Mitigation Plan
for the Maritime Transport Sector in Fiji

Executive Summary

A comprehensive mitigation plan for maritime transport in Fiji is presented, forming part of a wider vision for the sector: delivering good service, connecting the islands, and ensuring access to health, education, and employment for the people of Fiji. The mitigation plan is focussed on domestic shipping, including passenger and cargo transport, fishing, tourism, and other activities, such as dredging. A wide variety of ships, from roro ferries all the way down to outboard motored 'fibres', and business models, including private sector, a government franchise scheme, and Government Shipping Services, provide shipping services. Greenhouse gas emissions from all types of domestic shipping together are estimated at 230kt of CO_2 in 2016. However, the uncertainty in this estimate is large, making the collection and management of fuel import and consumption data an immediate priority.

There are a number of barriers to overcome towards the transition away from complete reliance on imported fossil fuels, including a lack of maritime industrial capacity, e.g. shipyards and associated professional shipbuilding skills; potentially conflicting near term objectives, e.g. the prerogative of cost, and the need for long term, strategic policy oversight in delivering investment projects. There exists a body of reports and policies laying out the aspiration of taking climate change mitigation action in Fiji's shipping sector. The mitigation plan presented here builds on this literature.

First, fleet and infrastructure mitigation opportunities are identified. The mitigation potential of wind propulsion technology, biofuels, battery-electric propulsion, and a suite of energy efficiency measures is quantified in a scenario over the time period from 2020 to 2040, distinguishing between small, outboard motored boats, and larger, diesel-powered vessels (achieving a reduction in CO_2 intensity of up to 80% in 2040). Beside technological, operational, and infrastructure measures, enabling policy and regulatory, and capacity development measures are prerequisite to successful mitigation. The mitigation plan addresses all these categories, and is structured into four parts: wind propulsion, alternative fuels, energy efficiency, and enabling measures. Thirteen specific measures ready to take immediately are distilled from the mitigation plan:

- A small sailing boat investment project
- Procurement of a GSS wind propulsion vessel
- A sailing training programme
- Implementing a hub and spoke scheme of operation on an inter-island route
- A dry docking facility investment project
- Trials of battery-electric powered outboards
- Trials of a battery-electric powered ferry
- A trial of biodiesel as a drop-in fuel
- Defining and legislating fuel monitoring requirements
- Mandating an energy efficiency management plan
- Reviewing and adjusting taxes and duties with a view to energy efficiency
- Review of government franchise scheme
- Setting policy priorities on sustainable sea transport.

Some of these measures require investment, typically between FJD0.5m. and FJD5.0m. Trials and demonstration projects are first steps towards unlocking the markets for alternative energy sources and energy efficiency solutions in maritime transport. Based on the quantitative scenarios, Fiji has the opportunity to match the Republic of the Marshall Islands' target of reducing greenhouse gas emissions from maritime transport by 27% in 2030, bolstering leadership of the Pacific region in international climate policy, even as the International Maritime Organization is working to define its greenhouse gas strategy for international shipping.

Fiji relies on maritime transport like few other countries. It also relies entirely on imported fossil fuels. Contingent on the political will, together with adequate access to finance, Fiji now has the opportunity to gain energy security and lead the way in unfolding a transition towards low carbon sea transport – making its shipping sector environmentally, socially, and economically sustainable.

1. Project aim

The aim of this work is the development of a climate change mitigation plan for Fiji's domestic maritime sector, providing inspiration for decarbonisation in the international maritime sector and leadership on international climate policy. This aim is an integral part of a wider vision for maritime transport in Fiji. Perhaps most fundamental to this vision is delivering good service, connecting the islands, and ensuring access to health, education, and employment for the people of Fiji. Economic aspects of the vision include: resilient infrastructure; increasing employment in building, crewing, and servicing vessels; reducing reliance on imported fossil fuel and achieving energy security. The environmental aspect means reducing local pollution and delivering health benefits. Socially and politically, Fiji can take on a leadership role, regionally and in the world, as a champion in the challenge to achieve sustainable and affordable sea transport.

This wider vision provides the backdrop to the project, and helps shape the mitigation plan, presented as follows: Section 2 presents the status quo of maritime transport in Fiji. Building on this starting point, Section 3 identifies mitigation opportunities that are compiled into a quantitative greenhouse gas emission abatement scenario, including indicative cost estimates for the individual scenario elements. Section 4 integrates the mitigation opportunities into a comprehensive framework plan for maritime transport and, as part of the plan, defines actionable measures. Section 5 gives a summary and concludes.

2. National circumstances - maritime transport in Fiji

2.1 Context

As a Pacific island nation, Fiji relies on maritime transport of both passengers and cargo. Fiji is also at the forefront of climate change impacts. Progress towards a more sustainable shipping sector is therefore of outstanding importance, as is progress of the international shipping sector towards meaningful climate change mitigation in line with the goals of the Paris Agreement.

The headline goals of the Paris Agreement include "Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels". To make good on this stated goal, deep cuts to greenhouse gas emissions are needed urgently, with virtually full decarbonization in the longer term. The Paris Agreement addresses this by declaring the "aim to reach global peaking of greenhouse gas emissions as soon as possible ... so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century" [1]. For the more ambitious 1.5°C goal, virtually full decarbonisation well before mid-21st century is, in fact, necessary [2].

Under the Paris Agreement, nationally determined contributions (NDC) provide the main mechanism for achieving emission reductions and, ultimately, decarbonization. Each party to the Paris Agreement is to declare its NDCs, with the objective of subsequent NDCs ratcheting up the ambition of preceding ones. One year after entry into force of the Paris Agreement, most countries have submitted their first NDC. Fiji is currently in the process of revising its first NDC [3], with a view to submitting its second NDC.

The focus of this work is on CO_2 because it is the largest contributor to radiative forcing; it is very long-lived (with atmospheric subsidence times of centuries to millennia); and it is the dominant greenhouse gas emitted by ships, through combustion of fossil fuels for propulsion and auxiliary purposes. Fiji imports all of its fossil fuels, at a cost of FJD660m. in 2012 [4]. A transition away from fossil fuels would therefore reduce a financial burden and increase energy independence for Fiji.

2.2 Composition of Fiji's shipping sector

Table 1 presents a categorisation of Fiji's shipping activities. The division into sub-sectors facilitates the development of an action and implementation plan for Fiji's maritime transport sector. Measures aimed at reducing greenhouse gas emissions from the sector may be applicable, and may be tailored to specific sub-sectors; and the potential impact on the whole sector can be gauged by analysing measures' impact on the individual sub-sectors.

First, shipping activity is split between domestic and international shipping. The latter is difficult to address unilaterally. The main avenue for addressing emissions from international shipping is therefore international policy, although domestic policy can –e.g. by setting examples and demonstrating leadership– influence the international debate (cf. Section 2.3). Domestic navigation is more directly amenable to measures on the national level. In the longer term, what is possible to achieve for domestic navigation will also be determined by progress on the international level, and vice versa, e.g. as research and development paves the way for sustainable, low-carbon fuels. International shipping is sub-divided into cargo, cruise, yacht/leisure, and fishing.

Domestic navigation is sub-divided into combined cargo and passenger transport, fishing, tourism, and other. The combined inter-island cargo and passenger transport provides a vital network for Fiji's social and economic fabric. It is further sub-divided into Government Shipping Services, which is fully government-controlled, therefore providing the most immediate potential for government action; the government's franchise scheme for routes that would otherwise be un-economical for the private sector to serve; the inter-island routes that are economical to serve (for which the government is planning to bring online a route licensing scheme); and the ubiquitous transport provided by small boats –typically called 'fibres'– on shorter routes.

Table 1: *A categorisation of Fiji's shipping activities*

Domestic	Combined cargo & passenger	Government Shipping Services
		Uneconomical routes
		Economic routes
		Small boats
	Fishing	
	Tourism	
	Other	
International	Cargo	
	Cruise	
	Yacht/leisure	
	Fishing	

All of these sub-sectors provide crucial services; but each of the sub-sectors is subject to its own paradigm in terms of both regulation and technology. The small boats, or 'fibres', for instance, are characterised by a very simple hull without superstructure, powered by an outboard motor – Figure 1 shows a typical specimen (on a school run) on the left hand side.

Figure 1*: A typical 'fibre' boat (left hand side); and a roro vessel providing inter-island passenger and cargo transport (right hand side).*

Vessels belonging in one of the other domestic sub-categories are more diverse, ranging from small fishing or tourist boats to larger roro ferries (as shown in the right hand side of Figure 1), and including more specialised vessels like tugs or dredgers. Generally, all but the small boats are powered by an inboard diesel engine, sometimes including auxiliary engines. The categorisation is not unique or even well-defined as there is clearly some overlap between the sub-categories - e.g. some small boats are used for fishing or in tourism. But it is useful in producing an estimate of domestic shipping emissions (see Section 2.4), and identifying mitigation opportunities (see Section 3.1).

2.3 Distinguishing between domestic and international shipping

Under UNFCCC rules [5], emissions from domestic navigation count towards a country's greenhouse gas inventory. Therefore, they fall under the scope of a country's NDC. For instance, the Republic of the Marshall Islands (RMI) has explicitly included domestic shipping in its NDC. However, most other countries have not. As an island nation relying on domestic shipping far more than most other nations, it is therefore appropriate for Fiji to address the sector in its NDC.

