Regional e-mobility policy framework and technical guidelines in the Pacific Island Countries

Final Report

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Abbreviations and acronyms

ADB	Asian Development Bank
BAU	Business-as-usual
BELCO	Bermuda Electric Light Company
BESS	Battery Energy Storage System
BEV	Battery-Electric Vehicles
BMS	Battery management system
BOT	Build-Operate-Transfer
CIF	Cost, Insurance and Freight
CNG	Compressed natural gas
ECA	Economic Consulting Associates
EE	Energy efficiency
ETS	Emissions Trading Scheme
EV	Electric vehicle
EVSE	Electric vehicle supply equipment
GGGI	Global Green Growth Institute
GHG	Greenhouse gases
HEV	Hybrid Electric Vehicles
ICE	Internal combustion engine
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
IRP	Integrated Resource Plan
KGGTF	Korean Green Growth Trust Fund
KPI	Key performance indicators
LFO	Light fuel oil
LPG	Liquefied petroleum gas
MPE	Materials, parts, and equipment
NDC	Nationally Determined Contributions
O&M	Operations and management
PCREEE	Pacific Centre for Renewable Energy and Energy Efficiency
PBSP	Pacific Blue Shipping Partnership
PHEV	Plug-in hybrid vehicles
PPA	Pacific Power Association
PPP	Public-private partnerships
PRIF	Pacific Region Infrastructure Facility
RCD	Residual current device
RE	Renewable Energy

SAE	Society of automotive engineering
SOC	State-of-charge
SPC	Pacific Community
TEC	Tuvalu Electricity Corporation
TOU	Time-of-use
TTA	Trama TecnoAmbiental
UNIDO	United Nations Industrial Development Organization
VAT	Value Added Tax

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- Kaupule Funafuti
- Marshalls Energy Company
- Marshall Island Police Department

Executive summary

Introduction and status of e-mobility

This report sets out a regional e-mobility policy roadmap for the Pacific Island Countries

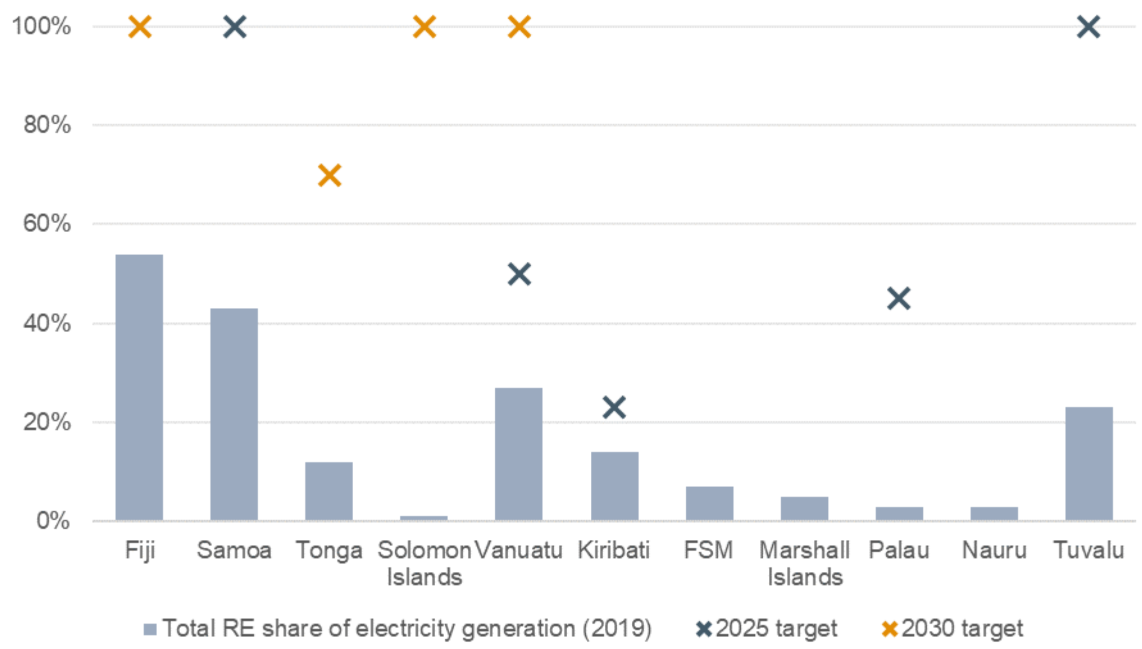
The World Bank contracted Economic Consulting Associates (ECA) and Trama TecnoAmbiental (TTA) to develop this regional e-mobility policy roadmap for the Pacific Island Countries. Its focus is on assessing the feasibility of large scale electric vehicle (EV) deployment in the Pacific Island Countries and on providing policy recommendations to promote e-mobility uptake.

