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Potential Tangible and Intangible Benefits of Sustainable Shipping in Small Island Developing States

Jennifer Teeter, Kyoto University, Kyoto, Japan

ABSTRACT

Small island development states (SIDS) have called for a 25% reduction in fossil fuel used by transport by 2033 at COP21 in 2015. Recognizing that the current global shipping system based on the container ship model is effectively wreaking havoc on the global environment while marginalizing people in their countries, attention is being turned to small-scaled, durable, affordable, energy-efficient, renewable-energy powered wind ships built to fit the needs, means and context of the communities that use them. After outlining the impacts of the current shipping system, this article turning to an analysis of the Greenheart Project. Greenheart Project aims to create a network of vessels powered by solar and wind technologies for transportation purposes, while developing a means for further regional and international cooperation, sustainability, and ethical business that prioritizes the unique and differing needs of communities. This paper will evaluate the Greenheart Project model of small-scaled cargo transport, measuring its tangible and intangible benefits and discussing potential applications in the South Pacific for regional trade and transport networks.

KEYWORDS

Greenheart Project, International Maritime Organization (IMO), Small Island Development States (SIDS), South Pacific, Sustainable Shipping

INTRODUCTION

Recent analysis has highlighted the potential of implementing renewable energy sourced shipping in the Pacific Islands at a reduced cost with additional social and environmental benefit (Nuttall, Newell, Bola, Kaitu'u, and Prasad, 2014). Despite the ease at which these transitions can be made, the current global shipping system continues to depend on a model focusing on the efficiency in transporting items/persons from location X to location Y as quickly and efficiently as possible enabling convenience for those with access to this so-called hub-and-spoke system, this model is effectively wreaking havoc on the global environment while leaving important sectors of the world, often the poorest and most vulnerable, excluded from shipping networks.

In 1993, the Economic and Social Commission for Asia and the Pacific (1993: 12) declared, "the non-availability of a well-developed transport infrastructure in many developing countries in the region has been identified as one of the critical bottlenecks for industrial development" (p.12). Twenty years later, this is still the case. For the millions of people marginalized from the system who

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also need appropriate ships, often the only option is costly small-scaled diesel powered vessels that can potentially produce more pollution per freight-ton-kilometer than ocean-going container ships.

Small island developing states (SIDS) have recognized the need to reduce dependence on fossil fuels for transport. The Marshall Islands set a target to make a 20% reduction in fuel used by transport (Majuro Declaration, 2013) and through the SIDS Dock Initiative, as of present, 32 SIDS have agreed to aim for a 25% decrease in conventional transportation fuel use by 2033 (SIDS Dock Forum, 2015). Furthermore, the UN Conference on SIDS developed a platform of action based around advancing land, sea, and air transportation to encourage sustainability, based on the fundamental premise that "transportation and mobility are central to the sustainable development" (S.A.M.O.A. Pathway, 2014). Therefore, developing transportation solutions is viewed as crucial area in encouraging sustainable development in SIDS.

One solution -- small-scaled, durable, affordable, energy-efficient, renewable-energy powered wind ships built to fit the needs, means and context of the communities that use them. This article will explore the history of the shipping industry in SIDS, and detail the impacts of shipping on the global environment. After discussing the special needs of coastal communities marginalized out of the global shipping system, it will describe the potential for sustainable shipping based on wind technology, specifically turning to the Greenheart Project. Greenheart Project aims not only to create a network of sailing vessel (S/V) powered by solar and wind technologies for transportation purposes, but to create a means for further regional and international cooperation, sustainability, and ethical business.

The remainder of the chapter will evaluate this model of small-scaled cargo ships presented by the Greenheart Project, measuring the tangible and intangible benefits for the project and discussing its potential applications in the South Pacific for regional trade and transport networks.

FROM WIND TO CARBON

Throughout history, shipping has played an important part in societies around the world. In some regions, it is central to most parts of society, such as in Oceana where sea-routes are the lifelines of the islands there, while ocean voyaging maintains a history of more than 6000 years. Pacific islanders had colonized the entirety of the Pacific Ocean in fast double hulled sailing ships when Europeans were still mainly using only coastal vessels (Nuttall, D'Arcy; Philp, 2014).

Vessels powered by the wind alone were instrumental in the history and development of coastal regions and islands (Couper, 2009). From earlier than the 3rd century, wind powered ships contributed to the development of the Asian trading routes from the South China Seas to India, to eventually the Mediterranean (Manguin, 1993) until recently, when these ships were almost completely replaced with European sail, then carbon-fuelled vessels. Sail has been the primary power source of ships for far longer than any modern fossil fuel-based source. Innovations in sailing ships brought upon fast clippers ships, but with increasing European immigration overseas and technological innovation, the even faster steam ships began developing in niche-markets sufficiently enough to eventually start to replace them (Geels & Schot, 2007).

Nonetheless, due to innovation in harnessing the wind, sail ships did not suddenly disappear, but evolved in usage. Through their continued construction wind ships made gains in gross tonnage for nearly 100 years past the introduction of steam. Sail sustained itself in smaller niche markets where speed of shipment was not a priority (Grübler, 1990) In Britain, however, steam eventually replaced most sail by an estimated 1940 (Grübler, 1990), and by 1940 motor replaced steam, leaving steam with only residual market shares (Grübler & Nakićenović, 1991). Although there has been insufficient research in the actual usage of small scale sail vessels for transport, sail ships continue to be used in small sail sectors in small island developing states (SIDS) in the Caribbean, and also in East Africa and West Africa (Boerne, 1999). Nonetheless, motorized ships now dominate regional and international shipping routes, and sail is mainly used for recreation and tourism.