In contrast to domestic shipping, emissions from *international* shipping do not fall under countries' greenhouse gas inventories - in fact, they are omitted from the Paris Agreement altogether. Instead, the debate on how to control and reduce greenhouse gas emissions from international shipping has been taking place at the International Maritime Organization (IMO) since the IMO received a mandate from the Kyoto Protocol in 1997. Beside the EEDI, an energy efficiency standard for new-build ships, and the SEEMP, a mandatory (and, as of 2017, largely un-specified) energy efficiency management plan, no rules to control or reduce greenhouse gas emissions from shipping have yet been agreed at the IMO. At the 70th meeting of its Marine Environment Protection Committee (MEPC), the IMO approved a "draft roadmap for developing a comprehensive IMO strategy on reduction of GHG emissions from ships" [6], with a view to the adoption of an initial IMO strategy at MEPC 72 in spring 2018, and adoption of a revised strategy to actually include measures, with implementation schedules, at MEPC 80 in spring 2023. At present, i.e. prior to the adoption of a prospective strategy, outlooks for the international sector and its greenhouse gas emissions are not aligned with the Paris Agreement's temperature goals [7]; and the timeline for the adoption of the final strategy implies that it will be unlikely to align the sector with the more ambitious 1.5°C goal [2].

Given the global nature of shipping, it would be a difficult task for any country, or group of countries, to unilaterally implement a mitigation plan for international shipping. This certainly holds for Fiji, as a small country. At present, Fiji has not ratified MARPOL Annex VI, the IMO treaty dealing with shipping emissions to air - a step that Fiji could consider. In terms of mitigation action, the framework plan, including specific measures, is focused on domestic shipping.

Since 2015, the Pacific region, including Fiji, have taken an increasingly active role at the IMO, shaping and pushing forward the debate on greenhouse gas emissions from shipping. Progression of mitigation in Fiji's domestic shipping sector will give authority to Fiji's voice in the international debate. Fiji has the opportunity to take on a leadership role and champion the transition towards more sustainable maritime transport.

2.4 GHG emissions from Fiji's domestic shipping sector

As a starting point for the development of a mitigation plan, estimating the size of the sector, and its greenhouse gas emissions, is useful in many ways. The scale of the issue can help determine priorities, e.g. vis-á-vis other sectors; it underpins indicative estimates of the costs, investment needed, and economic opportunities of a mitigation plan (cf. Section 4); and, perhaps most importantly, establishing a transparent and consistent methodology makes it possible to measure progress over time.

At the time of writing, in November 2017, a transparent and consistent methodology does not exist. While Fiji's first national communication to UNFCCC ignored domestic shipping activity altogether [8], its second national communication gave an estimate of 211kt of CO_2, for the base year 2005 [9]. However, it acknowledged the paucity of data and presented little information about the collection process for the data underpinning this estimate.

Therefore, an updated estimate of Fiji's domestic shipping activities is presented here. The details of the methodology are given in Section A.1, in order to allow for a meaningful comparison, if and when other estimates are made. Figure 2 shows CO_2 emissions from the various sub-sectors (cf. Section 2.2), adding up to a total of 227kt in 2016. Clearly, there is some overlap between the sub-sectors, as defined here. For instance, small, outboard-motor driven boats are used for fishing. However, for the purpose of quantifying the contributions from the various categories of shipping activity, and identifying suitable mitigation measures, the taxonomy used is adequate.

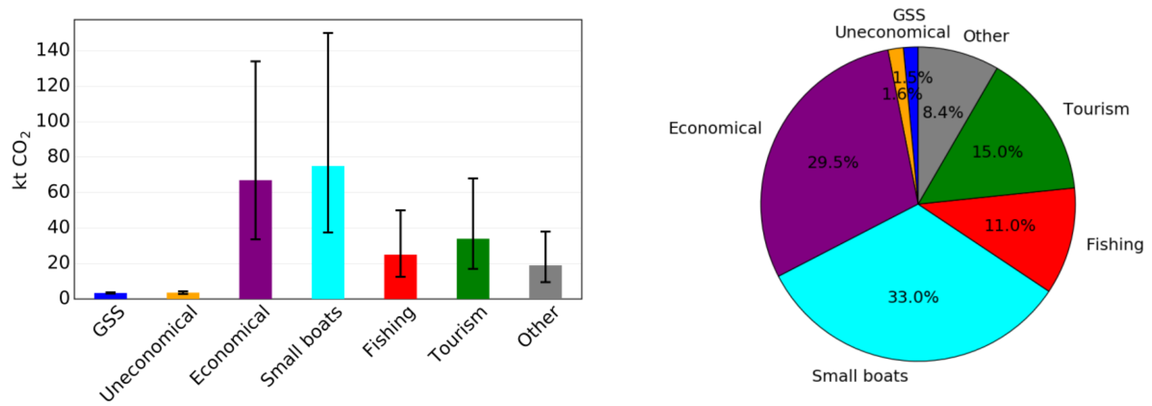

Figure 2*: Estimates of CO_2 emissions from domestic shipping, composed of contributions from Government Shipping Services (GSS), uneconomical and economical routes, small boats, fishing, tourism, and other (e.g. dredging).The results show that the 'small boats' or 'fibres' account for about a third of Fiji's CO_2 emissions from domestic sea transport. Results also highlight the large uncertainty with respect to fuel consumption and emissions.*

Due to the paucity of available data, the uncertainties are large - of the same order as the emission estimates, for some sub-sectors. Therefore, more accurate data need to be collected, in order to facilitate monitoring of progress as mitigation measures are implemented (cf. Section 4.4).

The emission estimates indicate that domestic shipping indeed constitutes a significant share of Fiji's total CO_2 emissions; and that the small boat sector constitutes a significant share of domestic shipping emissions.

In terms of greenhouse gas emissions, this report focuses exclusively on CO_2, as it is by far the most important greenhouse gas from shipping, in terms of its long term impact on climate. In terms of local pollution, there are other major emissions, to air and to sea, from domestic shipping, for example from 2-stroke outboard motors (cf. Section 3.1). While local pollution is not the focus of this report, this is worth noting in relation to implementing a mitigation plan, and with a view to the overarching vision (cf. Section 1).

2.5 Existing plans and policies

This report builds on a range of existing reports, strategy plans, and policies on Fiji's maritime transport sector and/or climate change.

In September 2015, the heads of state of 15 Pacific island nations, including the prime minister of Fiji, made the Suva Declaration on Climate Change [10]. The Suva Declaration includes a call to limit global average temperature increase to below 1.5°C above pre-industrial levels, which was subsequently enshrined in the Paris Agreement at COP21 in December 2015 [1]. The Suva Declaration also includes a call for "an integrated approach to transitioning Pacific countries to low carbon transport futures, in particular sea transport given its central role in providing connectivity for Pacific Small Island Developing States, including a regional strategy to advocate for and monitor implementation of sector targets through relevant UN agencies commensurate with the 1.5°C threshold".

Fiji's first Nationally Determined Contribution sets the goal of reducing its CO_2 emissions by 30% [3], compared to a BAU scenario in 2030. While it makes no reference to maritime transport, it assigns a key role in delivering the unconditional (10%) share of the target to Fiji's Green Growth Framework [11]. Two main challenges for maritime transport are defined in this: "Provision of a regular, affordable and sustainable domestic shipping industry", and "a need for compliance with IMO regulations for shipping industry". Alongside the challenges, short (up to two years), medium (three to five years) and long (over five years) actions and indicators are formulated, e.g. to "Incorporate incentives for trialing and adoption of low carbon technologies for domestic shipping in relevant strategies, policies and plans". As in this example, existing strategies and plans are mostly expressed in terms of goals or aspirations and are not associated with an implementation plan. As highlighted in one of the meetings with government representatives (cf. Section A.2), this lack of a specific implementation plan can make it difficult for potential actors within government to take specific steps.

Fiji's Maritime Transport Policy [12] addresses climate change mitigation and adaptation, building on the Green Growth Framework [11]. Cutting across transport sectors, it sets the objectives of encouraging fuel-efficient transport equipment, uptake of sustainable biofuels, and of monitoring fuel consumption and CO_2 emissions. For the maritime transport sector, it proposes a whole set of measures, including: "operational initiatives (e.g. slow steaming, weather routing) and retrofitting or replacement with more energy/carbon efficient propulsion systems and hull designs"; "the use of more efficient vessels such as smaller craft better suited to the routes and demand for transport"; "purchase of a renewable energy (biofuel/solar/sail assisted) vessel through a partnership between GSS and private sector investors and in close consultation with interested communities as a catalyst demonstration project"; "reinvigorating traditional knowledge of using small canoe and camakau boats for accessing jetties from coastal villages".

Fiji also has a national climate policy [13]. It identifies the transport sector as Fiji's largest fuel consumer. However, it focuses almost exclusively on land based transport. For example, it suggests setting fiscal incentives to support the introduction of energy-efficient vehicles but does not consider the same for boats or ships.

On the regional level, in 2011 SPC produced its 'Framework for Action on Transport Services' [14], listing seven guiding principles, including recognition of climate change, and seven themes for action, including environmental impact. However, the immediate priorities of the action themes are stated in generic terms. The safety and security action theme calls for "Adoption of emerging technologies", for instance, and the environmental impact, technology and energy theme calls for "Enabling national policies and laws". Perhaps the most comprehensive plan on sustainable sea transport is the framework produced by the University of the South Pacific [15]. It considers actions across a range of categories –policy, economics, heritage, practical trials, teaching, and additional research– stressing that a strategic and comprehensive approach is necessary for a transition to low carbon transport to be successful.

