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SUSTAINABLE MARITIME TRANSPORT IN THE PACIFIC ISLANDS REGION:

does alternative energy have a role?

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Prepared by the Economic Development Division
Secretariat of the Pacific Community
Suva, Fiji
2014

Secretariat of the Pacific Community
Suva, 2014

Original text: English

Secretariat of the Pacific Community Cataloguing-in-publication data

Sustainable maritime transport in the Pacific Island region: does alternative energy have a role? /
Secretariat of the Pacific Community

1. Transportation — Oceania.
Navigation – Law and legislation – Oceania.
Power resources — Oceania.
2. Energy – Oceania.

I. Title II. Secretariat of the Pacific Community

343.0966 AACR2

ISBN: 978-982-00-0715-4

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Acknowledgement

This paper was written by Julian Joy of Navskills Ltd. for the the Economic Development Division of the Secretariat of the Pacific Community.

Abbreviations

ADB	Asian Development Bank
CO_2	carbon dioxide, including equivalent gases when included in databases
EDD	Economic Development Division
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
FCL	full container load
GHG	greenhouse gas
GRT	Gross register tonnage
HFO	heavy fuel oil
IEA	International Energy Agency
IFO	intermediate fuel oil
IMO	International Maritime Organization
LED	Light emitting diodes
LNG	liquid natural gas
LPG	liquid petroleum gas
MDO	marine diesel oil
MGO	marine gas oil
PICTs	Pacific Island countries and territories
SIDS	small island developing states
SOPAC	Applied Geoscience and Technology Division
SPC	Secretariat of the Pacific Community
SPREP	Secretariat of the Pacific Regional Environment Programme
TEU	twenty-foot equivalent unit, a standard 20-foot shipping container
TOWT	Transoceanic Wind Transport
UNCTAD	United Nations Conference on Trade and Development
UNOSD	United Nations Office for Sustainable Development

Summary

This paper examines the use of sail assistance for shipping propulsion in Pacific Island countries and territories (PICTs). It considers the topic within the framework of sustainable supply chain management, within which the ships concerned must operate and conduct their functions. The paper is based on current developments and past research and experimentation, including the ADB-funded experiment in Fiji. It also draws on the author's experience in Pacific shipping, including recent experience in Tuvalu, examining that country's maritime logistics.

The International Maritime Organization (IMO) adopted the United Nations (UN) sustainable development principles, which are relevant to PICTs, and focused them on the maritime sector, concluding that this required well organised administrations, and coordinated support from shore-side entities intrinsic to shipping.[1] IMO developed some goals to assist moving along the sustainable path, covering efficiency in the ship-shore interface, a holistic energy efficiency logistics concept, availability of good quality clean fuels, and a fair societal cost distribution for the increasing costs of cleaner fuels.

Overall, the safety of lives of crew and passengers on ships must always be at the forefront of the considerations. Reliability and quality of scheduling has always been a supply chain priority, and in the current more complex global supply chains the local 'last mile' is the difficult one, needing focus. Freight costs are decreasing in PICTs, and reliability demands are increasing; however, the PICT administration effort does not appear to have matched the demands and needs.

It is important that the full aspects are considered and examined carefully, rather than looking at emotive popular issues that do not have immediate local impacts. Carbon dioxide (CO_2) emissions, for example, are very low already in PICTs, so there is little reason to spend scarce resources on that; indeed some of the programmes being implemented, such as installing plastic water tanks instead of concrete water tanks, probably have a more significant negative climatic and disposal effect than do ship operations; land (and air) transport is a far greater producer of air and water pollutants than is shipping.

Small inter-island ships burning marine diesel are actually very clean ships on the global scale; the pressure has been on the large ships of the world to burn diesel when in coastal waters. Marine diesel oil (MDO) or marine gas oil (MGO) has less than 10% of the sulphur and other pollutants compared to intermediate fuel oil (IFO) or heavy fuel oil (HFO), and is the standard fuel for PICT ships due to their small size (International Chamber of Shipping, 2012).

Methods of saving costs in shipping are always being studied, and some of the key items are available at the design stage; in addition, there are readily available operational methods, such as weather routing and good logical schedule management, that are used in effective shipping management.

Wind power, unsupported by other means of propulsion, is today used for sport, adventure and recreation. America's cup racing, for example, could be said to be the development of extreme wind power technology with unquestionably significant efficiencies; however, the use of these for PICT commercial operation is indeed limited.

There is clearly a market for sailing and hybrid ships today; the question is not whether they work – obviously they do in the right market – the question is whether they are the type of vessel appropriate for PICTs' feeder shipping services for cargo and passengers.

Comparing studies completed by ADB and others, and considering the costs of wind power options today, it is concluded that sail assistance on ships involved in regular relatively large-scale scheduled inter-island services for freight and passengers of all kinds for PICTs is not a good investment financially or operationally.

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[1] Paper prepared for the Symposium on Sustainable Maritime Transportation System, World Maritime Day, 26th September 2013.

In analysing the priorities for supply chains for PICTs, it is considered that focusing on reduction of CO_2 emissions is not the priority for the decision on ship propulsion methods. Rather the total life cost for the ship and its cargo needs to be considered, and then the emphasis must be on hull form and engine efficiency. Experimenting with kites and sails is difficult to justify for a PICT.

Requirements of service reliability and predictability make the management and governance issues of greater significance than the ship propulsion method, and effort needs to be placed in that direction.

Hybrid sail assisted vessels for PICTs are not considered a realistic commercial option. It is not in the author's view a valid area for scarce resources such as aid funding to be spent. The development of sail or hybrid systems should, therefore, be conducted on a user pays or cultural basis, rather than by emotional pressure based around CO_2 emissions. For some roles in tourism sectors and other niche operations, sail and hybrid propulsion systems certainly have a place.

Sustainability for PICTs

The definition of 'sustainability' which is currently used by IMO for its work on sustainable shipping services as well as in this paper is taken from the one given by the World Commission on Environment and Development, which is now the United Nations Office for Sustainable Development (UNOSD[2]), a part of the United Nations Department of Economic and Social Affairs:

> 1. Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:
>   - the concept of 'needs', in particular the essential needs of the world's poor, to which
>   - overriding priority should be given; and
>   - the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.
>
> 2. Thus the goals of economic and social development must be defined in terms of sustainability in all countries – developed or developing, market-oriented or centrally planned. Interpretations will vary, but must share certain general features and must flow from a consensus on the basic concept of sustainable development and on a broad strategic framework for achieving it.
>
> 3. Development involves a progressive transformation of economy and society. A development path that is sustainable in a physical sense could theoretically be pursued even in a rigid social and political setting. But physical sustainability cannot be secured unless development policies pay attention to such considerations as changes in access to resources and in the distribution of costs and benefits. Even the narrow notion of physical sustainability implies a concern for social equity between generations, a concern that must logically be extended to equity within each generation.[3]

The IMO study on sustainable shipping is summarised in the document entitled *World Maritime Day: a concept of a sustainable maritime transport system*.[4] In this study, sustainability goals are set and the key points emphasised are the following:

> A sustainable Maritime Transport System requires well organised administrations…coordinated support from the shore side entities intrinsic to shipping, such as providers of aids to navigation… port facilities, trade facilitation measures, and cargo handling and logistics systems.

A key element of the sustainability issue for PICTs is to ensure that the differing needs of industry sectors are not confused; clearly, using solar and wind technology to avoid the use of fossil fuels makes a lot of sense for land-based communities such as the urban or rural areas, and developments in this direction are to be continued. Solar power infrastructure for lighting in villages, for local navigation lights, and for many other purposes has made significant benefits to standards of comfort and safety. However, when considering applying the 'alternative energy' features to the shipping industry infrastructure, the great needs of safety of life and reliability of the ship operation take on very much higher priorities and must dominate the decision-making process. Care must be taken to consider the differences between land-based strategies and maritime strategies.

The fundamental infrastructure needs for transport for sustainable development were highlighted at the 2013 Small Island Developing States conference in Nadi, 2013 (Pacific SIDS, 2013), and will undoubtedly be a topic for consideration at the SIDS conference in Apia in September 2014.[5]

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[2] http://www.unosd.org

[3] (World Commission on Environment and Development, 1987).
Copy available at http://www.un-documents.net/our-common-future.pdf

[4] Paper prepared for the Symposium on Sustainable Maritime Transportation System, World Maritime Day, 26th September 2013.