SHIPPING AND THE ENVIRONMENT

Shipping itself accounts for 90% of global commerce and the expansion in global trade is directly related to expansion in shipping (United Nations Environment Program (UNEP), 2012 The expansion of the shipping industry also directly impacts the environment through the release of greenhouse gasses (GHG) such as CO2, pollution of waterways and oceans through cargo or bunker oil spills and accidents, and the destruction of sea beds and coral reefs through dredging and land reclamation for ports.

The international shipping industry is considered to be a significant contributor to global greenhouse gas emissions (GHG). Although there is some disagreement about the exact amount of emissions shipping has produced, total shipping is estimated to be currently responsible for at least 3.1% of the global emissions (Smith, et al., 2015) . Furthermore, Smith, et al. (2015) foresees an increase by 50-250% by 2050.The majority of these GHG emissions originate from the consumption of heavy fuel oil (HFO), which due to its affordability, has traditionally been used in the shipping. Ships are specifically designed to use this low cost fuel in order to decrease operating costs, and 95% of two-stroke engines, and 70% of four-stroke engines use HFO (Corbett & Winebrake, 2008: 14). The increasing amounts of carbon dioxide and sulfuric acid being absorbed by the oceans, is destroying marine food webs that all creatures depend on. Acidification is severely impacting coral reefs and other organisms that produce calcium carbonate shells and skeletons (Feely et al., 2004). The oceans are also warming, which is causing sea ice to melt and sea levels to rise, all of which disrupts marine ecosystems and ocean circulation. Humans too, will be directly affected by these changes as huge swaths of coastline will be lost, weather patterns will change and food production methods will be altered. The future of the ocean as a source of biodiversity, food and climate regulation is in peril.

The regular operation of a ship also is responsible for a variety of other pollutants (United Nations Environment Program (UNEP), 2012):

- Oil, chemical and liquefied gases leakage;
- Sewage;
- Garbage;
- Transfer of invasive species through ballast water and biofouling;
- Engine exhaust (including sulfur, nitrous oxides and carbon dioxide);
- Cargo vapor emissions;
- Chlorofluorocarbons (CFCs);
- Halons; and
- Noise.

This pollution occurs during transit, and also locally while ships are in ports (Corbett & Winebrake, 2008; International Maritime Organization, 2009) and the economies of coastal states, especially SIDS dependent on marine resources, are at risk from oil pollution from ships.

Although the operation of a ship itself is responsible for the majority of the pollution it produces, 92% in the case of a fishing vessel (Tincelin, Mermier, Pierson, Pelerin, & Jouanne, 2010), the construction and docking of ships can also be a dirty business. Runoffs of oily water from machinery spaces, and accidental oil spillages are common problems. Furthermore, painting and removing paint from ships through abrasive grit blasting, creates sewage and waste (Chen, et al., 2012; Pacific Northwest Pollution Prevention Resource Center, 1997). Heavy metals, such as copper and tributyl tin (TBT), from antifouling paint used to prevent marine organisms from attaching themselves to hulls and thereby reducing fuel efficiency, are also a concern. There conventional antifoulants, pinpointed as instigators of marine life decline, constantly release biocides, 80-90% of which leak into the ocean within 3-5 years (Reynolds, 2004).

In order to deepen navigation passages to allow for large container ships to enter a port or harbor area, dredging or land reclamation is required. However, these processes may cause adverse impacts on the marine environment (U.S. Army Corps of Engineers, 1983; UK Marine Sacs Project, 1999). Reine, Dickerson, and Clarke (1998) note that release of sediments or sediment-born constituents during dredging and the disposal of dredged material impacts marine systems in the following ways:

- Physical disturbing of nesting and spawning;
- Habitat destruction;
- Detrimental effects of turbidity, suspended sediments and sedimentations;
- Barriers to migration;
- Hydraulic entrainment;
- Vessel strikes; and
- Degradation of water quality.

Furthermore, dredging can destroy the ecosystems that communities depend on for their livelihoods, especially if the dredging occurs near coral reefs or sea grass beds. Sea grass beds, for instance, play an enormous role in fisheries (Jackson, Rowden, Attrill, Bossey, & Jones, 2001), and in protecting coasts from erosion (Fonseca, 1989). In many cases, dredging has led to a direct decrease in these vital sea beds. Dredging in Tampa Bay, Florida for instance, caused a loss of 81% of the sea beds (Lewis, 1976). A loss of 232 ha of sea grass and an additional predicted loss of 168 ha by 2014 was a result of dredging from 1950-2002 in Western Australia (Walker, Hillman, Kendrick, & Lavery, 2001). Dredging in Rio de Janeiro, Brazil led to deposits of heavy metals in the sea beds (Amado Filho, Creed, Andrade, & Pfeiffer, 2004). Dredging for the Gulf of Porto-Vecchio, Corsica Port in France saw the complete disappearance of sea beds (Pasqualini, Pergent-Martini, & Pergent, 1999). Although stricter regulations, and mitigation measures are sometimes in place to lessen the impact of dredging, if theses measures are not taken, it is often the case that sea grass restoration measures are not effective (Moberg & Rönnbäck, 2003).

When a ship reaches the end of its lifecycle, which is normally 20-25 years, there are other potential environmental pollutants. These include oil and toxic chemical leakage due to dismantling and scrapping (Reynolds, 2004; Tibbetts, 2001).

When old ships are decommissioned and taken apart, primarily to recover steel, there are toxic components that must be disposed of, including asbestos, PCBs, and toxic metals such as mercury and lead. Toxic wastes, though only around 5 percent of the total weight of an average ship, can be a significant source of hazards for workers and environmental pollution (Clapp, 2010: 101).

