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Turning the Tide: the need for sustainable sea transport in the Pacific

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ABSTRACT

This paper reports on progress in developing a regional research and education strategy for Pacific Island countries and communities wishing to transition to a low carbon sea transport future. Sea transport is an absolute necessity for most such communities. All current services are fossil fuel based and are becoming increasingly unaffordable and unsustainable. The countries in the Pacific region are the most dependent on imported fossil fuels in the world, importing more than 95% of needs. Such dependency is having a crippling effect on national budgets and major impacts on key productive sectors. The region's transport issues are unique; small and vulnerable economies scattered at the ends of some of the longest transportation routes in the world and arguably the most challenging to maintain per capita and per sea mile. Alternatives to current fossil fuel powered sea transport have been almost totally ignored in recent regional and national debates and the issue has been largely invisible within the policy and donor strategy space at all levels despite concerted efforts over more than two decades to transition Pacific countries' electricity sector fossil fuel use. The University of the South Pacific has been collaborating with a network of stakeholders and knowledge partners since 2012 to advance this agenda, building off previous doctoral research and the resultant Sustainable Sea Transport Talanoa 2012. Prasad et al. (2013) set out the basis for a catalytic research program following from the consensually agreed outputs of SSTT 2012 and this paper records the progress made since.

1. Introduction

In 2013, a newly formed interdisciplinary research team at The University of the South Pacific (USP)[1] set out the objectives of a one-year project designed as a catalyst to populate and invigorate an informed debate for Pacific Island Countries (PICs) and communities of Oceania seeking low carbon alternatives for current and future sea transport [1]. The initial research design aimed at positioning a much longer-term program of research and education for this critical but hitherto largely unexplored field by initiating and maintaining key relationships, preparing a detailed long-term strategy and commencing a number of case studies.

The program is predicated on the assumption that a collaborative effort of multiple partners at various levels will be required to achieve a transition of any meaningful scale over time. The PICs need to reach out to expertize beyond its own region. In effect this requires the development of a transformative knowledge network to backstop a paradigm shift (see Hackmann and St. Clair [2], for an overview of the concept of transformation knowledge networks). In the initial paper [1], USP committed to reporting back after one year. This paper provides a synopsis of the current sea transport challenges; a summary of the evolving research results; and an overview of the support needed for an ongoing research agenda for Oceania.

2. Synopsis: Oceania and its shipping

Oceania, with some 10 million people and over 25,000 islands scattered across more than 3 million square miles of the world's largest ocean, represents arguably the most dependent region on sea transport (Fig. 1). Displaying great diversity, from small island states such as Tuvalu (with an area of 26 km^2 and a population of just over 10,000) to Papua New Guinea (PNG) (approximately 462,800 km^2 and over 6 million people), the island and atoll states of this maritime region face similar challenges in terms of finding sustainable solutions for transitioning to low carbon shipping.

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[1] USP is one of two regional universities in the world. USP's 12 member countries are: Cook Islands, Fiji Islands, Kiribati, Republic of Marshall Islands, Nauru, Niue, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu and Vanuatu.

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Sea transport, especially at the domestic level, has always presented a difficult issue for PICs to find long-term, sustainable, and cost-viable solutions for, even in periods of low fuel costs [3–5]. The unique characteristics of Pacific shipping (minute economies at the end of long routes, imbalance in inward/outward loadings, financing barriers, high operational risk, and high infrastructural costs) present a greater challenge than for most other countries and regions. This is particularly true for the domestic local and country scenarios.

All current options are fossil fuel powered. Imported fuel prices and the demand for global emissions reduction will continue to rise in the long-term. The PICs are the most imported fossil fuel dependent in the world with 95% dependency, 99% if PNG and Fiji are excluded [6]. Inversely to global sector apportionment, transport uses some 70% of the total fuel imported regionally and sea transport is the majority fuel user for some PICs [5,7,8]. Tuvalu, for example, reported that 38% of total fuel imports or 64% of all transport fuel in 2012 was for maritime use or ~38% of total fuel imports [9]. Many existing maritime services are increasingly unaffordable and unsustainable. Ships are often old, poorly maintained and inefficient. Fossil fuels represent a significant proportion of shipping operating costs, often the largest single cost. Accessing asset and operational finances is difficult. This results in a vicious cycle of old ships being replaced with old ships, and the need for larger ships to achieve economies of scale. This, combined with narrow reef passages, small harbors and small cargos and numbers of passengers, leads to many routes being commercially marginal or even unviable. Governments are often required to subsidize or service these routes if communities are to have access to transport [5,10].

3. The invisibility of low carbon shipping in regional development

Despite the identified need and the increasing availability of alternatives, meaningful steps to address this sector have yet to eventuate [11]. Low carbon sea transport solutions have been almost invisible in the policy space at national, regional and particularly donor levels. The issues have been well characterized [1,10,12]. One representative case example is offered. On the Fijian island of Kadavu in 2008, outboard fuel prices rose to more than US$ 1.39/litre. In direct response the children from neighboring Ono Island were taken home from boarding school because the villagers could not afford the cost of weekly food rations trips, and in Kavala Bay the health nurse replaced her fortnightly pregnancy checks to monthly visits [6]. Similar examples are the norm across the region, which expects the need for and the cost of sea transport to increase for the foreseeable future [13–15].

Global interest in low carbon technologies for shipping is growing, but solutions at the small-scale level appropriate to the domestic needs of PICs have yet to be seriously explored. Past research and recent findings highlight strong potential for such technology to provide practical and multiple benefits to PICs, measureable across economic, environment, social and cultural baselines [1,6,10]. However the focus across the region to reduce fuel dependency to date has been almost exclusively on electricity generation. The regional renewable energy discourse has become largely synonymous with electricity, reflecting global perceptions, agency and consultant bias but not necessarily Pacific realities. Commitment of more than US$ 535 million targeted at diesel dependency reduction by donors at the Pacific Energy Summit in Auckland in 2013 was confined almost exclusively to electricity programs with no projects directed specifically at sea transport [5].

There has been no concerted program to apply such priority to PIC sea transport. The barriers are complex and poorly understood [11]. A growing range of technological solutions are available or emergent [16,17]. There were a number of small but critically important experiments conducted in this field during the last oil crisis, several in the Pacific, but the lessons of these have largely been lost to history [6,10,18–24]. These experiments showed that for modest investments major savings in fuel use from existing proven technologies were available for local shipping.

Recent published studies identify barriers to transformation in Pacific, Norwegian and global shipping [16,25–28]. These studies concur that institutional barriers, including access to financing, managerial practices and legal constraints, sit alongside technology issues constraining transition to low carbon shipping. This is similar to USP's findings for the Pacific [11] that policy and financing barriers are as great if not greater challenges than availability of technology. Many of the barriers are perceptual as much as factual but appear deeply entrenched. Such conclusions have been foreshadowed in previous theoretical studies looking at barriers to transport de-carbonization programming [29,30].

Increasing concern over PICs' fossil fuel dependency, the search for low carbon futures and the crucial role of sea transport for Oceanic communities make the establishment of such a research agenda a logical priority. There are two critical focal areas for research and action: at an international level in terms of greenhouse gas (GHG) emissions causing climate change [31] and at a regional, national, community and household level where the maritime sector is often the single largest user of imported fossil fuels [5,7,8,10,32].

4. The relationship between local shipping need and the global emissions discourse

Shipping is a major and increasing source of global GHG emissions, estimated in 2009 at 3.3% of global totals and projected to rise by 150–250% by 2050 (see in particular [33–35]). Nitrous Oxide (NO*x*) and Sulfur Oxide (SO*x*) emissions are disproportionally high for shipping, ranging from 10% to 15% and 4% to 9% of global anthropogenic emissions respectively [33,36–38].

