a diesel engine. The fuel cell electric system is similar in "tentative pricing," as the cost of the fuel cell (pre-commercial), storage (pre-commercial), fuel (no green hydrogen available) and maintenance costs (fuel cells have not been commercially tested over a 20-year period) is similar to a battery-electric initially, but it is more expensive than the diesel and electric systems over the 20 years.

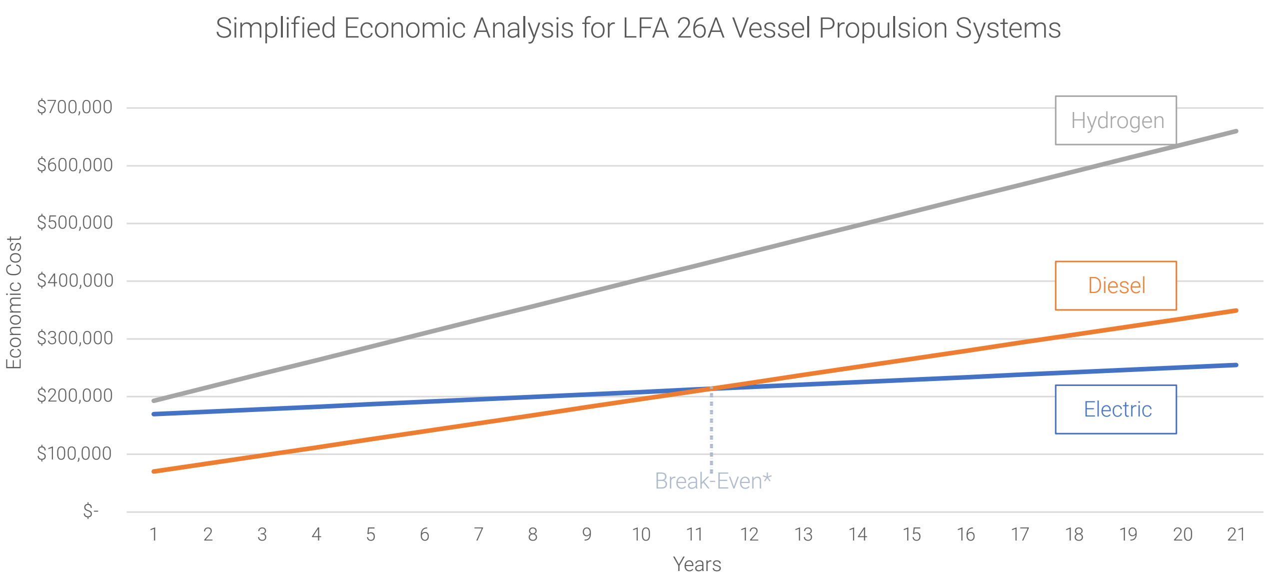
The analysis presented here represents a specific vessel, but the general patterns can be extrapolated to other parts of the fleet and a similar approach can be applied to various daily energy requirements to show fleet-wide perspectives. Electricity for battery charging is less expensive than diesel fuel, so vessels that have more charge cycles will pay back more quickly. Conversely, vessels that make overnight trips would require larger batteries and charge less frequently so they will have a longer pay-back period. Refueling with hydrogen is more expensive than electricity under these assumptions, but the cost of hydrogen storage is less than purchasing additional battery capacity. Therefore, hydrogen is more favourable for vessels making longer and overnight trips.

Summary of Vessel Economics

While the simplified cost analysis is useful to highlight the savings potential for fishers over a 20-year period based on the cost of purchasing and operating an all-electric system, additional research is required to develop a true Total Cost of Ownership analysis. This would include the cost of a new efficient hull and shoreside infrastructure, which would increase the capital cost. However, this would also consider elements that would tip the scales towards zero-emission solutions. These include the year-by-year increases in diesel costs, an escalating price on carbon, and the inclusion of incentive programs such as grants, fuel switching incentives through the Clean Fuel Regulation credits, and the potential for financial benefit from providing V2G services.

Incentives are expected to play an important role in helping to close the gap between the upfront costs of diesel and zero-emission technologies and reduce barriers for vessel owners. This will encourage early adopters and help the market for zero-emission technologies reach a tipping point where the adoption of decarbonized vessels is greatly accelerated.

Figure 12 - Comparative Analysis of Propulsion System Costs



*Break-even point without considering future price increases for diesel and financial incentives for zero-emission technologies

Chapter Four

Benefits and Incentives

There are strong economic and environmental benefits to the system-wide adoption of decarbonized vessels in Nova Scotia's inshore lobster fishery.

