Connecting the dots: policy connections between Pacific Island shipping and global CO_2 and pollutant emission reduction



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Elisabeth Holland[1], Peter Nuttall*[2], Alison Newell[2], Biman Prasad[3], Joeli Veitayaki[4], Amelia Bola[2] & John Kaitu'u[2]

The relationships between the global discourse on emissions reduction, particularly in regard to international shipping, and the need for more sustainable Pacific Island sea transport services are discussed. Renewable energy applications for such shipping are not currently considered in the drive to reduce fossil fuel dependency in the region. The domestic Pacific Island shipping scenario and international shipping and emissions reduction efforts are summarized. Data availability is limited; however, the authors extrapolate from Fiji data to give a 'best guess' of the likely range of emissions produced by the Pacific Island shipping and argue that reduction targets are achievable based on results of experiments in the last oil crisis. Five policy areas are identified that connect the local need with the global discourse and give rise to the promotion of sustainable, low-carbon maritime transport for this unique region.

This paper provides context for an emerging discussion on the relationships between global CO_2 and other pollutant emissions (in particular the contributions from global shipping), and the sea transport scenario for Pacific Island countries (PICs). There is a recent agenda by governments and development partners to reduce the Pacific region's almost total reliance on imported fossil fuels, in large part by adopting renewable energy alternatives. Sea transport, however, has not been included to any great extent. Unlike previous periods of high fuel price, this current agenda is occurring simultaneously with a global discourse on climate change. While there is little PICs can do to assist in the reduction of global emissions efforts physically, we suggest the context raises various policy areas of connectivity that warrant further consideration and analysis.

Such linkages have not previously been explored in any detail for the maritime sector, unlike other energy sector uses and sources of Pacific emissions, in particular electricity generation. This is illogical given the importance of sea transport to all aspects of Pacific life and the dependence on imported fossil fuels, for which transport is the greatest sector user. Previous papers have argued that technological solutions using renewable energy are either available or emerging, and that the principal barriers to setting realistic targets for fuel consumption reduction for domestic Pacific sea transport are primarily a lack of visibility and appropriate policy and financing [1–3]. Initial exploratory work by Rojon found that this pattern is not unique to the Pacific but an identifiable global trend [4]. Rojon also suggests there is little hope of traction for this field being led by international regulators, in particular the International Maritime Organization (IMO).

The local context: PIC sea transport scenario

It is difficult to over emphasize the importance of sea transport to Pacific Island societies. It is a basic need, especially for remote island communities [2]. The interrelationship of sea transport with all levels of socioeconomic development in this region is well recognized and the dire situation concerning domestic shipping in particular

[1]Pacific Centre for Environment & Sustainable Development, University of the South Pacific, Laucala Campus, Private Bag, Suva, Fiji Islands
[2]Sustainable Sea Transport Research Programme, University of the South Pacific, Laucala Campus, Private Bag, Suva, Fiji Islands
[3]School of Economics, University of the South Pacific, Laucala Campus, Private Bag, Suva, Fiji Islands
[4]International Oceans Institute & School of Marine Studies, University of the South Pacific, Laucala Campus, Private Bag, Suva, Fiji Islands
*Author for correspondence: Tel.: +679 9979072; Fax: +679 3231558; E-mail: peter.nuttall@usp.ac.fj

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Key terms

Pacific shipping: Shipping servicing Pacific Island countries, characterized by some of the longest sea lanes and marginally economic routes in the world. The Pacific domestic fleet is typically made up of old, poorly maintained fossil fuel powered vessels. Costs of fossil fuel mean that operators have to use larger vessels in order to achieve economies of scale, thus reducing their ability to service smaller ports and islands or where cargos and passenger numbers are too small.

Sustainable Sea Transport: Safe, secure, affordable, appropriate and reliable maritime transport services that may use a variety of approaches to be sustainable in the long term. For example, using one or a combination of renewable energy technologies or vessel design to reduce or eliminate fossil fuel consumption. Use of reliable, appropriate vessels that are affordable to the communities that they service, and that maximize benefits to the region.

Renewable energy applications for shipping: Commercial ships that use renewable energy technology for power either fully or as an auxiliary to fossil fuels, including wind (kites, sails, rotors), solar and biofuel/biogas. Use of some of these technologies allows for fleets of smaller vessels that can service small ports and communities and carry small loads as the economies of scale to cover fossil fuel cost are not required. Such technologies can be used on a variety of vessels including ferries, bulk carriers, freighters, tankers, containerships, fishing vessels and barges.

has been identified and documented over time [5–10]. Since the end of the 1973–1986 oil crisis there has been no consideration of renewable energy alternatives [2,4,11] (although critical experiments at that time indicated significant fuel savings were available using proven and cost-effective technologies [12–18]).

The region's transport issues are unique: small and often vulnerable economies scattered at the ends of some of the longest transportation routes in the world [9], and arguably the most challenging network to maintain per capita and per sea mile given the small resource base available to support it [11]. Providing adequate, efficient and reliable domestic shipping is one of the most difficult challenges for PIC governments [6,7,9]. Lack of regular connectivity amongst the many islands within countries is considered one of the binding constraints to domestic economic activities and international trade [3,9]. Many routes are commercially marginal and many are simply economically unviable. Governments are required to subsidies or otherwise provide for these, with ever-increasing costs [2]. Many lack the fiscal space to provide subsidies for the provision of regular domestic shipping.

Long distances, high fuel costs and low economies of scale make the cost of developing and maintaining transport infrastructure high [9]. Trade in remote locations is limited by high freight costs leading to increasing urbanization [7]. Where it is lacking, access to reliable and affordable shipping is a major impediment to development at all levels of Pacific economies [8,9]. The marginal nature of the industry has always meant that financing shipping investment, either for governments or private operators, is difficult [3]. Ships used are sometimes unsuitable, often old and in poor condition. Most **Pacific shipping** is trapped in a cycle of old ships being replaced by old ships [7].