Emissions from shipping have grown substantially [38,39] due to growth in demand outpacing the growth in efficiency [26]. International regulation of this sector has lagged behind other major international energy use sectors [40,41]. Shipping emissions must be dramatically reduced if global targets for climate change are to be achieved. The only alternative is for other sectors to perform above target to compensate. Ship emissions reductions were placed outside of Kyoto and similar agreements.

The speed of change in achieving overall reductions of global emissions is of critical importance to Oceania. The 2013 Pacific leaders' Majuro Declaration for Climate Leadership called for urgent action at all levels to reduce GHG emissions. Most PICs have set ambitious targets for reducing their own emissions, although any reductions they achieve will have no impact on global totals. It may however have an impact on global trends by demonstrating PICs' commitment to 'punch above their weight' and lead by example.

5. The relationship between PIC sea transport and fossil fuel dependency

The Pacific Island Countries and Territories' (PICTs)[2] fuel bill in

[2] The regional political grouping varies depending on whether the various colonies, territories and dependencies (such as French Polynesia, Tokelau, American Samoa, New Caledonia) are included alongside independent countries.

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2013 was US$ 6.392 billion [42]. At the domestic level fuel imports remain a major drain on already scant national budgets. This varies from country to country and across the region there are issues with data capture, reliability and disclosure that hinder more accurate analysis [3,5]. Using Tuvalu as an example; reported national expenditure for imported goods in 2010 was US$ 23,830,418 of which 32% was imported food and 21% was imported fuel. Transport is the single largest imported fuel user [9]. In 2012, 64% of all transport fuel was used by the combined Tuvaluan merchant fleet (2 freighters; 1 fishing vessel, 1 patrol craft, 300+ outboard motors). Sea transport is essential for the nine islands of Tuvalu and maintaining connectivity that underpins socio-economic activity. The high cost of transport hinders all development efforts. The longer producing a sustainable and more cost effective solution takes, the greater lost economic opportunity cost. As the greater majority of Tuvalu's income is aid and remittances, it also equates to an increasing continuation of international aid dependency to pay for the ever-rising costs of such imports.

While Tuvalu (like other PICs) has set a target of 100% electricity from renewables by 2020, it has not set any firm targets for reduction of transport's profile. Of the PICs, only the Republic of Marshall Islands (RMI) has set a target for reducing transport fuel reliance (20% by 2020) although 13 PICs are signatories to the Small Islands Developing States (SIDS) DOCK initiative that pledged 25% transport fuel use reduction by 2033. It is not clear from that agreement what baseline such reductions are to be calculated from; the electricity related targets are set against 2005 usage. Nor is there policy for sub-sectors of transport; land, air and marine.

Fig. 2 shows a reduction of 25% for sea transport by 2033 against a nominal estimated 2012 baseline of 250 million liters used regionally, allowing for nil, 1%, 3% and 5% annual growth in fuel use. The nil growth scenario requires achieving savings of 62.5 million liters p.a. within 18 years; 3% requires approximately 250 million liters (or the same as nominal current use) of alternative non fossil fuel or equivalent efficiency savings. There are two possible extremes of argument as to the best strategy for achieving such targets: to try and achieve savings earlier or delay until maximum technological and operational efficiency is developed elsewhere and can be transferred to the Pacific at lowest cost for greatest reduction.

To this assessment of quantity of fuel saved must be factored future changes in maritime bunker costs to access cost savings. Most sources concur on further increases to the current historical trend and are illustrated in Fig. 3a and b.

Fig. 3a shows the wholesale price increase of the two main global maritime fuel types, Marine Diesel Oil (MDO) and Heavy Fuel Oil (HFO) since 2001. Pacific wholesale prices will be higher reflecting costs of shipment and foreign exchange rates. Fig. 3b gives projected increases in costs of maritime bunker reflecting both predicted base price increases and increasing compliance penalties due to International Maritime Organization (IMO) regulation for cleaner fuel. Overall GL were predicting marine fuel costs to increase by between two and three times of 2010 cost by 2030. Again, transportation and exchange charges will increase such costs for PICs.

6. What options are available to PICs seeking transition to low carbons sea transport?

International shipping is undergoing an unprecedented and increasing search for energy efficiency and reduced reliance on traditional fossil fuels driven primarily by the fluctuating but escalating costs of marine fuels, international agreements to reduce GHG emissions, and increasing awareness of environmental and public health risk from shipping emissions. Since 2007 fuel costs have become the crucial parameter deciding where funds for new tonnage are placed, not the cost of the asset or ship operation [15,43]. This trend is highly likely to increase given predicted future cost of fuel and increasing compliance costs of meeting international regulations on fuel content and efficiency.

At the global scale, a number of studies have now identified the main options available to the industry and regulators to reduce fuel use and emissions [29,44,45]. These can be grouped into four categories: improving energy efficiency (i.e. increasing productivity using the same amount of energy), using renewable energy (e.g. solar and wind), using fuels with lower carbon content (e.g. Liquefied Natural Gas and biofuels) and using emission reduction technologies (e.g. through chemical conversion, capture and storage). Of course 'hybrid' or combinations of measures are available.

The unique characteristics of PIC sea transport means the options available to the global theater are not necessarily the most accessible or appropriate, particularly for smaller countries and communities. This is due to a range of factors including the characteristics of local demand; the Pacific merchant fleet (blue water but small and old, higher proportion of petrol to diesel); a lack of access to financing for new technologies; and the prohibitive cost and practicality of establishing extensive bunkering and support infrastructure for alternative fuels. There is considerable scope for operational efficiency improvements for both the current vessels and related infrastructure (port design and options, feeder transport networks, etc.) and this will be true regardless of the fuel type used by shipping[3] (Fig. 4).

USP's initial research is predicated on the assumption that these same factors are likely to make renewable energy technologies more appropriate for a range of Pacific applications than at a global scale. As discussed previously, there were a number of critical experiments in the last oil crisis that tend to support this view, corroborated by increasing current work by global researchers and innovators [16,17]. To the designs from the last crisis, can now be added major advances in wind power, particularly using rotors for retrofits, advances in sail design, solar capture and electricity assisted power and propulsion. Biofuels, both liquid from coconut oil (CNO) and biomethanes, have strong potential, again especially for more isolated communities with high biomass availability.

7. Setting the groundwork for transition

The current program builds on Fiji-focused research into the potential use of sail, on-going since 2008 [6,12]. That research proved catalytic to a small but growing collaboration of stakeholder interest, both locally (in particular from USP, NGOs such as International Union for Conservation of Nature's (IUCN) Oceania Regional Office, World Wide Fund for Nature (WWF) South Pacific Programme, local communities and traditional sailing societies) and from international innovators (including the NZ based Sailing for Sustainability Trust, Japan/UK registered NGO Greenheart Project and B9 Shipping in the UK) with regular *talanoa*[4], workshops, exchange of ideas, knowledge and contacts.

Various attempts were made to engage the conventional regional agencies with related responsibilities in this field, such as Secretariat of the Pacific Community (SPC), Secretariat of the Pacific Regional Environment Programme (SPREP), Asian Development Bank (ADB), UN Development Programme (UNDP) and the

[3] This area is the subject of on-going work by SPC's Regional Maritime Programme.

[4] *Talanoa* ('tell stories') is a traditional Pacific Islander way of discussing issues of common concern, without an obligation to reach a conclusion or consensus.

