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A review of sustainable sea-transport for Oceania: Providing context for renewable energy shipping for the Pacific

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ABSTRACT

This paper summarises research and options for sustainable sea transport in Oceania with a focus on domestic shipping. This debate is situated initially within the context of the current Pacific domestic shipping scenario, a region of minute economies connected by some of the longest sea transport routes in the world. All current options are fossil fuel powered and increasingly uneconomic and unsustainable. Many routes are marginal or unviable and a vicious cycle of old ships replaced with old ships prevails. Although a central and essential issue of many Pacific communities, the option of pursuing sustainable sea transport is currently invisible within the policy space at all levels. Various renewable energy options are possible and increasingly available. Recent research finds that these have strong potential for providing benefits across multiple wellbeings. The barriers to pursing this agenda are complex and poorly understood but are perceptual and institutional more than technological. A small number of critical experiments during the last oil crisis provide critical lessons and direction.

1. Introduction

This paper provides a summary of research and options for sustainable sea-transport in Oceania. Sea transport is an absolute necessity for most Oceanic communities. All current services are fossil fuel based and increasingly unaffordable and unsustainable.

The Pacific region is the most dependent on imported fossil fuels in the world with Pacific Island Countries importing more than 95% of needs [1]. Such dependency is recognised as having a crippling effect on national budgets and revenues and impacts on key productive sectors in the region [2]. Various strategies to reduce this dependency are being considered and implemented, primarily targeted at electricity generation. In March 2013 donors committed $NZ613M at the Pacific Energy Summit in Auckland for programmes in this sector.

Transport generally has received far less attention, despite being the region's single largest sector user of imported fuel (48% regional average) [3]. There is no reliable data to calculate what percentage is attributable to sea transport but Mayhew [3] considers it could be as high as 75% of all fuel used for some PICs. Alternatives to current sea transport options are almost totally ignored in current regional and national debates and the issue is invisible within the policy and donor strategy space at all levels.

Recent Fiji centred research [4]·[5] suggests that renewable energy options for Oceania sea transport, if proven viable, offer numerous benefits for Pacific communities at local, provincial, and national levels and advocates for them to be pursued as a priority issue. A recent international conference, the Sustainable Sea Transport Talanoa 2012[1] saw input from leading expertise and has provided a starting point for this critical debate. Such findings have general relevance to a number of Pacific settings. This paper provides an overview of the subject and summarises relevant issues and options.

2. The current Pacific domestic shipping scenario

Issues of sea-transport remain universal and primary, a basic human need of Oceanic peoples today and tomorrow as throughout all past human interaction with the Pacific. The region's transport issues are unique; tiny economies scattered at the ends of some of the longest transportation routes in the world and arguably the most challenging network to maintain per capita and per sea mile with the resource base available to support it [5]. Sea-transport is essential at all levels of society from fishing and local transport needs of small isolated islands and villages to inter-regional shipping needs of nation states [6].

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[1] This conference was hosted by USP on behalf of a collaborative network of stakeholders. See https://www.usp.ac.fj/index.php?id=12456 for programme, presentations and outcomes record.

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All sources concur that policy priorities for Pacific shipping lie on the domestic front ([2,6–8]). There are an estimated 2100 domestic ships providing services at various levels in PICs [6]. Despite fuel now comprising ~40–60% of domestic fleet operating costs [9] and this figure projected to show an increasing trend over time, the search for alternatives is barely emergent. Prosecution of global-scale mitigation measures currently in train under the International Maritime Organisation (IMO) leadership are likely to lead only to increased costs and barriers for Oceania, whose contribution to the global issue is so minute as to be irrelevant, resulting in a double penalty for no visible benefit [5]. The changes to the MARPOL[2] Annex VI regulations, aimed at cutting levels of SO_X emissions from global shipping, will alone contribute a ~60% price increase in marine fuel for PICs at current oil prices by 2020 for all vessels over 400 gross ton [5]. Current domestic shipping, despite being often financially marginal and employing aged assets, maintains sufficient monopoly control of the industry to continue to use fossil fuel technology because there is a lack of sufficient incentive to adopt new technologies and a lack of research and working models of viable alternatives.