The previous chapters illustrate the opportunity presented by the inshore lobster fishery to advance commercially ready zero-emission solutions for marine vessels. More than 70% of the lobster fleet fishes within 20 km of shore and the research completed for this report shows that the energy needs of at least 60% of those boats are likely to be well suited to electrification. The 40% of the vessels remaining within 20 km of shore may be either battery-electric or fuel cell hybrid electric. Beyond 20 km, this report finds hybrid fuel cell systems could be the best option to provide the power required to travel longer distances. This option will become more commercially viable as low carbon intensity hydrogen becomes more readily available and fuel cell marine systems become more technologically advanced.

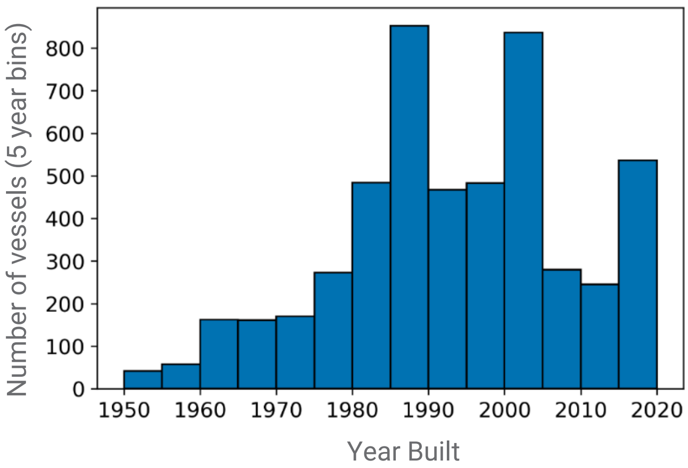
Economic Benefits

The economics for battery-electric propulsion systems combined with efficient hull designs is competitive or potentially lower than traditional diesel-powered vessels, especially when compared over a 20-year timeframe. There are higher upfront capital costs with battery-electric vessels compared to traditional diesel-powered vessels, but there can be significant savings for boat owners when it comes to operating and maintenance costs. This was clearly demonstrated through the comparative analysis in Chapter Three, where a battery electric system for a vessel fishing in LFA 26A was shown to have operating and maintenance costs that were about one-third the cost of a diesel system. This same economic scenario is playing out in the automotive space, where the higher capital costs of battery-electric vehicles are recouped within 3 or 4 years of service through lower operating and maintenance costs. These lower operating and maintenance costs for battery-electric vessels are of particular interest to fishers as this directly addresses the cost of diesel. Diesel is the most significant and variable input for operations, accounting for upwards of 30% of a fisher's annual operating expenses today, and this percentage is only expected to grow as fuel prices continue to rise in the near and midterm. Today, the cost of purchasing electricity to propel a boat is less than one-third the cost of purchasing fuel to do the same job.

From a high-level economic perspective, the transition to battery-electric or fuel cell electric systems could have the potential to create new jobs and sustainable economic growth. The development of a modern, emission-free lobster fleet in Nova Scotia could be a model for Atlantic Canada, the country, and the rest of the world. Being first to adopt these systems will put Nova Scotia in the lead when it comes to commercializing them for broader use in other fisheries as well as non-fishing vessels.

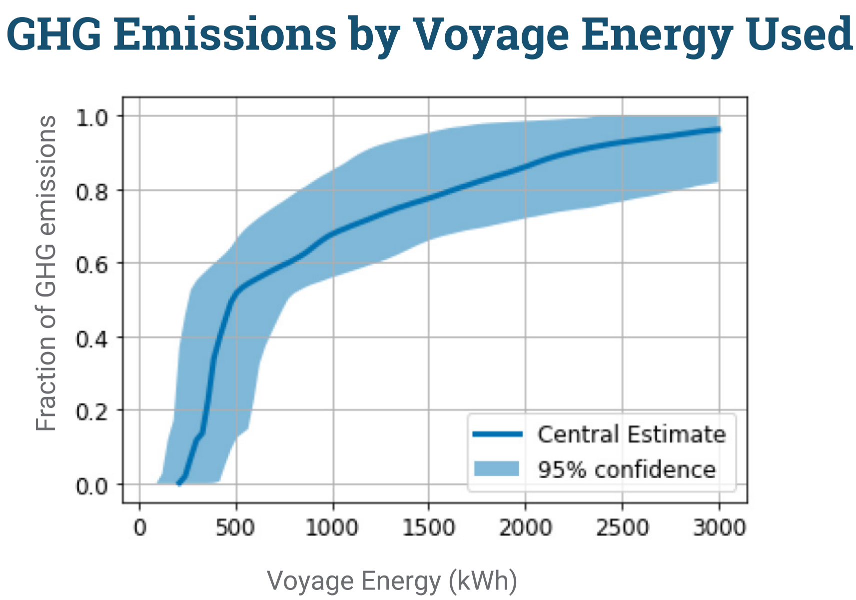
The boatbuilding industry in Nova Scotia has the capacity for scale. While the average production capability of the boatbuilding industry in Nova Scotia is typically less than 100 vessels per year, the industry has proved it can respond to increased demand during three periods in recent decades. TThere were significant increases in the number of vessels built in the 1980s, '90s and early 2000s as engines were converted from gas to diesel and hulls moved from wood to fiberglass. More recently there was an uptick in demand following the 2008 recession (see Figure 13).