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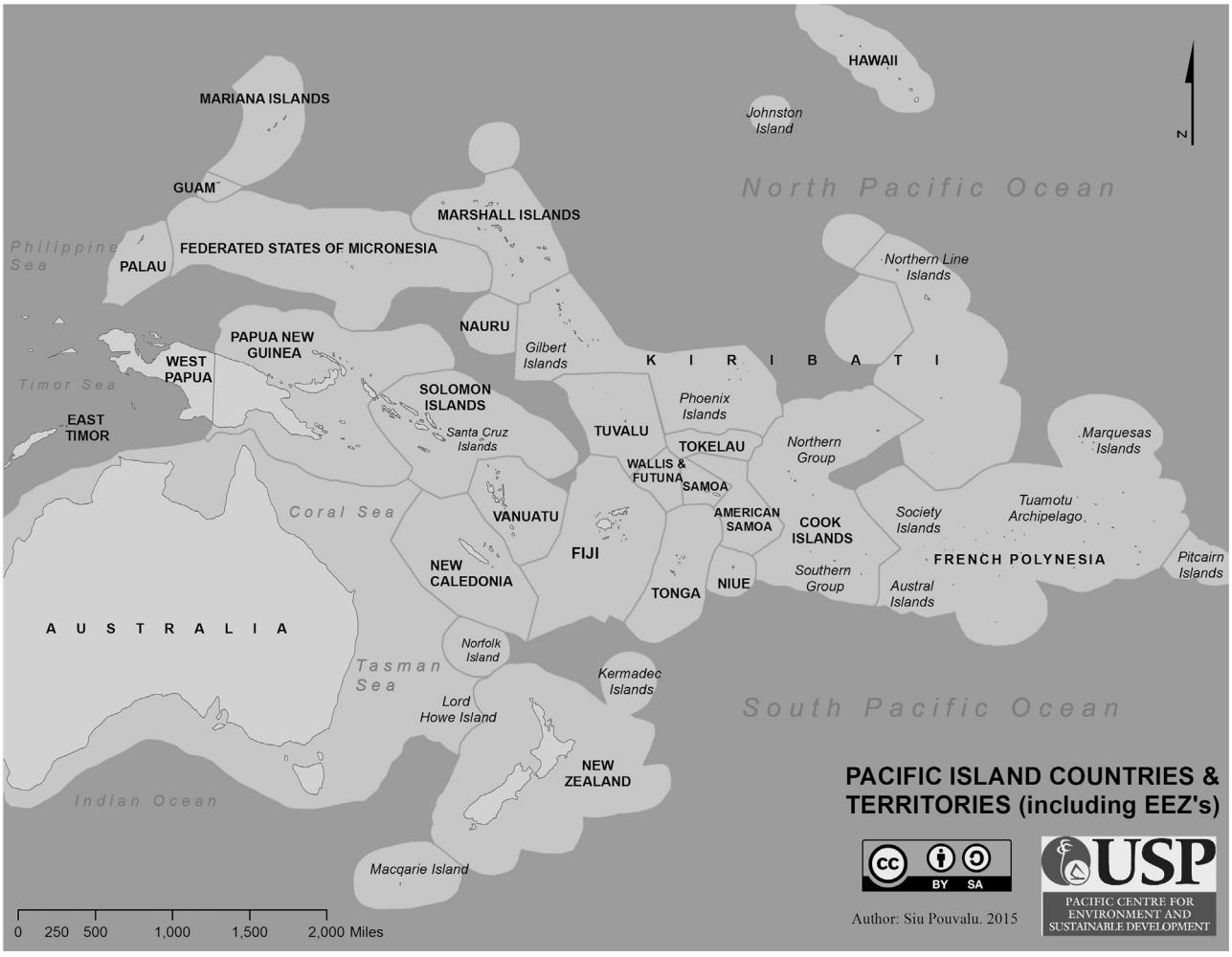

Fig. 1. Map of Oceania.
Source: Siu Pouvalu.

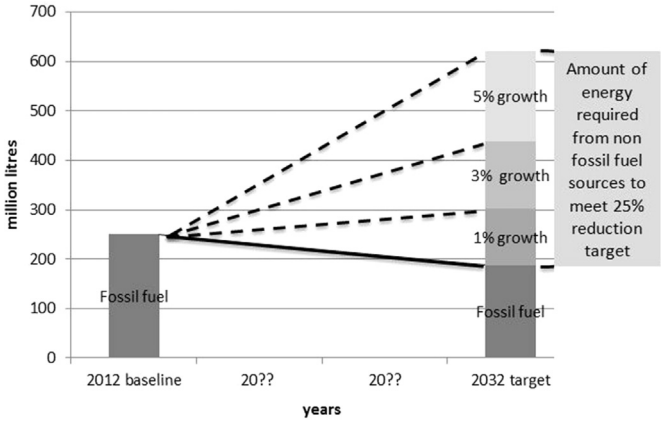

Fig. 2. Amount of non-fossil fuel energy required to achieve a 25% reduction in fossil fuel use by sea transport by 2032 for PICs under different annual growth scenarios.
Source: [11].

various major bilateral donors and aid programs e.g. Germany's Gesellschaft für Internationale Zusammenarbeit (GIZ), European Union (EU), Australia's Department of Foreign Affairs and Trade (DFAT), New Zealand's Ministry of Foreign Affairs and Trade (MFAT), Japan International Cooperation Agency (JICA). All were enthusiastic in response to the initiative but without exception, have to date declined to formally endorse or adopt specific work pointing to the limitation of their already determined budgets and the overwhelming commitment to concentrating on the 'low-hanging fruit' of substituting fuel use for electricity generation.

It is not entirely clear how this generic policy decision was made but appears to be predicated on two principal assumptions; that it is easier and most cost effective to generate meaningful savings at scale from the electricity sector and that the technological barriers to reducing transport fuel use are high, and the technology itself is unavailable or unproven and therefore of much higher risk. It is arguable whether either assumption can be substantiated on available evidence. There is little publicly available analysis to date to show that the substantive investment in renewable energy electricity across the region has produced proportionate benefit. Again using Tuvalu as an example where primarily photovoltaic technologies have been progressively introduced over several years, 0.2% of the total national energy supply in 2012 was reported to be now from solar [9].

There is simply insufficient available data to assess what degree of benefit could have been gained from a similar investment in sea transport. The limited evidence is that significant savings have been achieved at favorable rates of return on investment, in particular the detailed analysis undertaken by Southampton University of the Fijian sail retrofitted ferries [20,23,46]. Current

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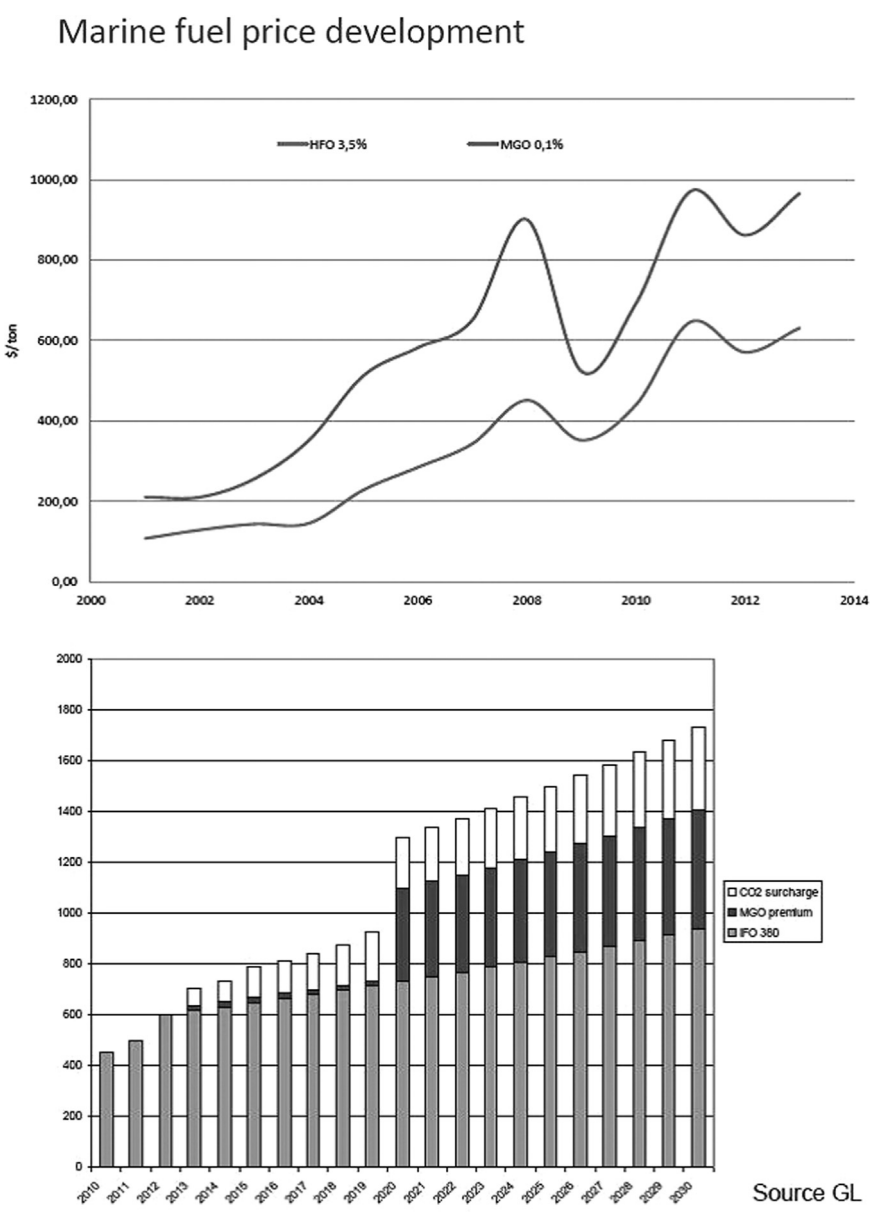