The University of the South Pacific has recently established a **Sustainable Sea Transport** Research Programme, an interdisciplinary team formed with the goal of being a catalyst for ongoing research into **renewable energy applications for shipping** and other sustainable sea transport solutions for PICs [3]. Analysis in this field is hampered by a lack of comprehensive and verified data, especially for domestic sea transport and associated fuel use [6,9]. All sources concur that this domestic need is the most critical area for PIC governments to address [6,7,9,10].

Climate change & PIC shipping

The IPCC Fifth Assessment Report Summary for Policy makers states that warming of the climate system is unequivocal and unprecedented over decades to millennia, measured in atmospheric and ocean warming, snow and ice reduction, sea-level rise and concentrations of GHGs. Human influence is extremely likely to have been the dominant cause. Continued GHG emissions will cause further changes in all components of the climate system and limiting this will require substantial and sustained reductions of emissions [19].

Climate change is already having, and will increasingly have, severe and unique impacts on PICs. The people of these nations are among the world's most exposed to changes in ocean characteristics (especially sea levels and acidity), rainfall and extreme weather events [20–22]. Maclellan *et al.* advises that communities are already feeling the effects of climate change across the Pacific in *"food supply, nutrition, health, education, livelihoods, and social cohesion"* [23]. The impacts of climate change hit the region's poor first and worst [24,25].

Clearly the well-being and, in many cases, the survival of Pacific communities is inherently linked to global measures to limit GHG and other pollutant emissions. PICs' historical contribution to this global crisis is, at best, marginal and there is no rational argument that these countries should be held responsible for the current maelstrom they find themselves in. The overall contribution of PICs shipping emissions to global sums is minute. Any emissions reduction achieved through the region moving to a low-carbon or renewable energy shipping scenario will not have any real effect on the universal situation.

Why then should research into the connection between global emissions reduction and Pacific island shipping issues be considered further and prioritized? After summarizing both local and global scenarios and discussing the problems related to availability of data for this sector we conclude there are five primary policy areas that connect Pacific sea transport and the current global discourse on emissions; namely:

- The role of PICs as good global citizens;
- The regional correlation between fossil fuel dependency reduction and emissions reduction or mitigation;
- The need to attract alternative sources of financing for sea transport;

- The need for more appropriate domestic shipping;
- The emissions from shipping occurring in the Pacific from sources that have no direct benefit to PICs.

In discussing these five areas we suggest there is valid rationale for further research in this field as a priority measure to support Pacific policy planners and decision-makers.

Situating the local in the global

PIC's share of any aspect of the global shipping profile is so minute as to be almost immeasurable. As an example, the archipelago country of Vanuatu (population 245,786 [101]) was reported in 2008 as having a domestic commercial fleet of 40 vessels (the largest being 400 tonnes) with an average age of 28 years [26]. The 20 smaller vessels (under 80 tonnes) had an average age of 40 years and none were of a survey standard. There is no available verified data for the number of ships in the Pacific Island fleet although the Secretariat of the Pacific Community have estimated 2100 domestic ships [9]. Some countries do not keep records [6].

All current sea transport services in the Pacific are fossil fuel powered and therefore contribute directly to global emissions of CO_2 and other pollutants. Using available data it is not possible to define exactly what this contribution is as a proportion of regional or global totals. Global shipping emission inventories base their results on data obtained from databases such as the Comprehensive Ocean–Atmosphere Data Set and the Automated Mutual-Assistance Vessel Rescue System. As small ships of the type in most common usage by PICs do not report to such sources, they are not captured.

PIC's capacity to influence trends in shipping technology is negligible, as are their contribution to the adverse effects of the activity. Reliant as they are at all levels, but especially the domestic, on aging vessels imported from the rest of the world, any advances in efficiency in new vessels are unlikely to be affordable to the region for at least two decades. Costs of retrofitting existing vessels with alternative technologies are likely to be prohibitive to most government and private shipping providers in the region without external assistance [11]. Domestic shipping continues to use fossil fuel because there is a lack of sufficient incentive to adopt new technologies and a lack of research and working models of viable alternatives [2,11].

Global shipping: the handmaiden of global commerce & consumerism

At a macrolevel, commercial shipping is arguably the most international of the world's industries (Figure 1). The size of the global fleet is generally agreed; the International Chamber of Shipping (ICS) states *"over 50,000 merchant ships trading internationally, transporting every kind of cargo"* [102]. Buhaug *et al.* state: *"the world fleet in 2007 comprised more than 100,000 ships of more than 100 gross tonnes, of which just less than half are cargo ships [27]. However cargo ships account for 89% of total gross tonnage"*. The financial value of shipping is gargantuan. Buhaug *et al.* calculated an *"annual turnover for marine activities of US$1.3 trillion in 2004 … about one-third is related to merchant shipping"*, but notes also that other studies *"value the world marine market at US$2.7 trillion, with the shipbuilding industry as the largest global market value"* [27]. Quantities of volumes moved are equally large with more than 8.4 billion tonnes transported in 2012 [102]. No-one quite knows exactly how big or valuable global shipping really is but most sources cite that it moves 80–90% of all goods and raw materials [27,28,102,103].

Although the industry reported a major downturn in shipping volumes and economic returns post the oil spike of 2006 and the global slowdown of 2008, recent reports are that shipping volumes are now recovering to precrisis levels. For example, Drewry, a prominent maritime research organization, gives the latest container port demand forecast projection of compound average global growth of 5.4% per annum through to 2017, as shown in Figure 2 [104]. At this level, growth will reach 30% over 5 years.