[5] See information at http://www.sids2014.org

Sustainable supply chains for PICTs

The supply chains to PICTs have utilised the globalisation developments that have occurred throughout the world since the 1970s, with the associated increased length and complexity of supply chains. However, regardless of technology, the fundamental priorities for all supply chains remain in this order:

1. the goods (cargo or passenger)
2. the condition
3. the place
4. the time
5. the cost.

Although all these components should be given consideration, the order of priority remains of critical importance; items 1, 2 and 3 are non-negotiable – the goods or passengers must be delivered in good condition to the right place. Item 4 has some variability according to the type of good and other social factors, and item 5 is the least important. For example, a New Zealand study (Rockpoint Corporate Finance Ltd, 2009) on that country's coastal shipping services based on business surveys has established the following ranking for the logistics factors (ranking on a scale to 5):

Reliability	4.75
Product care	4.65
Safety	4.58
Timeliness	4.31
Cost	4.23

Although slightly differing terminology is used, the ranking conclusion is clear.

By using the economic specialisations of nations, including the fundamental basics of cheap labour supply and economies of scale, supply chains to PICTs have changed significantly over the years. Countries of source of supply have changed, and freight rates have decreased due to lower container rates on the main sea routes. The final sector of the supply chain, however, is always the difficult one – that's the one involving 'the Last Mile'[6], where the standard economies of scale no longer apply – and it is particularly significant for PICTs and also to landlocked countries. The 'last mile' is that portion of the global supply chain that takes the goods or the passenger to the final destination, such as into the individual household.

The 'last mile' principle applies also to both air and maritime transport, and for cargo and passenger supply chains. For example, on Fiji Airways, the lowest economy fare for flying about 8855 km from Los Angeles to Nadi is about USD 750 (FJD 1,500), which is a cost of USD 0.09 (FJD 0.17) per km, and the lowest economy fare for flying about 1180 km from Nadi to Funafuti (via Suva) is about USD 453 (FJD 856) which is a cost of USD 0.38 (FJD 0.73) per km.[7] Similarly, from the Fiji hub port of Suva to Tuvalu's port at Funafuti sea freight rates per full container load (FCL) TEU are about AUD 3,000 for general cargo, and around AUD 6,500 for refrigerated cargo. Freight rates for the same cargo on the high volume trans-Pacific sectors such as Los Angeles to Tokyo can be as low as AUD 1,500.

Figure 1[8] shows a significant if not dramatic decrease in the relative costs of freight as a percentage of imports costs for Pacific Islands – grouped here as Developing Oceania – from averaging around 12% from 1984 to 2000, then decreasing to just under 9% in 2010.

This proportion is comparable with that of 'Developing Asia' and 'Developing America', the three groupings averaging about 8%, compared to the 'Developed economies' at about 7%.

'Developing Africa' has a significantly higher proportion of freight in import prices, at about 11%, due largely to the landlocked nations and to the lack of effective infrastructure such as reliable rail, roadways and port facilities.

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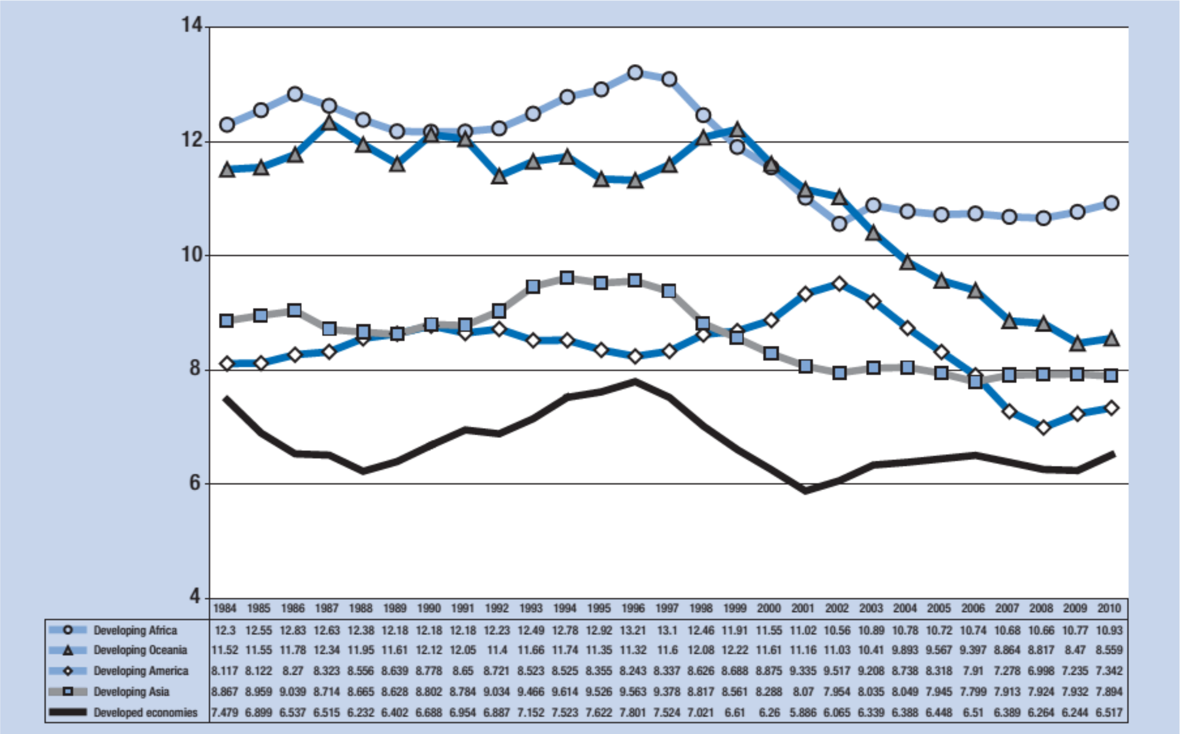
[6] The 'last mile' is a common feature of supply chain analysis where the final destinations of goods or passengers from a high-volume long-distance transport system (e.g. the container service USA to Fiji) causes distribution complexity when the economies of scale are broken down by the complex spread of these final destinations (e.g. to outer islands or small rural villages).

[7] Calculations by author for a sample flight Los Angeles to Funafuti, based on Fiji Airway's Bula Saver fares on http://booking.fijiairways.com January 2014.

[8] Sourced from UNCTAD, Review of Maritime Transport, 2012, page 74.



	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Developing Africa	12.3	12.55	12.83	12.63	12.38	12.18	12.18	12.18	12.23	12.49	12.78	12.92	13.21	13.1	12.46	11.91	11.55	11.02	10.56	10.89	10.78	10.72	10.74	10.68	10.66	10.77	10.93
Developing Oceania	11.52	11.55	11.78	12.34	11.95	11.61	12.12	12.05	11.4	11.66	11.74	11.35	11.32	11.6	12.08	12.22	11.61	11.16	11.03	10.41	9.893	9.567	9.397	8.864	8.817	8.47	8.559
Developing America	8.117	8.122	8.27	8.323	8.556	8.639	8.778	8.65	8.721	8.523	8.525	8.355	8.243	8.337	8.626	8.688	8.875	9.335	9.517	9.208	8.738	8.318	7.91	7.278	6.998	7.235	7.342
Developing Asia	8.867	8.959	9.039	8.714	8.665	8.628	8.802	8.784	9.034	9.466	9.614	9.526	9.563	9.378	8.817	8.561	8.288	8.07	7.954	8.035	8.049	7.945	7.799	7.913	7.924	7.932	7.894
Developed economies	7.479	6.899	6.537	6.515	6.232	6.402	6.688	6.954	6.887	7.152	7.523	7.622	7.801	7.524	7.021	6.61	6.26	5.886	6.065	6.339	6.388	6.448	6.51	6.389	6.264	6.244	6.517

Figure 1: Freight costs as a proportion of import product value

Much of the improvement in the Pacific can be considered as being due in large part to the container ship hub system, enabling economies of scale on the main sectors of trade.