Providing adequate, efficient, and reliable domestic shipping is one of the most difficult challenges for PICs. Coastal and inter-island shipping services are generally operated by governments or small, independent shipping companies. Many routes are commercially marginal and a significant proportion are simply unviable. Governments are required to subsidise or otherwise provide for these, with ever increasing costs. Given that the vast bulk of commodities and manufactured goods are transported by ship in the Pacific, and that much domestic travel is by sea, the cost and quality of shipping immediately affects the welfare of the poor as consumers and producers [8]. Transport is a priority area for Pacific Forum Leaders under the Pacific Plan and its importance as a facilitator of economic growth is recognised [2].

The provision of transport services is affected by numerous geographical, socio-economic, and technical factors including population mobility, susceptibility to natural disasters and other effects of climate change, national policies and regulations, and international instruments. Additional factors include appropriate vessel/craft operation and maintenance, route profitability, existing petroleum supply (quantity and quality), level of infrastructure, technical capacity, proximity of maintenance facilities, as well as mandatory safety and security auditing services [6]. Large distances, high fuel costs and low economies of scale make the cost of developing and maintaining transport infrastructure relatively high. Narrow markets for local products and dependence on international trade create vulnerability to global developments as well as fewer employment and livelihood options. Trade in remote locations is limited by high freight costs leading to increasing urbanisation [2]. Where it is lacking, access to reliable and affordable shipping is a major impediment to development at all levels of Pacific economies.

The marginal nature of the industry has always meant that financing shipping investment, either for governments or private operators, is difficult. The ships used are sometimes unsuitable, often old and in poor condition [7]. The current global economic environment has only exacerbated this with industry advisors pointing to the finance market becoming increasingly cautious of such investments. Many vessels do not meet recognised safety standards, and arguably should be banned from service. However, because they provide essential services to remote communities, this step is rarely taken [8]. Shipping disasters directly attributable to substandard ships are regular events, the *Princess Ashika* in Tonga with loss of 74 lives in 2009 and the *Rabual Queen* in PNG in 2012 (more than 200 lives lost) drew international headlines; smaller scale tragedies are common place.

3. Options for reducing shipping fossil fuel dependency

Studies by the International Council on Clean Transportation [10] and IMO [11] concur on the range of technological and operational strategies available to the current global fleet. These include innovation in: propeller polishing, hull cleaning, speed reduction, autopilot upgrade, air lubrication, main engine retrofits, water flow optimization, hull coating, speed controlled pumps and fans, weather routing, high-efficiency lighting, propeller upgrade, waste heat reduction, alternative fuels, wind power, and solar technology. These analyses also note that, the last three items apart, these are largely already available and most responsible operators are already, at least partially, using. None of these measures individually achieves more than minor savings, nor do they represent any major paradigm shift. The cost of many of these innovations makes them unavailable to Pacific shipping where much of the asset is at the end of its working life and is uneconomic or impractical to upgrade.

Most international operators already employ a policy of 'slow steaming', reducing average passage speeds to reduce fuel consumption, particularly since the global economic slow down since 2008. Production of larger ships to employ greater economies of scale and new generation designs incorporating more efficient hull and motors are coming on stream. LNG is increasingly being targeted as the primary fuel for large and new shipping. Such developments will almost exclusively benefit the large-scale shipping market and offers little immediate potential for the Oceanic scenario where ships are smaller and older. It could be some decades before such technology is affordable in second hand mode to Pacific operators. It can be described as a classic North–South divide scenario. Those operators that can access investment capital to procure new technology have an operating advantage. Those that can only afford second (third, fourth or fifth) hand ships will have to wait in line and pay ever-increasing costs and penalties.

What options are available from renewable energy? There are a range of solutions potentially available, ranging from various measures to retrofit existing fossil fuel powered vessels with renewable energy technologies, to hybrid vessels combining both renewable energy and fossil fuel power, to custom built non-fossil fuel designs. Each has various advantages and disadvantages

Fig. 1. B9 Ship designs.
Source: B9 Shipping Ltd.

[2] The International Convention for the Prevention of Pollution From Ships, 1973 as modified by the Protocol of 1978.

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Fig. 2. *S.V. Greenheart*, 220 t Sail/Solar Freighter.
Source: Greenheart.

depending on their application. Numerous researchers are investigating innovations in hull and engine design and wind (harnessed by sails, kites and rotors), solar, biogas/biofuel for vessels of all types, although investment is nothing of the scale dedicated to developing conventional shipping. Again, most initiatives into new technology solutions have focused on large-scale shipping.