Approximately 12,500 ships are dismantled annually (Shipbreaking Platform, 2015), and over the past couple of decades, shipbreaking has been transferred to developing countries such as the scrap yards of India, China, Pakistan, Bangladesh, the Philippines, and Vietnam where often times the handling of toxic chemicals is less regulated and waste disposal is less expensive (Furtado, 2000; Puthucherril, 2010). Reducing the impact of a ship at every stage of its life-cycle is critical to Solutions to these problems caused by the life-cycle issues.

MARGINALIZED SMALL ISLAND STATES AND COASTAL COMMUNITIES

The definition of small island developing states (SIDS) varies, but is a term that is self-appointed by the country itself. These countries share characteristics such as small size, remoteness, vulnerability to external shock, a narrow resources base, and exposure to global environmental issues. Relative to their size they receive more development aid than other countries. In 2008, SIDS represented more than half of the top 20 recipients of Official Development Assistance (ODA) countries (Bah & Ward, 2011). For analytical purposes, the United Nations developed a subgroup of SIDS for analysis (see

Table 3) and found that in comparison to accelerating growth in other developing countries, the growth rate of these countries had a contracted from 1990 to 2000 of about 0.6% from 3.2% to 2.6% (United Nations, 2010). Therefore, it has been argued that it is paramount for development in SIDS be sustainable to reduce their dependence on aid (Boerne, 1999).

Not just SIDS, but many countries with coastal access make up the lowest rankings in term of gross national income (GNI) adjusted for Proportional Purchasing Power (PPP) and the Human Development Index (HDI) (see Table 1). GNI per capita shows the basic wealth of a country in terms of income in dollars, and if adjusted for PPP per capita it is possible to know the actual spending capacity of the GNI dollars within the countries economy. HDI gives a composite of the levels of development in health, education, and living standards. Although these figures alone cannot capture levels of income or development in a country completely, since they do not take into consideration factors such as individual vulnerability (Blancard & Hoarau, 2012) or distribution of wealth, they do provide a broad picture. In Table 1, the vast majority of countries that make up the countries with the lowest GNI are countries that have access to the ocean. Compare that to the top GNI countries with ocean access, and a huge disparity can be seen.

For all SIDS as a group in total, the GNI is $5,397 and levels of human development as calculated by HDI are also comparably low. Regardless, the small economic size of SIDS may provide them an

Table 1. Countries with lowest GNI

	2012 GNI	2012 HDI	2012 LSC
Congo (Democratic Republic of)	319	.304	4.01
Zimbabwe	424	.397	n/d
Liberia	480	.388	5.88
Eritrea	531	.351	4.02
Burundi	544	.355	n/d
Niger	701	.304	n/d
Central African Republic	722	.352	n/d
Malawi	744	.418	n/d
Madagascar	828	.483	11.85
Mali	853	.344	n/d
Sierra Leone	881	.359	5.15
Mozambique	906	.327	10.23
Togo	928	.459	14.76
Guinea	941	.355	8.06
Comoros	986	.429	5.22
Afghanistan	1000	.374	n/d
Ethiopia	1017	.396	n/d
Guinea-Bissau	1042	.346	4
Haiti	1070	.456	5.12
Nepal	1137	.463	n/d

Note: GNI per capita in PPP terms (Constant 2005 International $)
Bold countries have access to the oceans
n/d = no data available

advantage. The "Optimal" Sustainable Human Development Indicator (OSHDI) has been developed to take into consideration the special needs of SIDS and Small Island Economies (SIE). Taking into consideration economic vulnerability and environmental sustainability, SIDS score on average .09 higher if calculations are made based on the OSHDI (Blancard & Hoarau, 2012: 15). Small size likely increases social cohesion, thereby facilitating the establishment of policies that benefit citizens (Blancard & Hoarau, 2012; Bayon, 2007).

In terms of transportation, for many riverside and coastal communities, especially SIDS, accessibility to transportation hubs is limited. While there remains to be a clear definition of accessibility as it can vary depending on context (Cullinane & Wang, 2009), it can be related to the proximity to destinations or services (Gutierrez, 2009; Litman, 2003); compounded by the time and cost of accessing such services; "the potential of opportunities for interaction" (Hansen, 1959:73); and connectivity (Baradaran & Farideh, 2001). Some definitions are contingent on whether or not individuals are free to decide to participate in activities (Burns, 1979). Taking all of these definitions into consideration, from a transportation context, the extent at which a location is accessible can be determined by analyzing the faculty of connecting with other locations via roads, rail, sail, or harbors through a variety of services, while keeping in mind efficiency of cost and travel. The Liner Shipping Connectivity (LSC) Index (LSCI) measured countries levels of integration into linear shipping networks, assessing a country's ability to access global trade. It has four components: the number of ships, the total container-carrying capacity of those ships, the maximum vessel size, the number of services, and the number of companies that deploy container ships on services from and to a country's ports (UNCTAD, 2013). With the exception of Iceland, Ireland, Finland, Brunei Darussalam, Norway, Kuwait and Qatar, many of which depend on land transport for their trade, there is a huge disparity in LSC rankings between the countries with ocean access that rank lowest in GNI, those at the top and SIDS (see Tables 1, 2, and 3). The top 20 GNI countries with ocean access for 2012 have on average a rating of 51 for their connectivity, while SIDS receive a 9, showing that there is a significant connectivity gap (see Tables 1 and 3). For countries with ocean access the context of moving towards a low carbon future, where do countries in the developing world fit in?