The UN has developed a 'liner shipping connectivity index' to compare access to liner container services. The Liner Shipping Connectivity Index captures how well countries are connected to global container liner shipping networks. It is computed by the United Nations Conference on Trade and Development (UNCTAD) based on five components of the maritime transport:

1. the number of container companies serving the country;
2. the container-carrying capacity (TEU) of the largest ship serving the country;
3. the number of different services serving the country;
4. the total number of ships; and
5. the total container capacity (TEU) of all the ships serving the country.

Positive changes to the connectivity indicate an improvement in service options. Figure 2[9] shows changes for available nations in the Pacific area. The table shows that direct connectivity has dramatically increased for Fiji, Palau and Solomon Islands, but reduced everywhere else. This reflects the increased role of these countries as feeder ports for the smaller PICTs as the size of container ships increases for the longer voyages, such as from USA. Many of the cargoes carried in the container ships are subject to a second transhipment or domestic logistics movement by sea, usually in a breakbulk form, and the index does not consider this type of service.

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[9] Based on connectivity index data available at http://unctadstat.unctad.org/TableViewer/tableView.aspx?ReportId=92

Country	**Connectivity Index 2013**	**% Change since 2004**
Fiji	12.05	45.9% improvement
French Polynesia	9.9	–5.4%
Guam	7.85	–25.2%
Kiribati	2.91	–4.9%
Marshall Islands	2.91	–16.6%
FSM	2.17	–22.5%
New Caledonia	9.23	–6.1%
New Zealand (for comparison)	18.95	–9.2%
Northern Marianas	1.37	–36.9%
Palau	2.17	108.7% improvement
PNG	6.61	–5.2%
Samoa	4.19	–23%
Singapore (for comparison)	106.91	30.6% improvement
Solomon Islands	6.04	66.9% improvement
Tonga	3.17	–16.8%
Vanuatu	3.42	–12.8%

Figure 2: Liner service connectivity for the Pacific region

Therefore, the key development area for PICTs must be efficient feeder service operators from these hub port areas, which means efficient ports and related services. For cargo moving from a hub port to a smaller feeder or destination port, the most significant cost items are related to the ports and their operation, including stevedoring, time lost due to official and organisational activity delays, equipment limitations, and working practices and organisation in the ports.[10]

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[10] World Bank and UNCTAD are focusing on this issue as it has been identified as the source of major cost issues in African countries.

What are PICTs' maritime transport problems that need solutions?

To achieve a sustainable PICT maritime transportation system, first it is necessary to examine the current situation, compare it to the global shipping situation, and consider possible actions for improvement. These improvements must be related to the logistics of the goods, their condition, place, time and cost.

The first three items – getting the right goods to the right place in the right condition – are unchanged over history and have always been the main priority items in logistics, but the fourth item, time, is significantly changed in recent years by increasing demand for a shorter and more reliable time of achieving the first three items. This is, of course, a global change, and it is probably safe to say that PICTs are increasingly involved in desiring shortened time frames for events, which is why air transport is often a preferred mode of transport where available. Air transport has developed a relatively good reputation for reliability in the Pacific region compared to shipping, often for political reasons.

It is important to define, when considering the 'cost' item, whether economic external costs are included in the calculations; for business calculations, external economic or social costs and benefits are not considered.

The most common complaint received from small islands states that do not have a hub port centre is the unreliability of the scheduling of ships, i.e. the predictability of the time of arrival or departure, not the frequency of service. Reliability and predictability are crucial for business and personal planning. A weekly or monthly service is acceptable and can be planned for as long as it is reliable. Pitcairn Island, for example, has a service funded by the UK Government and supplied by a New Zealand private operator (Stoney Creek Shipping Company's vessel *Claymore II*). The schedule is planned and advertised well ahead,[11] enabling persons to plan and schedule events early. The Pitcairn schedule is not daily, nor weekly, nor is it evenly spaced, but it is predictable and reliable. This predictability has assisted Pitcairn Island to develop a niche tourism industry, coupled with visits by cruise liners.

A schedule two years ahead such as this is an indicator of the importance of reliability, and most PICTs could begin to emulate such management logic; even a six-monthly or at most an annual schedule would be of significant improvement in value to users of the services, and save significant costs in the supply chain due to less expediting and less loss of product.

Many products need to be procured and sourced three or more months ahead of the desired delivery time at the final destination island, so scheduling of local shipping further ahead than that is important to enable adequate procurement planning. In addition, the significant health and social costs related to an unpredictable shipping service are intuitively well known; it is the political will to establish the required reliability that is needed.[12]

Added to this are the environmental factors that PICTs wish to consider as their islands become, in common with many parts of the world, under huge population pressure. Resulting political efforts have often focused on long-term topics such as climate change, air pollution, CO_2 and so on, sometimes at the expense of immediate, real, pressing, local issues such as rubbish treatment, water and health.

Monitoring press items from Tuvalu and Kiribati, for example, could lead a reader to believe that environmental issues due to global climate change are destroying the nations' islands, whereas it is equally arguably not the case. Local governance issues such as water supply, waste-water treatment, rubbish removal, and health and social issues have a much wider and more immediate impact, and are largely under the control of PICT governments.

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[11] The Pitcairn Island schedule for all of 2014 and 2015 can be seen here and in the appendix: http://www.visitpitcairn.pn/visitpitcairn/shipping/index.html

[12] Documentation of this is not adequate; however, a recent study, as yet incomplete and unpublished, for NZAID in Tuvalu referred to examples of the costs to life and health because of unpredictable and unreliable shipping services to and from the outer islands of Tuvalu. (Beca International Consultants, 2014).

Some of these real priority factors are selected here from the SPREP Pacific Environment and Climate Change Outlook report.

- Housing, food and other needs of growing population are placing limited land resources under intense pressure.
- Organic and chemical waste has become a major problem for both land and sea.
- Availability of freshwater varies highly, but demand is rising across the region.
- Leakage in water systems affects up to 50 per cent of water supply.
- Water conservation practices (e.g. rainwater collection) have not been taken up widely.
- Plastics (including marine litter) are a priority pollution threat.[13]

What is important here is that the full aspects are considered and examined carefully, rather than looking at emotive popular issues that do not have immediate local impacts. CO_2 emissions, for example, are very low already in PICTs, so there is little reason to spend scarce resources on that as such action will have no effect on any of the above-listed items. Indeed, some of the programmes being implemented, such as installing plastic water tanks instead of concrete water tanks, probably have a more significant negative climatic and disposal effect than ship operations.

In addition, in 2011, 75% of global CO_2 emissions from transport were caused by road transport, 11% by other domestic transport, 6% by aviation, and the remaining 8% by maritime transport.[14] PICT administrations can make significant improvements in CO_2 emission by ensuring that existing road vehicles are better maintained, for example.

Figure 3 shows CO_2 emissions for 2010 from all sources, from all transport sources and from maritme sources for PICTs and selected other nations for comparison.[15]

Country or group of countries	**Total all sources, kg CO_2**	**All transport sources; 22% of total**	**Maritime transport sources; 8% of all transport**
World total	**4,900**	**1,078**	**86**
United States of America	17,600	3,872	310
OECD members	10,100	2,222	178
Caribbean small states	9,900	2,178	174
EU area	7,300	1,606	128
China	6,200	1,364	109
East Asia & Pacific	4,900	1,078	86
South Asia	1,400	1,400	25
PICTs	**1,100**	**242**	**19**
'PICTs' Includes:			
Fiji	1,500	330	26
Kiribati	600	132	11
Marshall Islands	2,000	440	35
FSM	1,000	220	18
Palau	10,600	2,332	187
Samoa	900	198	16
Solomon Islands	400	88	7
Tonga	1,500	330	26
Tuvalu*	60	13	1
Vanuatu	500	110	9

Figure 3: CO_2 emissions, kilograms per capita, for 2010

* *Tuvalu's greenhouse gas emissions are too small to register on these global databases; the amount of 60 kg per person is calculated by the author simply on population proportions, based on Kiribati, so probably overstates the emissions. (Kiribati population 110,000, Tuvalu population11,000)*

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[13] SPREP report sourced http://www.unep.org/pdf/PEECO.pdf.