In summary, there is a body of government (or government-approved) policy reports which stress the overall aim of improving energy efficiency, reducing CO_2 emissions, and contributing to climate change mitigation. Some include specific measures - but they generally do not include implementation plans, consider cost, or identify the responsible agents to realise the suggested measures. There is also no quantification of the fuel and emissions savings potential of suggested measures. Addressing all of these issues, this report defines both a mitigation plan, and specific actionable measures that will deliver progress towards decarbonisation.

2.6 Heritage

Fiji and the Pacific region have a long and proud history of shipping, including a sophisticated shipbuilding economy, extending over many islands providing specialised manufacturing steps [16, 17]. This heritage holds a visible place in Fijian culture. When Fiji's rugby sevens team won the Olympic goal medal in 2016, they wore an image of a traditional drua on their jerseys; public phone booths are designed to resemble the sail and mast of a drua; and when Fiji officially organised COP23 held in Bonn in November 2017, Fiji presented a purpose-built drua to host nation Germany. The 2016 animated motion picture *Moana* incorporated traditional Pacific sailing designs. But, even though traditional sailing culture holds a place in national and international (pop) culture, it plays no significant role in the present realities of maritime transport in Fiji.

Fiji was also at the centre of the 1980s renaissance of wind-powered propulsion. The shipping crisis of the first half of the 1980s, triggered by high oil prices, provided the motivation to search for ways of increasing the fuel efficiency of ships, and for alternative means of propulsion. Around the world, a number of wind propulsion vessels were built. For instance, in a joint project by ADB and the government of Fiji, the 300 tonne *Na Mataisau* was retrofitted with a soft sail system at the Suva Government Shipyard. The project consultants reported an IRR of 20-40% on all but the least favourable route [18]. However, as oil prices fell and freight rates rose, the quest for more sustainable (or merely cheaper) alternatives to pure diesel-powered shipping was abandoned during the second half of the decade.

Since then, Fiji has also lost much of its shipbuilding capacity, and it has become a technology taker, often relying on old vessels past their economical lives in other parts of the world. In summary, Fiji has been at the helm of alternative technological paradigms to the current one, which has become unsustainable. Its heritage, together with its reliance on maritime transport, suggest that in pursuing decarbonisation, Fiji can pursue social and economic sustainability, beside the environmental motivation. However, the loss and resultant lack of capacity is a challenge.

2.7 Challenges towards low carbon sector

In elaborating a mitigation plan for maritime transport in Fiji, a number of challenges is considered.

The first type of challenge is concerned with lacking capacity. Fiji has become a technology taker, importing –in many cases old– ships. This point came up in many of the meetings held as part of this project (cf. Section A.2). There is little industrial capacity. If Suva Government Shipyard successfully retrofitted the *Na Mataisau* (cf. Section 2.6), many stakeholders mentioned that, following privatisation, shipbuilding capabilities have been lost since. Similarly, service and maintenance capacity may be lacking (for example, according to anecdotal evidence from stakeholder meetings, some larger vessels had to be brought to New Zealand to go into dry docking). As with industrial capacity, there is a professional skills need – meeting it will be a challenge.

Second, while the aim of this project has been placed in the context of a wider vision for maritime transport in Fiji (see Section 1), there may be other objectives in conflict with climate change mitigation. In particular, there is a cost imperative that cannot be neglected. More fuel-efficient ships or equipment may be more expensive to acquire but more cost efficient in the long term, once fuel savings are taken into account. Adequate financing mechanisms may provide the solution in such cases. But whether otherwise preferable solutions are cost-competitive, and how they can become cost-competitive if not, is an important question to consider. Provision, and expansion of service is the other objective that may conflict with climate change mitigation. In the short run, the two objectives may need to be weighed against each other. In the longer run, the prerequisite of decarbonisation of sea transport implies that mitigation is a condition for the provision of service.

Third, delivering a meaningful mitigation plan will require strategic oversight. Data paucity constitutes the most obvious lack of oversight encountered in this project. Even though Fiji imports all of its fossil fuels, it proved impossible to get data on fuel consumption for the whole maritime sector, from any of the government agencies (cf. Section 2.4). Data were only available some elements of the domestic shipping sector, e.g. GSS and the uneconomical routes; and available data needed to be collated from different government organizations, e.g. GSS and MoIT. Even more challenging will be ensuring institutional oversight. In a region where many infrastructure and/or technology projects are driven by organisations, with often short project lifespans and correspondingly high fluctuation of people, and little overall coordination, sound and consistent management of a transition to low carbon sea transport will be important.

3. Identification of the mitigation opportunities, and scenarios

3.1 Fleet and infrastructure mitigation opportunities

Fleet of small boats:

Small boats provide mobility, mainly short (though sometimes long) distance. For Fiji, as a Pacific island nation, mobility is a crucial service, with both social and economic aspects. The dominant technological solution for the propulsion of the large number of small boats, is a 2-stroke outboard motor. The dominant type of 2-stroke motor are cheap, and they are characterised by their simplicity and robustness. I.e. they are comparatively easy to maintain and service; and they are robust in operation, for instance, they tolerate relatively large water content in the fuel. On the other hand, they cause pollution and are, in fact, banned in many other jurisdictions, like the US and Australia. In terms of greenhouse gas emissions, outboard motors are entirely fossil-fuelled; and the dominant 2-stroke type is less energy-efficient than more complex four-stroke motors, although the difference in energy efficiency is most pronounced for larger engines.

The main opportunities for decarbonisation are therefore: reliance on the most energy efficient motor models in the short term; and a move towards alternative fuels or energy sources in the medium to long term.

With a view to implementation, a set of wider aspects deserves consideration: first of all, the feasibility of any alternative must be ensured. This includes the economics of capital cost, but also the need to ensure that any equipment can be adequately serviced and maintained. Wider environmental considerations indicate significant co-benefits of moving away from the currently dominant technology; and there are safety aspects, considering that small boats with a single engine often venture on to the high seas, at significant risk.

Among alternative energy sources wind deserves particular attention, for two main reasons: first, Fiji's sailing heritage is a source of identity and pride, even though sailing is not practised widely at present. The outstanding cultural significance of sailing is a clear co-benefit of wind propulsion. Second, it is relatively cheap and thus a natural candidate to include as an alternative propulsion system on board small vessels, not only reducing greenhouse gas emissions, but also reducing the risk of failure of all propulsion systems [19].

The other main candidates for alternative energy sources considered include biofuels and battery-electric propulsion. For both, key questions include the (land-side) availability of the fuel/energy source, and the associated greenhouse gas emissions savings over the full life-cycle. Beyond propulsion, boat hulls are likely, in most cases, not as hydrodynamically efficient as could be.

Ships:

For the purposes of the mitigation plan, ships are all vessels other than the 'small boats' operated by outboard motors. As a category, this encompasses a wide range of types and sizes. Nonetheless, all (or nearly all) are propelled by diesel-powered engines. Generally, emissions abatement can be achieved through: increased energy efficiency; and alternative fuels or energy sources that produce less CO_2.

Energy efficiency can be increased in many ways, both in design and operation. Hull and propeller design, for instance, are a major factor in determining a vessel's energy efficiency. Due to the variety of vessels, there are no specific design measures applicable to all. Rather, it has to be the aim to place emphasis on energy efficiency in the procurement process of each individual vessel. For example, in one of the meetings held (cf. Section A.2), it was highlighted that energy efficiency was not an important consideration in the ongoing specification and early design stage of a new government vessel, even though energy efficiency, or lack thereof, has an obvious impact on the fuel bill.

Similarly, in terms of ship operations, perhaps the most important measure is to take energy efficiency into consideration. For example, simply switching off machinery and equipment not needed at the moment can generate fuel savings. For larger vessels, trim and ballast optimisation can generate significant savings. Route optimisation –optimising the geographic route and the voyage speed along the route, taking into account weather information– is of particular relevance in conjunction with wind-assisted propulsion.

Beyond general emphasis on energy efficiency in design and operation, there are two concepts worth addressing explicitly, hull and propeller maintenance, and slow steaming.

Over time, a ship's fuel efficiency deteriorates as hull and propeller are affected by fouling, increasing fuel consumption, cost, and greenhouse gas emissions, not rarely by up to 50%. The best approach is to monitor fuel consumption and performance closely, and run an optimised maintenance schedule for each individual ship. Prerequisite to an optimised maintenance schedule is the capacity to perform hull and propeller maintenance. The most simple hull and propeller cleanings can be performed by divers. However, dry docking operations are necessary in order to optimise a vessel's fuel economy.

Resistance, and therefore engine power and fuel consumption, is strongly dependent on speed (typically with an exponent >3). Therefore fuel can be saved by reducing speed. Following the global financial crisis of 2008, for instance, operating speeds reduced in many parts of the world merchant fleet, as a response to over-supply and low freight rates. Lower design speeds are also the most important parameter for new-build vessels achieving low EEDI values. In Fiji, large passenger and cargo vessels operate at low speeds of typically around 9 knots, according to both public and private stakeholders consulted during the project. For this reason, reducing speed is not a primary focus in the mitigation plan. However, there is a risk that energy efficiency savings do not result in emissions savings but in higher speeds. For example, a full hull and propeller cleaning may reduce fuel consumption by 20%; or it may increase operating speed by one knot.