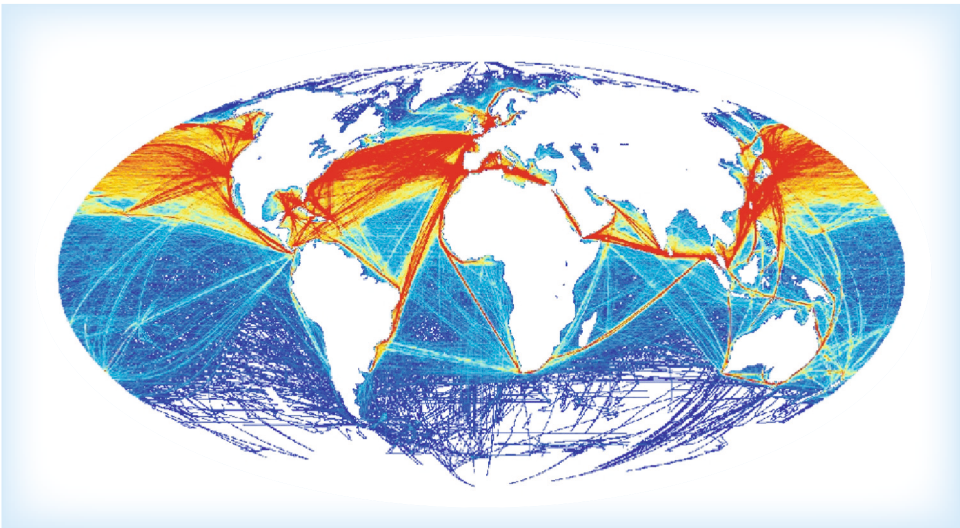

Figure 1. Global commercial shipping activity.
Adapted with permission from the National Center for Ecological Analysis and Synthesis [111].

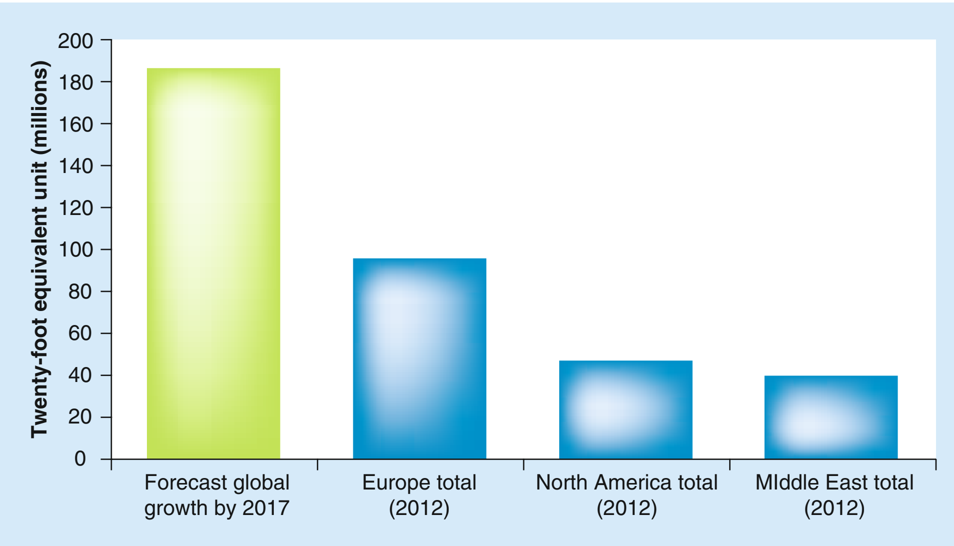

Figure 2. Forecast global container port demand growth in context (million twenty-foot equivalent unit).
Adapted with permission from Drewry [105].

Global shipping & emissions

World transport predominantly relies on petroleum, which supplies 95% of the total energy used. Shipping is estimated to use 9.5% of the world's transport energy budget [28]. Globally, sea transport is a major contributor to GHG emissions [27]. Large ships are essentially unregulated power stations burning heavy fuel oil, the byproduct of refining cleaner fuels for terrestrial transport and aviation. Emissions from the transportation sector affect climate and regional air quality, and health and include sulfur and nitrous oxides (SO_x and NO_x) and particulate matter as well as GHGs such as CO_2 [29–31]. 2007 estimates were that international shipping contributes 870 million metric tonnes (mmt) of CO_2, with an additional 180 mmt attributable to domestic and inland ships, for a total of 1050 mmt [32]. Shipping is responsible for disproportionately high levels of SO_x and NO_x emissions [29–33]. Combustion of low-quality fuel produces large amounts of aerosols and aerosol precursors [30].

The nature of shipping's contribution to climate change is complex. In addition to warming by CO_2 emissions, ship emissions of SO_2 cause cooling, while NO_x increase the levels of the GHG O_3 and reduce CH_4. All studies, however, agree that the central estimate of present day net radiative forcing due to shipping is strongly negative. Reduction of SO_x and NO_x, the current primary IMO targets, while reducing harmful effects on human health and water/soil acidification, will also reduce the sector's cooling effects. Shipping meeting the IMO SO_x reduction targets will therefore impart a 'double warming' effect: one from CO_2 emissions, and one from the reduction of SO_x emissions. After some decades the net climate effect of shipping will shift from cooling to warming [29,31].

The opposite effects of shipping emissions – a short-term cooling and long-term warming – put this sector in a special position, both scientifically and in the context of policy making [29]. Emissions from seagoing ships are one of the least controlled sources of anthropogenic emissions [30]. Primary regulatory responsibility falls to the IMO, established in 1949 as a specialized UN agency. Since the 1954 OILPOL Convention, the IMO has assumed responsibility for pollution issues arising from shipping discharges to water and has adopted a wide range of measures to prevent and control this, resulting in reducing trends in oil spills, and so on [105]. However, IMO leadership on the issues of emissions to air has been tardy [2,11].

The global response to shipping emissions

Although the harm caused by shipping emissions has been flagged for decades, the IMO has only recently begun an audible debate on GHG emissions from shipping, reflecting the political complexity of enforcing nationally ratified policy and regulation at the international level. The IMO response was finally forced by the 1997 Kyoto Conference that left all control of international shipping emissions to the IMO [27]. The First Intercessional Meeting of IMO's Working Group on Greenhouse Gas Emissions from Ships only took place only in 2008 [103].