Accessibility to transportation is a key factor in coastal and island development (Brookfield, 1980; Hoyle, 1999). Often times, the only option for transportation is via sea- or river- routes. One such example is Indonesia, the most extensive archipelago in the world. The farther a port town is away from Java, and the more difficult it is for a person to reach a port be land, the less frequent the port is to receive calls to port by governmental passenger ships (Rutz & Coull, 1996). In the Philippines, sea-transport is the main means of domestic trade and is playing an ever-growing role in the country's international transport. In cargo transport for instance routes between the two major ports of Manila and Cebu have only one competitor and the majority of routes are monopolized (Austria, 2002). Only one service provider may be necessary, but this could leave consumers open to manipulation and abuse.

Often times when a small amount of companies control transport, this leads to lessened connectivity, as was the case with the U.S. airline industry. A lack of competition as a result of consolidation led to fare hikes and reduced availability (Tam & Hansman, 2003). Smaller markets were threatened by the lack of connectivity According to Lekakou and Vitsounis (2011), lack of competition is also driving up prices for consumers of interisland passenger ships in Greece.

In a study of the international shipping companies that control 70% of international trade, it was found that the majority of shipping lines are concentrated in the Northern Hemisphere and there are relatively few shipping lines between the Northern and Southern Hemisphere. Furthermore, there is a lack of shipping lines between East and West Africa, and the East and West coasts of South America. Therefore, although the current global shipping transport network is currently referred to as a hub-and-spoke system, it does not accurately describe its nature (Wang & Wang, 2011).

Table 2. Top ranking GNI countries with access to the oceans[i]

	0212 GNI*	2012 HDI	2012 LSC
Spain	25947	.885	70.4
Italy	26158	.881	67.26
Israel	26224	.9	32.42
Bahamas	27401	.794	26.41
Korea (Republic of)	28231	.909	100.42
Ireland	28671	.916	12.68
Iceland	29176	.906	4.66
France	30277	.893	74.94
Finland	32510	.892	9.34
United Kingdom	32538	.875	87.72
Japan	32545	.912	65.68
Belgium	33429	.897	82.21
Denmark	33518	.901	38.67
Australia	34340	.938	29.87
Canada	35369	.911	38.44
Germany	35431	.92	88.61
Sweden	36143	.916	42.32
Netherlands	37282	.921	87.46
United Arab Emirates	42716	.818	66.97
United States	43480	.937	92.8
Brunei Darussalam	45690	.855	4.61
Norway	48688	.955	5.28
Singapore	52613	.895	106.91
Kuwait	52793	.79	7.12
Qatar	87478	.834	3.35

*GNI per capita in PPP terms (Constant 2005 International $)

Furthermore, governmental institutions, NGOs, and the private sector maintain that "sustainable" development is a priority, while in practice these aspirations often remain unrealized (Crossley & Sprague, 2013). There are numerous definitions of sustainable development, one of the most recognized definitions from what is known as "Brundtland Report" maintaining that "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Our Common Future, 1987: 41).

Increasingly, the literature on sustainable development has recognized that in addition to addressing social, economic, and environmental concerns (Barbier, 1987), and the interactions of aspects of well-being (economic, ecological, and social) (Ciegis, Ramanauskiene, & Martinkus, 2009), culture is a paramount fourth aspect that needs to be taken into consideration (Duxbury & Gillette, 2007). Specifically, the incorporation of indigenous knowledge contributes to the efficiency,

Table 3. GNI, HDI, and LSC of SIDS 2012[i]

SIDS	2012 GNI*	2012 HDI	2012 LSC
Antigua and Barbuda	13883	.076	2.43
Bahamas	27401	.794	26.41
Barbados	17308	.825	5.18
Cape Verde	3609	.586	4.12
Comoros	986	.429	5.12
Dominica	10977	.745	1.59
Fiji	4087	.702	12.05
Grenada	9257	.77	4.59
Jamaica	6701	.73	25.32
Maldives	7478	.688	8.12
Mauritius	13300	.737	24.72
Papua New Guinea	2386	.466	6.61
Saint Kitts and Nevis	12460	.745	2.58
Saint Lucia	7971	.725	4.93
Saint Vincent & the Grenadines	9367	.733	4.1
Samoa	3928	.702	4.19
Sao Tome and Principe	1864	.525	6.87
Seychelles	22615	.806	8.08
Solomon Islands	2172	.53	6.04
Timor-Leste	5446	.576	n/d
Togo	928	.459	14.76
Trinidad and Tobago	21941	.76	17.26
Vanuatu	3960	.626	3.42

*GNI per capita in PPP terms (Constant 2005 International $)
n/d = no data available

effectiveness, and development process by empowering communities to take the lead in developing sustainable programs, rather than imposing (Gorjestani, 2000). Unfortunately, many projects fail, as they are imposed in a top down nature, rather than engendered from the grassroots level. As Elliot and Fagan (2010: 82) note:

Many current adaptation programmes are being conducted in similar ways to most development work (that is, top down with limited community engagement) ... A crucial task is to create better mechanisms to allow communication and decision making among donors, governments, and affected communities.

SUSTAINABLE SHIPPING

With knowledge of the environmental impacts of shipping on ecosystems spreading, making shipping sustainable is considered by some to be the largest global challenge of this century (Fet, 2003). A sustainable shipping initiative can be defined as a scheme "encourage(s) shipping to go beyond standard compliance of environmental behaviour and become exemplary in their [its] approach to shipping operations and the environment" (Pike, Butt, Johnson, & Walmsley, 2011: 1).

Unfortunately, many sustainable shipping initiatives seem to only touch the surface of the issues, failing to take holistic sustainable approaches to sustainability. Until 2008, the shipping industry remained relatively unregulated compared to other forms of transportation. The International Maritime Organization (IMO), established by the UN to regulate the shipping industry in 1949 expanded its mandate on environmental concerns to include greenhouse gas emissions with the 2008 First Intercessional Meeting of IMO's Working Group on Greenhouse Gas Emissions from Ships. Although the IMO is considered the most important regulatory body for the shipping industry, overseeing over 20 international conventions on marine environmental safety with 167 member countries and 3 associate members, the decision-making process of the IMO are lengthy and there are not effective incentives or enforcement mechanisms for its decisions (Wuisan, van Leeuwen, & van Koppen, 2012).