Decarbonisation also requires a switch to alternative energy sources. The candidates are mostly the same as for small boats, with battery-electric and biofuels the most promising options at present. Biofuels have the potential to act as a drop-in fuel, offering the same functionality as fossil diesel. Here, the key question in relation to the type of vessel (or, rather, the type of engine) regards compatibility, which needs to be ensured.

Battery-electric propulsion implies a more fundamental change in technology, and in how a ship is operated. Batteries cannot match the energy density of diesel. Furthermore, batteries are expensive.

Therefore, a ship on a frequent and regular voyage schedule, e.g. between Viti Levu and Kadavu, would be an optimal candidate for trialling battery-electric propulsion.

Infrastructure and systemic operations:
Infrastructure is a prerequisite to utilisation of alternative energy sources. In the case of biofuels, this means fuelling stations and, of course, the supply chains needed in the background. In the case of battery-electric, this means charging stations. Since charging a battery places a load on the grid, integrating charging patterns into grid operations is necessary and not straightforward. In the best case, the batteries act as an energy store that is replenished at times of abundant grid electricity supply, effectively flattening spikes and troughs in grid load. Trialling and learning are necessary before uptake of battery-electric propulsion on a large scale can become feasible.

Beyond the energy efficiency and the greenhouse gas intensity of individual vessels, there are also aspects of how the wider system, including infrastructure, is operated. For example, some islands lack jetties. Vessels calling on those islands, e.g. under the government franchise scheme, have to keep engines running even during loading and offloading. In addition to this added fuel consumption, it protracts boarding and loading the vessel and makes it more cumbersome. There are two potential solutions. Building jetties removes the problem. Operating routes in a hub and spoke scheme is the other way of optimising service to islands. For instance some routes under the government franchise scheme connect Suva with a group of islands at the outer end of the voyage. Calling on only one island (with a jetty), while providing connections between the other islands and the main route stop with smaller vessels, can reduce overall voyage times, fuel consumption and cost, and the number of required jetties. The benefits, in terms of both service and reduced costs, depend on the geography of the route, and on the demand from the individual islands currently served by a route. Given the need of integrating services provided by larger and smaller vessels, and the existing role of government under its franchise scheme, implementing a hub and spoke model is a promising candidate for trialling and demonstrating other mitigation measures, in particular wind propulsion technology.

3.2 Mitigation scenarios for Fiji's domestic shipping emissions

Using the mitigation opportunities identified in Section 3.1 as building blocks, two quantitative mitigation scenarios are built, one for 'small boats', and the other for ships, i.e. all vessels larger and more complex than a simple hull propelled by an outboard motor.

Mitigation scenario - small boats:
The small boats scenario comprises assumptions about the emissions saving potential of sail technology; biofuels; and battery-electric motors. Each holds the potential of reducing emissions for an individual boat, compared to the current paradigm, a petrol-powered outboard motor. The total emissions saving potential for the whole fleet is then determined by the penetration of the operational fleet by the technology under consideration.

Figure 3 shows the CO_2 intensity scenario for small boats over the time period 2020 to 2040. None of the mitigation options are immediately ready for fleet-wide uptake at present - but could be within a few years.

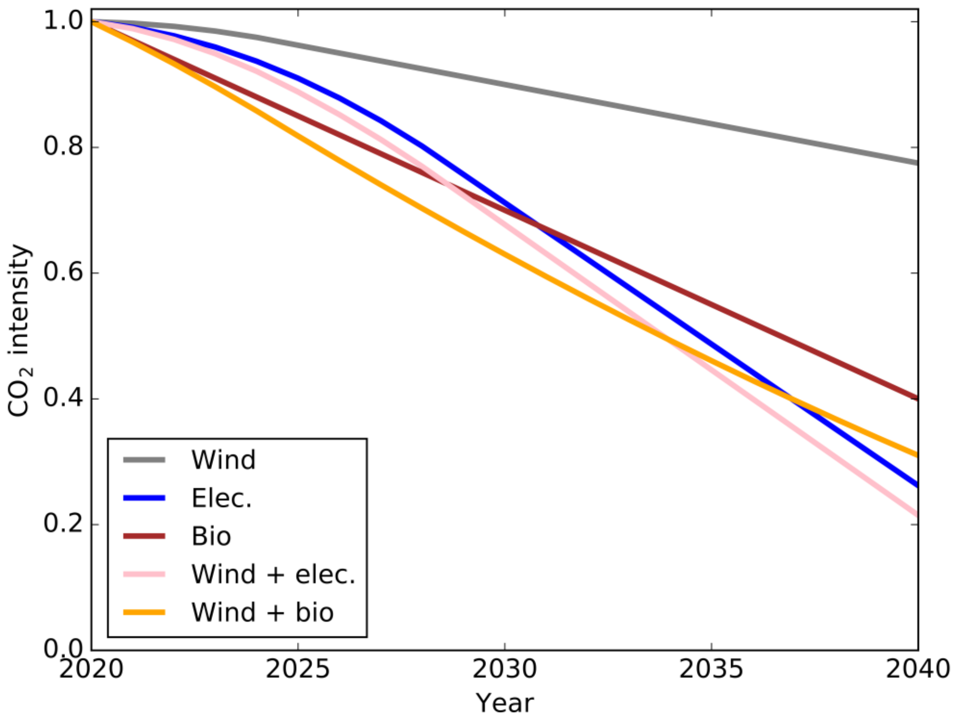

Figure 3: *Mitigation scenario: 'small boats'.*

In fact, cutting emissions in line with the temperature goals of the Paris Agreement requires deep mitigation to start within only a few years, with decarbonisation by mid-century, motivating the timeframe for the scenarios. Detailed scenario assumptions are given in Appendix A.3.

Introducing sail technology can, on its own, provide a significant wedge, in terms of relative emission reductions, of the order of 20%, over the time period 2020-40. Biofuels are attractive as a drop-in fuel. Replacing (imported) fossil fuel with (locally produced) biofuel can significantly reduce greenhouse gas emissions. However, biofuels are, depending on the production pathway, not entirely greenhouse gas emission free. In this scenario, biofuel has fully replaced fossil fuels by 2040, at 40% of CO_2-equivalent emissions. Sail technology can be ideally combined with alternative energy sources. Uptake of sail technology and biofuels reduces CO_2 intensity by about 70% by 2040.

Under the (strong) assumption of near-zero emission grid electricity, battery-electric powered motors can deliver even deeper CO_2 intensity reductions, of the order of 70%, and up to 80% in combination with sail technology.

Mitigation scenario - ships:

For ships, in particular larger passenger and cargo ships, wind-powered propulsion is used in hybrid mode, e.g. as wind-assisted propulsion. In addition to wind-assisted propulsion, biofuel, and battery-electric powered propulsion, the scenarios for ships (comprising a large variety of ship types and sizes) includes energy efficiency as an additional element. As detailed in Section 3.1, the energy efficiency category comprises a whole range of both design and operational measures. Figure 4 shows the results (cf. Section A.3 for specific assumptions). The emissions reduction from wind-assisted propulsion alone is slightly smaller than for small sailing boats. Large cuts to emissions, of the order of 30%, are possible from incremental increases in energy efficiency. Furthermore, when combining energy efficiency measures and wind-assisted propulsion, relative savings from the latter are higher than in the wind-assist only case, as the wind force can provide a larger share of the force required to propel an efficient hull than an inefficient one. Together, increasing energy efficiency and employing wind propulsion technology can reduce CO_2 intensity by around 50%, by 2040.

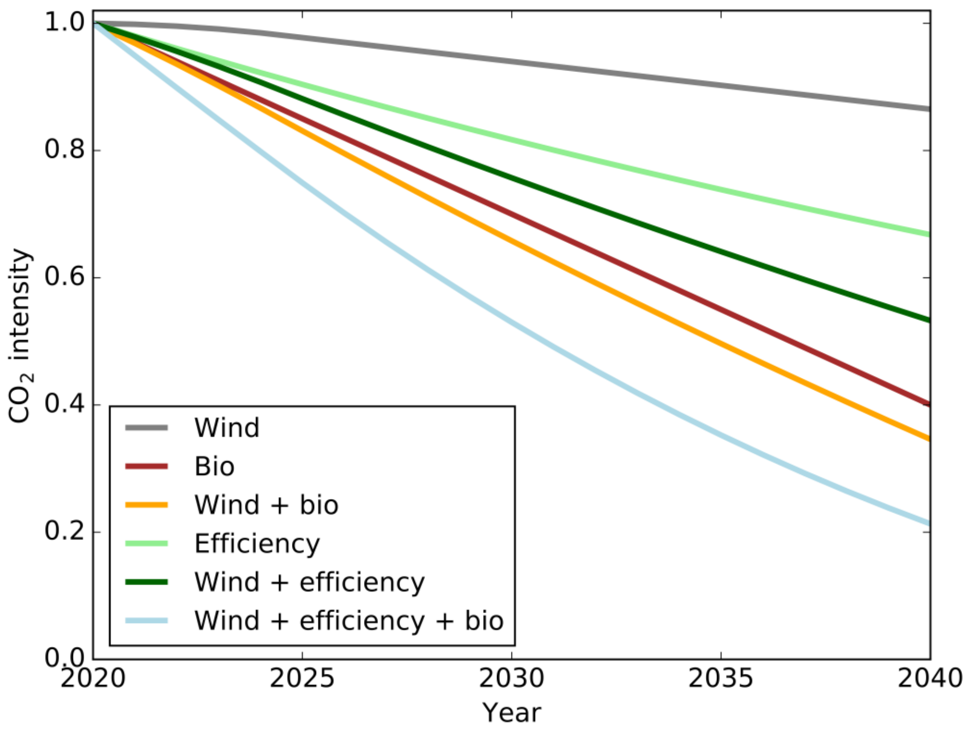

Figure 4*: Mitigation scenario: 'ships'.*

As in the 'small boat' scenario, biofuels simply replace fossil fuels. Increasing energy efficiency, employing wind propulsion technology, and a switch to biofuels can together reduce emissions by 80% by 2040.