There is little work being done on the 10,000 t and smaller vessels which service most of the developing world and contribute ~26% of all global shipping emissions whilst carrying only ~4% of global cargo load [12]. There are popular misconceptions that hamper serious discussion of the issues of renewable energy vessels at this scale, including that such vessels will be slower and less reliable, that sail and rotor rigs increase instability in bad weather (when the reality is the opposite), and that larger ships are inherently safer and more efficient. Leading examples include the B9 3000 dwt bulk carrier, the 7000 dwt Ecoliner container ship and Enercon's 127 m E-Ship1 Fig. 1.

Although any number of potential technologies have been mentioned in the literature and websites, the leading contenders break down primarily to alternative fuels such as bio-fuels or biogas (for which there are question marks over the overall environmental benefit at the scale required), wind and solar[3] . In Oceania bio-fuels/gases from local crop production (coconut and cassava both have high potential) or by-product (e.g. molasses from the Fiji sugar industry) offer possibilities. Ultimately it will come down to the economics of production of such fuels versus the cost of import of fossil fuels as to how fast development and uptake happens. Solar has potential as an auxiliary to other fuels but is not sufficiently advanced to provide primary propulsion. Wind energy has strong potential in a variety of deployments, is well understood and proven. Hybrid vessels, combining more than one type of energy source, offer a 'best of both worlds' approach.

One vessel design by a Japan based not-for-profit organisation, Greenheart, offers strong potential for extremely cost effective 220 t, 100% renewable energy powered freighters for inter-island and inter-regional trade conservatively displacing around one and a half ton of fuel per day. A pilot vessel is under construction in Bangladesh. Work has been ongoing into the use of small scale (4–10 dwt) cargo/passenger catamarans for more than three decades in different Pacific locations. None of these initiatives have been successful in attracting adequate research and development funding, unlike other renewable energy technologies, despite their demonstrated potential for both fuel savings and positive contribution to economic development Fig. 2.

[3] Work has been ongoing in regard to nuclear propulsion technologies led largely by the US military industrial complex and this still remains the Pentagon's preferred future alternative shipping fuel technology [13]. Even if it could be used cost-effectively, the political stance of PICs effectively rules it out of any contention for Oceania.

Renewable energy shipping offers benefits across multiple wellbeings: economic, environment, social, and cultural [5]. It offers a potential future where fleets of smaller but sustainable new ships can replace current single, aged, large vessel operations. Realisation of this requires practical demonstration of commercially viable models if up-take on any scale is to be achieved. The agenda needs to be viewed ultimately from its potential to revitalise all aspects of the domestic Pacific industry from ship construction to transport operations to maintenance and end re-cycling—a cradle to cradle approach. Operation of the new transport asset is obviously the first critical aspect to practically demonstrate, but the long-term opportunity is broader and includes design, research, construction, maintenance, and auxiliary industries as well as seafaring.

While this paper focuses primarily on domestic shipping, renewable energy vessels have strong potential for inter-state trade, particularly directly between PICs. Currently, exporters in countries such as Fiji must trans-ship via Sydney or Auckland making many sub-regional trade opportunities uneconomic and increasing PICs' dependence on imports from the developed world. Vessels such as the Greenheart design are capable of direct container shipping of small consignments reliably and regularly, with far lower overheads than the current large container ships.

4. Lessons from the past: The 1970s oil crisis.

The oil crisis of the late 1970s resulted in a small number of critical experiments in the Pacific with results showing strong savings in fuel use and improved ship performance from known and available renewable energy technologies and these provide leadership for the search for innovation today. Research at this time paralleled the current situation in identifying a number of key obstacles, in particular a reluctance of donor/development agencies to provide financing for practical trialling. The relatively short duration of the crisis and the subsequent fall in fossil fuel prices saw further research curtailed at this time.

In 1981 three UN agencies, UNDAT, UNCTAD and UNESCAP, combined resources to undertake a series of studies in the Ha'apai Group of the Kingdom of Tonga [14]. The principal objective was to investigate an energy efficient government-operated vessel. Having comprehensively mapped the need and the options available, the project moved toward an implementation stage in 1983. Securing funding proved difficult with donors citing "insufficient insight into the financial and technical feasibility of the project" [14 p:133–134]. Yet without the funding, a formal feasibility study was not possible. The vicious circle was broken in the end with UNESCAP and ADB providing the resources to recruit prominent UK naval engineers to undertake the necessary evaluations and designs, the latter was remarkably similar to the Greenheart design in scale and approach. That study also mirrored recent findings in Fiji that a combination of small trading catamarans and energy efficient small freighters are the most