Figure 13 - Nova Scotia Vessel Build Dates



The market for zero-emission fishing vessels and technology could become a valuable economic driver for Nova Scotia. There are 15,000 fishing vessels 8-20 metres in length registered with Transport Canada[21] and approximately 25,000 commercial fishing vessels in the US.[22] In a net-zero economy, all these vessels will need to be replaced or converted with zero-emission alternatives. The economic opportunity to modernize Canada's fishing fleet is estimated to be at least $10 billion when simply considering the cost to replace the existing fleet with new builds and shoreside charging infrastructure. Building the experience and expertise in implementing existing and emerging zero-emission technologies in marine environments before other jurisdictions will position Nova Scotia to lock in economic and social benefits rather than needing to import expertise or technology. This transition may also help to attract new people, and new groups of people, to boatbuilding careers, supporting industry growth.

Figure 14 - GHG Emissions by Voyage Energy Used



Environmental and Social Benefits

Replacing traditional diesel-powered lobster vessels with battery-electric or fuel cell electric vessels will have lasting environmental and social benefits. Battery-electric lobster vessels do not produce emissions, meaning that harmful particulate matter, NOx and CO_2e are eliminated. In addition, battery-electric vessels run relatively silent compared to diesel engines. This will have a multitude of benefits for fishers, who can work in a quieter environment without breathing in diesel fumes. Quieter vessels are also expected to have a positive impact on marine ecosystems, which have been demonstrated to be negatively impacted by underwater noise pollution.[23]

The most important benefit is the reduction of harmful GHGs caused by the burning of fossil fuels, which is directly responsible for causing climate change and associated disasters such as the increased frequency and intensity of hurricanes and forest fires. Fuel consumption for the entire inshore lobster fleet was estimated to be 31 million litres per year.[24] Based on fuel consumption estimates, the total GHG emissions are calculated to be 82 million kg of C02e each year, about the same as up to 35,000 cars.

As shown in Figure 14, the fleet-wide energy assessment has identified that almost 40% of the total emissions (33 million kg of CO_2e annually) from the Nova Scotia inshore lobster fleet could be eliminated by transitioning to battery-electric vessels that require 400 kWh of voyage energy or less. The fleet-wide energy assessment also shows that a full 60% of emissions from vessels operating within 20 km of shore would be eliminated if all near-shore vessels requiring up to 600 kWh of voyage energy were converted to battery-electric or fuel cell electric propulsion systems.

Unlike the challenges with decarbonizing ocean-going vessels, where the fuels and technologies are still under development and a massive build-out of shoreside infrastructure is needed to create a global network of zero-emission trade corridors, the technologies required to decarbonize near-shore vessels exist today and are already commercially available in many light and heavy-duty automotive applications. Battery-electric propulsion systems are already in widespread operation in ferries and workboats around the world.

The fleet-wide energy assessment shows that there are nearly 2,300 lobster vessels that are good candidates for electrification. The remaining fleet of 1000 boats are expected to be candidates for larger battery-electric systems or hybrid fuel cell electric systems as they become available. What's needed is a strong and supportive policy environment to encourage market adoption.

The Role of Government

To realize the environmental, social, and economic benefits of building a modern, emission-free lobster fleet, governments have an important role to play in providing a framework that sets clear technology adoption goals and includes financial incentives to achieve them. The federal framework to support the adoption of zero-emission light-duty vehicles is a good example of the clear goals and incentives that have been established for the adoption of electric vehicles and the building of vehicle charging infrastructure. Similarly, the zero-emission transit and school bus programs are providing real incentives such as direct grants and low-interest loans repaid out of operational savings to replace existing diesel fleets with battery-electric and hydrogen-powered buses. The zero-emission bus programs are driving Canadian innovations in the development of zero-emission buses that are serving markets around the world.