It was just in January 2013 that the IMO adopted "mandatory" measures to reduce GHG emissions (International Maritime Organization (IMO), 2013) To fill in the gap, non-state actors have stepped in to monitor and provide incentives to the shipping industry to minimize environmental impact. The Green Award Foundation (2009) established in 1994 certifies and gives financial and non-financial benefits to "extra clean and extra safe" ships in order to make sustainable shipping economically attractive. The Clean Cargo Working Group has members from 30 shipping companies, including 11 of the top 15 world liner fleet operators and 12 global shippers. It was created by Businesses for Social Responsibility (2013) in the early 2000s to calculate ocean transport footprints, review environmental performance, and form a network of partners to improve environmental performance. In 2008, the Shipping Key Performance Index was released by Intermanager, MARINTEX, and the Research Council of Norway (2013) to analyze Shipping Performance Indexes (SPI) in seven areas, including environmental performance. In 2010, the Environmental Ship Index was created by the World Ports Climate Initiative (2013) to be an evolving and free index used by ports to specifically encourage the reduction of GHG emissions. In the same year, the Carbon War Room (2013a) launched SustainableEfficiency.org so that anyone with Internet access could calculate and compare the energy efficiency of 60,000 existing ships. The Vessel Design Tool Package has also been developed to assess the lifetime environmental impact of ships from cradle to grave (Ellingsen, Fet, & Aanondsen, 2002).

According to the Carbon War Room (2013b), with fuel prices at record highs, gains in efficiency could save the shipping industry $50 billion a year in fuel costs while reducing emissions by 220 million tons per year. In fact, since fuel is the costliest aspect of running a ship, operators have an incentive to find ways to reduce fuel consumption (United Nations Environment Program (UNEP), 2012). However, some analysts would disagree. Buhaug (2009) argues that there are some technical and operational measures that can be implemented to reduce emissions, but there are non-cost related barriers to their implementation. Those measures include "improving energy efficiency" of ship design, "using renewable energy sources," "using fuels with less total fuel-cycle emissions," and using emission reduction technologies to "reduce emissions through chemical capture, capture and storage, and other options" (Buhaug et al., 2009: 44). Applying these technologies and practices could reduce a ship's emissions by 25-75%. However, since these measures to improve efficiency often lack incentives, even despite the growing number of non-state actors providing such incentives, it is impossible to predict whether, despite the availability of technology, if the compromises, effort and extra costs will be taken to implement these measures. As for the use of emissions reduction technologies, Buhaug (2009) also concludes that while it is possible to remove CO2 from exhaust through chemical conversion, it is not feasible and there is always a tradeoff. The reduction of emissions of one GHG, such as NO2, is accompanied by an increase in CO2 and PM. Furthermore, these types of solutions could be considered band-aid solutions that fail to address the root causes of the problem.

Although there may be long-term savings for ship operators that make efficiency improvements in their vessels, the short-term costs could be especially costly, especially for those living in developing countries. These countries are facing new challenges due to the regulations that require all vessels built after 2019 to meet compliance measures of the new Energy Efficiency Design Index (EEDI). Although developing countries are permitted a waiver until 2019, there are other factors that could make meeting regulatory standards difficult. As time passes, more and more regulations and tax policies are being drafted.

Taking these factors into consideration, how can coastal towns that are effectively isolated from marine transportation systems develop without shouldering extreme costs and harming local environments? Some researchers argue that it would be impossible for these towns to develop without expanding emissions, pointing to the Kenyan export horticulture development model, where Kenya exports to the United Kingdom 70% of the green beans consumed (MacGregor & Vorley, 2006). This could be ideal for countries with the ecological space to follow this model, but the export of produce on this scale requires the construction of a port for large container ships, on land transportation services to access the port, the impact on the natural environment detailed above.

The IMO standards seek to encourage the use of vessels that produce fewer emissions rather than cutting emissions where they start. They also do not address other environmental impacts regarding shipping. Rather than simply taking moves to mitigate emissions, ambitious sustainable shipping measures that seek to create little to no emissions and little environmental impact for new ships can be pursued by combining technology from the recent past, wind, with technology of today.

However, shipping is not only based on technology alone, but the infrastructures on shore (Tongzon & Sang-Yoon, 2015). If the organizations and infrastructures used to implement a sustainable shipping initiative are not in harmony with local conditions, no matter how technologically advanced and affordable a ship may be, it may not work effectively in the community for which it is intended.

PAST APPLICATIONS OF HYBRID SAIL

Sail is increasingly being turned to for technical innovations in sustainable shipping. In fact, re-introducing sail to maritime shipping is not a new concept. During the oil shocks of the 1970s and 1980s, in both Fiji and Japan experiments were conducted by adding sail to ships, resulting in fuel savings of up to 30%. The Fijian experiments were ADB funded using government service ships. The Japanese were private enterprise.

The 1,600 deadweight tonnage (dwt) tanker *Shin Aitoku Maru* was retrofitted with computer-directed, self-raising sails that oriented themselves toward the wind. The sails replaced the need for stabilizers making the roll and pitch of the boat greatly reduced meaning that the ship could operate in stronger weather. The sails were able to be used in situations where the motors failed and due to the sails alone, this ship saw fuel savings of up to 10% (Ouchi, 2011), but with the return of affordable fuel and costly sail maintenance, these two projects were abandoned (Hobson et al., 2007).

