UNIVERSITY OF THE PHILIPPINES
CENTER FOR INTEGRATIVE AND DEVELOPMENT STUDIES
POLITICAL ECONOMY PROGRAM
POLICY BRIEF
ISSN 2619-7278 (PRINT) • ISSN 2619-7286 (ONLINE)

UP CIDS POLICY BRIEF 2022-09

Retrofitting Small Marine Vessels for Range Extension and Emissions Reduction

Paul Rodgers,[1] Antoinette Raquiza, PhD,[2] and Kiwanis Abunda[3]

Introduction

Increasing concerns about climate change and environmental degradation in the Philippines have led to the passage of policies that promote green and clean energy use in different sectors. The transport sector has been a huge source of carbon emissions. Therefore, the government has begun to incentivize operators of land-based vehicles and marine vessels that shift to full or partial use of renewable or electric energy. In December 2021, for instance, the Senate approved the Republic Act (RA) No. 11697, or the Electric Vehicle Industry Development Act. This law "sets common standards and specifications of EVs [electric vehicles], charging stations and equipment, parts and components, batteries, and related facilities."[4] As for the maritime sector, the government has ratified International Maritime Organization (IMO) conventions that call for the drastic reduction of greenhouse gas (GHG) emissions in the seas.[5]

This study seeks to contribute to the country's promotion of green and clean energy use in the transportation sector and, in particular, for micro and small marine vessels. So far, the transition to a green maritime transport system, for instance, has included experiments in the use of electric and hybrid power for ferry operations in the country. Nevertheless, compared to programs promoting electric and hybrid vehicles, those for maritime vessels are relatively recent. They mainly focus on medium-sized and large ships that largely consume fossil fuels and emit GHGs.

In this light, the paper focuses on the micro and small-scale vessels, including municipal fishing vessels, toward highlighting the relevance of this subsector to the maritime and fisheries industry of the country. Municipal vessels make up the majority of the Philippine fleet and are important modes of transportation for people and goods. The latest available data from the Southeast Asian Fisheries Development Center (SEAFDEC) show that a total of 247,146 municipal fishing vessels were registered in 2017 compared to the 3,473 commercial fishing vessels registered in 2016 (Lamarca 2022). Given this, the development of affordable and energy-efficient

[1] Assistant Professor, Department of Mechanical Engineering, College of Engineering, University of the Philippines Diliman. E-mail address: plrodgers@up.edu.ph.

[2] Professor, Asian Center, University of the Philippines Diliman; Convenor, Political Economy Program, UP Center for Integrative and Development Studies. E-mail address: arraquiza@up.edu.ph.

[3] Junior Project Associate, Political Economy Program, UP Center for Integrative and Development Studies. E-mail address: kmabunda@up.edu.ph.

[4] Republic Act No. 11697, or the Electric Vehicle Industry Development Act, created the "Comprehensive Roadmap for the Electric Vehicle Industry." It is a national policy framework on the adoption and development of electric vehicles both in the public and private sectors.

[5] As global community seeks to control, if not reverse climate change, the IMO has set regulations aiming to reduce GHGs and other pollutants in the sea, namely the International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI Convention. The Philippine government, through the Maritime Industry Authority (MARINA), has acceded to the IMO regulations in 2018. Options to meet the regulations include the use of cleaner fuels with less than 0.5 percent of sulfur dioxide (SO2) content, the use of liquefied natural gas (LNG) as fuel, use of exhaust gas treatment technologies, use of hybrid and/or full electric systems, use of hydrogen as fuel, and hydrogen fuel cells as the source of power.

technology needs to begin in order to reduce the carbon footprint and fuel expenses of small vessels. Government support through policies, programs, and incentives to promote such technologies will help grow the maritime industries, specifically municipal fishing and transportation.

Considering that the cost of fully electric-powered boats is beyond the reach of small boat owners and operators, this paper explores the option of retrofitting small vessels with hybrid electric engines that can increase range but use fuel more efficiently. Retrofitting would retain the reliable propulsion system and could potentially improve performance while also incurring lower costs than a complete system replacement. The paper explores this technology for use in coastal communities, with municipal fishers as potential target beneficiaries. The introduction of hybrid energy-powered boats would not only promote fishing communities' participation in reducing GHG emissions in municipal waters but also help improve their livelihood.

The paper is organized as follows. The next section provides an overview of the municipal maritime sector, specifically the municipal fishing subsector, to stress the need to include it in the country's push to promote green energy in transportation. This section is followed by a discussion of the proposed retrofitting technologies for small vessels. The conclusion provides a few policies incentivizing the development and use of green and efficient energy that might be tapped to support the development of the proposed technology.

The Municipal Fishing Sector and Fishing Vessels

The fishing industry remains a valuable sector and an important contributor to the national economy. For instance, in 2015, the fishing industry contributed 1.7 percent to the country's gross domestic product (GDP) and generated 1.6 million jobs nationwide (BFAR 2015), while municipal fishing comprised 1,102,262.36 metric tons or 25.04 percent of the volume of fisheries production in 2020 (PSA 2021).