[14] Sourced online at: http://www.iea.org/publications/freepublications/publication/CO2EmissionsFromFuelCombustionHighlights2013.pdf

[15] Calculations based on the IEA and World Bank data sources, from data at http://data.worldbank.org/topic/environment.

Therefore, when considering the operation of a sustainable supply chain, and the type of shipping services needed for the local distribution sector of that chain, it is important to prioritise factors logically. Apart from perhaps Palau, PICTs should not be subsidising the rest of the world for carbon emissions.

Clearly however, if a PICT can obtain investment funds for alternative shore-based energy sources, such as solar, wind or hydro power, for lighting and other needs to reduce the cost of importing liquid or gas fossil fuels, then this certainly needs pursuing as a potential sound investment.

In the following section, the PICT ship as a transport unit in the supply chain is examined.

The PICT maritime transport unit – the ship

While container ships or bulk tankers are used to deliver to hub ports such as Suva or Funafuti, from there on it is handling units or 'breakbulk' ships that transport goods to the smaller islands. This type of ship is also called a general cargo ship; it carries pallets and individual units such as loose bags, roofing material and LPG gas bottles.

A possible allocation of the costs involved in operating a typical small PICT ship could be as follows, with a total of USD 1.5 million per annum.[16]

Cost item	Indicative USD	% of costs	Action available to reduce costs
Crew costs	355,000	24%	Careful management is needed
Fuel	620,000	41%	Careful management & scheduling of ships
Maintenance	150,000	10%	Usually not enough, needs increasing
Management	115,000	8%	Usually not enough, needs increasing
Insurance allowance	60,000	4%	Probably self-insured
Capital	200,000	13%	If a fully aid-funded project, zero cash capital cost occurs; however, the equivalent lost opportunity cost must be included.
Total annual	1,500,000	100%	

Figure 4: Cost allocations of typical inter-island feeder ship

Currently, PICT governments or shipping operators make their savings in (a) the capital cost by buying old ships[17] or being totally dependent on aid programmes to supply new ships;[18] (b) in the maintenance cost by not doing it and/or installing low standard parts; and (c) in the management cost by not having enough of it.

The significant PICT problems are the low level of reliability and predictability of schedules. This is a management issue firstly, and a resulting technical issue, secondly. Following that is the operational cost control and how fuel costs can be decreased or maintained as appropriate.

It is interesting to note that these problems are a focus of Objectives 3 and 4 of the Secretariat of the Pacific Community (SPC) through its Economic Development Division (EDD) (Economic Development Division SPC, 2013), which can be read as follow:

> 3: To strengthen institutions and expertise in the energy and transport sectors.
> 4: To improve access to affordable and efficient energy and transport services.[19]

Methods of saving costs in ship design and construction are always being studied, and the following useful summary (Johnson, 2013) in Figure 5 lists some of the key items that are available at the design stage; in addition there are readily available operational methods, such as weather routing and good logical schedule management, that are used in effective shipping management.

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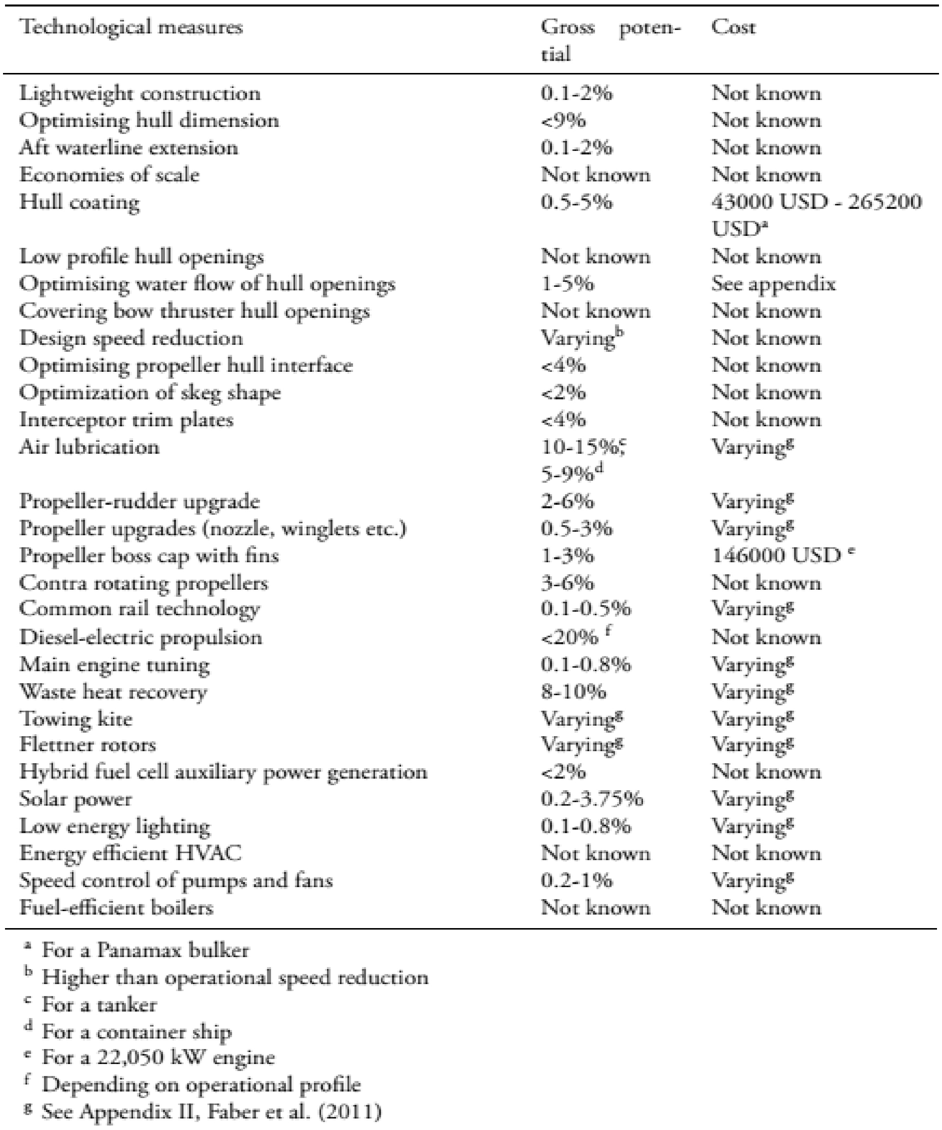
[16] Based on several ships' data, modified and averaged by the author.

[17] 'Old ship' does not necessarily mean an unsafe ship. *Claymore II*, for example, servicing Pitcairn Islands, was built in 1966 – the difference is in the maintenance standards and that is where the PICTs incur difficulties.

[18] For example, Tuvalu has its ships supplied as gifts by UK *(Nivaga II)* and Japan (*Manu Falou* and the 2016 *Nivaga II's* replacement); Tokelau by New Zealand (currently a chartered vessel and new build costing about USD 10 million). Neither of these two countries could afford to purchase or operate the standard of ship that they are given under these aid programmes.

[19] SPC EDD Strategic Plan 2013–2015 page 9



Technological measures	Gross potential	Cost
Lightweight construction	0.1-2%	Not known
Optimising hull dimension	<9%	Not known
Aft waterline extension	0.1-2%	Not known
Economies of scale	Not known	Not known
Hull coating	0.5-5%	43000 USD - 265200 USD[a]
Low profile hull openings	Not known	Not known
Optimising water flow of hull openings	1-5%	See appendix
Covering bow thruster hull openings	Not known	Not known
Design speed reduction	Varying[b]	Not known
Optimising propeller hull interface	<4%	Not known
Optimization of skeg shape	<2%	Not known
Interceptor trim plates	<4%	Not known
Air lubrication	10-15%[c] 5-9%[d]	Varying[g]
Propeller-rudder upgrade	2-6%	Varying[g]
Propeller upgrades (nozzle, winglets etc.)	0.5-3%	Varying[g]
Propeller boss cap with fins	1-3%	146000 USD [e]
Contra rotating propellers	3-6%	Not known
Common rail technology	0.1-0.5%	Varying[g]
Diesel-electric propulsion	<20% [f]	Not known
Main engine tuning	0.1-0.8%	Varying[g]
Waste heat recovery	8-10%	Varying[g]
Towing kite	Varying[g]	Varying[g]
Flettner rotors	Varying[g]	Varying[g]
Hybrid fuel cell auxiliary power generation	<2%	Not known
Solar power	0.2-3.75%	Varying[g]
Low energy lighting	0.1-0.8%	Varying[g]
Energy efficient HVAC	Not known	Not known
Speed control of pumps and fans	0.2-1%	Varying[g]
Fuel-efficient boilers	Not known	Not known