Government support has proven crucial in the initial stages of technology adoption, helping to reach the tipping point where technologies become lower in cost and the markets become more competitive. Technology transitions often follow an S-curve: after a period of slow growth, as the technology is first tested in the market, there is a period of exponential growth as the technology quickly gains market share, followed by a levelling off as the technology reaches full market penetration. In the case of marine decarbonization, research suggests that 15% of the domestic fleet will have to run on zero-emission energy sources by 2030 in order to reach a tipping point that will put the sector on a trajectory to achieve zero emissions by 2050.[25]

Recommendations

To support the decarbonization of the Nova Scotia lobster fleet, the following recommendations should be followed by federal and provincial policymakers:

1. **Use the Canadian Marine Climate Action Plan to set Paris-aligned emission reduction targets for Canada's domestic fleet with 2030, 2040 and 2050 targets.**
   a. Include commercial fisheries in Canada's Marine Climate Action Plan and develop specific pathways to achieve net-zero emissions.
   b. Set a goal to have at least 10% of the lobster fleet (approximately 300 boats) powered by electricity or zero-emission fuels such as green hydrogen by 2030.
   c. Prohibit the sale of new diesel-powered commercial fishing (including lobster) vessels by 2035 using ZEV regulations being developed for the transportation sector.
2. **Incentivize adoption of zero-emission technologies calibrated to achieve the 10% goal by 2030.**
   a. Support feasibility assessments for individual fishers and boat owners to encourage early adopters of zero-emission technologies and further inform broader infrastructure investment needs.
   b. Provide direct incentives for boatbuilders to develop new, more efficient hull designs and systems integrations for zero-emission technologies.
   c. Provide grants for the commercial demonstration of battery electric and fuel-cell electric fishing vessels and bidirectional charging systems.
   d. Provide a combination of grants and zero-interest financing to individuals and fleet operators to purchase zero-emission vessels.
3. **Build the long-term infrastructure needed for zero-emission technologies to succeed.**
   a. Include marine shore charging applications in existing electric charging infrastructure programs.
   b. Fund electricity grid upgrades to increase the 3-phase hosting capacity at all harbours including modern electricity grid management technology.
   c. Introduce or enable commercial structures that enable fishers and boat owners to realize the financial benefits of providing V2G services and improving grid reliability and resilience for local communities.
   d. Fund training and skills centres including technical colleges, guilds, and industry associations, to purchase technologies and training equipment, retrofit buildings, and accredit new workers to build and maintain zero-emission fleets and infrastructure.

Final Thoughts

The environmental changes taking place around the globe are a call to action for governments and all sectors of the economy to reduce emissions – including Atlantic Canada's largest commercial fishery and the boatbuilding industry that supports it. Transitioning the economy away from fossil fuels will require creativity and ingenuity from across the entire marine supply chain: power utilities, renewable energy developers, companies that supply and service engines, technology integrators, and fishers. The economic, environmental, and social benefits of advancing zero-emission solutions in fishing vessels and workboats have the potential to put Atlantic Canada on the cutting edge of the maritime energy transition that is underway around the globe.

The Nova Scotia inshore lobster fleet has not been top-of-mind for policymakers looking to advance the adoption of zero-emission technologies. This is a missed opportunity. The Nova Scotia inshore lobster fleet is a prime candidate for the adoption of zero-emission technologies. The nature of the inshore fleet provides an opportunity to demonstrate localized success to operators, which could have a significant impact in laying a foundation for scaling up technologies to address emissions associated with offshore, multi-day missions.

This report concludes that battery-electric propulsion system technologies are ready for commercial application, with hybrid electric hydrogen fuel cell systems also expected to play a role for longer voyages. Vessels fishing within 20 km of shore typically require less than 400 kWh per voyage and would be very good candidates for battery-electric systems. The report further finds that while the upfront costs of battery-electric propulsion systems are significantly higher than diesel, these costs would be offset for many vessels in the medium-term (break-even is estimated at year 11) thanks to much lower operating costs.

Leadership in decarbonizing the Nova Scotia lobster fleet will create business and export opportunities for all the players in the ecosystem: naval architects, boatbuilders, propulsion system manufacturers, battery researchers and manufacturers, and others. The private sector in the region is showing leadership and investment as they recognize the shrinking window to lead—and not be displaced by—the transition to emission-free vessels.

The case for moving forward with decarbonizing the inshore lobster fleet is strong, but it won't be possible without government supports to help build the market and offset/defer the upfront costs associated with new zero-emission technologies. With the right supports and investment, this report concludes that many of the vessels fishing within 20 km of their home port could move to zero-emission propulsion systems with technologies that exist today (primarily battery-electric).

Endnotes

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