Transitioning to Green Maritime Transportation in Philippines: Mapping of Potential Sites for Electric Ferry Operations

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Abstract—**Philippine maritime industry is considered as a vital component in achieving inclusive growth and socio-economic progress. Philippines has been known as one of the susceptible to the impact of climate change countries, and generally the changing climate hampers its economic development. The government committed to reduce carbon emissions to 70% by 2030 during the 2015 Paris climate conference. This study aims to map the potential sites and vessels for electric ferry operation for transitioning to green maritime transportation in Philippines. At present there are 83 ports and 110 ferries in the country with 33670 registered vessels as of December 2017. It was identified that the 9201 vessels with 10≥GRT≥3 will be used for electrification as a kickoff in implementing electric ferry since these vessels are feasible for retrofitting the electric system. Implementing green energy sources in the country's marine transportation will reduce CO_2 emission by 22.09% in the transport sector.**

Keywords-transitioning; green energy source; electric ferry; CO_2 emission

I. INTRODUCTION

Energy security, sustainability, pollution and climate change impact are among the major challenges the world is facing nowadays [1]. The need of energy has been increased with population growth and the advancement of technology. Finding and exploiting new energy sources has become a very important topic globally [2]. A sharp increase occurred in the usage of renewable energy in the past decade because of the RE promotion to make energy more secure in response to the consumer needs and to the climate change impact which became essential in transitioning to a sustainable future [3]. The transition of energy in different sectors, particularly in the transportation sector faces challenges regarding sustainability [4]. But because the renewable energy availability is now coupled with innovative technology, the energy transition to maritime sector is very possible nowadays. Furthermore, transitioning to green maritime transportation contributes to solve the problem in CO_2 emissions and reduces the dependency on fossil fuels. Maritime petroleum dependency resulted to a consumption of about five million barrels per day which is equivalent to 1Gt of CO_2 emissions annually [5], bringing the shipping industry into a great pressure to reduce environmental impact in CO_2 emissions which is projected to increase 50-250% by 2050 [6]. This industry is one of the stakeholders in the environmental issues, but still a better alternative among other transportation means. Still, the European Union and United Nation Framework Convention (UNFCCC) regulate emissions in all sectors and the International Maritime Organization (IMO) is working on the regulation of the emission in shipping industry [7]. IMO works towards developing a comprehensive regime aimed to protect the environment from pollution caused by ships [8]. With the transition to renewable energy sources, the maritime sector might achieve the aim of reducing carbon emissions or even eliminate them in the near future [9].

Philippine maritime industry is considered as one of the vital components of the country's economy. There is a major infrastructure connecting Philippine islands and the country to global commerce and trade [10]. Philippines have been known as one of the susceptible countries to the impact of climate change, only in 2013, a typhoon resulted to the loss of 7,000 lives. The changing climate might hamper the economic development of the country, so the Philippine government committed, during the 2015 Paris Climate Conference, to reduce carbon emissions coming from energy, transport, waste, forestry and industry sectors by 70% by 2030, even though the country is one of the lowest CO_2 emitting countries in the world [11]. With that envision, the Philippine government needs to implement policies to ensure the provision of the ecosystem and green services to address the GHG emission and environmental degradation [12]. The government decision to reduce carbon emissions and environmental degradation brings us to the aim of this study of paving the way of transitioning to green maritime transportation in Philippines: Mapping of potential sites for electric ferry operations. The transition to green energy sources will serve as an example to solve the

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energy security, sustainability, pollution and climate change impact that the country is currently experiencing.

II. E-FERRY: NEW PARADIGM

In aiming green source transition in maritime sector, E-ferry concept was derived for transporting goods and passengers. Ferry electrification in Europe emerged because of the coupling of environment considerations with new battery innovations and the increasing fuel prices in order to address the urgent need of reducing the increasing European CO_2 emissions from waterborne transportation [5]. The electric ferry was considered in navigating close to the coast of the Cinque Terre Natural Park in transporting passengers for its noiseless and slow boating that allows transforming a connection route to a touristic journey in a wonderful natural site without impacting with the local environment [13]. It is worth remembering the advantages of using green energy sources in the maritime transport sector. It reduces emissions in air and water, the energy source can be obtained directly from renewable resources like the sun or the wind, and it has a strong reduction in noise [13]. Another eco-friendly electric propulsion boat aiming to have zero emissions was used for public transport in Lake Trasimeno. The boat is powered by lithium-ion batteries that can be charged at any harbor visit [14].