Neither battery-electric propulsion and biofuels are readily available solutions. While battery-electric is not shown in Figure 4, both options are candidates that merit further pursuit, in order to establish appropriate production pathways (for electricity, and biofuels), and explore and exploit their potential.

The scenarios provide an indication of the cuts to greenhouse emissions that can be achieved through uptake of a suite of measures or technologies. Beside the uncertainty in the size of emissions, transitioning to, for example, battery-electric propulsion is not straightforward or even technologically feasible at *present*. In order to achieve a successful transition as described by the scenarios, many factors need to work together. The following Sections 3.4 and 3.5 identify relevant enabling measures.

3.3 Indicative cost estimates

In this Section, indicative cost estimates are given for the technological transitions represented by the scenarios. In the first step, cost is estimated per unit, e.g. per vessel. In a second step, the total market size of the technology transition under the scenario is estimated over the period 2020 to 2040. Underlying assumptions are detailed in Section A.3.

Wind propulsion:

The indicative cost estimate of building a small sail boat (or, alternatively, retrofitting a sail system on a small boat) is FJD5,000. The Opex benefit is a saving of FJD1,700 p.a. Under a discount rate of 10% and a time horizon of ten years, the NPV of a small boat sail installation is FJD5,300. The payback period is less than four years. The market of small boat sail installations totals FJD45m. over the period 2020-40.

In the sample case of a larger ship, fitting wind propulsion technology comes at Capex of FJD500,000 and saves FJD150,000 p.a. in Opex. Installation cost, fuel price, and days spent at sea are the key parameters determining the indicative Capex and Opex estimates. Under a discount rate of 10% and a time horizon of the years, the NPV amounts to FJD145,000. The payback period is just under seven years. The market of (retro-)fitting wind propulsion technology to ships totals FJD34m. over the time period 2020-40.

Biofuels:

In the presented scenario, biofuels serve as a drop-in fuel, providing a like-for-like replacement for fossil fuel. All Capex costs are therefore incurred shore-side. For import, biofuels are generally not cost-competitive [20]. Domestically, no biodiesel is produced at present, and only marginal amounts of biofuel are produced, and not cost-competitively. For example, the price of crude coconut oil is around FJD3 per litre, compared to a diesel price of FJD2 per kg as assumed in the scenarios. Whether biofuels become cost-competitive in the future depends on many factors. For example, there are a number of potential feedstocks and production pathways for biofuels, including the potential for second and third generation biofuels. Similarly, market conditions are subject to change over time, and relative prices are influenced by rules and regulations (cf. Section 3.4). The general assumption underpinning the biofuels element of the scenarios is that biofuels are just cost-competitive with fossil fuels, at a constant price of FJD2; and that biofuels are produced domestically, for wider sustainability reasons.

The total market for biofuels for sea transport amounts to FJD1.5bn. over the period 2020-40.

Battery-electric:

Battery technology and cost is one key determinant of the economic feasibility of battery-electric propulsion. In the scenarios, the price of one kWh of fossil fuel is FJD0.50; the price of one kWh of electricity is FJD0.33 (cf. Section A.3). Recharging a battery is cheaper than refilling the tank, saving FJD0.17 per kWh. However, the cost of the tank is negligible while the cost of batteries is high. Assuming a battery price of FJD300 per kWh, battery-electric breaks even at 288 charging cycles per year (i.e. a battery installation has an NPV=0, for a discount rate of 10% over a ten year horizon). Under the scenario, the total market of installations amounts to FJD75m. over the time period 2020-2040 while the market for grid electricity for charging batteries amounts to FJD240m. over the same time period, in each the outboard motor segment, and in inboard-motored ship segment, i.e. the total market for installations is FJD150m., and the total market for electricity is FJD480m. The total fuel consumption by outboard motors is smaller, but their electric share is larger, as larger vessels mostly serve longer routes, which are not as suitable for battery-electric as shorter routes, which allow for more frequent re-charging cycles.

Energy efficiency:
The cost estimation of energy efficiency measures is limited to hull and propeller maintenance. In the representative sample case (cf. Section A.3), a full service in dry docking comes at a Capex of FJD24,000. In terms of Opex, this saves FJD130,000 during the first year. Savings reduce over the cycle between dry dockings, typically of the order of five years. Under a discount rate of 10% and a time horizon of five years, the NPV is FJD290,000. The total market over the time period 2020-40 amounts to FJD12m.

3.4 Policy measures

Generally, a suitable framework of norms and rules is a criterion for markets to flourish. With respect to the specific aim of making progress towards sustainable sea transport, policy too has a role in adjusting the regulatory and institutional framework. Three broad categories of policy levers are discussed here: direct government action; setting hard rules and standards; and setting (more flexible) incentives.

Direct government action:
Transport infrastructure is often government-owned. In Fiji this typically includes jetties, and extending the existing network of jetties is an example of potential government action (cf. Section 3.1). Shipbuilding and maintenance infrastructure may be owned by the public or the private sector. In fact, Suva shipyards were government-owned before privatisation took place. Finally, there is a potential role for governments in owning and operating ships. Competitive markets are typically easier to establish for ships and shipping services than for the necessary infrastructure. Nonetheless, Fiji's government already has a part in shipping: actively through GSS; and more passively through its franchise scheme for uneconomical routes.

Rules and standards:
Government has ample scope for setting rules and standards that any domestic ship operators must adhere to. In Fiji, ship operators must register their ship with MSAF, which provides an opportunity for regulatory control. For instance, there was a rule that a vessel must not be older than 20 years to be imported into Fiji. However, this rule was subsequently scrapped in order to allow for an older roro ferry to be imported. The event highlights the potential for conflicts, as the imported vessel might be able to provide a service that the existing fleet could not.

Setting incentives:
Government is also in a position to steer markets through setting incentives. Germany's Renewable Energy Sources Act, or the feed-in tariffs paid in the UK are pertinent international examples.

In Fiji, various levers for setting incentives already exist. This includes import duties and/or taxes on fossil fuels; duties and taxes, as well as duty waivers and tax holidays on equipment in the shipping sector; and a points system under the government franchise scheme. However, energy efficiency and greenhouse gas emission abatement are not typically a design criterion. In setting incentives, too, there is scope for conflicting objectives. Often, the specific consequences of such policy instruments are hard to predict. For instance, raising duties on fossil fuel imports clearly incentivises switching to alternatives. But it might also risk putting sections of the population into fuel poverty. Clearly, this is not an argument against all incentive setting policy instruments. But it does mean that careful consideration as well as political will are required.

3.5 Capacity development

A transition in shipping technology means building, operating, and servicing and maintaining ships and infrastructure, such as fuelling or charging stations. The capacity to do so is necessary for a successful transition (cf. [15]). Here, capacity development is presented in three categories: industrial capacity; professional skills; and public education and awareness.

Industrial capacity:

Fiji imports all of its transport fuels. Ships, and most equipment for the maritime industry are also imported. Imported ships, in particular, are often old, and past their useful life in other parts of the world. Championing a transition towards more sustainable sea transport means that Fiji may also change from being a technology taker to being a technology leader, in line with the vision of generating employment and other economic opportunities. Among the most salient capacity requirements are shipbuilding and dry docking facilities.

Professional skills:

Ship operation requires professional skills. Changes in ship technology therefore require new sets of skills. Without adequate skills capacity, delivering technology risks that either the technology is not used to the fullest benefit, or that it falls into disrepair, or both. Similarly, a sustainable transition in technology requires the capacity of maintaining and servicing the technology in an adequate, and economical way.

In addition, a transition in technology is contingent on adequate business and finance models; and in order to ensure that the transition is successful and sustainable, international co-operation, best practice sharing, and institutional oversight through the public sector are all important, likely crucial elements.

Public education and awareness:

A successful transition requires the support not just from government but also from the public. First, political will is dependent on support from the public. Second, as far as non-commercial sea transport is concerned, a transition to sailing boats is contingent on sailing skills, for instance. Third, inter-island sea transport has a central role in public life in Fiji – therefore only if the transition is carried by the public can it be socially sustainable.

4. Framework sea transport plan

So far, mitigation opportunities for domestic shipping have been identified and combined into a plausible mitigation scenario. In addition, policy and wider capacity development have also been identified.