Two ships in Fiji were retrofitted with sails in 1984 and 1985. The *Na Mataisau* saw "fuel savings of 16% at 9 to 10 knots, 23% at 8 to 9 knots and 34% at 7 to 8 knots" (Macalister, 1985: 175). Like its Japanese counterpart, the *Na Mataisau*'s stability was increased as engine wear lessened by 30%. A 1985 typhoon grounded the *Na Mataisau*, but only after the ship brought its crew to safety via sail alone since its engines had failed. *Na Mataisau's* rigs were installed onto the *Cagidonu*, which saw other positive gains in fuel savings, "36.5% with main, mizzen and jib sails and 21.2% with mizzen and jib only" (Satchwell, 1986: 9). From 1982- 1989, more than 350 artisanal fishing vessels were equipped with sails several Pacific Islands, but uptake of the vessels was inhibited by a lack of confidence in the functionality and economic viability of the ships (Gulbrandsen & Savins, 1987; Nuttall, et al. 2014).

MODERN EXAMPLES

With current concerns of environmental degradation and rising fuel costs, again ship operators are investigating the possibilities of sail propulsion through towing kites, wind engines, and sail. Towing

Kites, such as those developed by Sky Sails are attached to the bow of a ship to provide a thrust force from the wind that substitute for engine power (Faber, Wang, Nelissen, Russell, & St Amand, 2011). Sky Sails (2011) reports that the installation of their towing kites can potentially reduce the fuel consumption of a cargo vessel by 10 to 35% depending on wind conditions. Purchasing costs are still rather high ranging from \$480,000 and \$3.43 million for kites between $320m^2$ and $5000m^2$ with yearly operational savings ranging from 5-15% of the purchasing price (Buhaug et al., 2009).

The most well-known wind engine is the rotor designed by Flettner, which is a spinning vertical rotor that converts wind power into propulsive energy based on the Magnus effect. First developed in 1922, in 2010 the German wind-turbine manufacturer Enercon launched its new 123m rotor-ship E-Ship 1 with modern Flettner-rotors. Fuel savings of ships equipped with Flettner rotors are estimated to be 30% (Crist, 2009). The American maritime shipping technology firm Magnuss, the Singapore-based company Windagain, and the UK-based environmental NGO Greenwave, have all been working with sailing with or producing technology based on Flettner models as well (Rojon, 2013). To manufacture and install Flettner rotors on a bulk carrier, for instance, range from \$960,000 to \$1.2 million, and for a crude oil tanker from \$720,000 to \$900,000 (Faber et al., 2011).

The Japan based NYK's Super Eco Ship 2030 is a design 352-meter container ship supplemented by sail and solar power. Fuel savings estimates are as high as 69%, although Tomo Kiyama, the general manager of the environment group at NYK's Line Technical Headquarters, has stated that he cannot guarantee that this ship will ever come into existence (Sasaki, 2012). Fairtransport currently runs the pure-sail brigantine *Tres Hombres* and is developing a hybrid sail Ecoliner with dynarig sails (Fair Transport, n.d.), similar to B9 Shipping. B9 Shipping, is developing a 3000-ton cargo carrier powered by wind from dynarig sails and a Rolls Royce biogas engine. Dynarig sails are composed of a square rig and rotating masts and fuel savings on particular routes are estimated to reach as much as 50% or 60% (Giltrow, 2012: 67). The yards do not swing, but are attached permanently to the mast. The crews handle the rig electronically; one rig is made up of several sails, so it is easy to replace; and sails can be trimmed electronically to maximize wind power (B9 Shipping, 2011b). The B9 shipping prototype is expected to cost around \$25 million (Proefrock, 2010).

Several companies are exploring the options of supplementing sail with solar power. Australian-based Solar Sail produces a solar powered sail and has signed an agreement with Chinese firm COSCO to install sails on its two ships in 2010, maintaining that the sails reduce fuel costs by 20-40% while meeting 5% of the energy needs of the ship (Cubby, 2008; McLaren, 2008). Eco Marine Power Co. Ltd. Based in Fukuoka, Japan is working on retrofitting vessels with sail panels fitted with solar modules to collect wind and solar energy to "lower their fuel consumption, lessen the vessels noxious gas emissions and reduce their carbon footprint" (Atkinson, 2011). Sauter Carbon Offset Design is working on designs for ships that could harness energy from not just the sun and wind, but from waves as well (Einemo, 2010).

While these technologies are estimated to or have proven to effectively increase fuel efficiency, they have not entered the market at a scale large enough to have a significant impact. As Rojon (2013) maintains this is the case because these technologies have yet to fulfill the requirements necessary to diffuse into the market if viewed from the Technological Innovation Systems (TIS) perspective. TIS maintains that technological change occurs when Entrepreneurial activities, Knowledge development, Knowledge exchange, Guidance of the search, Market formation, Resource mobilization, and the Creation of legitimacy have been achieved:

The main problem with the TIS for towing kites is the dependence of TIS development on its main actor (Skysails). This made the system vulnerable to external shocks which came about in the form of the economic crisis, leading to the cancellation of orders and resource shortages. Fluctuating oil prices mainly inhibited the development of the TIS for Flettner rotors. When these were high, interest in the technology grew and entrepreneurial and knowledge development activities were reported. Once oil prices fell, the technology was not considered economically viable anymore, resulting in a complete *halt of all activities. This fluctuating TIS development prevented the build-up of a knowledge base and the diffusion of knowledge. (Rojon, 2013: 81-82)*

Rojon (2013) considers the TIS of sail to be slightly more developed because of the involvement of established and start-up companies as well as public research institutes.