III. POTENTIALITY FOR E-FERRY IN PHILIPPINES

A. Philippine Ports and Sites

Philippines is an archipelago, with a total land area of 299,404km^2 having three major island groups namely Luzon, Visayas and Mindanao, with large mountainous terrains, narrow coastal plains and interior valleys and plains. Philippines covers water area of 2.2 million km^2, of which 12% equivalent to 267,000km^2 are coastal water and 88% (1.934 million km^2) are oceanic water. Philippines has a total discontinuous coast line approximately 32,400km with 80% of provinces and 65% of cities and municipalities sharing the coast [15]. In Philippines, there are 8 gulfs, 7 seas and 10 straits. All ports used for maritime transportation are managed by the Philippine Port Authority (PPA). This agency monitors not only ports but also the ferry terminals. At present there are 83 ports and 110 ferry terminals in the country [16]. Existing ferries and small boats are potentially useful to electric maritime transport sector in Philippines.

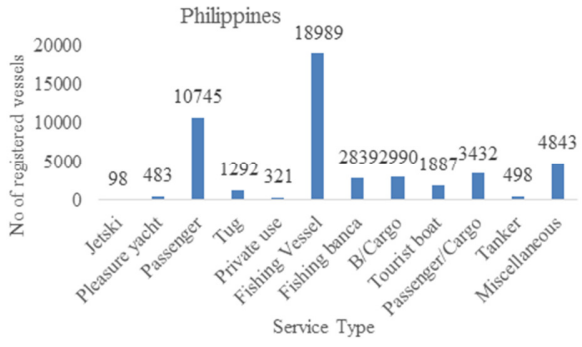

Fig. 1. Registered domestic vessels in Philippines

B. Philippine Vessel/Ferry

All maritime transportation, particularly domestic vessels are registered in the government agency under the Maritime Industry Authority (MARINA) Philippines. As of December 2017, there are 33670 vessels registered in the country with different service types as illustrated in Figure 1 [17]. Figure 2 shows the breakdown of different service types of vessels in the three major Islands in Philippines. These vessels help the economy improve and increase the quality of life. However, they contribute to the increase in the CO_2 emissions and depletion of fossil fuels.

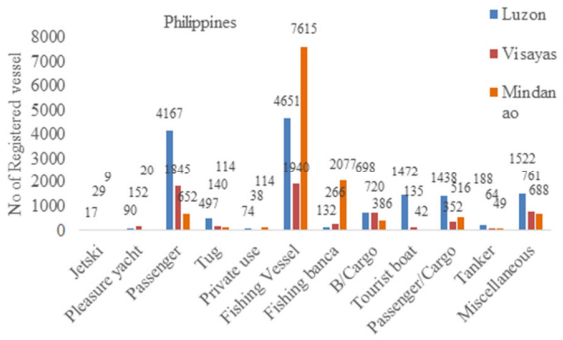

Fig. 2. Registered vessel per island group

Data coming from the MARINA Philippine were analyzed, to derive potential vessels for electric ferry in maritime transport sector. Table I displays the 9201 vessels that have 10≥GRT≥3 and are potentially useful for electric propulsion in Philippines. For instance, in Mindanao, such ferryboats are the ones that operate in Davao to Paradise Samal beach resort. The resort has 12 ferryboats operating in the area. Each boat operates 16 times a day for six days in a week. The operator uses 16L of diesel fuel that cost 800 Php per day. One liter of diesel fuel contributes a 2.68kg of CO_2 in the environment. Figure 3 shows the CO_2 emissions of one ferryboat operating in the island. If all the registered ferryboats shown in Table I use the same fuel consumption (16L/day), the total CO_2 emission is 5.184Mt in a period of 8 years as shown in Figure 5 and it serves as an indicator that Philippines need to address the CO_2 caused by transportation in maritime sector by advocating green energy sources for ferryboat operation.