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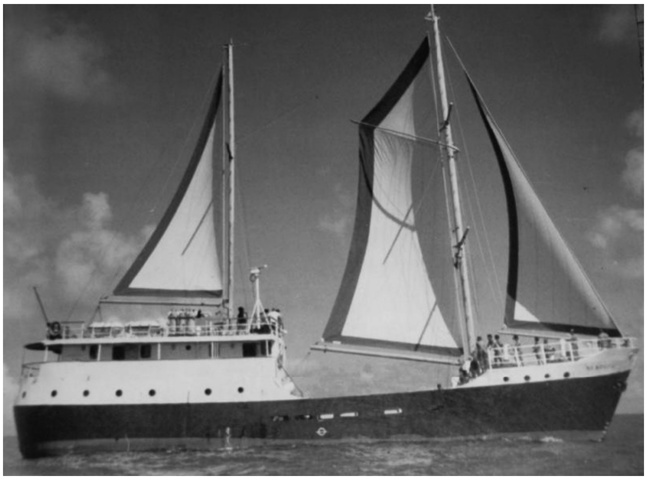

Fig. 3. *Na Mataisau*, Fiji, 1984.
Source: [16].

Fig. 4. *Shin Aitoku Maru*.
Source: http://seaspout.wordpress.com/2012/08/03/propulsion-revolution-2/

appropriate technology options [5]. It is assumed the sharp fall in oil prices after 1985 was the cause of no further development work happening on this project.

In related research, ADB also funded the same engineers working with the Fijian Government and experts from Southampton University to undertake the retrofitting of two small (~300 gt) passenger/cargo ships with auxiliary sail rigs. These performed above expectation, resulting in fuel savings of 23–30%, increased stability, increased passage speeds, and much reduced engine wear. The IRR on the US$40,000 cost of the retrofit of the first vessel was calculated at an impressive 123% on the most favourable routes and 30% on 'average' routes [15]. A decrease in just one knot of average speed would have pushed the IRR to 180% on the 'best' routes. These calculations included maintenance of the equipment but did not factor in benefits other than fuel savings Fig. 3.

In Japan, oil tanker owners successfully trialled modern square sails, initially on a 900 t vessel, *Shin Aitoku Maru,* using aircraft wing manufacturing technology and computer-controlled rigs. These rigs were an evolution of the historic "square-rigger" design. The reported results were impressive with overall fuel savings of more than 30%, increased passage speeds, increased stability and greatly reduced engine wear. Contrary to initial concerns, the sail-fitted vessels were able to safely maintain course in typhoon conditions where sister vessels had to heave to [17]. Over three years a fleet of eight ships ranging from 600 to 31,000 t was commissioned. However, plummeting oil prices meant the IRR on the technology was uneconomic, especially given the cost and limits of the computer technology employed, and the experiment was largely discontinued Fig. 4.

Also in this period Save the Children Fund in Tuvalu and FAO/UNDP initiated practical research into the potential of using either pure sail or sail assisted vessels for artisanal and small-scale commercial fishing in the Pacific. A variety of vessel types from one-person dugouts to 11 m trimarans were built and some 300 vessels of different designs were distributed in eight PICs ([17–19]). Again, the end of the oil crisis coinciding with the end of the project funding and impetus saw this research largely curtailed, although locally built, energy efficient catamarans are still being built and used in Kiribati. The designs that resulted from this research have as much applicability today as they did then.

The work in this period culminated in an ADB sponsored conference into potential wind ship technology for the Asia-Pacific region in Manila in 1985 [16]. There are strong parallels between this conference and the USP hosted SSTT 2012, with a similar range of expertise, needs, solutions and barriers identified.

The examples cited above provide a number of core lessons and important directional indicators. For example, the research underscored the absolute need for such technology to be appropriate and affordable to the local operating environment. High-tech and high-cost assets introduced from outside the region were unlikely to have significant uptake or prove sustainable. The catalytic nature and benefits in all these cases from what were really quite minimal amounts of donor investment appear clear. A coordinated programme of work and research as opposed to disjointed short-term pilot projects was shown to be necessary. The situation today is certainly not a case of there being a technology vacuum. The designs of the 1980s, particularly in terms of both trading catamarans and inter-island/inter-state renewable energy powered freighters appear valid for current operating environments with the added advantage that improvements in photovoltaic and electric engine technology can be applied to further decrease fossil fuel use.