In order to embark on a pathway in line with the mitigation scenario, and make the fundamental transition towards more sustainable sea transport, significant action is needed. Pursuing environmental, economic, and social sustainability, in accordance with the vision outlined in Section 1, significant, long term strategic action, supported by political willingness, is needed. This section develops a comprehensive framework plan, comprising four main parts: wind propulsion, alternative fuels, energy efficiency, and enabling measures. Each part addresses five categories –technology, operations, infrastructure, policy and regulation, and capacity development– with the exception of the part concerned with enabling measures, which only addresses policy and regulation, and capacity development.

Finally, focusing on specific next steps, a set of actionable measures are distilled from the framework plan.

4.1 Wind propulsion technology

Table 2 presents the wind propulsion part of the framework mitigation plan. In terms of technology, the immediate, short term goal is the specification, design, and build or retrofit of a wind-assisted passenger ship, and the design and build or retrofit of a fleet of small sailing boats to replace outboard motor powered 'fibres'. These wind-powered vessels act as demonstrators that can produce empirical information on practical feasibility, technical performance, and economic performance, and initiate build-up of a local skills base. Experiences gathered during a trial phase can feed into second generation designs, initial up-take by the private sector and, in the longer term, large scale roll-out.

Table 2: *Mitigation plan - wind propulsion technology.*

Wind propulsion	Fleet		Infrastructure	Policy & regulation	Capacity development
	Technology	Operations			
Short term	Specification, design, & build/retrofit of demonstrators	Provision of weather prediction and routeing services	Involvement of local stakeholders from the outset	Direct government purchase	Sail training for professionals and public
Medium term	Trial phase and 2nd generation designs		Preference for and support of local manufacturing and service industry	Subsidies & preferential treatment under e.g. franchise scheme	Support of professional training in maritime industries
Long term	Roll-out				

In terms of operations, the provision of weather prediction and routeing services can support optimal performance. With a view to infrastructure, the wind propulsion technology framework plan includes involving local stakeholders, and a preference for and support of the local manufacturing and service industry, in order to reap the full economic benefits of investment in new technology.

Uncertainty about the technical and economic performance of wind propulsion technology remains one of the main obstacles to uptake by the private sector. Therefore the plan is for government to take the lead and use a government-owned vessel as a demonstrator. In the medium to long term, subsidies and preferential treatment under its franchise scheme, or other licensing schemes, can support uptake in the private sector. Finally, providing training to both professionals and public is an important enabling measure. Similarly, professional training in maritime industries is important to support the industrial base.

4.2 Alternative fuels

At present, there is no readily available alternative low carbon fuel, or energy source, to replace fossil fuels [21]. Both biofuels and battery-electric propulsion are promising candidates. Before they can deliver deep reductions in greenhouse gas emissions at significant scale, progress on various aspects is needed - for example in battery technology (and cost), or regarding production pathways for second and third generation biofuels. Beside these issues, which are beyond the scope of this mitigation plan, there are many other issues to be resolved specifically in order to put Fiji's sea transport sector in a position to scale up use of these alternative energy sources. This includes the compatibility of engines with domestically produced biodiesel; the establishment of sustainable production pathways for biofuel feedstocks, ensuring that greenhouse gas emission savings are realised over the whole life-cycle of the fuel. For battery-electric propulsion, this includes provision of charging stations; interaction of boat or ship batteries with local mini-grids; and others. Therefore, demonstration projects that can provide learning outcomes and best practice solutions to the various issues are an important step to take immediately.

The first step in the plan, as presented by Table 3, is the specification and design of biofuel and battery-electric propulsion trials. In the medium term, information can be gathered from the trials, preparing the way for large scale take-up in the longer term. In terms of operations, the main objective is to trial the technologies, and identifying best practices, and suitable routes (e.g. allowing for frequent recharging).

Table 3: *Mitigation plan - alternative fuels.*

Alternative fuels	Fleet		Infrastructure	Policy & regulation	Capacity development
	Technology	Operations			
Short term	Specification and design of biofuel and battery-electric propulsion trials	Application on suitable routes (e.g. allowing for frequent recharging)	Review potential supply chains; align with wider energy strategy	Government lead; PPP possible	Intl. co-operation, research, training for professionals and public
Medium term	Trial phase		Trial of refuelling stations	Regulatory oversight & steering function (e.g. subsidies)	
Long term	Review and roll-out		Network of refuelling stations		

Infrastructure, i.e. shore-side production and bunkering (or charging) facilities, are clearly critical to the success, or otherwise, of any alternative fuel. From the outset, the mitigation plan includes reviewing potential supply chains, and aligning the push for alternative fuels for sea transport with Fiji's wider energy strategy. Refuelling facilities are part of trial projects, and as part of large scale take-up of any alternative fuels, a network of refuelling stations is required in the longer term.

In the short term, it is incumbent on government to take the lead. Shore-side, government already has a lead role, both in the production and provision of electricity; and in parts of the bio-energy industry, e.g. in the establishment of copra-processing oil mills. In the medium to long term, large scale take-up will involve the private sector. Government will retain regulatory oversight as well as a steering function, e.g. through subsidies.

The capacity development pillar of the alternative fuels plan comprises international co-operation, research (building on existing expertise and equipment at USP), and training for professionals and public.

4.3 Energy efficiency

There are many ways of improving and optimising ship energy efficiency. The mitigation plan addresses two of them explicitly, with other measures aimed at fostering energy efficiency in general.

Hull and propeller maintenance is the first main element. Monitoring ship performance and fuel consumption is useful for scheduling maintenance operations. Mandating ship operators to maintain energy efficiency management plans, logging ship movements and fuel consumption among other things, can furthermore help put energy efficiency (and reduced fuel costs) at the focus. Availability of dry docking facilities are prerequisite to optimal hull and propeller maintenance regimes, with a responsibility for government to ensure this prerequisite is met.

Table 4: *Mitigation plan: energy efficiency measures.*

<table>
<tr><th rowspan="2">Energy efficiency</th><th colspan="2">Fleet</th><th rowspan="2">Infrastructure</th><th rowspan="2">Policy & regulation</th><th rowspan="2">Capacity development</th></tr>
<tr><th>Technology</th><th>Operations</th></tr>
<tr><td>Short term</td><td>Hull & propeller maintenance</td><td rowspan="2">Hub & spoke model for inter-island routes;</td><td rowspan="3">Dry docking facilities</td><td>Mandatory energy efficiency management plans</td><td rowspan="3">Training for professionals on energy efficiency and related regulations</td></tr>
<tr><td>Medium term</td><td rowspan="2">Energy efficiency audits for new-build or imported vessels</td><td rowspan="2">Set incentives for energy efficient vessels</td></tr>
<tr><td>Long term</td><td>Monitoring & controlling voyage speed</td></tr>
</table>

The second main element is the implementation of hub and spoke schemes of operating geographically suitable inter-island routes. A hub and spoke scheme can be more efficient, reducing the need for jetties at the outer end of the spokes, and reducing the time and fuel spent by the larger vessel operating the main route between the hubs. Furthermore, a hub and spoke scheme on one of the inter-island routes provides a natural test case for trialling vessels fitted with wind propulsion technology - both larger ships (operating between the hubs) and smaller boats (operating along the spokes).

Table 4 summarises the plan for enhancing energy efficiency. Mandatory energy efficiency management plans for commercially operated vessels can be complemented by energy efficiency audits for new-build or imported vessels. In the longer term, suitable incentives aimed at increased energy efficiency can be defined.

There is a risk that increasing energy efficiency increases operating speeds instead of reducing fuel consumption and greenhouse gas emissions. In the medium to long term, monitoring and, if necessary, controlling speed is therefore indicated.

Finally, training for professionals in the maritime industries is needed to promote best practice and to ensure compliance with regulations, such as keeping energy efficiency management plans, can be provided at little cost and effort.

4.4 Enabling measures

Completing the mitigation plan are a set of general enabling measures, summarised in Table 5. The first is to legislate requirements to monitor fossil fuel imports, and fossil fuel use. This measure is of critical importance to monitoring progress and delivering the mitigation plan. Much of the data on fuel imports, subject to import duties, is already recorded, in principle. Mandatory energy efficiency management plans (see Section 4.3) would hold data on fuel use. Beside producing the data, it is necessary that the data are kept in an accessible and transparent way, within government. At present, relevant government institutions either do not have, or cannot access, data on fuel imports, for instance (cf. Section A.2).

The second enabling measure encompassing all other parts of the mitigation plan is fossil fuel taxation, which needs to be aligned with wider policy objectives in the medium term. In the longer term, this (and other rules and regulations, in particular those regarding the franchise scheme and the route licensing scheme) may be subject to review and adjustment.

Finally, communicating progress, or otherwise, public awareness raising, and engaging in the international policy process are all part of the overarching aim of climate change mitigation.

Table 5: *Mitigation plan - enabling measures.*

Enabling measures	Policy & regulation	Capacity development
Short term	Define and legislate monitoring requirements for fossil fuel imports and use	Communicating progress; public awareness raising; engagement in the international policy process
Medium term	Fossil fuel taxation	
Long term	Review and adjust rules and regulations	

4.5 Actionable measures

Sections 4.1 - 4.4 have presented a comprehensive mitigation plan for Fiji's maritime transport sector. The plan considers action across five categories: fleet technology; fleet operation; infrastructure; policy and regulation; and capacity development. All are critical to delivering a sustainable transition away from fossil fuels.

This section distils a set of actionable measures from the plan, specifically considering indicative estimates of their cost; and identifying appropriate government institutions to take the lead on implementation.