TABLE I. POTENTIAL VESSELS FOR USE OF GREEN ENERGY

Place of Registry	No. of registered boats with 10≥GRT≥3
Luzon	5226
Visayas	2190
Mindanao	1785

IV. SIGNIFICANCE OF TRANSITIONING TO GREEN MARITIME TRANSPORTATION

Philippines is a minor emitter of greenhouse gases (GHG), but still needs to address the problem as the country is one of the signatories of the 1992 United Nation Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol [18]. The country is the 4th ASEAN CO_2 emitter with

8% of the total global CO_2 emissions from 1990 to 2014 which grew 4% annually during this period. DENR passed laws concerning climate change and one of them is the RA 9513 which is the promotion of the development of renewable energy resources [19]. Data from the Department of Energy (DOE) showed an annual average of 69Mt from 2000 to 2014 CO_2 emissions which mainly derives from electricity generation (41%) and transportation (34%) [19]. This study focuses on water transportation or maritime transport, aiming to reduce CO_2 in this sector. As shown in Figure 1, there are 33670 vessels registered in the country with different service types, and 9201 vessels were put into consideration as being suitable for converting into electric ferryboats. Electrifying these vessels will reduce CO_2 emissions under maritime by 5.18424Mt in a period of 8 years. Transitioning to green energy is also significant because is meeting the aims of reducing 70% carbon emissions by 2030, helping to solve the energy security, sustainability, pollution and climate change impact that the country is currently experiencing.

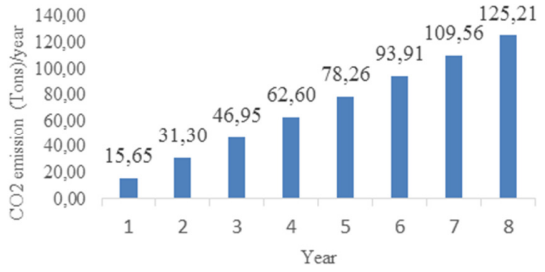

Fig. 3. CO_2 emissions of one ferryboat

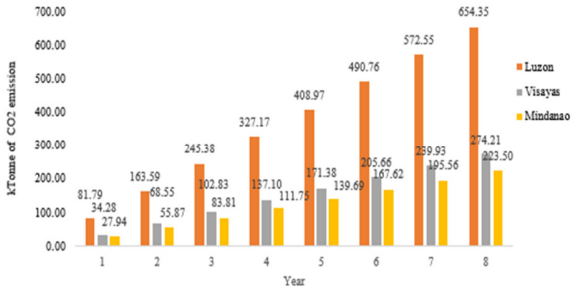

Fig. 4. CO_2 Emissions per island

V. Environmental Impact over the Cost of Electric Ferryboat

As part of the carbon cycle, CO_2 is a natural part of the atmosphere [19]. But, activities like fossil fuel combustion, especially in the transportation which is one of the primary GHG emission sources, are contributing to the climate change. Electrification of some, if not all, vessels will reduce CO_2 emissions. The cost of converting the existing ferryboats comes into consideration. Table II shows the costs of converting diesel ferries to electric ones. The total cost is $19582.03 for one ferry and the total reduction of CO_2 emissions in a period of 8 years is 547.9155Tons. If all 9201 potential ferryboats in Philippines were converted to electric ferries, the reduction of the carbon would be 5.18424Mt in 8 years. Some CO_2 is absorbed in the ocean: from the 7 billion tons of CO_2 released into the atmosphere per year, the ocean takes 2 billion tons, causing an increase of 26% in the concentration of the hydrogen ions, which decreases the pH by 0.1 [20]. CO_2 reduction also results to saving the marine life ecosystem by not reducing the seawater pH level.

TABLE II. COST OVER ENVIROMENTAL IMPACT

Capital Cost				Diesel CO_2 (Tons)/year		
Year	Diesel operating Cost	Electric operating cost	Annual Savings	Diesel CO_2*	CO_2 from manufacturing batteries (lead-acid)*	CO_2 emission reduction*
1	$ 6889	$ 3583	$ 3305	15.65	0.43	15.22
2	$ 13778	$ 7166	$ 6611	31.30	0.86	30.44
3	$ 20667	$ 10750	$ 9916	46.95	1.29	45.66
4	$ 27556	$ 14333	$ 13222	62.60	1.73	60.88
5	$ 34445	$ 17917	$ 16527	78.26	2.16	76.10
6	$ 41334	$ 21500	$19833	93.91	2.59	91.32
7	$ 48223	$ 25084	$ 23138	109.56	3.02	106.54
8	$ 55112	$ 28667	$ 26444	125.21	3.45	121.76

* Tons/year

VI. Conclusion

Transitioning to green energy sources in Philippines is a great help to counter climate change. Philippines is not one of the major CO_2 emitters in the world, but it is still ranked 4th among Asian countries. That's why the government looked to solve the problem of CO_2 emissions. This study considers the marine transportation sector which happens to contribute to 34% of CO_2 emissions of the transportation sector. Furthermore, this research contributes in identifying the potential sites and vessels for electric ferry operation in Philippines. With 33670 vessels registered in the country as of December 2017, it is concluded that 9201 vessels can be electrified. A boat with 10≥GRT≥3 travelling 2.13h per day at minimum, consumes 16L of fossil fuels. Converting this boat will reduce CO_2 emissions by 15.65tons per year. If green energy sources in the marine transportation will be implemented in all 9201 vessels, the CO_2 emissions will be reduced by 22.09% in the transportation sector, preventing the increase of ocean acidification and solving the energy security, pollution and climate change impact.