The fuel savings of all of these models are incredible, but given the cost it would take to produce many of these sail hybrids, and the slow rate of diffusion of these technologies into the market, it is unlikely that the technology will reach developing countries any time soon. Boerne (1999: 7) argues based on his study of small island states in the Caribbean that "un-subsidized transport to remote, insular, and economically poor places that would either demand subsidized transport or receive none at all."

Most of the modern solutions being developed above assume the retrofitting of a large-scaled ship, which would not fit the needs of these communities. While the trend has been to maximize the tonnage of ships to create economies of scale (Yip, Lun, & Lau, 2012), markets for smaller tonnage ships are being left behind (B9 Shipping, 2011a). B9 Shipping explains:

The shipping industry's trend towards larger ships effectively isolates small island economies from participation in world trade as they cannot support large volumes of either import nor export, nor do they possess the necessary port facilities to accommodate large vessels. As a result, trade relies largely on consolidation and transshipment, this is slow, unreliable and expensive and effectively excludes small islands from world trade opportunities. (B9 Shipping, 2011a)

While the B9 project is not cost effective for these small-island and coastal economies, it is collaborating with Greenheart Project to work to provide solutions (personal communication 2011, Gavin Allwright).

GREENHEART PROJECT

The Greenheart Project, a Japan-based international NGO is designing a small-scaled solar (75 dwt) and wind powered ocean- and river-going ship specifically for coastal and river-going communities with limited economic resources. Under the guidance of Japanese naval architects, an international open source design team has developed the architectural plans for the ship based on three design criteria- simplicity, economy, and low-impact (see Table 4). The vessel is designed to be adaptable, being able to fulfill a variety of roles such as local transport, cargo shipping, and disaster response

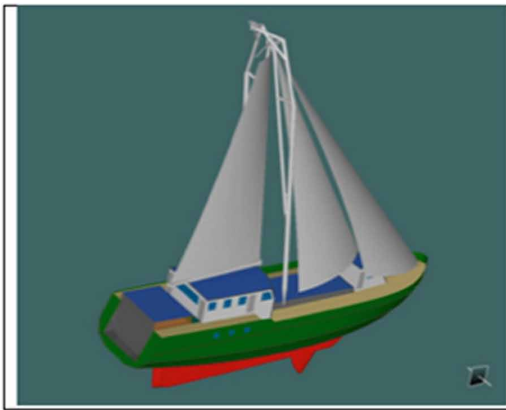
Table 4. Greenheart SV design criteria

SIMPLICITY	1) simplified sailing rigs and sail handling; 2) straightforward complementary electric drive; 3) minimize number of moving parts; 4) easy to adjust and repair
ECONOMY	1) PV provides free power at sea and in port; 2) savings from not having to refuel and clean up fuel spills; 3) maintenance for electric motors far lower than combustion engines
LOW-IMPACT	1) nearly pollution-free due to total absence of fuel; 2) shallow draught and low-clearance- needs no more than 2.3 meters of water; 3) able to pass under bridges as low as five meters above the water with a folding mast; 4) can use beaches, estuaries, and other undeveloped coastline to load and unload cargo without the need for facilities ashore

(Greenheart Project, 2011a) (see Figure 1 for specifications). It has the capability of carrying three TEU containers that can be independently loaded on and off of the ship with a unique folding crane mast (see Figure 2).

Since the ship will operate with no fuel with PV electric motors and sail alone, carbon emissions from use of the ship will be close to zero. The first ship will be built in the Western Marin Shipyards in Bangladesh in early 2014. The first ship is estimated by Greenheart to Western Marin Shiphards was $650,000 (personal communication, Pat Utley), however, with the rapid development of the PV and electric motor market, future ships could cost even less. The designs for the ship are also open source, so that they can be modified to fit changing local and global needs. In addition, Greenheart follows a cradle-to-cradle paradigm, ensuring that the majority of the parts can be reused in future ships. The ship's steel, batteries, motors, fittings are all highly recycle-able, while there is potential for the sails electronics, solar panels to be reused (personal communication, 2012, Pat Utley).

Figure 1. Greenheart specifications



GREENHEART SV SPECIFICATIONS

LOA: 32.5 m/ 106 ft
Beam: 7.8 m/ 25.5 ft
Displacement: 220 t
Sail area: 300 m² / 3230 ft²
Photovoltaic (PV) fixed array: 125 m/ 1313 ft²
Electric drive motors: 200kW DC x 2
Batteries: Lead/Acid traction
Cargo capacity: 3 TEU (20 ft standard containers)-volume 50 t – weight
Hull speed: 10-11 kn

Source: Greenheart Project Open Design Forum (2013)

Figure 2. Beach landing: Loading cargo on and off the vessel (Source: Greenheart Project (2011))

GREENHEART POTENTIAL

Greenheart ships, made with the needs of SIDS in mind, could make a large difference at minimal cost. A Greenheart ship, costing $500,000 or less, would be fuel-free, meaning there are never any fuel costs and no air or water pollution. Commonly, a ship the size of a Greenheart Ship, working commercially, would consume about the equivalent of its purchase cost in fuel every year. The cost savings of zero-fuel operations alone, over the 25-year life of such a ship would be more than 12 million dollars. There are additional savings resulting from significantly lower maintenance costs. In fact, the ship would generate energy as well through the solar panels, so the ship would eventually pay for itself. Since the ship can navigate without the dredging of a port, and up rivers and streams, the ship can be accessible to remote markets. With one ship, that can be recycled into a new one into the future, communities can bring their products to new markets without relying on larger ports or having to develop rail transport.