1. Small sailing boats investment: For small boats, sail technology is a straightforward, greenhouse gas-free option. Investing in a fleet of sailing boats can open up the potential of this option.
   Lead: MoIT, together with private and public partners.
   Indicative cost estimate: FJD1m.

2. GSS wind propulsion vessel: Specification, design, and purchase of wind propulsion technology, either new-build or retrofitting a Government Shipping Services vessel. There is a plethora of concepts and designs, but there are very few existing demonstrators, and even less available data on real life performance. The most valuable step forward is therefore to gather data in operation and demonstrate practical and economic feasibility. Therefore, a suitable approach is to maximise the expected return on investment rate. To this end, the vessel's expected operational profile (including days spent at sea, and wind climatologies) and practical considerations (in particular demands on the crew) need to be factored in, in order to technological concept, supplier, and specific design.
   Lead: GSS
   Indicative cost estimate: FJD3m.

3. Awareness raising and training programme: Raising awareness in the private sector and the public is critical to the success of a low carbon transition, or otherwise. Easy first steps may include regular postings on the Fiji Seafarers' facebook page and building up content on the low carbon transition in the FMA curriculum. Next steps may include a sailing training programme, for both members of the public and maritime professionals.
   Lead: FMA, MSAF, and FYA
   Indicative cost estimate: FJD0.5m.

4. Implementation of a hub and spoke scheme: Identifying a suitable route for a hub and spoke scheme of operation under the government franchise scheme.
   Lead: MoIT
   Indicative cost estimate: -

5. Shipyard/dry docking facility investment: Investment is needed to provide the infrastructure allowing for optimised maintenance and service of vessels, with the objective of increasing energy efficiency.
   Lead: MoIT and private stakeholders
   Indicative cost estimate: FJD5m.

6. Trial of battery-electric powered outboard: A programme to trial battery-electric powered outboard motors is needed before take-up on a larger scale is possible.
   Lead: MoE; involving MoIT, MSAF, FMA, and private stakeholders
   Indicative cost estimate: FJD1m.

7. Trial of battery-electric powered ferry: On a short, and regularly and frequently operated route, a battery-electric powered ferry is trialled. The measure includes fitting a battery-electric propulsion system to a vessel, as well as providing the shore-side charging infrastructure.
   Lead: MoE; including MoIT, MSAF, and private stakeholders
   Indicative cost estimate: FJD3m.

8. Trial of biodiesel as drop-in fuel: Biodiesel is a promising option – but no biodiesel is produced at present in Fiji. However, a number of bioenergy plants are active in Fiji, using various feedstocks. The aim of this measure is to identify a suitable candidate feedstock and biodiesel production pathway, ideally utilising one of the existing plants. In a second step, the biodiesel is trialled in marine diesel engines.
   Lead: MoE and MoIT
   Indicative cost estimate: A suitable feedstock and production pathway are to be determined before a cost estimate can be made.

9. Define and legislate fuel monitoring requirements: The elements of this measure include data collection and management. To be collected are fuel import data; fuel sales data (recording the intended use of the fuel); and fuel consumption data (in conjunction with ship energy efficiency management plans). All data are collated and coordinated in one central location.
   Lead: MoE is best placed to provide data management.
   Indicative cost estimate: The cost of collecting and managing the data is near-negligible.

10. Mandate energy efficiency management plan: Any commercially operated vessel is required to maintain an energy efficiency management plan.
    Lead: MoIT, MoE, and MSAF
    Indicative cost estimate: The cost of mandating energy efficiency management plans is incurred on ship operators and is near-negligible. Nonetheless, private stakeholders are likely to resist a measure requiring additional effort from them. Providing adequate training may facilitate compliance.

11. Review and adjust taxes and duties: Existing import duties and taxes are to be aligned with energy efficiency and emission abatement objectives. To what extent these measures raise revenues or otherwise depends on the details of any adjustments to existing regulation. Any adjustments are to be designed in line with wider policy objectives, considering the potential for unintended consequences, such as fuel poverty.
    Lead: MoE and FRCS
    Indicative cost estimate: -

12. Review of government franchise scheme: The rules of the government franchise scheme for the uneconomical routes and, if it comes to pass, the route licensing scheme covering the economical routes are to be aligned with the objectives of energy efficiency and renewable

energy transition potential. In some instances, trade-offs between delivering service and environmental objectives may be encountered (e.g. opting between an older and more inefficient but larger vessel, or otherwise). In such cases, it is incumbent on the pertinent government institutions to negotiate trade-offs. However, environmental performance may be considered and is to be included in the franchise scheme's points system and other regulations.
Lead: MoIT
Indicative cost estimate: -

13. Set policy priorities and strategic lead: The mitigation plan presented in this report aims at a fundamental transition towards more sustainable sea transport. This requires sustained political will and, to be achieved successfully, strategic coordination and leadership. As such, this measure can be considered as a starting point for the mitigation plan.
Lead: MoE (its climate change unit in particular) to provide strategic oversight
Cost: -

5. Summary and conclusions

Maritime transport is crucial to Fiji's economy, culture, and social fabric. Maritime transport is also accountable for a much larger share of Fiji's greenhouse gas emissions than in most other countries. The comprehensive mitigation plan presented is motivated by the need to cut greenhouse gas emissions deeply and urgently, while always considering the wider vision of delivering reliable service, and wider environmental, social, and economic benefits.

The mitigation plan is underpinned by the emission abatement potential of fleet and infrastructure mitigation opportunities, including a quantitative mitigation scenario. Technological, operational, and infrastructure measures are complemented by policy and regulatory measures, and capacity development.

Taking unilateral action to regulate international shipping is difficult. Therefore, the mitigation plan is focused on domestic shipping. Taking action domestically, however, will give authority to Fiji's voice in the international policy debate.

5.1 Fiji's NDC and international climate policy

In line with the scenarios presented in Section 3.2, Fiji could declare in its NDC a target of reducing greenhouse gas emissions from domestic maritime transport by 27% in 2030, matching that of the Republic of the Marshall Islands.

The Pacific region has shown leadership in international politics, arguing for limiting global temperature increase since pre-industrial times to 1.5°C, both at the UNFCCC, which included the goal in the Paris Agreement, and at the IMO, in the policy debate on international shipping.

The IMO is currently in the process of defining its greenhouse gas strategy. This presents an opportunity for Fiji to champion climate change mitigation in the shipping sector domestically, and thereby add momentum to the process on the international level.

5.2 Setting course for sustainable sea transport in Fiji, and beyond

Clearly, achieving the transition away from exclusive reliance on imported fossil fuels towards greenhouse gas emission-free, sustainable, and reliable maritime transport is an ambitious endeavour. The political will to take it on is the first prerequisite to success.

Some details of the mitigation plan are beyond the scope of this project, e.g. which biodiesel feedstock, and which production pathway, may be the best fit for a trial in Fiji. Similarly, some of the cost estimates are indicative and may be re-visited. However, specific actions –the first steps for embarking on the mitigation plan– have been defined in Section 4.5 and are ready to be taken.

In the wider Pacific region, other countries too are setting course for the transition towards more sustainable sea transport. The Republic of the Marshall Islands, in cooperation with Germany, for instance, have established the Micronesia Center for Sustainable Transport (MCST), seeking to trial renewable energy technology (also see [22]). Much larger Fiji may be ideally placed to utilise results, rolling technologies on a greater scale. More generally, there will be ample potential for exploiting synergies, and each step forward will add to the momentum of the transition – not just in Fiji but in the region and the world.

In summary, there is the opportunity to take leadership, as a champion, in the challenge of achieving sustainable, and affordable maritime transport, in Fiji and around the world.

Appendix

A.1 GHG emissions estimate methodology

Annual CO_2 emissions from the following sub-sectors: Government Shipping Services (GSS), uneconomical routes, and economical routes, small boats, fishing, tourism and other (e.g. dredging) are estimated for the reference year 2016. Together, they constitute the totality of domestic shipping in Fiji (cf. Section 2.2). The data sources and methodologies differed between the various sub-sectors, so details are given for each.

Government shipping services: GSS provided fuel consumption data for each of its vessels, totalling 1.11kt of diesel, resulting in emissions of 3.44kt of CO_2. The accounts tally with the annual GSS fuel bill of the order of FJD2m, and are considered accurate (we estimate an uncertainty of ~1%). The records account for both fuel sales and activity data, and therefore no separate bottom-up and top-down estimates are made. A caveat to be noted concerns the time period: available data cover the time period August 2016 to July 2017, rather than the reference year 2016.

Uneconomical routes: Fiji's Ministry of Infrastructure and Transport collate fuel consumption data from the vessels serving the uneconomical routes under the government franchise scheme. There are 14 monthly trips under the scheme, and data records were complete for three months in 2016 – January, July, and August. Fuel consumption in these three months were multiplied by four to approximate fuel consumption over the whole year, amounting to 1.29kt of fuel used, or 3.61kt of CO_2 emitted.

Economical routes: Emissions from this category are derived from an MSAF ship register (after excluding vessels that are either part of GSS or employed under the government franchise scheme), as per 27 Sep. 2016, via an activity-based fuel consumption model. All vessels whose type includes the word 'passenger' or 'cargo' (but not 'tourist' or 'fishing') are included. Vessels are assumed (on average) to spend 95 full days at sea, with an average engine load of 25% of installed engine power (as per the MSAF registry). Assuming a fuel burn of 250g per kWh gives the total fuel consumption of 22kt, amounting to 67kt of CO_2 emitted. Given the uncertainty in the factors of the activity-based model, we estimate an uncertainty range from half to twice the estimate fuel burn, i.e. an uncertainty of -50%/+100% (cf. Figure 2).