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References

[1] A. Garcia-Olivares, J. Sole, O. Osychenko, "Transportation in a 100% renewable energy system", Energy Conversion and Management, Vol. 158, pp. 266-285, 2018

[2] Y. A. Kaplan, "Overview of wind energy in the world and assessment of current wind energy policies in Turkey", Renewable and Sustainable Energy Reviews, Vol. 43, pp. 562-568, 2015

[3] N. Vidadili, E. Suleymanov, C. Bulut, C. Mahmudlu, "Transition to renewable energy and sustainable energy development in Azerbaijan", Renewable and Sustainable Energy Reviews, Vol. 80, pp. 1153-1161, 2017

[4] D. F. Dominkovic, I. Bacekovic, A. S. Pedersen, G. Krajacic, "The future of transportation in sustainable energy systems: Opportunities and barriers in a clean energy transition", Renewable and Sustainable Energy Reviews, Vol. 82, pp. 1823-1838, 2018

[5] E. Gagatsi, T. Estrup, A. Halatsis, "Exploring the Potentials of Electrical Waterborne Transport in Europe: The E-ferry Concept", Transportation Research Procedia, Vol. 14, pp. 1571-1580, 2016

[6] R. D. Geertsma, R. R. Negenborn, K. Visser, J. J. Hopman, "Design and control of hybrid power and propulsion systems for smart ships: A review of developments", Applied Energy, Vol. 194, pp. 30-54, 2017

[7] S. Sherbaz, W. Duan, "Propeller efficiency options for green ship", 9th International Bhurban Conference on Applied Sciences & Technology, Islamabad, Pakistan, January 9-12, 2012

[8] J. Prpic-Orsic, O. M. Faltinsen, M. Valcic, "Development strategies for greener shipping", ELMAR 2014, Zadar, Croatia, September 10-12, 2014

[9] M. Lange, G. Page, V. Cummins, "Governance challenges of marine renewable energy developments in the U.S. – Creating the enabling conditions for successful project development", Marine Policy, Vol. 90, pp. 37-46, 2018

[10] TESDA, The Philippine Maritime Industry Through the Years, TESDA, 2017

[11] https://data.worldbank.org/indicator/EN.ATM.CO2E.PC

[12] M. Mogato, "Philippines aims to cut carbon by 70 percent by 2030, if it gets help", available at: https://www.reuters.com/article/us-climatechange-summit-philippines/philippines-aims-to-cut-carbon-by-70-percent-by-2030-if-it-gets-help-idUSKCN0RW0KN20151002, 2015

[13] M. Bianucci, S. Merlino, M. Ferrando, L. Baruzzo, "The optimal hybrid/electric ferry for the liguria Natural Parks", OCEANS 2015 - Genova, Genoa, Italy, May 18-21, 2015

[14] G. S. Spagnolo, D. Papalilo, A. Martocchia, "Eco friendly electric propulsion boat", 10th International Conference on Environment and Electrical Engineering, Rome, Italy, May 8-11, 2011

[15] Government of the Philippines, The Philippines' Initial National Communication on Climate Change, 1999

[16] PPA, List of Ports Covered in PPA Statistics, PPA, 2016

[17] Maritime Industry Authority, "List of Philippines Registered Vessels as of December 2017", MARINA, 2017

[18] TTPI Inc, CPI Energy Phils. Inc, "A Strategic Approach to Climate Change in the Philippines", TTPI Inc, CPI Energy Phils. Inc, 2010

[19] E. M. Nejar, "Feasibility of Imposing a Tax on the Emissions of Carbon Dioxide in the Philippines", NTRC Tax Research Journal, Vol. 28, No. 3. pp. 15-38, 2016

[20] M. Briffa, K. de La Haye, P. L. Munday, "High CO2 and marine animal behaviour : Potential mechanisms and ecological consequences", Marine Pollution Bulletin, Vol. 64, No. 8, pp. 1519-1528, 2012