The University of the South Pacific (USP) has been seeking funding and sector collaboration since 2013 to undertake a 6-year research program into sustainable shipping. This has included a number of applications to trial the Greenheart design on three routes in Fiji to determine the economic viability, fuel savings, socio-cultural impacts, and other benefits of the ship. USP has provided a three-phase operations schedule:

A 1-year scoping and design phase, a 3-year research phase where USP would operate the vessels under a controlled methodology and a third 2-year phase where the ownership and operation of the vessels would be transferred to identified community or stakeholder commercial organizations. (The University of the South Pacific, 2013:8-9)

The Greenheart project had previously discussed with New Zealand Government regarding the use of a Greenheart-type ship for the Tokelau given the New Zealand government announcement in June 2012 (New Zealand Government, 2012 June 12) that it was seeking a replacement for the failing MV Tokelau, a similar sized vessel to the Greenheart design. If the vessel based on Greenheart designs were to follow the routes of the Motor Vessel Tokelau currently in use, the projected cost and fuel savings could be substantial (see Table 5).

The Greenheart design has potential to be cost effective and allow direct shipments within and between island countries in the region without the expensive transshipment via Auckland and Sydney that is currently required on many containerized shipping routes. Providing transport and trade relationships like this are also projected to help to strengthen the partnerships between Pacific Island countries (The University of the South Pacific, 2013).

Table 5. Potential cost comparison between the MV Tokelau and Greenheart SV (Source: Personal Communication 2012 with Gavin Alwright; Personal Communication 2015 with Dr. Peter Nuttall)

	MV Tokelau	Greenheart SV
Fuel	MDO 3.24 t/dy (700-900/t)	Solar/Sail- no fuel
Servicing Cost	$300,000/yr	$100,000/yr
Speed	9kn max (13kn design)	10-11 kn max/6-7 kn op
Capacity	40 pas /40t (mix)	12 pas (cargo)/ 75t
Crew	5-6 (commercial)	5-6 (local trained crew)
Replacement	$8 mil/2 yr tender + $6 mil new build (2015)	$800,00- $1m

ANALYSIS AND CONCLUSION

This chapter has presented a variety of sail applications for sustainable shipping. Should sail and solar be retrofitted to existing ships and used for auxiliary power, similar to the examples of *Shin Aitoku Maru*, *Na Mataisau,* and *Cagidonu,* or ships that have had towing kites attached, fuel savings could be seen in the range of 20 to 30%. Hybrid ships, like those being developed by NYK, Fair Transport, Solar Sail, and Sauter Carbon Offset Design, which use a combination of solely renewable sources, or a combination of renewable and non-renewable, have also been developed, however, none of them are currently ready for the market. Unfortunately, the investment heavy nature of the aforementioned ships makes them economically prohibitive for SIDS. Even for the economies where these ships are affordable, it is still unlikely that these sustainable ships can be introduced on a large scale at this point.

However, due to its simplicity of design, Greenheart can prove to be a realistic solution for SIDS. Furthermore, the investment in a Greenheart ship would pay for itself in the future. In addition to no fuel costs, it also serves as floating solar power station. One drawback may be the unavailability of PV fuel cells in SIDS. However, with the advance and diffusion of technology, the availability of PVs around the world will keep increasing, and the procurement costs will continue to reduce.

While most sustainable shipping initiatives focus on fuel efficiency, sometimes fuel efficiency alone is not enough to mitigate environmental impacts or high costs. The cradle-to-cradle design of the Greenheart ship ensures its sustainability. The entire life cycle of the ship has been taken into consideration in the design of the Greenheart ship. Beyond the construction phase, the ship produces no GHGs, polluting runoff from oil use, or noise pollution from motors. The Greenheart ship has minimal impact on the environment, which is critical for SIDS that depend on marine life for sustenance. In fact, the life cycle of a Greenheart ship never ends, most of its parts being able to be reused in a future ship. If reused correctly, rusted skeletons of former Greenheart ships will not be seen haunting the scrap yards of developing countries and will not be contributing to the health damage of scrap yard workers. Furthermore, while many sustainable shipping projects are focusing on economies of scale, they are not compatible with the smaller markets often found in SIDS. Greenheart is a small simple ship that can be used in the small market situations of SIDS. The only aspect that cannot be completely accounted for is the process for constructing and repairing a Greenheart ship. It is paramount that when ships are built, the health of workers and environmental aspects of shipbuilding, repair, and scrapping are taken into consideration.

Since a Greenheart ship does not require the development of shore-side facilities for the ship to come ashore, not only are the environmental impacts of dredging eliminated, but communities that are disadvantaged by or segregated from transport hubs can be reached. In the paradigm promoted by Greenheart, and being planned for at the University of the South Pacific, the ships will be community-owned, meaning people that once had to rely on transport through a company, can control where, how, to whom, and for what price their items or people are being transported. Greenheart ships can greatly increase the accessibility for people that have been historically excluded from the transport system.

Since the Greenheart Project has a philosophy based open design, the ship can be adapted to a variety of situations with no copyright costs. This is crucial for development work, as it is critical that communities are engaged and involved at every level for a development project to bear fruit and ships are compatible with the needs of the people using them. The program being developed by the University of the South Pacific that includes Greenheart ships is reflective of the need to integrate culture and community into a participatory development program. Not only is the ship being evaluated for its technological abilities, but a specific plan is being developed to make the ships a part of the communities they intend to serve so that the initiative does not go to waste like the artisanal ships retrofitted with sail in Fiji in the 80s.

The state of the environment has reached a point, where sustainable shipping must become a priority, especially for SIDS that have a high potential to be impacted by environmental destruction. Sustainable and appropriate solar/sail shipping based on small ships like Greenheart, could provide large advantages to those who use them. Furthermore, if these simple, economic, and low-impact ships take a hold in SIDS, they're success in that niche market can potentially lead to technological innovation in larger markets worldwide.

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