Fig. 3. a. Cost of Wholesale Marine Diesel Oil and Heavy Fuel Oil 2001–2013.
Source: [13] (based on Germanischer Lloyd (GL) data). b. Fuel Oil Price Scenario.
Source: [14] (based on GL data).

Fig. 4. Container ship entering Suva Port.

research shows a range of available or emergent options, most using mature and proven technologies available at relatively low investment costs. The immediate gap is in the research development effort needed to move to proof-of-concept commercial trials.

In November 2012, in preparation for meeting the challenges in this emergent field and on behalf of a growing network, USP hosted the Sustainable Sea Transport Talanoa (SSTT) 2012[5]. This three-day international workshop focused on the potential for developing alternative energy sea transport options for Oceania communities. This was the first major conference on this subject since a similar event hosted by the ADB in Manila in 1985.

The SSTT 2012 included both celebration of Oceania's seafaring heritage and consideration of future sustainable sea transport. Participants included representatives from communities, women and youth, Pacific seafarers, universities (including research leaders such as University College of London), international agencies and NGOs (such as United Nations Economic and Social

[5] See URL ⟨https://www.usp.ac.fj/index.php?id=12456⟩.

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Table 1
Work Stream Priorities agreed by SSTT 2012.
Source: [54]

Work Stream	Keywords	Themes
Heritage	Drua, iconic, culture, tradition; excellence in seafaring and vessel design and construction; ocean as highway not barrier.	Cultural history, archeology, traditional revival, carving, weaving, navigation, seafaring, voyaging
SSTT 2014	International symposium and drua festival.	Celebrate the Past, Plan for the Future
Strategic Blueprint	Policy frameworks. Regulatory frameworks; economic analysis; quadruple bottom- line reporting; industry-wide assessment; data gathering and management; integrated approach; initial route identification; collaborative relationships.	Carbon credits, cost–benefit, Project v program, biofuel and/or solar and/or wind, Owner/operator option analysis, Private/public, Markets/uneconomic
Demonstration Models	USP research vessels; targeted destinations – Gau, Kadavu, Lau, Rotuma.	Intra-island: sustainable village vessels, inter-island: Greenheart, barges, fishing vessels, inter-state: B9 shipping, disaster relief
Gender and Youth	Leadership, capacity building, skill development, business opportunities, community focus.	Training, mentoring, team building

Commission for Asia and the Pacific (UNESCAP), UNDP, SPC, IUCN, WWF and Greenheart Project), industry (including leading naval architects, B9 Shipping, GL and Det Norske Veritas), government departments (including heritage, maritime safety, transport, and energy), donors, and country representatives. The SSTT 2012 Outcomes Record agreed a series of work streams as priorities for future work as summarized in Table 1. Participants expressed strong interest in working collaboratively in the Pacific and in attending a more formal conference in 2014.

The success of the SSTT 2012 means that the first hurdle of simply establishing a profile for this critical research area has now been addressed. A small but significant and broad ranging body of background work has been highlighted and disseminated amongst key stakeholders to the extent that the subject is now being raised in forums such as the Fiji National Energy and Transport strategies and plans and the Pacific Islands Development Forum (PIDF). Cabinet papers and ministerial advice is being provided to an increasing number of Pacific leaders.

Resulting from the response to SSTT 2012, USP committed seed funding to support a program of research to benefit its PIC member countries, initially focusing on several case studies of isolated island communities in Fiji to determine their transport needs [1]. The research team is small (two dedicated research associates and two masters students supported by a number of senior staff including Heads of School for Economics, Marine Studies and Climate Change). The team has addressed capacity and research capabilities needs through postgraduate research and the design of two undergraduate courses as part of the revised programs in the School of Marine Studies.

As a result of the SSTT 2012, the team is now engaged in negotiations with universities in the UK and Germany in particular, although interest has been indicated in aspects of USP's work from sources as far away as Boulder University in Colorado. The overwhelming priority is to build a basis for on-going collaboration through expert and postgraduate exchange programs as the best path to building long-term capacity for the region. Such endeavors need to be selective as USP's capacity to respond is still low. The need though is great. USP's core constituency, of 12 PICs[6] each have Transport, Energy, Finance and Climate Change departments or ministries headed by Ministers, national planning offices, port authorities, government shipping services, all trying to stay abreast of ever increasing local to international development in multiple sectors involving multiple actors.

The research agenda on Pacific shipping generally, and more sustainable alternatives particularly, is broad and sparsely populated. As noted in Prasad et al. [1] it is hoped that, by careful selection of manageable outputs, the current USP research initiative can provide sufficient results to be catalytic to a broader program of research, trials and teaching. The research was commissioned under USP's Strategic Research Theme program and is spread across three related clusters, namely: Economic Growth, Trade and Integration; Pacific Ocean and Natural Resources; and Climate Change, Adaptation and Mitigation. The research approach is an interdisciplinary one and seeks to combine expertize associated with economics, marine science, technology and engineering, heritage and carbon management.

The capacity of USP to maintain such a program on its own is limited and the current research represents a significant investment from USP's internal research budget. The project needs to produce sufficient results to secure both on-going academic support and external research funding if it is to be progressed in terms of scale and influence. Ideally, a portfolio of research is needed that will require a collaborative investment from multiple research partners (locally, regionally and internationally) to be successful. USP, in making such a research investment at this time, is seeking to act as catalyst, navigator and facilitator. It is a role USP has played previously in other critical sectors, a leading example being the region's Local Managed Marine Area program [47,48], also a transformation knowledge network initiated and supported by many of the same partners engaged with now in relationship to sea transport.

8. Reporting back. What has been achieved so far?

The initial research design called for three primary outputs: organization of a second international conference; planning for a six year multi-disciplinary research program and initiating a small number of key case studies. Building relationships with stakeholders and knowledge partners at all levels is central to the overall program. The major milestones achieved are summarized below.

The program continues to generate interest, encouragement, support and offers of partnerships from various sectors. However, dedicated funding has yet to be secured, either for the research or the identified primary intervention projects. USP has extended its investment for a further year, convinced that a longer incubation period is required and defendable. The priority would be to move to practical trials of a range of technologies and vessel types to demonstrate 'proof of concept'. However, the reality of funding for this sector, despite multiple completed concept notes and donor applications, has yet to allow this.