5. What are the barriers to developing sustainable sea transport for Oceania?

There are numerous challenges to further investigation and practical trialling of renewable energy shipping in order to fully prove its validity. These are complex and poorly characterized or understood. Issues of policy, ownership, financing and management, not the technology itself, are the central ones to now grapple with. It is essential to recognise that the industrial application needs to occur within a wider setting than just an economic or commercial sphere; especially in Oceania where traditional culture and society continue to play roles.

Findings from a recent analysis [5] mirrored the lessons from the Ha'apai study in the 1980s and conclude that the primary barriers to research and practical trialling of alternatives are both structural and perceptual in nature. Sea transport generally is considered a private investment issue with public or donor investment restricted exclusively to shore infrastructure (primarily ports), policy and regulation. Financing for shipping asset is notoriously difficult to access in any regard for this often marginal industry. Old ships being replaced with old ships or reliance on donated and often inappropriate vessels is the established norm in most PICs. Commercial banks do not find domestic island shipping attractive for lending because of the high risk for low returns and lack of adequate collateral. There are also cultural barriers. Larger and faster engines and ships are seen as markers of increasing development while use of technologies such as sails are perceived as a step away from progress and development. There is also popular misconception that renewable energy technology will be slower and less efficient than fossil fuelled counterparts.

Unfortunately, despite the inherent logic of exploring sustainable sea transport as a regional priority, there has yet to be any uptake either by the commercial industry or the development/policy agencies. One of the primary barriers to accessing funding for any aspect of alternative shipping here and globally is the near total invisibility of sea transport in the policy space. Sustainable shipping is not mentioned in any Pacific national, regional or development agency energy, transport, or climate change strategy to date.

Such barriers have also been found to be true at a global level. Rojon [20] considered the potential for the IMO to promote the reintroduction of wind powered technologies for international shipping and examined the uptake in development of fixed sails, kites, and rotor technology over the past century. That study found that several structural barriers exist, including a lack of policies and incentive schemes promoting wind propulsion, lack of financial resources, insufficient collaboration among different actor groups, and conservative and risk-averse attitudes prevalent in the maritime industry. It concluded that the number and severity of the structural barriers outweigh those of the mostly emerging structural drivers.

Even though proposals for renewable energy shipping largely use mature and proven technology to reduce fuel consumption, practical demonstration options are either in their early development stages or have only been adopted on a very small scale. This is often the case for new technologies as they usually cannot immediately compete in the market against established technologies [20]. Current regulations, infrastructure, user practices, and maintenance networks are aligned with the existing technology, which means that new technologies often face a mismatch with the established socio-institutional framework [20]. The same applies to current Pacific government subsidies. This being the case, three key and related priorities emerge: inclusion of renewable energy shipping as a priority within the policy space at national, regional and agency levels; the need for comprehensive economic modelling of the primary, secondary and tertiary costs and benefits of alterative technologies and approaches; and accessing development financing for practical trials of commercial alternatives [21].

There is unlikely to be major private investment until there is wind shift in both the policy space and donor prioritization. Without such intervention it is unlikely that practical demonstration of alternatives will proceed at any scale, and certainly not at the level needed for meaningful change. In looking back to the last oil crisis we find there is nothing new in the negative responses to what otherwise is a logical and rational approach to a central issue of high strategic importance to most PICs and the current situation is largely a rerun of events of more than 30 years ago.

The biggest change in the resourcing environment since the 1980s is climate change. Yet, despite the inherent logic of renewable energy shipping as a priority adaptation focus, the sector is again penalized. Because shipping internationally is considered only as a mitigation priority, sustainable sea transport is not generally considered to meet the criteria for such funds. Even when intervention is left to the private sector, shipping does not meet the criteria for current financing facilities, such as the World Bank's loans under the SEFF programme, because it would not be displacing fuel used for electricity generation.

6. Windward to the future

Following the Auckland 2013 Pacific Energy Summit, organisers advised that no PIC had suggested shipping as a priority issue. The question has to be asked. Has anyone advised them that renewable energy options may be available to them? Ultimately, sheer necessity will require the hitherto unexplored needs of shipping to be addressed in the context of low carbon technologies. Putting this off only condemns PICs to a fossil fuel dependent and ever more expensive future and ignores the potential benefits, especially to small and remote communities, that alternative options to current shipping offers. The case for resourcing a revolution in sea transport toward renewable energy options appears obvious and rational. The lessons from the past show that the level of investment required is relatively small.

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