Progress since has been predictably slow given the global recession and its economic implications for shipping and its continued diversion of attention from any long-term climate change focus. The IMO's failure to act earlier and decisively on emissions comes down to its international nature, a failure by nation members to achieve consensus and the self-interest of the industry. The IMO has had mandate for dealing with all shipping discharges, arguably since its inception and at least since the 'International Convention for the Prevention of Pollution from Ships in 1973 as modified by the Protocol of 1978', which covers not only accidental and operational oil pollution, but also air pollution. The IMO waited until 1997 to enact the 'Regulations for the Prevention of Air Pollution from Ships' and until 2005 to give effect to it [106].

As terrestrial fossil fuel use grows slowly cleaner, pollutants from sea transport increase as a proportion of global totals. Estimates of total shipping emissions vary with sources to 2010 regularly reporting it to be between 1.8 and 3.5% of all GHG emissions, making the industry an emitter on the scale of Germany and on par with aviation [27,28,33,107]. Mid-range emission scenarios from 2007 suggest that by 2050, in the absence of reduction policies, ship emissions may grow by 150–250% as a result of the growth in world trade [27]. *"If the climate is to be stabilized at no more than 2°C warming over preindustrial levels by 2100 and emissions from shipping continue as projected … they would constitute between 12% and 18% of the global total CO_2 emissions in 2050"* [28].

The IMO finally approved mechanisms to reduce sulfur emissions in 2008. In a stepped program, by 2020 all shipping has either to use fuels with limited sulfur content or use scrubbing technology to clean their exhaust gases. In August 2013, the IMO decided to delay the introduction of strict emission controls for NO_X, which had been due to come into effect in 2016 until 2021.

Both industry and regulators point to the steady reductions in O_3 damaging refrigerant emissions and modeling for projected amounts of SO_X under the 'International Convention for the Prevention of Pollution from Ships in 1973 as modified by the Protocol of 1978' agreements as evidence that the IMO-led regulatory process has capacity. The cost of marine diesel oil compliant with these standards is currently 60% higher than fuel used today in many PICs. Fuel is currently approximately 40–60% of Pacific ship operating costs depending on the type of vessel and operation [34], so the cost of this global mitigation strategy means an imminent increase of approximately 24–36% in the cost of shipping for these PICs regardless of any other factor. Compensation mechanisms to rectify this imbalance for penalized states such as the PICs were mooted by the IMO but have little likelihood of eventuating.

It is generally recognized by the world's shipping industry that, historically, fuel efficiency has not been a motivating factor and increased fuel charges were simply passed on to the consumer. This is changing, albeit slowly, with rising fuel costs, international pressure and an increasingly competitive industry. Despite this, the IMO do not expect this to transform into any quick or large changes to the status quo [27,28].

Averaging effects of global shipping emissions across the industry disguises the reality that larger and newer vessels have lower proportional effects and that it is the smaller, domestic and older ships, the type most common in PICs, which are the worst offenders, as shown in **Figure 1**. Preliminary analysis of IMO data undertaken by University College London for B9 Shipping Ltd shows that vessels of less than 10,000 tonnes – the type used by PICs – carry only approximately 4% of global cargo but contribute around 25% of all shipping emissions – approximately 1% of global totals [35] **(Figure 3)**.

Claims that shipping is a dirty business and has done little to clean up its operations are strongly refuted by the industry and related agencies. The defense is based on two principal lines of argument: first, that it is less polluting and far more efficient than any other form of transport per tonne of goods moved; second, that emissions are mitigated by the positive contribution the industry makes to 'sustainable development'. The following quote from the ICS is typical of the industry position: *"Shipping is a very powerful and positive force, making a major contribution to global trade and prosperity in a way that has only a relatively small negative impact on the global environment. Shipping … is, statistically, the least environmentally damaging mode of transport, when its productive value is taken into consideration"* [108].

Similar statements are echoed by the IMO [103], ICS [102] and International Council on Clean Transportation [32]. However, this is a far cry from saying that shipping is as efficient as it can or should be. IMO predicted in 2008 that tonne-miles of goods moved globally will increase 2–4% annually to 2050, causing a near tripling of GHG emissions [27]. At these rates of increase, shipping CO_2 emission is expected to climb to between 2500 and 3650 mmt by 2050 [32].

Responses by the global industry

Industry representatives to international climate change congresses have steadfastly reiterated the industry's ultra-conservative position, insisting that substantial savings will ultimately be achieved through technical and operational efficiencies and market-based mechanisms derived through IMO-negotiated global regulation [109,110]. The ICS is representative when it states: *"CO_2 emissions from international shipping cannot be reduced effectively and meaningfully through the incorporation of shipping into any regional financial instrument"* [109].

The above summarizes the size and scale of the global problem. What can be done? An International Council on Clean Transportation assessment summarized analyses of 50 ship efficiency measures and concluded: *"by 2020 the industry's growing fleet could reduce annual CO_2 emissions by 436 mmt, or 33% of the projected annual total. Of that amount, 340 mmt (26% of the total) could be achieved for a net negative cost after fuel and other savings are accounted for"*. But they caution that these are *"broad-based estimates, lacking sufficient detail and transparency"* [32]. Today, there are still very few working models of energy efficient vessels, unlike the immense strides being taken in other renewable energy sectors [4].