Municipal fishing refers to the fishing activities done exclusively by small fishers in municipal waters within 15 kilometers from the shoreline; they use small vessels that are no more than three gross tons.[6] Municipal fishing vessels are categorized as follows: (1) boats with engines and outriggers, (2) boats with engines but without outriggers, (3) boats without engines but with outriggers, and (4) boats without engines and outriggers (PSA 2012). Available data counted 740,307 municipal fishing vessels in the country; of these, more than half (415,530) had engines, with 325,376 belonging to owner-operators (PSA 2012). That the majority of the boats have either an engine or outrigger, not both, or no engine and outrigger, suggests that they are used mainly to sail short distances (Table 1).

TABLE 1. Number of Fishing Boats/Vessels Used by Municipal Fishing Operators, by Type of Fishing Boat/Vessel, Ownership of Fishing Boat/Vessel, Region and Province: Philippines, 2012. Source: PSA (2012). The title of the table, and the terms from the PSA data are used verbatim.

Type of Fishing Boat/Vessel	Owned	Not Owned	Total
Boat with engine and outrigger	282,257	80,570	362,827
Boat with engine but without outrigger	43,119	9,584	52,703
Boat without engine but with outrigger	182,171	38,498	220,669
Boat without engine and outrigger	68,337	15,491	83,828
TOTAL	593,212	147,095	740,307

[6] Republic Act No. 8550, or the Philippine Fisheries Code of 1998, is a breakthrough legislation in the fisheries industry. It enforces exclusive fishing privileges to municipal fishers and cooperatives at 15 kilometers from shore, as granted by the local government.

It can be said that municipal fishers with engines are the immediate target adaptors of retrofitting. Nevertheless, it is hoped that with support from the government, especially the local government units, others in the sector will be able to benefit from the technology as well.

Retrofitting for Longer-distance Travel and Reduced Emissions

Full electric passenger ferries have been proposed for short-distance routes (Palconit and Abundo 2018). Full electric vessels have limited range due to a lower battery capacity. Facilities are also necessary to charge vessel battery systems while the vessels load/unload at the ports.

Small hybrid electric vessel retrofits are considered for small boat owners and operators for range extension, fuel consumption, and emissions reduction. Typical municipal fishing boats are composed of the main hull with outriggers and are powered by a conventional single-cylinder gasoline engine with a power rating varying from 5 to 25 horsepower. Emissions and fuel costs are a challenge for small boat owners, particularly for municipal fishers. Reducing fuel consumption and emissions and increasing range are desirable. Gasoline-powered boats have proven to be highly reliable and can often supply the necessary power to achieve speed. Thus, small boat owners hesitate to shift completely from engine-powered boats to fully electric boats. However, increasing fuel prices and increased government pressure to reduce emissions have prompted ship owners and fishermen to consider any means of augmenting the current propulsion system to augment the range of the boats and reduce fuel consumption and emissions.

While several options exist for retrofitting small boats, one option of interest is to add a battery storage system in the vessel, together with an electric motor, creating a hybrid propulsion system. Engines operate at highest efficiency at a specific operating speed, and the vessel's propulsion system is designed around this operating condition. Fishing vessels and workboats also operate at off-design conditions, such as trolling or surveying where lower speeds incur lower engine efficiencies and higher emissions. In these cases, the vessel could be operated using electric propulsion, with the benefit of reducing emissions and increasing operating efficiency. The battery charge can be recharged with a solar charging system or with a petrol engine.

Components necessary to retrofit existing vessels to hybrid electric systems include the battery system, motor-alternator, controls, and a mechanical clutch. The motor-alternator can be positioned in the propulsion system between the gasoline engine and the propeller driveshaft, with a clutch between the gas engine and motor. The clutch allows operation with the engine or with the electric motor, or both. For engine-only operations, the clutch is engaged, and the motor is electrically isolated to prevent additional load on the engine. If the clutch is engaged, the motor can augment additional power to the propulsion shaft, or the motor-alternator can charge the batteries. For motor-only operation, the clutch linking the engine and motor is disengaged, and propulsive power is extracted only from the batteries. Solar panels may be added to the system that can be used to charge the batteries.

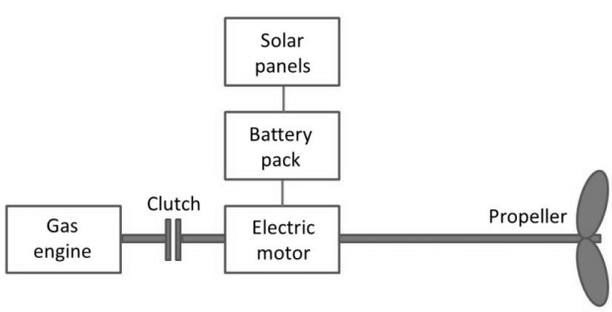

FIGURE 1. Hybrid electric propulsion for small vessels. Source: Asst. Prof. Paul Rodgers

Lithium iron phosphate batteries (LiFePo) are preferred since they are less susceptible to thermal runaway, fire, and explosion, and are lightweight compared to lead acid batteries. The batteries may be configured in a modular pattern to fit the motor voltage and power and capacity requirements to suit applications. LiFePo batteries cost about PhP10 per watt hour. For 120 ampere hours, 12-volt systems, they would cost about PhP10,000. Solar cells cost about PhP10 per watt, and a 500-watt solar panel would cost about PhP5,000, including the charge controller.