[a] For a Panamax bulker
[b] Higher than operational speed reduction
[c] For a tanker
[d] For a container ship
[e] For a 22,050 kW engine
[f] Depending on operational profile
[g] See Appendix II, Faber et al. (2011)

Figure 5: Sample list of design options for ship efficiency

Several design improvements to ships have been made in recent times, as shown in Figure 5. These include the bulbous bow and asymmetrical hull forms, designed to improve the movement of the ship through the water, as friction experienced by a ship is significant. Other areas of design importance are the bow area, hull surface friction, the aft area, the rudder, and propeller efficiency; these can readily be improved and efficiencies are significant. In addition, huge efficiency gains have been achieved in diesel engine outputs in the past years – the diesel engine is currently a far more efficient, less polluting, and more cost effective option for vehicles on land than any hybrid, and this is also the case for ships with their larger engines. In the EU, for example, ships produce 13.9 grams of CO_2 per tonne.km, compared to rail at 22.8 grams of CO_2 per tonne.km, and road transport at 123.1 grams of CO_2 per tonne.km.[20] Air transport is, of course, significantly higher for CO_2 output, at over 500 grams per tonne.km.

Clearly, the hull forms of *Earthrace* and *Turanor,* for example, are designed for efficiency through the water, not cargo carrying capability, but they illustrate the changes in hull design efficiencies currently in practice for ferries and other such ships.

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[20] Source: European Environment Agency TERM 2003 27 EEA 31. A comparison is also available at (International Chamber of Shipping, 2012).

Looking at inter-island shipping fuel, although the use of sail-assisted shipping has been a popular item for academics,[21] it has not been adequately proven to be economic or practical in today's global commercial environment – otherwise it would have been implemented on a significant scale.

Small inter-island ships burning marine diesel are actually very clean ships on the global scale. The pressure has been on the large ships of the world to burn diesel when in coastal waters, such as in emission control areas agreed on by IMO in several high shipping volume areas of the world (the Baltic, North Sea, North America, USA and Caribbean),[22] where large ships are required to switch to cleaner distillate fuels such as diesel or gas.[23] MDO or MGO has less than 10% of the sulphur and other pollutants compared to IFO or HFO, and is the standard fuel for PICT ships due to their small size. Modern diesel engines are very green when maintained correctly. The new Tuvalu ship to be supplied by Japan complies with IMO Tier II requirements.

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[21] For example (Nuttall, Sailing for Sustainability, 2013), thesis for Ph D at Victoria University. This was based on the ADB sponsored Fiji experiments reported in 'Proceedings of Regional Conference on Sail-Motor propulsion' 1985. In addition, the University of the South Pacific in Suva is conducting a "2nd International Sustainable Sea Transport in the Pacific Talanoa – Celebrating the past – sailing into the future" in July 2014. The aim of the conference is to 'continue the conversation amongst key stakeholders to progress towards a low-carbon sea transport future for the Pacific.'

[22] Information on the IMO emission control levels and areas can be seen at the IMO website describing the three tiers of emission control, and also at http://www.imo.org/OurWork/Environment/PollutionPrevention/SpecialAreasUnderMARPOL/Pages/Default.aspx

[23] MGO (marine gas oil, No. 1 distillate, 'automotive diesel') is used in high-speed, small diesel engines such as cars, buses, trucks, generators; this is the grade that must be used inland in the EU. MDO (marine diesel oil, No.2 distillate) is slightly heavier and is also used in high-speed diesel engines such as some cars, buses, trucks, generators, and small ships.

Propulsion systems available for PICT ships

Currently available propulsion systems that have or are being used for ocean passages are:

- wind power (using, e.g. sails, with no underwater propulsion method);
- fossil fuel power (using e.g. coal, heavy fuel oil, diesel, LPG transmitted through propellers of various types above or below the water);
- biological based fuel power (using plant or other bio material, transmitted through propellers of various types above or below the water);
- solar power (using battery power, transmitted through propellers of various types above or below the water);
- fuel cell power (using fossil or hydrogen fuel, transmitted through propellers of various types above or below the water);
- nuclear power;
- other developing power systems; and
- manpower (e.g. using oars).

All these systems have and are being used currently for a variety of vessels covering distances equal to or greater than distances in the PICT areas; the task is to examine these and find the appropriate methods for sustainable maritime supply chains (and therefore 'safe sustainable shipping' using IMO discussion points) in PICTs. This task is coordinated by SPC as acknowledged by Pacific Leaders:

> SPC is also working with key international and regional stakeholders to encourage the development and use of viable alternative means of propulsion for shipping in a post-carbon economy. In other areas of the transport sector, CROP[24] agencies have focused on helping to improve the safety, reliability, and accessibility of the maritime and aviation services that are essential for regional trade, travel, and tourism.[25]

Each system will be considered in turn.

1. Wind power

Wind, supplemented only by manpower for manoeuvring, was the earliest method of voyaging propulsion. Pacific voyaging *waka* have been travelling the high seas for generations and many are now reviving the practice with modern technology additions. Currently, very few PICTs have vessels that use wind power as a sole means of propulsion, and usually those that do are 'small, isolated, resource poor, and have only a limited cash economy'. (Gillet, Ianelli, Waqavakatoqa, & Qica, 1993) In that context, sail power certainly has a potential place, provided that modern social and safety issues are maintained. It is relevant to require 21st century safety considerations be applied to such craft because, in the event of an accident or disaster, the sailors and passengers will undoubtedly expect, or at least hope for, 'modern' style assistance.

Wind power technology developed until the era of the great 'square riggers', undertaking global trade at high speed and high risk. Large crews were needed, often as many as 60 for a 2,000 tonnes ship, and additional crew were carried as it was common to lose someone overboard, when rounding Cape Horn for example, and to turn around one of those ships was extremely difficult. Sailing times varied significantly, depending on the wind. Famous tea clippers (such as the *Cutty Sark*) took around 69 days from UK to Shanghai, and 100 days return. The *Cutty Sark* could sail at 17 knots with the right wind but those conditions did not last. Her record from Sydney to London with wool was 71 days.

Sailing using wind power alone on global trade was also a dangerous occupation. For example, more than 2,000 wind-powered ships have been wrecked on the New Zealand coast since the 18th century.

Other countries had a worse time of it; in the 19th century, an average of about 2,000 British ships per year were lost,[26] and several enquiries were held, with one parliamentary enquiry conservatively stating:

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[24] CROP: Council of Regional Organisations in the Pacific

[25] (Pacific Islands Forum Secretariat, 2012).

[26] BOISSON, Philippe. Safety At Sea. Policies, Regulations and International Law. Preface by William A. O'Neil. Paris, Edition Bureau Veritas, 1999.

> ...the annual loss of life, occasioned by the wreck or foundering of British vessels at sea, may, on the same grounds (i.e. 'the boisterous nature of the weather and the badness of the ships'), be fairly estimated at not less than One Thousand persons in each year... (British Parliament Select Committee 1839). [27]

In 1896, when useful comparative figures are available, the death rate for seamen on sailing ships was 1 in 60; for those on the new coal fired steamships it was one third of that rate at 1 in 180. (Both were higher than any other industry, even including coal mining.) This is a useful comparison as it removes the issues of navigation techniques and weather forecasting developments, which have had hugely significant effects on improving safety of life at sea, and shows clearly the greater safety of the fossil fuel-powered ships. By comparison, in 2010, 172 ships were lost globally, and 250 seamen were killed at work, which is about 1 in 5,484. Over the five years to 2010 the average of all persons lost, including passengers, was just under 900 per year, about 1 in 1.7 million, indicating the vast safety improvements of modern shipping. (More than half of those lost in this period are passengers lost on a small number of events such as ferry sinkings.)[28]

Inadequate accuracy of navigation[29] and the hazards of weather continue to be responsible for many of the maritime accidents, regardless of the propulsion method, but numbers are very small in the 21st century.