8.1. Populating the literature

The existing literature for this field focused on PIC need is thin

[6] USP has a collaborative research partnership with 10 other Pacific universities under the Pacific Islands Universities Research Network (PIURN).

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and comprises a few historical analyses and case studies, and a small range of agency reports. The USP program has sought to populate it further with a range of papers starting with a broad overview and summary of the current scenario and future options [10,49], followed by more targeted analysis of the current research focus [1], the policy interrelationship between Pacific sea transport and carbon management [31], the policy and financing barriers to low carbon transition [11], the potential for application of rotor technology [50], a single maritime village transport and fuel survey [32,51], and an in-depth study of *Waqa Tabu*, the giant multihulled *drua*[7] of central Oceania [52].

Publishing in this manner has brought repeated contact with the international academy where ground-breaking work is emerging from numerous sectors which in turn can now be fed out to the Pacific region. This has included attracting the attention of colleagues at Columbia Law School's Center for Climate Change Law who recently published a White Paper assessing Pacific island states' legal authority to regulate greenhouse gas emissions from the international shipping sector [53]. Further such collaboration is desired. If “cargo is king” is the merchant marine slogan then “knowledge is queen” must be that for making informed decisions over transition to new paradigms. The challenge is how best to disseminate that knowledge to Pacific decision-makers from cabinet to village council. Capacity building of Pacific-based current and future expertize is essential and the USP program places high priority on such exchange at a regional and international level.

In addition to formal reviewed papers, the various presentations made at the SSTT 2012 and 2014[8] have been posted on USP's website along with the Outcomes Record. The program team has presented at range of conferences and workshops on various aspects of this research. Additionally, USP researchers are lead authors on a global technical review of the role of renewable energy for shipping for International Renewable Energy Agency (IRENA) [17].

8.2. Analysis of previous lessons learnt

As noted above, there were a number of experiments and projects during the last oil crisis using sail and sailing vessels for different applications and in differing Pacific locations. As much background material on these as possible has been collated in order to distil the lessons learnt [10–12]. These range from the Food and Agriculture Organization (FAO)/UNDP program with artisanal and small-scale commercial fishing vessels to retro-fitting auxiliary soft sails on a 274 ton passenger and cargo ferry in Fiji. Some projects resulted in critical analysis and vessel designs, though the end of the crisis and the subsequent fall in fuel costs meant the ships were never built. These included a range of designs for multihull vessels to meet most of Tuvalu's sea transport and fishing needs targeting savings of up to 60% [19] and an energy efficient sailing freighter for the Ha'apai Group in Tonga [21]. The Fijian projects clearly demonstrated that substantial fuel savings (in the order of 23–30%) could be achieved cost effectively. Satchwell [46] calculated the return on investment for the cost of the retrofit at an impressive 127% on the most favorable route and over 30% averaged across all Fiji routes. The key projects are summarized in Table 2.

The research from the 1980s provides a well-marked starting point for a fresh phase of work now; it is not necessarily a case of having to reinvent the wheel. In particular the catalytic role of UN agency/ADB-funded initiatives is highlighted [11]. The designs that resulted from this period would appear to have as much

Table 2
Pacific Island based programs for renewable energy shipping during 1980s oil crisis.
Source: [11] summarized from [12,18,19,22,23,46].

Project	Description	Outputs	Agencies	Comments
Fiji soft sail retrofit (1984–6)	Auxiliary rig designed and retrofitted to two government vessels of ~300 ton. Rigs built and installed in-country	Fuel savings 23–30%, but also 30% engine/prop wear reduction, greater stability, increased passage times. IRR on best route=127%, average route=33%	ADB, Southampton University, McAllister Elliot	Southampton University collated historical wind data for all Fiji routes and produced fuel saving ratios for all routes.
Lau Passenger/cargo Vessel (1984–7)	50-ton sail trading vessel, built on Kabara by local builders (1984–87). First of 3 vessels to service Lau and Lomaiviti Groups.	*Tai Kabara* became the main vessel operating on the Sth Lau route until she was scuttled in 2006. Used local materials wherever possible.	European Union	Construction of the other two ships was canceled when the oil crisis abated.
Ha'apai Energy efficient Freighter (1982–3)	Needs assessment led to commissioning vessel build plans	Needs assessment, transport census and full build plans for a 100-ton energy efficient freighter	UNESCAP, UNCTAD, UNDP, ADB	Vessel never constructed due to end of crisis. Similar needs assumed today.
Save the Children Fund/ Jim Brown (1981–3)	Save the Children Fund Tuvalu employed catamaran designer Brown to develop locally built boats for Tuvalu/Kiribati	A range of designs and processes for locally built/operated catamarans for artisanal and commercial fishing and local and inter-island transport. Training of local shipwrights. Local materials favored	Save the Children Fund	This project closely associated with the FAO/UNDP project. Local build/materials used wherever possible. Fuel savings of up to 60%.
FAO/UNDP (1982–9)	Multi-county fisheries program to develop RE artisanal/commercial vessels for local community benefit.	A portfolio of 10 designs from single dugouts to 11 m trimarans. 350 vessels built in 8 countries. Demonstrated need for vessels to be affordable and locally appropriate.	FAO UNDP	Uptake ceased with end of project and falling fuel prices. Communities with 'living tradition' of sail had greatest uptake.

[7] *Drua* – traditional Fijian double-hulled sailing vessels.
[8] See URL ⟨https://www.usp.ac.fj/sstt2014⟩.

applicability now as they did then. USP's research to date indicates there would be strong potential for multiple benefits from revisiting this body of practical work now, especially given advances such as in rotor technology, sail design, photovoltaics and battery storage.

USP has repeatedly approached all the agencies that were involved in financing renewable energy innovations for shipping in the Pacific in the past, including ADB, UNDP, UNESCAP and the EU. While all have been sympathetic, all have stated that it is not a current priority area and all have declined to consider funding, either by grant or loan, for this sector. The reasons for this are complex and an attempt has been made to identify these in a recent paper on policy and financing barriers [11], using ADB as a particular case study given that ADB has long been the principal loan source for infrastructure and transport in the Pacific. Whether such agencies can be convinced to change their priorities and include low carbon transport solutions in future funding rounds will largely depend on whether this call is taken up with any strength by Pacific Island leaders and then how effectively the agencies can respond. As it has not already been prioritized in the major agency work plans, in a competitive funding environment with multiple demands and priorities, sustainable sea transport is penalized.

There are some encouraging signs of an imminent wind shift by some agencies. The current UNDP climate change adaption program provides a good example. UNDP are currently advertising internationally to lease a vessel for three years to transport one to five tons of cargo and 5–15 passengers between Tuvalu islands and atolls to support their existing programs. In 1981 Jim Brown, working for Save the Children in Tuvalu proposed a design of a 62-foot trimaran capable of carrying 10 ton of cargo and 25 passengers that would save 60+% of fuel for exactly this type of project [55]. USP researchers contacted UNDP to ask if a low carbon solution is possible. Prior to this approach the current UNDP staff were all unaware of the previous work, not surprisingly as it is over 30 years ago. Yet Jim, his sons and his boats are well remembered by older Tuvaluans talked to, including the Prime Minister and Foreign Minister. Although UNDP's planning cycle is well advanced they have indicated a strong willingness to consider low carbon transport solutions for this project and to investigate a low carbon transport program for Tuvalu in the future.

Working with partners in the Republic of the Marshall Islands (RMI) USP is seeking funding to develop an “intra-lagoon transporter” specifically for the needs of atoll communities. Again, the groundwork was undertaken by Jim Brown and his sons, who in the 1980s built an 11 m prototype that operated successfully in Tuvalu. She was designed to carrying 10 people or 1000 coconuts. Such a vessel would have immediate application for all atoll communities throughout the Pacific and strong interest has been expressed from Tuvalu and Tokelau. Again, it is case of waiting for the outcome of external donor organizations processes.