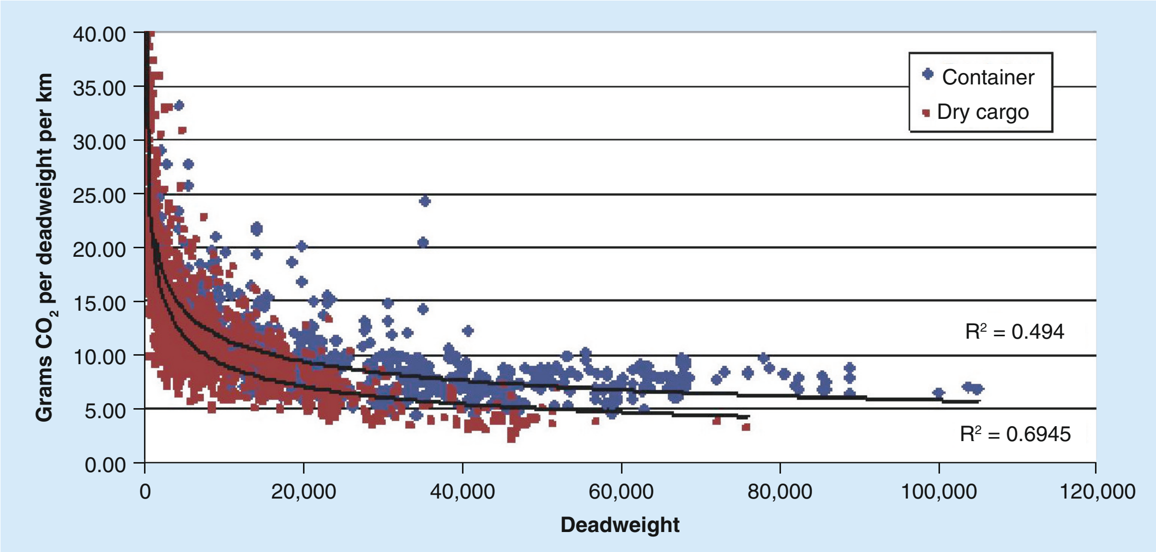

Figure 3. Effect of ship deadweight on CO_2 design index.
Adapted with permission from [27] © International Maritime Organization (2009).

Three broad categories of measures are available: regulatory regimes and economic instruments can demand cleaner shipping; the amount of goods transported can be reduced; and technological advances can be made and implemented. Arguably, none of these measures is overly helpful for PIC's without (proportionately) large external assistance or subsidization. Regulatory and economic measures will increase the cost to Pacific shippers (whose activities produce an insignificantly minute quantity of the problem) without a corresponding increase in revenues. Reductions in services would be an increasing penalty to Pacific communities and economies; and costs for new technology, in the main, make them prohibitive and are generally aimed at new generation assets employed by first-world operators on profitable routes. There is no current investment strategy into research and development of renewable energy solutions appropriate to the PIC shipping scenario.

Pacific fuel dependency & emissions

The Pacific is the most dependent region in the world on imported fuels at 95% dependency (99% if Papua New Guinea and Fiji are excluded). Imported petroleum products account for an average of 40% of PICs' GDP and fuel imports average 14–20% of foreign exchange earnings [7]. Using Fiji as an example, imports totaled FJ$765 million (~US$420 million) for 900 million liters in 2005 rising to FJ$1.2 billion (US$650 million) for 732 million liters in 2008 [36]. In 2010 Fiji spent 32% of the value of all its imports on petroleum products. Such reliance represents a major drain on economies, a barrier to development and a source of vulnerability [37], and has seen the PICs suffer the full impact of the recent global fuel crisis [7]. Fossil fuel dependency is recognized as having a crippling effect on national budgets and revenues and key productive sectors such as fisheries, agriculture, and tourism [8,38].

Comprising approximately one third of the global area but less than 1% of global population, the Pacific's contribution to global emissions is negligible. On average, individual Pacific Islanders are responsible for producing approximately one quarter of the CO_2 emissions attributable to the average person worldwide [39]. Total Pacific emissions have been estimated at 0.03% of global totals [39]; others claim 0.06% [24]. There is insufficient data and research capacity to deliver more reliable estimates.

Estimating the role of sea transport in Pacific energy uses

If fuel use is taken as a proxy for emissions then we know that regionally 1.3 billion liters of fossil fuels were imported into the Pacific in 2011 at a total cost of US$873 million [40]. However, there are major discrepancies in opinions of how this fuel is used by sector. All sources agree on two fundamental points; first, transport is the largest sector user, second, that the data underlying any calculations is often dubious. For example, NZAid has calculated that transport uses 48% as a regional average compared with electricity at 36% [41]. In contrast, the International Renewable Energy Agency considers that on average transportation accounts for 75% of oil consumption, while electricity generation accounts for more than 20% [38]. There is also no reliable regional data to calculate what percentage of this is attributable to sea transport as a subsector but Mayhew considers it could be as high as 75% of all fuel used for some PICs [41]. In extreme cases, such as the small country of Tokelau, sea transport could account for up to 90% of the total national fuel use [11].

There is a dearth of reliable data for the domestic maritime sector from which to make informed conclusions and this is a critical inhibitor to ongoing analysis and research [6,9]. There has been almost no work done at local community level in particular; however, a recent study of one small village on an island in Fiji found sea transport constituted the largest single user (54%) of the village's fossil fuel footprint [42]. We contend this scenario is not unrepresentative and current work at the University of the South Pacific looks to replicate this research in other locations [3]. Rounds suggests that fuel could account for 40–60% of the region's domestic commercial shipping operators' overheads and Fijian interisland ferry operators report this is likely much higher [34].

There are a number of reasons for poor data availability. The region comprises independent countries, dependencies and colonial territories each with its own system of data collection and reporting. The small size of the countries and related regional organizations means there is a lack of capacity for collecting and maintaining datasets. The data needs to be collated from a number of sources and some organizations do not release records. Even where comprehensive records of fuel imports and distribution are available it is not always possible to differentiate between the end users. For example, the same grade of fuel is used for outboard motors as is used for chainsaws, brush cutters, portable generators and some motor vehicles. It is usually not possible to distinguish between diesel used for small ships, trucks, buses or commercial electricity generators.