Wind power, unsupported by other means of propulsion, is today used for sport, adventure and recreation. Americas Cup racing could be said to be the development of extreme wind power technology with unquestionably significant efficiencies. However, the use of these for PICT commercial operation is indeed limited. A basic principle of yachting applies for all wind-powered ships: The most dangerous thing on a sailboat is a calendar.

The vessels so powered usually need assistance in berthing, and have limited, if any, cargo or passenger carrying capacity. The role of these should not be confused with that of maintaining economic national supply chains; see the section headed Hybrid propulsion systems for developments in sail assisted ships.

Several groups are reviving the practice and study of traditional Pacific voyaging.[30] These vessels usually now also have auxiliary power, such as a solar-powered electric motor, a diesel engine, or a petrol-powered outboard motor, for safety and convenience, as well as for domestic purposes such as lighting and cooking. Alternatively, they are accompanied by motorised support boats for safety. The Pacific Voyagers fleet that sailed across the Pacific in 2012, for example, had a very well equipped fossil fuel and wind-powered support vessel, *Evohe*.[31]

2. Fossil fuel power

Until around the late 19th century, purely wind-powered ships carried more cargo globally than any other propulsion power. In 1869, the Suez canal opened and steam power began to dominate on the global trade routes as coaling stations became more accessible and common. It is generally considered that the decade centred on 1890 was the change-over period from sail to steam power for global trade; after about 1890, more cargo and passengers were carried on steamships than on sail ships. Around that time, ships were built for both methods of propulsion as the reliability of steam and propeller technology was still a developing art. These were the original sail-assisted ships.

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[27] Quoted in NOAA *The Deadliest Atlantic Tropical Cyclones, 1492–1996.*

[28] Calculated from data in the publication http://www.imo.org/KnowledgeCentre/ShipsAndShippingFactsAndFigures/TheRoleandImportanceofInternationalShipping/Documents/International%20Shipping%20-%20Facts%20and%20Figures.pdf

[29] It is often not realised by the current generation that the first moon landing, by Apollo 11 in 1969, was conducted using manual sextant navigation coupled with computer calculations (Mayer & Osburn, 1970).

[30] The author is a Director of Arawai Ltd and a Trust committee member of the charity operating Hector Busby's *waka Te Aurere* and *Ngahiraka mai Tawhiti* that completed the voyage NZ to Rapanui and back to NZ in 2012/13, using traditional navigation methods, without any support vessels. The two *waka* had solar panels for navigation lighting and radio, Iridium telephones, and a 40 HP outboard motor for safety and port manoeuvring. The author was responsible for the safety and legal compliance for the voyage. Hector Busby has been awarded an MBE, Northland Sailor of the year 2013 and, in 2014, was also awarded the honour of Officer of the New Zealand Order of Merit for his services to Maori Pacific voyaging and navigating. See the website www.teaurere.org.nz

[31] http://www.evohe.com/specifications.html

Progressively the use of coal as a fuel was changed to oil and this remains the most common marine fuel today, with grades of fuel used according to engine and ship size.

LPG- and LNG-powered ships are being built and other improvements in efficiency are being developed as the supply of fossil fuel diminishes and the price accordingly rises. Gas-to-liquid fuels have been developed with the advantage of the cleaner gas fuel but without the disadvantage of needing pressure vessels on the ship or truck.

However, due to the time it takes to develop alternative, and the significantly increasing efficiency of diesel engines and machinery, it is considered that fossil fuels will dominate shipping and large transport units for the next 10–20 years at least.

3. Biological-based oil

Any biological-based fuels, commonly referred to as biofuels, can be used on basic diesel engines with minor modifications, so the transition is smooth when supplies are available. These are fuels that have been also used for many years, and include oils from plants such as coconuts and sugar cane. The total costs of using a food source for fuel must, however, be considered.

Waste food and other materials such as animal manure have been successfully used to make small supplies of biofuel, but a reliable supply system of sufficient volume is always the problem, and most current biofuels require more energy input than is achieved as a fuel output. Waste wood and straw give carbon emissions 90% lower than for conventional fuels, but clearly the supply is limited and cannot sustain the required reliability for ships.[32] For example, Woodruff, in SOPAC Technical report 397 (Woodruff A, 2007) reports how, in Fiji, some coconut oil generator plants never ran effectively on coconut oil due to costs and unreliability of supply; the villagers continued to use diesel.

The latest potential development to reach a commercial stage is the production of oil from algae, using a sugar mix.

The vessel *Earthrace* completed a global circumnavigation fuelled by biofuel in 2008[33] in a world record time of 60 days 23 hours 49 minutes.

4. Solar power

Developing steadily, solar power has been used to circumnavigate the globe; MS *Tûranor PlanetSolar* (Switzerland) circumnavigated the world in a westward direction from Monaco in one year, seven months, seven days from 27 September 2010 to 4 May 2012 on solar power only.[34]

Solar power is used by many yachts and vessels for domestic power supplies as panels become more efficient. The 11,400 Tonne Nissan car carrier *Nichio Maru,* for example, claims to use about 18% less fuel because it supplies all its domestic power from 280 solar panels, uses LED lighting within the ship, and has other fuel-saving features incorporated in its design.

Tokelau has been funded by NZAID to have all its shore power delivered by solar power, saving about 800 litres of diesel per day (about 300 tonnes per year, thereby saving about USD 400,000). The capital cost of the solar plant was NZD 7.5 million, which is significant. An independent PICT could not do that without aid funding. However, the number of panels needed (4,000 panels for Tokelau) is still very significant and limits their use if they cannot be placed on areas such as large roofing spaces. In addition, very large battery systems are required and this is a significant safety, cost and weight issue for a ship. MS *Tûranor PlanetSolar,* for example, had 512 m^2 of solar panels and 8.5 tonnes of batteries, which cost € 12.5 million in 2010.

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[32] Useful information on practical examples are in (UNEP, 2009)

[33] See http://www.earthraceconservation.org/beginning

[34] Read more on http://www.guinnessworldrecords.com/world-records/1/first-circumnavigation-by-solar-powered-boat

5. Fuel cells

Fuel cells have the advantage of being virtually pollution free, but are currently very heavy at a ship's required size, and although emission free, they are no more efficient than using an old diesel engine. Therefore, these are not ready for basic commercial operation.[35]

Hydrogen fuel stations are being used in parts of Europe and USA for smaller hydrogen fuel cell engines.

6. Nuclear power

Tried and abandoned; expensive and there are safety issues.

7. Other developing power systems

Who knows what may develop.

8. Manpower

This is included because ocean passages have been and continue to be made using only manpower with oars or paddles for sporting challenges and adventure[36] A race is organised from California to Hawaii starting 7 June 2014 for those keen to go…[37]

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[35] A good summary of fuel cell operation for marine use can be found at http://www.dnv.com/binaries/fuel%20cell%20pospaper%20final_tcm4-525872.pdf

[36] See http://www.oceanrowers.com.

[37] Get your entry organised here: http://www.newoceanwave.com/great-pacific-race/

Hybrid propulsion systems

As with many things in the shipping business, one system alone is sometimes vulnerable and a backup is useful. Common blended systems in use commercially involve fossil fuel, wind and solar power, but only where those are used for propulsion are they considered here:

1. Wind power blended with solar power

A wind with solar power blend has not been adopted on a commercial scale for propulsion due to the reliability issue of both systems – wind and sun. In the region, the Pacific Voyagers Foundation has had built, in New Zealand, several *waka* style catamarans using wind and solar power. *Uto Ni Yalo* is one of these in Fiji. The issue with this blend is that, when required to use a motor during unfavourable weather, the motor can run for only two of three hours before needing to be recharged and, if no sun is available, no propulsion is possible. This is a significant safety and reliability issue. Schedule keeping ability is low.

Wind power and solar power with a fossil fuel motor is a common blend with cruising yachts. It enables global voyaging using cheap wind power for vessel propulsion, with the security of a fossil fuel engine for emergency or in-port manoeuvring, and some solar power for routine electricity needs. This gives a more safe and reliable combination.