8.3. Initiating case study research

Shipping movements and operations tend to be poorly documented and reported. The number of operators is small, data is viewed as being commercially sensitive, and real world reporting to regulatory authorities is often either missing or fabricated.

There is need to establish reliable data sources and to undertake preliminary economic analysis of the potential costs and benefits accruable by renewable energy shipping. Ultimately, there will not be substantial financial investment at any scale until the economic viability of the technology can be practically demonstrated to both industry regulators and operators. A comprehensive overview is beyond the resources currently available and so a series of complementary case studies will be used to highlight potential in differing operating scenarios. The case studies are being developed in postgraduate research theses by USP and visiting candidates and address different aspects of the priorities identified in SSTT 2012. They include development of a methodology for assessing village level sea transport demand and fuel use; modeling of an uneconomic shipping route in Southern Fiji; evaluation of potential for carbon trading in emissions reductions for Vanuatu; considering the role of PIC independent registries in climate change negotiations and development of a Marginal Abatement Cost Curve for Fiji's transport sector.

The use of masters and doctoral case study-based research as an initial means of covering the wide range of research needed to support a transition to low carbon transport would appear a judicious use of scant resources.

8.4. Planning a Regional Research and Education Strategy

One of the major outputs to date has been the preparation of a Regional Research and Education Strategy (RRES), a medium-term work plan designed to be complementary to existing regional transport, energy, climate change and economic development strategies. It favors a ‘bottom-up’ approach, focusing first on domestic local transport needs. The lack of profile to date on renewable energy transport allows us the opportunity to learn from the lessons of the electricity sector and to develop a region-wide, coordinated and monitored program of transition.

Supporting individual PIC country programs that provide a pathway to low carbon sea transport solutions is the prime objective. Each country has differing needs and priorities and PICs are at differing stages in policy development and fleet replacement cycles. Country scenarios range from major regional transshipment hubs to atolls without ports. There are also strong regional synergies and similarities. Country programs require consideration of policy in a number of sectors including energy, transport, climate change, economic development, infrastructure, and disaster management. Table 3 shows the template approach USP are suggesting using for developing country programs.

The program for implementing the RRES comprises four interrelated areas:

- *Partnerships, Networking and Advocacy*
  A successful pathway to low carbon shipping for PICs requires a strong country and regional network supported by international partners. It requires active collaboration with multiple actors and strong advocacy. The first step for USP has been to establish, in partnership with IUCN and WWF regional offices, the Oceania Centre for Sustainable Transport (OCST) as a knowledge exchange, research and education tool (see below).
- *Capacity Building and Education*
  Empowering today's decision-makers at all levels requires targeted training and exchange, and provision of quality information and analysis. Preparing future decision-makers and embedding in-country expertize through education and internships is also required. This applies to both focal points of the sea transport debate for Pacific leaders: the ‘home game’ of developing more appropriate and affordable transport solutions; and the global theater of GHG emissions.
- *Economic Analysis and Technology Development*
  Building collaborative programs with leading research centers to deliver quality economic and technical analysis and support at a scale to make significant difference over time will be essential. There is much to be gained through regional collaboration. For example, developing an appropriate solution for atoll states in northern Micronesia is likely to have strong potential for Tuvalu and Tokelau. Developing solutions in other SIDS and maritime countries, such as Indonesia, are likely to have important lessons and models for the Pacific.

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Table 3
Suggested Country Program Framework for Fiji.

	Policy								**Economics**							
	Strategic				Infrastructure				Fiji route case studies				International route case studies			
	International	Regional	National	Agency	Qualifications	Survey	Licensing	Finance: tax, insurance	Southern Lomaiviti	Kadavu	Lau	Rotuma	Central Polynesia	MSG	Micronesia	
Relevant Plans	IMO regulations – MARPOL Annex VI and associated MDM/MMBIs	Pacific Plan; FATS; FAESP; etc.	Transport, Energy, Climate Change; economic Development policies/plans,	World Bank; ADB; UNESCAP; UNDP; Bilateral donor strategies; etc.	Master/crew. Intentional standards, MSAF standards	MSAF regulation	MSAF, FIRCA									
Scoping (current, gap analysis, needs analysis)																
Research/Action Project Plan																
Monitoring and Reporting Framework																

	Heritage			**Practical Trials**				**Teaching**			**Additional Research**
	Traditional Knowledge	Vessel construction	Voyaging	SVV (Sustainable Village Vessels)	100 ton cargo/ pax	200–300 ton freighters	Retrofitting Sail/Rotor rigs	Practical	Theory		
								Seafaring (Mariner – Master IV), Construction, Naval Architecture, Engineering, Survey, Heritage)	Undergraduate (Dip , Bachelors)	Postgraduate (Dip, Masters, PhD)	Data collection (all sectors), MARPOL Annex VI, Carbon Trading (financial mechanisms), Flettner technology, Electric motors, Franchise/Subsidies, emerging technologies
Relevant Plans					Design, Build, Pilots, Ops, Ownership/Management models	Design, Build, Pilots, Ops, Ownership/Management models	Lease Pilot for trials. Ownership/Management models	Sail and Rotor designs, testing	Economics, Marine Studies, Physics, Technology, Climate Change, Law, Pac Studies, History		
Scoping (current, gap analysis, needs analysis)											
Research / Action Project Plan											
Monitoring and Reporting Framework											

- *Applied Research*
  Transition requires proof of concept in a commercial environment. It is argued here that this can best be achieved by applying research and development trials in the areas of greatest benefit.
  Despite the obvious correlation between sea transport and almost any other development sector in the region, shipping is considered under 'mitigation' rather than 'adaption' in climate change responses. This, coupled with the marginal economic viability of most domestic shipping in the Pacific and the high-risk investment nature of the industry, makes sourcing funding for research or financing of 'field trial' projects extremely difficult.
  While private-public partnerships have been mooted as the solution, the research suggests there is strong case for initial support from development agencies and donor or green-growth fund type programs acting alone if necessary.

RRES presents an ambitious program and implementation will require significant dedicated funding. This needs to be placed in the context of the more than US$ 500 million currently scheduled by the donor community to reducing diesel dependency for electricity generation – approximately 20% of the region's fuel use. Maintaining connectivity through appropriate affordable and accessible transport is at least as critical to the region's development and sustainability agendas as providing access to clean electricity.

8.5. Building foundations for long term relationships and a center of excellence

OCST has been established as a tool and focal point to provide information, technical knowledge and support and collaboration for PICs wishing to transit to low carbon transport. The partners offer OCST as a catalyst for collaboration and invite others to join. OCST is not claiming any ownership or dominance of this field and seeks partnerships with any willing and relevant party. OCST has no physical space but a common vision and a shared website.

USP's long-term vision is a virtual regional center of excellence providing a coordinated applied research, development and delivery hub for the Pacific Islands, providing capacity building, trialing, monitoring and assessment of alternative forms of transport. The reward would be a Centre that can act as a conduit for a broader transformative change of Pacific societies using nature-based solutions and driving ecosystems-based solutions to the development challenges.

9. Recent developments and conclusion

This paper was originally presented at the Tyndall Research hosted 'Conference on Shipping in Changing Climates', Liverpool, 18th–19th June 2014 and reported on the major outcomes of the work program undertaken since SSTT 2012. In the ensuing year a number of developments have occurred of direct relevance to the issues discussed above. This paper was reviewed prior to COP21.

Firstly, USP successfully hosted the second SSTT in July 2014. Building on the first successful SSTT held in Suva in 2012, the second SSTT again brought together key stakeholders from the region and internationally with an interest in heritage, culture, seafaring, science, vessel design, economics, policy, regulation, and industry to celebrate Oceania's seafaring heritage and progress planning towards a sustainable seafaring future.