To date insufficient research capacity has been dedicated to this to allow cleaner analysis of data, in other areas the base data does not exist. More work is needed before it is known what proportion of fuel is used by domestic maritime services, what is bunkered by transiting shipping and what is used by international fishing fleets before realistic apportionment between subsectors can be achieved. The Asian Development Bank recommended in 2007 that a regional agreement on the collection and sharing of key maritime sector data should be negotiated and implemented but this has yet to be done [6,9].

We have attempted to establish an initial regional figure for the domestic maritime bunker by extrapolating from Fiji data. Government statistics show that in 2011 Fiji imported 707 million liters of fuel worth FJ$1.17 billion (US$0.64 billion). Fiji is a major trans-shipment hub for other PICs; approximately 50% of fuel imported was retained in-country and the remainder re-exported to other PICs [36]. Crudely dividing the import figures gives a total of approximately FJ$585 million for Fijian national use. In the same year, approximately FJ$100 million of fuel was reported for commercial electricity generation. Transport collectively used 64% of the total: land transport (16%), air (26%) and marine (22%) [36]. This leaves 17% of other use, some of which includes noncommercial off-grid electricity generation, household lighting and cooking. Sea transport appears on this evidence a single user roughly equivalent to all electricity generation.

Extrapolating further, if we take 50% of 707 million liters then the domestic use for Fiji in 2011 was 353 million liters. 22% of this, the amount estimated to be used by the maritime sector, gives a subsector total of around 78 million liters/year. If Fiji's breakdown is used as a conservative starting point for discussion purposes for calculating a regional consumption profile then 22% of 1.3 billion liters gives 286 million liters for all PICs domestic maritime consumption.

Alternatively, using NZAid figures, dividing 1.3 billion liters by 48% gives 624 million liters used for transport regionally. In Fiji approximately one third of all fuel used for transport is maritime usage, which would equate to 208 million liters if applied regionally. Using the International Renewable Energy Agency's proportions of 75% use of fuel for regional transport this would give a total of 325 million liters.

While crude, this gives an estimated range of consumption of 208–325 million liters/year. If it is assumed that all maritime use was diesel, applying a coefficient of one liter of diesel weighing 0.83 kg allows conversion to tonnages of 172,000–270,000 tonnes used annually. Assuming that approximately 87% of this is carbon, one liter of diesel contains 0.722 kg of carbon, each atom of carbon weighs 12 atomic units. Combined with two atoms of oxygen it becomes CO_2, weighing 44 atomic units. The 0.722 kg of carbon in the original fuel then becomes approximately 2.65 kg of CO_2, which gives 0.456–0.716 million tonnes of CO_2 emitted regionally. This is an upper estimate as it does not account for emissions of carbonaceous aerosol resulting from incomplete combustion processes. Applying the same formula to the Fiji data gives a CO_2 emissions estimate of 0.172 million tonnes attributable to the Fiji national marine transport sector.

No individual PICs have yet set targets for reducing maritime transport fuel use or related emissions although many have set ambitious targets for reducing fuel use for electricity generation. For example, Fiji has a target of 90% renewable energy by 2015 [36]. Under the Small Island Developing States Dock initiative led by the Alliance of Small Island States, of which 13 PICs are members, a target has been agreed of 25% reduction in conventional transport fuel use by 2033

[40]. The regionally adopted Framework for Action on Transport Services 2011–2020 has a long-term objective of *"reduced emissions through a combination of technological and operational improvements, including in ports and port infrastructure, for all vessels that operate throughout the Pacific"* [9]. However, the key priorities for action are restricted to complying with international measures, particularly those set by the IMO and discussed above, and use of green technologies in relation to ports.

Experiments undertaken in Fiji and Japan during the 1973–1986 oil crisis demonstrated that savings of 23–30% were achievable for at least some common shipping types using available and affordable renewable energy technology [13,14,17,18]. If a conservative target of 10% reduction in marine fuel use were to be applied and achieved, then this would result in savings of around 46,000–72,000 tonnes of CO_2 emissions/year regionally and more than 17,000 tonnes for Fiji. Using an arbitrary price of $US1000/tonne for marine diesel oil landed in the Pacific this would mean annual savings for the national Fiji fuel bill of $US6.4 million and regional savings of $US17.2–27.0 million.

While it is acknowledged these calculations are crude, it does give an initial assessment that substantial savings are possible. At this point we would like to underscore the critical importance of sea transport to Pacific economies and the significant impediment that inadequate services and related loss of connectivity both internally within countries and regionally is to socioeconomic development. In previous papers we argued that renewable energy powered vessels could potentially be a major fuel and cost-saving adaptation, while simultaneously providing benefits measured across a range of wellbeings, for minimal investment [2,3]. This means that improved transport services based on renewable energy can do more than save fuel, they can increase development potential and reduce dependency [2,3,11]. This alone is sufficient to justify investment.

We strongly suspect that the overall benefit from such prioritization could be at least as significant as that created by current investment in renewable energy use for electricity generation. Increasing connectivity between communities and countries in the Pacific must be of the highest priority for sustainability planning for the region [3,9].

Policy linkages between Pacific shipping & global warming discourse

Despite the huge disparity between the impoverished domestic Pacific sea transport scenario, which inhibits development potential but contributes little to global emissions, and the powerful and wealthy global shipping industry, which underpins all international trade and growth, we find there is a direct correlation that warrants prioritized research, analysis and action. We identify five primary policy areas that connect Pacific sea transport and the current global discourse on CO_2 and other pollutant emissions.