2. Fossil fuel power blended with wind power

Fossil fuel power blended with wind power, sometimes referred to as sail-assisted shipping, has been in place for many years and clearly can continue to be used; the point is that the type of ship and its propulsion must be appropriate to its role.

A historical example of many such ships is SS *Kaikoura* built in 1884, 4500 GRT (a large ship), a coal-fired steamer with a full set of sails. On one voyage to New Zealand the engine failed so she sailed for a few days until repairs were effected.

As the technology improved, reliability increased and the sails were removed from the standard ship. This enabled ships to be larger, carry more freight and/or passengers, thus achieving the economies of scale that we take for granted today.

There are many examples of fossil fuel/wind power hybrid systems in use commercially around the world. Some are described below.

Windstar Cruises aims for the luxury cruise market; their four ships were all built between 1986 and 1989, and are advertised as steaming at 10–12 knots using diesel electric propulsion, and up to 15 knots when sails are added in a good wind.[38]

In Fiji, there is the *Spirit of the Pacific* of Captain Cook cruises, aimed for the tourist market.[39] Bookings can be made for voyages on sailing ships, such as on the USA site: http://www.sailingshipadventures.com/

The luxury market is also targeted by the *Maltese Falcon*, which can be chartered at € 350,000 per week.[40] This vessel, built in 2006, is larger at 88 m (length overall) than most PICT traders, has 2,400 m^2 sail area with two diesel engines and can steam at 19 knots. The sail design has developed into variations experimented with on tankers and other ships.

Such ships can be purchased. For example: http://www.woodenships.co.uk/sailing-yachts/65-baltic-trader.

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[38] See their website: http://www.windstarcruises.com/blog/2013/01/windstars-guests-chart-course-for-tahiti/
[39] http://www.captaincook.com.fj/fiji-ships/spirit-of-the-pacific/default.htm
[40] http://www.symaltesefalcon.com/charter.php

Current work on sail-assisted shipping has focused on trying to reduce the costs and complexity of the rigging and the handling needs of the sails. Therefore, all systems have a high input of computer control, thereby being immediately vulnerable in a Pacific marine environment. In addition, the wind resistance of masts and associated appendages is very high for unfavourable wind directions, and the effect of this on reductions to speed achieved has not usually been adequately considered in the studies.

A good summary report of some considerations is contained in the ADB-funded study, reported in their publication *Proceedings of regional conference on sail-motor propulsion, Manila, November 1985*. This includes a report on the Fiji experiment, funded by ADB, on *Na Mata-I-Sau,* a small trader fitted with sails to supplement the diesel engine. Some useful data are included, and overall a saving is achieved of one litre per mile, steaming at the normal speed range between 7 and 10 knots.[41]

For a typical PICT ship, steaming 10,000 miles per year, one litre per mile represents a maximum saving of about 10,000 litres per year, which at USD 1.25 per litre is about USD 12,500 per year. The capital budget for sails in the *Na Mata-I-Sau* study was USD 40,000. Adding in the maintenance and other costs, it is clear that the reason sail-assisted motor ships have not developed hugely is that the equipment and operating life cycle costs are not sufficiently in favour of the blended option.

Figure 4 of typical costs is copied in Figure 6 and re-examined with a view to the effect of sail assistance.

Cost item	Indicative USD	% of costs	Change in annual costs if sail assistance is added	Indicative USD with sail assist	% of costs
Crew costs	355,000	24%	Training must be more complex, but allow same cost	355,000	23%
Fuel	620,000	41%	Assume overall saving of 5%, about UDS 30,000	590,000	39%
Maintenance	150,000	10%	Will increase significantly; allow about USD 30,000	180,000	12%
Management	115,000	8%	Slight increase due extra crew needs, weather routing etc; allow about USD 10,000	125,000	8%
Insurance allowance	60,000	4%	No change	60,000	4%
Capital	200,000	13%	Increased capital cost, allow about USD 10,000 p.a. If a fully aid funded project, zero cash capital cost occurs; however, the equivalent lost opportunity cost must be included	210,000	14%
Total annual	1,500,000	100%		1,520,000	100%

Figure 6: Figure 4 costs amended with addition of sail assistance technology equipment.

With the figures shown in Fugure 6, it is difficult to justify a PICT adopting sail-assisted shipping for its infrastructure, where reliability and simplicity are prime requirements.

It is interesting that the new Tokelau ship, funded by New Zealand, is reportedly becoming part of the global experiment with wind assistance, using a Skysails kite to assist propulsion.[42] If full costing is applied, however, at NZD 10 million for the shipping service for 2014, it is difficult to see how that can be possibly justified.

> A unique feature that will be incorporated into the ship is the use of wind power through the use of aerodynamically efficient marine kites from Skysails Hamburg. This arrangement will provide some auxiliary power to the ship.[43]

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[41] From the fuel consumption graph on page 365 of the report.

[42] Skysails information can be found on http://www.skysails.info/english/skysails-marine

[43] Reported in the Bangladesh Daily Star and also in *World Maritime News*, 17 December 2013.

The estimated cost of a 320 m^2 Skysails kite is about USD 1 million and can perhaps save 5% of the propulsion fuel cost.

Other issues raised regarding the kite arrangements is that of potential costs of losing the kite into the sea, which could have serious effects, depending on the drop location.

One potential area in PICTs for sail assistance is for small fishing dories to carry a collapsible jury rig sail arrangement, so that if they have engine failure they can at least slowly sail home. This has been in place for some years under FAO safety programmes, and is credited with some saving of lives, even though on one occasion the sail was simply used as shelter and to collect rainwater for drinking.

However, FAO found that there was poor acceptance of the need for safety enforcement and stated: 'A major sea disaster may be required to generate political will to improve sea safety' (FAO Fisheries Circular 993, 2003).

A broad summary of the systems, shown in Figure 7, indicates the features that need consideration when propulsion method is being considered.

Method of propulsion	**Reliability of schedule keeping**	**Condition of goods & people on delivery**	**Ability to service Pacific ports and islands**	**Speed of delivery**	**Cost – fuel**	**Cost – capital**
Pure wind	lowest	variable	Varies, seasonal	Large variation	lowest	equal
Wind + Solar	low	variable	Varies, seasonal	Large variation	low	high
Wind + diesel	high	good	good	Fast, some variation	Possibly 5% less than pure diesel	higher
Pure diesel	highest	good	good	Fast, less variation	highest	equal

Figure 7: Generalised features of principal propulsion methods

Hybrid ships can have a role in certain niche markets. For example, the company Fairtransport Ltd,[44] operating the sailing ship *Tres Hombres*, offers a service for European customers and is reported to be sufficiently profitable to be self-sustaining. This is because the freight rates on this ship are about three times the normal rate, as the target market is the affluent 'green' buyer in Europe. The ship is also small, carrying only 35 tonnes of cargo, and the company has developed its own brand of niche products such as Tres Hombres Rum, so the operation is a vertically integrated business model.

Trans Ocean Wind Transport (TOWT)[45] operates a small fleet of sailing and hybrid sail/motor vessels, often refurbished historic vessels, and trades or charters them around Europe. 'Wind propulsion will play a great role in the future. If not in two years' time then in 22 years,' Guillaume Le Grand, the founder of TOWT, says. 'In the 21st century [traders] will have to rediscover sail and capitalise on new technologies now available to make it efficient.'

Other hybrid vessels can readily be purchased around the world; the question is not whether such vessels are available, but rather: Are they appropriate for the role of a fundamental service provider in PICTs' infrastructure?

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[44] See the website: http://www.fairtransport.eu

[45] http://towt.eu

Conclusion

There is clearly a market for sailing and hybrid ships today; the question is not whether they work – obviously they do in the right market – the question is whether they are the type of vessel appropriate for PICTs' feeder shipping services for a wide range of cargo types and passengers with a wide range of transportability characteristics.

In analysing the priorities for supply chains in PICTs, it is considered that focusing on reduction of CO_2 emissions is not the priority for a decision about the ship propulsion method. Rather, the total life cost for the ship and its cargo needs to be considered, and then the emphasis must be on hull form and engine efficiency.

Requirements of service reliability and predictability make the management and governance issues of greater significance than the ship propulsion method, and effort needs to be placed in that direction.