Secondly, the discourse has continued against a backdrop of falling world oil prices since the third quarter of 2014 by about half from record highs of well over US$ 100 a barrel. This change in price trend caught all commentators by surprise and the longevity of this price reduction is unknown.

Thirdly, the past year has seen the centrality of sea transport to PICs and the need for low carbon shipping solutions for Pacific and international scenarios increasingly highlighted in strategic level policy including the "S.A.M.O.A. Pathway" [56], Fiji's "Green Growth Framework" [57], the PIDF "Suva Declaration on Climate Change" [58], and the Pacific Smaller Island States' "Port Moresby Declaration on Climate Change" [59]. The specific references emanating from the S.A.M.O.A. Pathway are particularly encouraging. While previously recognized as a major impediment to development, sea transport's inclusion into architecture such as the Sustainable Development Goals has been in the nature of a 'cross-cutting' issue and this has contributed to its invisibly in lower order and donor policy instruments.

In May 2015 the RMI, supported by other Pacific states, requested the IMO commit to ambitious sector wide shipping emission reduction targets in advance of 21st Conference of the Parties (COP21). Although the IMO declined this submission at the time, its subsequent endorsement by PIDF and the Pacific Smaller Island States will now see the request revisited in 2016 meetings of the IMO.

The RMI has mirrored its call for global action on shipping with an Intended Nationally Determined Contribution commitment to COP21 of a reduction of 16% of its own transport emissions by 2025 and will establish the Micronesian Sustainable Transport Center as a center of excellence to spearhead a Micronesian transition to low carbon transport, commencing with sea transport. This catalytic action strategy by the RMI government has subsequently been endorsed by the 15th Micronesian Presidents' Summit in its "Boknake Haus Communiqué" [60].

In keeping with the action research program design as articulated in Prasad et al. [1] a further paper will be presented in 2016 covering the program outcomes and principal findings in the period ending with Paris Agreement achieved at COP21 at the end of 2016. The Paris Agreement, the current dramatic fall in world oil prices and the critical forthcoming 69th meeting of the Maritime Environment Protection Committee scheduled at the IMO in April 2016 herald major wind shifts in the international maritime transport sector. Each potentially will have profound effects on the unique sea transport scenario of PICs.

References

[1] B. Prasad, J. Veitayaki, E. Holland, et al., Sustainable sea transport research programme: toward a research-based programme of investigation for Oceania, J. Pac. Stud. 33 (2013) 78–94.
[2] H. Hackmann, A.L. St. Clair, Transformative Cornerstones of Social Science Research for Global Change. International Social Science Council, May 2012. ⟨http://www.worldsocialscience.org/documents/transformative-cornerstones.pdf⟩.
[3] Asian Development Bank, Oceanic Voyagers: Shipping in the Pacific, Asian Development Bank, Manila, 2007.
[4] A.D. Couper, Sailors and Traders: A Maritime History of the Pacific Peoples, University of Hawai'i Press, Honolulu, 2009.
[5] Secretariat of the Pacific Community, Framework for Action on Transport Services 2011–2020, Improving the Efficiency, Effectiveness and Sustainability of Pacific Transport Services. Secretariat of the Pacific Community, Suva, 2011.
[6] P. Nuttall, Sailing for Sustainability: The Potential of Sail Technology as an Adaptation Tool for Oceania Ph.D thesis, Victoria University, Wellington, 2013.
[7] L. Mofor, M. Isaka, H. Wade, A. Soakai, Pacific Lighthouses, Renewable Energy Roadmapping for Islands, IRENA, Bonn, 2013.
[8] S. Fifita, Prospects of the use of renewable energy in transportation sector. Presented at the Japan IRENA joint workshop: Accelerating renewable energy deployment in the Pacific region: Meeting the challenges. 25–26 May. Okinawa, 2011.
[9] Tuvalu Department of Energy. 2012 Energy Statistical Report: Tuvalu. Ministry of Public Utilities, Funafuti, 2012.
[10] P. Nuttall, A. Newell, B. Prasad, et al., A review of sustainable sea-transport for Oceania: providing context for renewable energy shipping for the Pacific, Mar. Policy 43 (2014) 283–287.
[11] P. Nuttall, A. Newell, A. Bola, et al., Policy and financing—why is sea transport

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currently invisible in the search for a low carbon future for Pacific Island Countries? Front. Mar. Sci. 1 (20) (2014) 1–10, http://dx.doi.org/10.3389/fmars.2014.00020.

[12] P. Nuttall, Steering a course for the future with sticks, stones, grass and a little sharkskin: the case for revitalisation of sail technology and sailing culture as a practical sea-transport response to climate change and fossil fuel dependence/supply issues in Fiji, J. Pac. Stud. 32 (2012) 163–175.

[13] P. Fagerlund, B. Ramne, Background, structure and objectives of the EffShip project. Presentation to the EffShip Project, Final Seminar, Gothenburg, March 21, 2013. ⟨http://effship.com/PublicPresentations/Final_Seminar_2013-03-21/01_EffShip-Background,_structure_and_objectives_of_the_EffShip_project-Bengt_Ramne,_Per_Fagerlund_ScandiNAOS.pdf⟩.

[14] B. Allenstrom, Wind propulsion. Presentation to the EffShip Project, Final Seminar, Gothenburg, March 21, 2013. ⟨http://www.effship.com/PublicPresentations/Final_Seminar_2013-03-21/06_EffShipWind_propulsion-Bjorn_Allenstrom_SSPA.pdf⟩.

[15] M. Stopford, How shipping has changed the world and the social impact of shipping, Global Maritime Environmental Congress 7th September 2010, SMM Hamburg, 2010.

[16] Lloyd's Register. Wind-powered shipping: a review of the commercial, regulatory and technical factors affecting uptake of wind-assisted propulsion. Lloyd's Register, London, 2015.

[17] L. Mofor, P. Nuttall, A. Newell, Renewable Energy Options for Shipping: Technology Brief, IRENA, Bonn, 2015.

[18] Asian Development Bank, Proceedings of Regional Conference on Sail–Motor Propulsion. Manila, Philippines: Asian Development Bank, pp. 18–21 November, 1985.

[19] J. Brown, New Water Working Craft: Special Report. The National Conference on Applications of Sail-Assisted Power Technology, Norfolk, Virginia, 1981.

[20] B.R. Clayton, Wind Assisted Ship Propulsion, Phys. Technol. 18 (1987) 53–60.

[21] J.L. Eyre, C.E. Philp, General Purpose Sailing Vessel to Service Ha'apai Group, UNDAT, Suva, 1982.

[22] Food and Agriculture Organisation of the United Nations. Artisanal Fishing Craft of the Pacific Islands. Based on the Work of Ø. Gulbrandsen and M. Savins. Suva: FAO/UNDP Regional Fishery Support Programme, RAS/87/002, 1987.

[23] C.J. Satchwell, Windship Technology, in: Proceedings of the International Symposium on Windship Technology (Windtech '85). Southampton, UK, April 24–25, 1985.

[24] United Nations Economic and Social Commission for Asia and the Pacific. Wind-Powered Vessels for Coastal and Inter-Island Use in the Asian and Pacific Region. Technical papers submitted to the Meeting of Experts on the Application of Windpower in Shipping. Tokyo/Niigata, 14–16 April 1984.

[25] M. Acciaro, P.N. Hoffman, M.S. Eide, The energy efficiency gap in maritime transport, J. Shipp. Ocean Eng. 3 (1–2) (2013) 1–10.

[26] M. Acciaro, P.N. Hoffman, M.S. Eide, Identifying and Overcoming Barriers to the Implementation of Emission Reduction Measures in Shipping, Det Norske Veritas Report No. 2010–1800, 2012.

[27] I. Rojon, Blowin' in the wind? Possibilities of the International Maritime Organization to Promote the Uptake of Wind Propulsion in International Shipping Master's thesis, Utrecht University, The Netherlands, 2013.