▪ PICs as good global citizens

Reducing the emissions profile of PICs as a climate change mitigation measure is a symbolic gesture. The Pacific's contribution to global emissions, either in total or per capita, is minute. Even if all PIC-caused shipping emissions were reduced to zero it would have no impact on the global profile. A mid-range 7000 twenty-foot equivalent unit container ship will burn approximately 217 tonnes/day. By contrast, the conservatively estimated marine fuel bunker to service the shipping needs of Tokelau is probably less than 1000 tonnes/year [11]. Pacific leaders are aware that the immense and long-term danger facing their countries, region and ocean from global emissions is of only limited political weight compared with the short-term security, trade and domestic concerns of major world powers. Being good global citizens and doing whatever is possible to demonstrate a commitment to reducing the already negligible emissions profile of their countries adds to Pacific leaders' political leverage at the global negotiating table and provides insurance of the moral high ground.

There are mixed reactions from Pacific politicians as to whether the priority should be demanding drastic emissions reductions from major emitting countries and industries (including international shipping) or securing adequate global compensation to facilitate the Pacific adapting successfully to the effects of climate change. There are some who say that without achieving a drastic global shift in mitigation action, no amount of adaptation can save many Pacific communities from inevitable catastrophe. Under this line of argument adaptation measures are only serving to distract global decision-making from the primary target of huge emissions reductions. Pacific measures to reduce their own profiles in this context are demonstrative of PICs desire to serve as role models.

Pacific politicians tend to be pragmatic people. Speaking to the December 2008 global climate change conference in Poland, Tuvalu's Prime Minister Apisai Ielemia stated: *"We need a new arrangement for least developed countries and Small Island Developing States to pursue a low carbon future. We need strong international assistance to allow us to develop and deploy renewable energy and energy efficiency technologies so that we are guaranteed energy security. We cannot afford to be held hostage to continual leaps in the price of imported fuels".* Ielemia makes no mention of requiring such assistance to reduce Oceania's minimalist GHG emissions; his concern is much more practically orientated. *"Every PIC has an interest in the use of renewable energy to reduce the costs for government revenue and assist household budgets for rural villagers"* [43].

▪ Correlation between fossil fuel dependency reduction & emissions reduction or mitigation

Reducing the region's dependency on imported fuel is arguably a more practical and higher priority for decision-makers than reducing emissions caused by burning that fuel. The crippling effect of such dependency on all aspects of Pacific economies is well recognized. The only options are to increase the efficiency of current fuel use, reduce fuel consumption, which would come at a high social and development cost or introduce alternatives. In many cases there is a serendipitous correlation between use of alternatives and emissions reduction. In the past decade there has been an increasing and concentrated effort by PICs supported by international donors to introduce a range of renewable energy technologies to substitute fossil fuel use for electricity generation. Despite electricity being a minority user sector of fossil fuel for PICs, several donors have seen this as the 'low hanging fruit' of Pacific fuel use. In March 2013, New Zealand and the EU hosted a summit in Auckland where NZ$635 million was committed to such measures. There is insufficient analysis to yet demonstrate that these measures are ultimately cost effective and sustainable over their lifetime. It is also worth noting that not a single project emanating from the summit targets sea transport.

It is important to note that the Auckland energy summit was couched in terms of reducing the Pacific's dependency on imported fuel and not in terms of reducing Pacific emissions profiles. It is questionable whether there would have been this level of interest in this cause without the wider impetus of the global context of climate change as much of the financing comes via climate change or emissions related programs.

▪ The need to attract alternative sources of financing for sea transport

The lack of adequate policy and financing have been identified as major constraints to developing more appropriate sea transport services for PICs [2–4]. There is nothing new in this; Pacific commercial shipping, especially at a domestic level, has always been a financially marginal and high-risk concern that many PICs are unable to fund without external assistance [5,9,10]. The biggest change in the resourcing environment since the 1980s has been climate change, in particular the various related financing mechanisms provided by the developed world. Yet, despite the inherent logic of investing in renewable energy shipping for PICs as a priority climate change adaptation focus, the sector is penalized. Because shipping internationally is generally considered by donor agencies only as a mitigation priority and donor priorities are confined currently to the electricity sector, 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 many current renewable energy financing facilities because it would not be displacing fuel used for electricity generation [2], the current priority sector set by external donors.

The Asian Development Bank 2007 shipping overview is typical of expert opinion that delivery of shipping service is best left to private investment and the market [6]. Couper was also of this opinion when discussing the arrival of Ro-Ro domestic services for Fiji in the 1970s [5]. The marginal and high-risk nature has always meant that financing shipping, either for governments or private operators, is difficult. The current global economic environment has only exacerbated this with the finance market becoming increasingly cautious of such investments. The assumption that the private sector acting alone or unaided is best situated to provide services needs to be re-examined. Certainly there is a case for governments and agencies to play a role in providing access to vessel and industry financing through various mechanisms, potentially including providing loan security and preferred operator status for renewable energy powered or retrofitted vessels [3].

Just as global concern over emissions has provided the financial impetus for investment in renewable energy alternatives for electricity generation, there appears no reason why similar mechanisms and processes should not now be utilized to underpin financing to upgrade Pacific shipping with more efficient and appropriate vessels. Even if this means continuation of use of fossil fuel powered vessels, introducing newer assets is likely to be more efficient and therefore lead to some overall fuel dependency reduction. If such mechanisms were weighted to promote introduction of renewable energy alternatives then the reduction in fuel dependency and emissions will be increased simultaneously. At the very least, sufficient and immediate investment in research and development to prove the commercial viability of regionally appropriate renewable energy vessels is an essential and easily justifiable action.

It is possible to envisage a future scenario where the use of renewable energy for shipping in the region is of sufficient scale to claim carbon credits or justify use of similar cost-offsetting mechanisms. Currently, global carbon credit trading mechanisms have not proved effective and the international price of carbon is low as is the immediate potential for increasing trade in this area. Given global concerns over GHG emissions and the broader field of climate change, as well as concerns

Key term

Carbon management: Use of carbon trading markets and other financial mechanisms, including CDM to supplement income for ships using renewable energy technology to reduce fossil fuel consumption and as a potential means to support the uptake of renewable energy technology by the maritime sector.

over projected ever increasing costs of fossil fuel, this situation can be expected to change in the future. Investment in the necessary research to underpin such initiatives is needed now.