The costs of experimenting with kites and sails is difficult to justify for a PICT; in a small scale local situation, of course, there is and always has been a place for sail or hybrid propulsion.

Any development of sail or hybrid systems in PICTs should therefore be conducted on a user pays basis, or on a cultural basis, rather than by social pressure based around CO_2 emissions.

Appendices

1. Fuel price indicators

Approximate prices in USD October 2013 to January 2014 at Singapore.[46]

Small quantity purchases at retail level will, of course, be significantly higher. For example, MGO in Suva was about USD 1250 per tonne (USD 1.25 per litre) during this period.

Grade	Indicative average USD per Tonne (1000 litres)
MGO	930
MDO	920
IFO low sulphur 180	690
IFO low sulphur 380	690
IFO180	620
IFO380	610

2. Freight costs

For many consumer items, less than 1% of their retail *cost* is due to seafreight, but most of the item's *value* is derived *because* of the seafreight. In other words the economic value is only there because the shipping service moved the goods from, for example, Los Angeles to Suva, so the buyer could enjoy the benefit. Generally, 10% is a good working figure to use for transport cost as a portion of an 'average' product's price, but for a low-value product such as sand it could be as high as 30% or more.

As an example, the cost of transporting a 20-foot container from New Zealand to Funafuti, is about AUD 8,000 (FJD 12,000), including local handling. This represents approximately AUD 0.30 (FJD 0.40) per litre or AUD 0.70 (FJD 1.00) per kilogram on average of the contents. Some of these goods can retail at observed prices of between AUD 4.00 and AUD 5.00 per litre so the transport represents in those cases between 6% to 8% of the retail price. The key is careful procurement and planning, which in turn needs predictable shipping.

Procurement officials for government and for private businesses in PICTs must be very careful in their buying patterns so they are not paying excessive freight due to inadequate management of the shipment. Much of the criticism regarding prices in PICTs is misplaced, as often it is due to the retail markups. For example, in Suva in 2013, a small bottle of Fiji Water could be purchased by a retail customer at prices varying from FJD 1.80 to FJD 6.00; the only difference being the final supplier's markup. This is a common feature of most products and nations, not just PICTs, and it must be carefully taken into consideration when discussing transport costs.

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[46] Based on information at http://www.bunkerworld.com/prices/port/sg/sin/ and http://shipandbunker.com/prices/apac/sea/sg-sin-singapore#MDO

3. Pitcairn Island shipping schedule 2014 and 2015

This is a screen shot of http://www.visitpitcairn.pn/visitpitcairn/shipping/index.html downloaded on 18 January 2014. It clearly shows the level of management in scheduling that is possible and indeed necessary for PICTs.

Pitcairn Islands Tourism

Come Explore... The Legendary Pitcairn Islands

Shipping Schedule

For all bookings and inquires, please contact the *Pitcairn Islands Tourism Department.*

All air line bookings are to be made by the traveller or agent. Departures from Mangareva are only on Tuesday flights. If you fly on another date then accommodation in Mangareva is to be met by the Traveller.

Currently Claymore II rotations enable a 4 or 11 day stay. In 2014, there will also be an 18 day stay option.

Below is the current Shipping Schedule, updated regularly.

Current Shipping Schedule for MV Claymore II UPATED January 5th, 2014

2014 Shipping Schedule

February / March 2014
First Rotation:

- Depart Mangareva February 25th
- Arrive Pitcairn February 27th
- Depart Pitcairn March 2nd
- Arrive Mangareva March 4th

Second Rotation

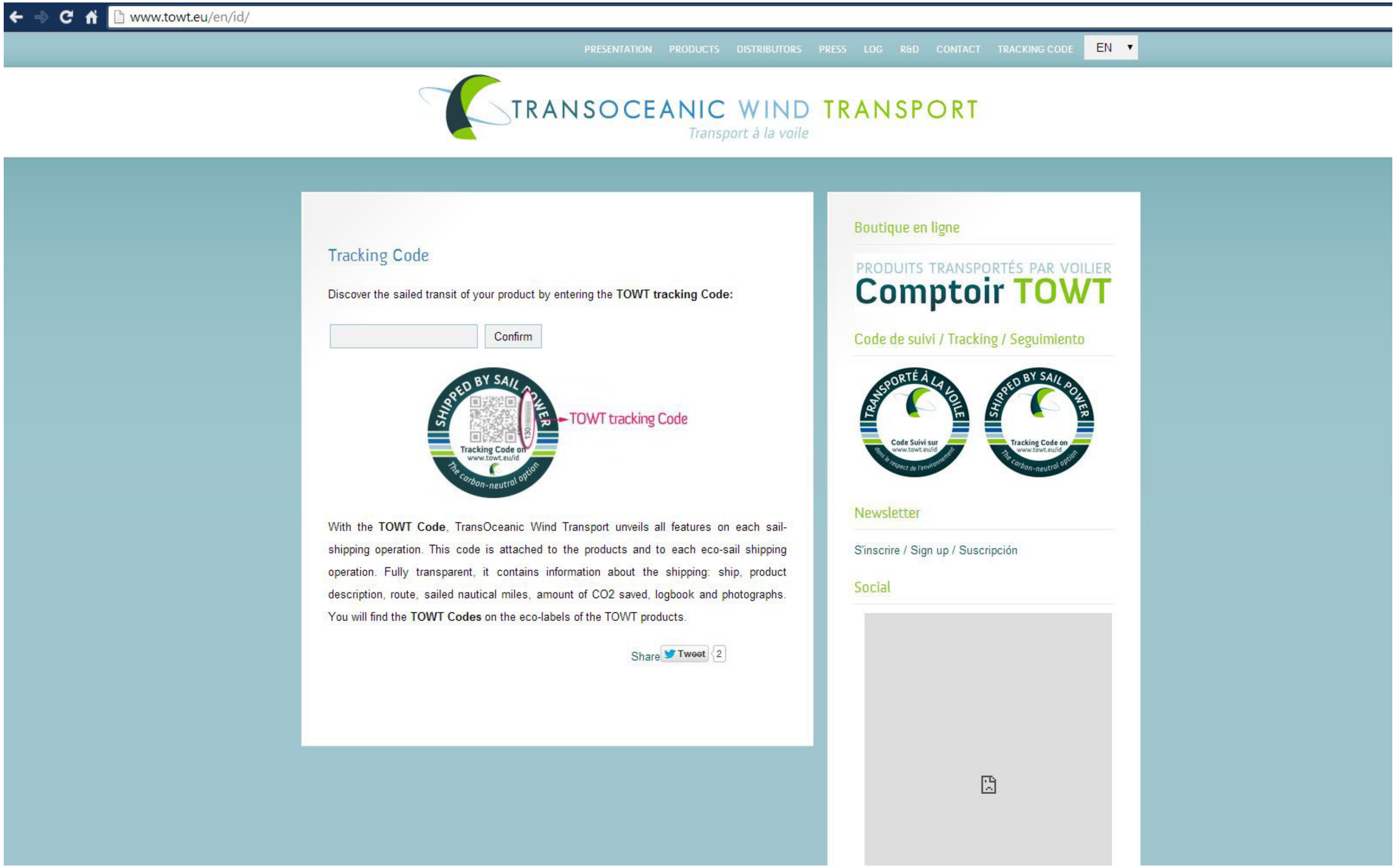
2015 Shipping Schedule

February / March 2015
First Rotation:

- Depart Mangareva February 24th
- Arrive Pitcairn February 26th
- Depart Pitcairn March 1st
- Arrive Mangareva March 3rd

Second Rotation

4. Screen page from TOWT tracking code



Tracking Code

Discover the sailed transit of your product by entering the **TOWT tracking Code:**

With the **TOWT Code**, TransOceanic Wind Transport unveils all features on each sail-shipping operation. This code is attached to the products and to each eco-sail shipping operation. Fully transparent, it contains information about the shipping: ship, product description, route, sailed nautical miles, amount of CO2 saved, logbook and photographs. You will find the **TOWT Codes** on the eco-labels of the TOWT products.

This page from the company's website indicates the niche market of the company; customers pay a higher price for the CO_2 reduction.

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