Brushless direct current (BLDC) motors or brushed DC electric motors may be used. BLDC motor prices range from about PhP11,000 (1-kilowatt motor) to about PhP32,000 (5-kilowatt motor). Brushed DC motors cost about half of BLDC motors but are larger and heavier. A cheaper option is to use alternators converted to three phase motors, with speed control using three phase motor controllers. Alternators from land vehicles are robust, cheap, and readily available, costing about PhP2,500 for common sizes.

The hybridization of municipal vessels should be considered and studied further since these could potentially help reduce emissions and increase the efficiency and range of these vessels. Further technical and economic feasibility studies are recommended to find a means to provide affordable prices to municipal fishermen and develop policies to incentivize such. Demonstration or pilot projects may be supported to validate costs and demonstrate the viability and economy of hybrid electric systems for small vessels.

Needed: An Enabling Policy Environment

The retrofitting of traditional small vessels into hybrid electric-powered ones is in keeping with the national government's commitment to the 2015 Paris Agreement, which seeks to reduce carbon emissions and limit, if not reverse, climate change. Helping small fishers and small boat operators acquire retrofit technology is also in line with the government's promotion of sustainable and inclusive development.

As earlier mentioned, there are no government policies or programs that directly could be tapped to support the proposed technology. National policies that promote electric and hybrid energy in the transport sector pertain to land-based vehicles. The Department of Science and Technology (DOST) has supported projects that develop electric and hybrid power in the seas, but these are mainly for medium-sized vessels.

This paper seeks to explore technologies for micro and small vessels that, in turn, would contribute to promoting green and efficient energy use in fishing and transporting goods and people in coastal and rural communities. Nevertheless, shifting to fully electric-powered boats also raises hesitation among municipal fishermen, because of the proven reliability of gasoline-powered boats, additional retrofit costs, and the uncertainty over any new technology. Instead of replacing engines with full electric components, retrofits to augment the gasoline-driven engines are a more attractive option, since these retrofits retain the reliable propulsion system but could potentially improve performance. They are also cheaper than complete system replacements.

That said, the success of current proposal, and similar efforts intended to benefit micro and small stakeholders will require government support, including the provision of incentives for developers and users. Such policies that provide incentives could include the following:

- Maritime Industry Development Plan (MIDP) 2019–28

  The development of a global maritime hub is one of the priority programs of the Maritime Industry Authority's (MARINA) "Ten-Year Industry Development Plan (2019–2028)," which is under the Department of Transportation. Among the target outputs under this program is the creation of an additional 1,070 new environmentally friendly and locally designed ships. It is an increase of 50 percent from the 2017 baseline figure of 2,140 ships.

- Republic Act No. 7638 or the Department of Energy Act of 1992

  This law stipulates that the Department of Energy (DOE) will oversee, formulate, and prepare plans and programs for the development of nonconventional energy systems and promotes the commercialization of such technologies. Under Section 16, the DOE grants incentives and privileges for the production, implementation, and replication of projects that are environment-friendly, use low-cost sources of energy, and promote energy conservation.

- Republic Act No. 11285 or the Energy Efficiency and Conservation Act

This law promotes the utilization of energy applications, plans, and programs such as energy efficient or renewable energy technologies and systems through fiscal and nonfiscal incentives and financial assistance. The Act supports the development of new technologies and the reworking of existing technologies for more efficient use of energy (i.e., reduce energy consumption and utility costs).

All told, municipal or small-scale vessels constitute a huge majority of the Philippine fleet. The proposed technology for small vessels could increase efficiency and range, improve fuel consumption efficiencies, and reduce GHG emissions. These projected benefits and the increasing fuel prices could compel small boat users and builders to consider retrofits to improve fuel efficiency and emissions reduction.

Equally important are the economic and equity concerns that the proposed project addresses. Giving municipal fishers access to new technology is necessary to help revitalize the local fisheries sector and, in turn, increase its contribution to the national economy.

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University of the Philippines
Center for Integrative and Development Studies (UP CIDS).

Editorial Office: Lower Ground Floor, Ang Bahay ng Alumni,
Magsaysay Avenue, University of the Philippines,
Diliman, Quezon City 1101
Telephone: 8981-8500 loc. 4266 to 4268 / 8426-0955
Email: cids@up.edu.ph / cidspublications@up.edu.ph

UNIVERSITY OF THE PHILIPPINES
CENTER FOR INTEGRATIVE AND DEVELOPMENT STUDIES

Lower Ground Floor, Ang Bahay ng Alumni
Magsaysay Avenue, University of the Philippines
Diliman, Quezon City 1101

Telephone: 8981-8500 loc. 4266 to 4268 / 8426-0955
Email: cids@up.edu.ph / cidspublications@up.edu.ph
Website: cids.up.edu.ph