The need for more appropriate domestic shipping for the Pacific

The current Pacific fossil fuel dominated shipping scenario limits the type of shipping services that can be provided. Fuel costs are the major component of shipping operators' costs. With conventional vessels there are only two primary options for reducing this cost; either employing 'slow steaming' where engine and therefore vessel speed is reduced, or by using larger vessels to achieve economies of scale by carrying larger consignments of passengers and cargo. Most operators already employ slow steaming wherever possible. Larger vessels are not necessarily a suitable solution for all situations and means smaller islands and centers are increasingly penalized as larger ships can only operate cost effectively where there is sufficient demand.

Because the operating costs of renewable energy powered or assisted vessels are not constrained by needing to achieve the same economies of scale to justify fuel overheads, they offer a potential future where fleets of smaller but sustainable new ships can supplement or replace current single, aged, large vessel operations [2]. Again, commercially viable examples need to be practically demonstrated before there is a likelihood of strong uptake by current government or commercial operators.

Emissions from shipping in the Pacific from sources that have no direct benefit to PICs

Although no analysis has been undertaken, we surmise that the largest proportion of emissions from shipping in the Pacific does not come from ships owned by, trading with or otherwise benefiting PICs, but from large vessels transiting Pacific waters whilst facilitating trade for non-Pacific countries and economies.

The central Pacific Ocean is sparsely used by global shipping while the north and continental margins are heavily used. It is obvious that most Pacific traffic is not generated by the current needs of the inhabitants of PICs. Despite the opposition of the global industry to regional financial mechanisms [109], we argue here that there is a case to be made for developing a compensation mechanism levied on such shipping to support PIC measures to move to a lower carbon footprint. Pollutant emissions from such shipping are contributing directly to the issues faced by PICs in regard to rising sea levels, changing climatic patterns and ocean acidification.

To place this argument in context, were an inadvertent stranding of a transiting oil tanker to cause a massive (or even small) oil spill disaster on a Pacific reef, there would be immediate and massive response to the resulting maritime pollution by the ship owners, governments, global environmental groups, insurance companies and bilateral donor countries. The response would be heightened if such a catastrophe endangered breeding, spawning or feeding grounds of an endangered species of Pacific marine life, more so if it was an iconic species such as a turtle or whale. The emissions from current conventional shipping are likely to be of a far greater magnitude and impact than a spill such as the Exxon Valdez or Torrey Canyon. Yet the daily pollution rained down on the Pacific from the passage of transiting global commerce that threatens all life in this ocean raises scarcely an eyebrow or a headline.

Conclusion

There is increasing international research into shipping in the context of global discourses on emissions. It is likely that low-carbon transport generally and sea transport in particular will now receive increased attention by regional and national planners and policymakers in the Pacific. Current international measures to address the contribution shipping makes to global emissions and thus climate change do not appear to offer much direct promise of solutions in the search for more sustainable shipping for PICs. It is likely that global measures will come at a direct economic and regulatory cost to local service providers for no compensating return. There is little current impetus in accelerating or greatly expanding investment in the development of renewable energy for shipping use globally and almost no consideration of the use of such technologies for vessel types of greatest need in the Pacific. This paper identifies five key policy connections that warrant prioritized attention.

Although there is no previous literature that considers the linkages between carbon and other emissions management and the Pacific domestic sea transport scenario, this paper suggests that these linkages provide sufficient justification for prioritization of policy development and further research. The paper is offered as a catalyst for initiating an ongoing informed debate, both within the region and with the wider international academy and industry.

Future perspective

We have previously described the need for more sustainable sea transport and in particular investment in renewable energy development for this sector as a 'missing link' in Pacific sustainability discourse [2,3]. It has the potential for significant application and research is generating growing interest and discussion amongst regional policy and decision-makers. Maintaining and increasing traction is likely to be highly dependent on shifting attention and priority more centrally within national and regional policy spaces, and attracting adequate interest and collaboration from international researchers across a range of disciplines, the donor community and industry developers. Through an optimistic lens, major shifts in both policy and financial support for renewable energy use in maritime transport are anticipated in the near future, as focus shifts from electricity generation to more significant sector users of fossil fuel in the Pacific. Carbon management is a critical component of this in terms of reducing fossil fuel dependency in the region as well as a potential financial mechanism for supporting the maritime sector to uptake technology that reduces GHG and other emissions. Technological advances already under investigation internationally are anticipated to become more widely available for commercial use as prototypes are trialed. Through less optimistic lenses the issues may continue to attract little interest or support and remain in the 'too hard basket'.

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The authors have no relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript. This includes employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties.

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Executive summary

Background

- The relationships between global emissions (in particular from global shipping) and the sea transport scenario for Pacific Island countries (PICs) is previously unexplored.

The local context: PIC sea transport scenario & climate change

- Sea transport is a critical need; the region's transport issues are unique – small and vulnerable economies, long distances, old ships of poor standard, entirely fossil fuel dependent and minute contribution to global emissions.

Global shipping & global emissions

- Shipping is an international industry, valued in trillions of dollars, moving 80–90% of world trade.
- The shipping industry produces approximately 3% of global emissions, and large proportions of SO_x and NO_x.
- Regulations of emissions is difficult given intentional nature of industry. In our opinion, leadership is not producing solutions appropriate to PICs.

Pacific fuel dependency & emissions

- The Pacific is the most dependent region on imported fuels; a major inhibitor of sustainable development for PICs.
- Currently, all focus is on alternatives in the electricity sector; ignoring transport as the major regional user of fuel.
- There is no previous literature on emissions from sea transport; but estimates are made.

Policy linkages between Pacific shipping & climate change discourse

- The Pacific contribution to global reduction targets is very small.
- Important policy connections related to: role of PICs as global citizens; access to carbon financing; more appropriate technologies.

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