Small boats: Emissions from this category are estimated from a household travel survey for Solodamu Village, on Kadavu [23], scaling results to the whole country, i.e. from the 22 households, representing 88 individuals (this study's estimate), to the whole population of Fiji of about 880,000.

The survey reports a monthly outboard motor fuel consumption of 225 litres per month. The scale up yields a total fuel consumption of 24kt p.a., resulting in CO_2 emissions of 75kt.

For reference purposes, an activity-based model was derived from expert opinion. Estimating a fleet of 20,000 outboard-motored 'fibres', with an average engine power of 30kW, a fuel consumption of 250g/kWh, an average daily activity equivalent to one hour at full engine power, results in an estimated annual fuel consumption of 55kt, and CO_2 emissions of 170kt, more than twice as much as the estimate based on the household survey. We use the former for the purpose of any further analysis in this report, estimating an uncertainty of -50%/+100%, roughly in line with the difference between the two estimates given.

Fishing: Emissions from this category are estimated by the same methodology as emissions from the 'Economical routes', including all vessels containing the word 'fishing' (but not the word 'tourist') in their type description. Total fuel burn from this category is 8kt, amounting to CO_2 emissions of 25kt.

Tourism: Emissions from this category are estimated by the same methodology as emissions from the 'Economical routes' and 'Fishing', including all vessels containing the word 'tourist' in their type description. Total fuel burn from this category is 11kt, amounting to CO_2 emissions of 34kt.

Other: Emissions from this category are estimated by the same methodology as emissions from the 'Economical routes', 'Fishing', and 'Tourism', including all vessels from the MSAF registry not included in any of the aforementioned categories. Total fuel burn from this category is 6kt, amounting to CO_2 emissions of 19kt.

In most cases, fuel consumption was reported in litres. A conversion factor of 0.9kg/l was applied, and an emission factor of 3.1 kg CO_2 per kg of fuel combusted. Fuel consumption and CO_2 emission estimates are summarised in Table A.1.

Table A.1: *Summary of fuel consumption and CO_2 emission estimates.*

Sub-sector	Fuel consumption [kt]	CO_2 emissions [kt]
Government Shipping Services	1.11	3.44
Uneconomical routes	1.29	3.61
Economical routes	22	67
Small boats	24	75
Fishing	8	25
Tourism	11	34
Other	6	19

A.2 Project timeline and meetings

Research and stakeholder engagement for the development of the mitigation plan for Fiji's maritime transport sector took place during October 2017. This report was produced in November 2017. A summary list of the various meetings between the project consultants and stakeholders is given in the following.

28 September 2017: Inception meeting, held at MoIT

The inception meeting was attended by representatives from FMA, FNU, GSS, MSAF, MoE, and MoIT, and the Asian Development Bank (ADB).

5 October 2017: The University of the South Pacific (USP)

USP provided papers and data held by the Sustainable Sea Transport Research Programme including household data and analysis of outboard fuel use, Pacific positioning in IMO, past retrofit trials and the Regional Research & Education Strategy for transitioning to low carbon sea transport [15].

7 October 2017: Ministry of Infrastructure and Transport (MoIT)

The availability of fuel consumption data, and the particulars of how the government franchise scheme is delivered were the primary topics of this meeting.

7 October 2017: Government Shipping Services (GSS)

Government Shipping Services provided data on its fleet during the meeting. Data on GSS's fleet fuel consumption were transferred after the meeting. In addition, the meeting was concerned with the processes of vessel procurement in GSS and potential for additional design criteria for new vessel purchase.

7 October 2017: Maritime Safety Authority of Fiji (MSAF)

MSAF keeps a registry of Fijian vessels. These data were requested in the meeting. In addition, MSAF suggested providing fuel import data. However, this proved impossible. Furthermore, MSAF are in charge of classifying vessels as 'fit for purpose' or otherwise – 'fit for purpose' being the replacement criterion after the 20 year age limit on vessels imported to Fiji was scrapped.

7 October 2017: Fiji Revenue and Customs Service (FCRS)

The meeting with FCRS focused on the various taxes and duties in place, and their potential role in setting incentives for increasing energy efficiency and reducing emissions. In addition, the meeting focused on the availability of national fuel import data - however, any data transferred proved unreliable, highlighting the need for a reliable scheme of collating and managing fuel import and consumption data.

12 October 2017: Stakeholder workshop, held at MoIT

The stakeholder workshop was attended by representatives from the Fiji government: FMA, GSS, MoE, MoIT, and MSAF; from the Pacific Island Development Forum, and the Pacific Community; from ADB; and by representatives of the private sector, including ship operators and port operators.

13 October 2017: Presentation of preliminary findings (MoE)

Initial findings presented to representatives from MoE, MSAF, GSS, MoIT, IUCN, and ADB.

23 October 2017: Ministry of Economy (MoE)

Informal meeting with representatives from MoE's climate change unit.

2 November 2017: Ministry of Economy (MoE)
Final project presentation, attended by representatives from the Global Green Growth Institute, FRCS, MoE, MoIT, MSAF, and University College London.

A.3 Detailed scenario assumptions

Both parts of the scenarios (i.e. 'small boats' and 'ships') are based on the assumption of a replacement rate of 5% p.a., and the size of the fleet remains static.

The wind propulsion element of the scenario means 10% of new-builds are sail equipped in 2020; 20% in 2021; and so on until 50% of new-builds are sail-equipped in 2025 and in every subsequent year. In the scenario for small boats, sail equipment reduces a vessel's fuel consumption by 50%; in the scenario for ships, wind propulsion technology reduces a vessel's fuel consumption by 30%. The cost estimate of FJD5,000 for a single small boat sail installation is based on elicited expert opinion. Annual savings of FJD1,700 per unit are the product of replacing half an hour's operation each day, at 30hp, 250g of fuel per kWh, and a fuel price of FJD2 per kg. The market size of installations is based on the scenario assumptions and a (constant) fleet size of 18,000.

For ships, the cost estimate for a single unit is also based on expert opinion and on information from various providers of wind propulsion technology equipment. Savings are the product of 12 hours spent at sea each day, effective energy savings of 60kW on average, 200g of fuel consumed per kWh of engine output, and a fuel price of FJD2 per kg.

The biofuel element of the scenario foresees replacing fossil fuels with biofuels, increasing the biofuel share by 5% p.a. from 0% in 2020, to 5% in 2021, ..., to 100% in 2040. In the scenario, the whole life cycle greenhouse gas emissions from biofuels are 40% of those of standard diesel.

The cost estimate of biofuels is based on the assumption that the biofuels share is just cost-competitive with fossil diesel fuel, at FJD2 per kg. The battery-electric element foresees an increasing share of battery-electric powered new-builds, from 10% in 2020, 20% in 2021, ..., to 100% in 2029 and subsequent years. Whole life-cycle emissions for battery-electric propulsion in the scenario are 10% relative to diesel.

For the battery-electric scenario element, the cost of fossil fuel is estimated as FJD0.50 per kWh motor output, corresponding to a fuel price of FJD2 per kg, and a specific fuel consumption of 250g/kWh. The cost of grid electric power is assumed constant at FJD0.33, based on [24], and neglecting all efficiency losses in electric propulsion. The estimate of FJD300 per kWh of battery capacity is optimistic at present, but battery cost is expected to decrease over time. In any case, the cost case mainly relies on the price differential between diesel and grid electricity, and a vessel's operational profile, in particular the number of charging cycles. In terms of the overall market, the cost of electricity is larger than the cost of battery installations, so uncertainty in electricity price and consumption dominates the uncertainty in the total size of the market over the study period.

Finally, the energy efficiency element foresees energy demand per vessel reducing by 2% p.a., in line with scenarios in the 3rd IMO GHG Study 2014 [25]. The cost estimate is derived from the following sample calculation: For a vessel of 40m length and a hull area of $800m^2$, and an effective cost of hull treatment of FJD30 per m^2, the cost of maintenance amounts to FJD24,000. Fuel savings are 20% in the first year following hull treatment, 16% in the second, 12% in the third, 8% in the fourth, 4% in the fifth year, before returning to dry dock. Fuel consumption is estimated from the following parameters: 5h at sea per day, an effective engine power output of ~900kW, 200g of fuel consumption per kWh. The total market is estimated from dry docking requirements, and the cost of providing dry docking facilities, plus associated services.

A.4 List of abbreviations

ADB	Asian Development Bank
BAU	Business as usual
EEDI	Energy efficiency design index
FMA	Fiji Maritime Academy
FNU	Fiji National University
FRCS	Fiji Revenue and Customs Service
GGGI	Global Green Growth Institute
GSS	Government Shipping Services
IMO	International Maritime Organisation
IRR	Internal rate of return
MEPC	Marine Environment Protection Committee
MoE	Ministry of Economy
MoIT	Ministry of Infrastructure and Transport
MSAF	Maritime Safety Authority of Fiji
NDC	Nationally determined contribution
PIDF	Pacific Islands Development Forum
SEEMP	Ship energy efficiency management plan
UNFCCC	United Nations Framework Convention on Climate Change
USP	University of the South Pacific

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