[28] I. Rojon, C. Dieperink, Blowin' in the wind? Drivers and barriers for the uptake of wind propulsion in international shipping, Energy Policy 67 (2014) 394–402.

[29] International Council on Clean Transportation 2011, Reducing Greenhouse Gas Emissions from Ships: Cost Effectiveness of Available Options. ICCT, Washington, 2011. ⟨http://shippingefficiency.org/userfiles/files/ICCT.pdf⟩.

[30] J.-P. Rodrique, Maritime transportation: drivers for the shipping and port industries. International Transport Forum on Transport and Innovation: Unleashing the Potential, Leipzig, 26-28 May, 2010. Forum Paper 2, 23 p.

[31] E. Holland, P. Nuttall, A. Newell, et al., Connecting the dots: policy connections between Pacific Island shipping and global CO_2 and pollutant emission reduction, Carbon Manag. 5 (1) (2014) 93–105.

[32] A. Newell, A. Bola, The Solodamu Surveys: determining fossil fuel use and sea transport need in a coastal village in Fiji, Front. Mar. Sci. 2 (2015) 59, http://dx.doi.org/10.3389/fmars.2015.00059.

[33] Ø. Buhaug, J. Corbett, Ø. Endresen, V. Eyring, J. Faber, S. Hanayama, D.S. Lee, D. Lee, H. Lindstad, A.Z. Markowska, A. Mjelde, D. Nelissen, J. Nilsen, C. Pålsson, J.J. Winebrake, W. Wu, K. Yoshida, Second IMO GHG Study 2009, International Maritime Organisation, London, 2009.

[34] Z. Bazari, T. Longva, Assessment of IMO Mandated Energy Efficiency Measures for International Shipping. Lloyds Register and Det Norske Veritas, 2011.

[35] M.S. Eide, O. Endresen, A. Mjelde, L.E. Magnset, G. Gravir, Ship emissions of the future. Report for EC Quantify project, Deliverable D1.2.3.2, Det Norske Veritas, 2007.

[36] J.J. Corbett, H.W. Kohler, Updated emissions from ocean shipping, J. Geophys. Res. (2003) 108, http://dx.doi.org/10.1029/2003JD003751.

[37] O. Endresen, E. Sorgard, J. Sundet, S. Dalsoren, I. Isaksen, T. Berglen, G. Gravir, Emission from international sea transportation and environmental impact, J. Geophys. Res.-Atmos. 108 (2003), No D17, 4560, 14-1 –14-22..

[38] V. Eyring, H.W. Kohler, A. Lauer, B. Lemper, Emissions from International Shipping: 2. Impact of future technologies on scenarios until 2050, J. Geophys. Res. 110 (2005) D17306.

[39] O. Endresen, S. Dalsoren, M. Eide, I.S. Isaksen, E. Sorgard, The environmental impacts of increased international maritime shipping, past trends and future perspectives. OECD/ITF Global Forum on Transport and Environment in a Globalising World, Guadalajara, Mexico, 2008.

[40] A. Bows, M. Traut, P. Gilbert, S. Mander, C. Walsh and K. Anderson. Aviation and shipping privileged – again? Briefing Note No. 47 December 2012. Tyndall Centre for Climate Change Research, Manchester University, Manchester.

[41] A. Bows-Larkin, Pathways to low-carbon international transport: a comparison of shipping and aviation. Paper delivered at the Low Carbon Shipping Conference, London 2013.

[42] A. Bartmanovich, Petroleum Pricing Assistance to PICTS. PowerPoint presented to Energy and Transport Officials Meeting Nadi, Fiji, 31, 2014.

[43] M. Stopford, The Tanker, Dry Cargo Outlook, Mareforum, Rome 8th May 2013, Rome.

[44] K.S. Ribeiro, S., Kobayashi, M. Beuthe, et al. Transport and its infrastructure. in: B. Metz, et al. (eds) Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press, 2007, pp. 323–385.

[45] Royal Academy of Engineering, Future Ship Powering Options: Exploring Alternative Methods of Ship Propulsion, Royal Academy of Engineering, London, 2013.

[46] C.J. Satchwell, Preliminary analysis of log data from the Fiji windship 'Cagidonu' Ship Science Reports, University of Southampton, Southampton (1986), p. 24.

[47] J. Veitayaki, B. Aalbersberg, A. Tawake, et al., Mainstreaming resource conservation: the Fiji Locally Managed Marine Area Network and its influence on National Policy Development, Resource Management in Asia-Pacific Working Paper No. 42, Resource Management in Asia-Pacific Program, Research School of Pacific and Asian Studies, ANU, Canberra, 2003.

[48] J. Veitayaki, D. Akosita, R. Nakoro, T. Sigarua, N. Bulai, On cultural factors and marine managed areas in Fiji in Pacific island heritage: archaeology, identity and community, Terra Aust. 35 (2011) 37–50.

[49] P. Nuttall, J. Veitayaki, South Pacific and small island developing states, Oceania is vast, canoe is centre, village is anchor, continent is margin. in: H.D. Smith, et al. (eds) Routledge Handbook of Ocean Resources and Management. Earthscan Publishers, 2016, Chapter 36, p.560-575. ISBN 978-0-415-53175-7.

[50] P. Nuttall, J. Kaitu'u, The Magnus Effect and the Flettner Rotor: potential application for future Oceanic Shipping, J. Pac. Stud. (In press).

[51] A. Newell. Solodamu: A survey of fuel and transport use in a coastal village on Kadavu, Fiji. Presentation to the 12th Pacific Science Inter-Congress 'Science for Human Security and Sustainable Development in the Pacific Islands and Rim'. Suva: University of the South Pacific; 8–12 July, 2013.

[52] P. Nuttall, P. D'Arcy, C. Philp, Waqa Tabu – sacred ships: the Fijian Drua, J. Int. Marit. Hist. 26 (3) (2014) 427–450, http://dx.doi.org/10.1177/0843871414542736.

[53] M. Wilensky, Authority Of Pacific Island States To Regulate Greenhouse Gases From The International Shipping Sector. Columbia Law School, Centre for Climate Change Law, 2014.

[54] University of the South Pacific/Sailing for Sustainability Trust, 2013. Sustainable Sea Transport Talanoa 2012 Outcomes Record, (unpublished paper).

[55] S.A. Brown, The Tuvalu Vara Project. SPC Fisheries Newsletter No. 28 January–March 1983. ⟨http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/FishNews/28/FishNews28_18_Brown.pdf⟩.

[56] United Nations SIDS Accelerated Modalities Of Action (S.A.M.O.A.) Pathway Outcome of the Third International Conference on Small Island Developing States (SIDS Conference). 1–4 September 2014, Apia, Samoa. ⟨http://www.sids2014.org/index.php?menu=1537⟩.

[57] Ministry of Strategic Planning, National Development and Statistics. A Green Growth Framework for Fiji: Restoring the Balance in Development that is Sustainable for Our Future. August, 2014, Suva, Fiji.

[58] Pacific Islands Development Forum. Suva Declaration on Climate Change. 2–4 September 2015, Pacific Islands Development Forum Secretariat, Suva, Fiji. ⟨http://pacificidf.org/wp-content/uploads/2013/06/PACIFIC-ISLAND-DEVELOPMENT-FORUM-SUVA-DECLARATION-ON-CLIMATE-CHANGE.v2.pdf⟩.

[59] The Smaller Island State Leaders. Port Moresby Declaration on Climate Change, 24th Smaller Island States Leaders Meeting, 7 September 2015, Port Moresby, Papua New Guinea.

[60] The Micronesian Presidents. Boknake Haus Communiqué, the 15th Micronesian Presidents' Summit, 14–15 July 2015, Majuro, Republic of Marshall Islands. ⟨http://pace.usp.ac.fj/Portals/18/OCST/Communique/BOKNAKE%20HAUS%20COMMUNIQUE.pdf⟩.

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