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Prospects for renewable energy for seaborne transportation—Taiwan example

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Abstract

This paper highlights the need for the development of a renewable infrastructure for marine transportation. The result of a survey performed in this study serves as information for public policy makers on the degree to which policy can or should attempt to provide guidelines and incentives in shaping the attitude or behaviors of the industry towards the application. There is a high degree of preference for renewable over fossil as energy source for both ship power and household electricity. While solar is the most favorable energy type for household electricity, hydrogen combustion (80%) is the most supported alternative for powering commercial shipping. The fuel cell (FC) is the next highly favored (64%) alternative energy that is applied onboard ship as perceived by the Taiwanese maritime industry. The result also indicates that the preference of a specific energy type onboard ship is also based upon other factors such as feasibility rather than the respondents' personal preference.

Keywords: Maritime; Ship; Alternative energy; Renewable energy; Fuel cell

1. Introduction

Conveniently situated in the main shipping route of East Asia, Taiwan has been for several decades an active player in the world economy and an important trader in the global market. Marine transportation has enjoyed rapid growth alongside with the economic development. Approximately 38,000 merchant vessels, carrying 560 million gross tonnages, visited Taiwan's six international ports in 2003 [1]. At the end of 2004, Taiwan had a fleet of 220 vessels over 100 gross tons for a total of 5.9 million dead weight tons [2]. Evergreen Marine Corporation, Taiwan, was the third largest container carrier in the world in 2003 [3].

In recent years the most important driver for Taiwan's economic growth was trade with Mainland China, [4,5]. As a result, marine transport across the Taiwan Straits plays a vital role in determining the economic performance of both Taiwan and Mainland China [4]. The shortest voyage across Taiwan Straits, between Taichun Port in Taiwan and Meichou Port in Mainland, is only 87 nautical miles [1]. The flow of tourists across the Straits also showed a high level of growth since the early 1990s [6]. However, this economic development in Taiwan has been achieved at the expense of adverse impacts on environmental quality and climate. For example, ships with medium to large engines running on heavy fuel oil (HFO) without emission controls cause an array of environmental impacts [7].

Secured energy is another main driver for renewable energy. Given their heavy dependence on imported petroleum energy, both the economies of Taiwan and Mainland China shall find such a prospect very appealing. Although Mainland China is the fifth largest oil-producing country in the world, it is unable to meet its petroleum demand and has started importing oil in 1993 [8]. The increase in petroleum use was clearly related to transportation [9]. Both Taiwan and Mainland China face the challenge of meeting CO_2 emission reduction targets [10]. CO_2 emissions in Taiwan increased approximately 6 percent annually between 1993 and 2003 [11].

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Other factors may also influence the growth and development of renewable energy application in the maritime industry. For example, there is marked increase over the past decade in the number of passenger ferry services operated with high-speed and high-comfort vessels. This trend is likely to continue with the demands for shorter travel and delivery time ever presented [12]. In preparing for the demand of clean and reliable energy for the years to come, this paper highlights the need for the development of a renewable infrastructure for marine transportation with sustainability in mind in both energy and environment.

2. Clean energy for marine shipping

2.1. Pollution from shipping

Ships can pollute the environment in many ways, mainly due to the use and carriage of petroleum oil. A spill of bunker fuel oil may cause an ecological disaster and a major setback to tourism [13]. Beside oil spill, the financial burdens for merchant ships deliberately dumping oily bilge or oily residue can be huge. Evergreen, for example, is required to pay $25 million US dollars for a case involving deliberate oil discharge in United States waters [14].

In addition, for more than a decade ago, several reports have addressed atmospheric emissions from marine shipping sector as a significant environmental problem [15]. The major atmospheric emissions related to ships that could affect human health and environmental quality include particulate matters (PM), volatile organic compounds (VOCs), nitrogen oxides (NO_x), and sulfur oxides (SO_x) [7]. The contribution of marine vessels to PM and NO_x are expected to double by 2020 [15]. The regulations for the Prevention of Air Pollution from Ships were enter into force by International Maritime Organization on May 19, 2005, following the ratification of Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) [16]. The current regulations controlling air pollution from ships in Taiwan are based on the provisions of the Exhaust Gas Standards of Air Pollutants from Mobile Vehicles of the Air Pollution Control Act, adopted in 1999 [17].

Much has been worked out in international maritime industries for onboard emission abatement strategies [7,16,18]. Approaches to mitigation encompass a range of possibilities from currently available, low-cost approaches, to more significant investments. The various control technologies that are currently available are listed in Table 1, with a comparison of their effectiveness in emission reductions and related costs [7,16,18,19].

2.2. Clean energy for marine shipping

Using equipments that run on alternative fuels such as compressed natural gas (NG) and biodiesel is also an option. Compared to conventional diesel technology, NG technology has shown in-use emissions reductions in the range of 50% for NO_x and 90% for PM [20]. Emission benefits of biodiesel and several other cleaner biofuels blends show a 10–20% improvement over regular diesel [20]. Additionally, the biodegradability of biodiesel makes it well suited for marine uses because of less environmental impact in case spilled [20].

While docked, ships generally use medium-speed (around 500 rpm) auxiliary diesel engines to run service systems such as lights, HVAC, air compressor, deck machineries, refrigerator, oil heater, and pumps. Shore-power has widely been considered as a possible supply to the use. The fossil fuel based shore power can be further replaced with renewable energies such as wind energy [21]. Germany port Lubeck has planed for similar electric ship-to-shore projects [22].

The transition to hydrogen economy is expected to begin by building on current infrastructures and capabilities. Developing and commercializing a range of technologies for using, producing, storing, and distributing hydrogen will be required to make further progress [23]. The use of fuel cells (FCs) in marine transportation is considered one of the most desirable applications from the standpoint of petroleum displacement [24].

The overall average power requirement for marine vessels is estimated to be about 0.8 kW/t [25]. Theoretically, hydrogen can be used as a fuel in internal combustion engines and turbines onboard ship, more efficiently than fossil fuels [21]. The combustion with oxygen results in

Table 1
Pollution reduction potential and related costs of control technologies currently available onboard ships

Technologies	NO_x	PM	CO	Fuel penalty	Cost (US$1000)
Selective catalytic reduction (SCR) onboard ships	95–98%	–	–	–	9850/engine of 48,840 kWxl04 rpm
Introduction of water	30–60%	–	–	–	1800/engine of 48,840 kWxl04 rpm
Active diesel particulate filter and NO_x reduction catalyst	25–35%	50–90%	50–90%	3–7%	15–18 per unit
Diesel oxidation catalysts	–	25%	30–90%	0–2%	1–3 per unit
Exhaust gas recirculation	20–50%	N/A	N/A	0–5%	13–15 per unit
Natural gas	50%	90%	Increase	N/A	N/A

Source: [7,16,19,20].