To realise their ambitious goals, the Pacific Island Countries must decarbonise their transport and electricity sectors in tandem

Pacific Island Countries face unique challenges related to climate change and have committed to ambitious goals to decarbonise their economies. A key component of this is decarbonising the transport sector.

Most of the Pacific Island Countries are falling behind on their decarbonisation targets and are still heavily reliant on diesel-fired electricity generation, as illustrated in the figure below. This results in high electricity tariffs and limits the environmental benefits of EVs, which both discourages e-mobility uptake. It is therefore critical that the transport and electricity sectors be decarbonised in tandem.

RE targets in Pacific Island Countries



The level of e-mobility uptake in the Pacific Island Countries is uncertain, but will likely not exceed 10% by 2030

The unique characteristics of the Pacific Island Countries work both for and against the uptake of EVs. Vehicle ownership is low and the distances travelled tend to be short, which both work against. But high fuel prices and the ease of trips being conducted on a single charge both work in favour EVs.

As we describe further below, the viability of EVs in the Pacific Island Countries varies a lot by EV type and their use cases. But our overall assessment is that electric cars, motorbikes, and vans have the most potential for uptake in the short to medium-term future, as summarised in the figure below.

Summary of potential e-mobility uptake in the Pacific Island Countries

Electric cars
- High, particularly for taxis and high-use customers

Electric motorbikes
- High in countries where motorbikes are already used

Electric vans and trucks
- High for delivery vans and transport, low for trucks

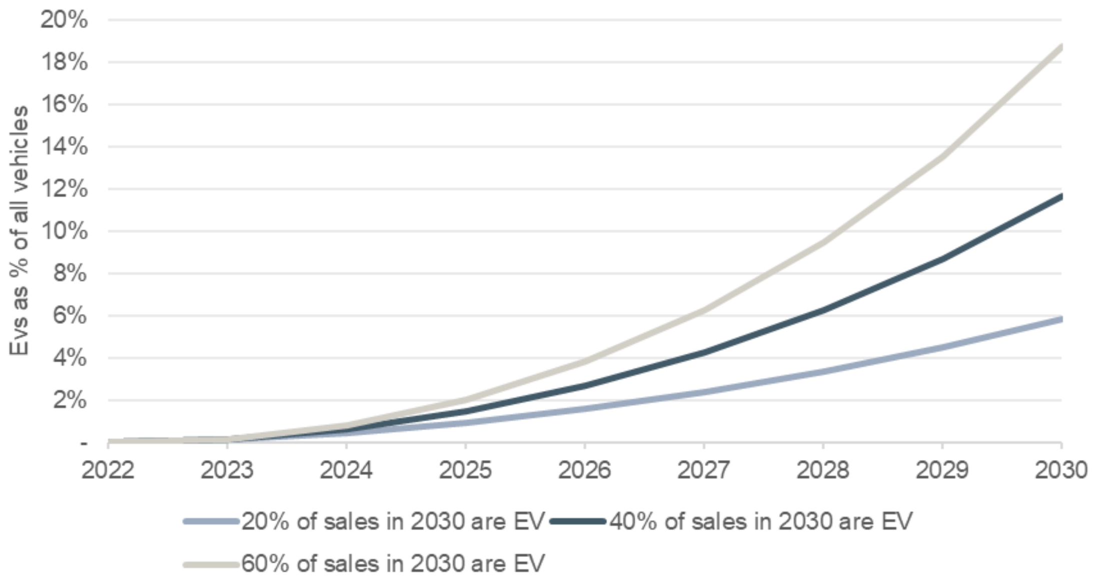
Electric buses
- Low unless heavily subsidised

Electric boats
- Low

Micro e-mobility
- Moderate to high, with only small barriers to entry

We estimate that the share of electric cars in the Pacific Island Countries will be between 6% and 19% of all cars by 2030, as shown in the figure below, with the lower end of this range more likely. This compares to industry estimates of global uptake of around 10% by 2030, although uptake is generally expected to be slower in low and middle-income countries due to a reliance on second-hand vehicles and lower incomes.

Potential electric car uptake in the Pacific Island Countries



In developing this e-mobility roadmap, we group the Pacific Island Countries into four categories

There is significant diversity across the 11 Pacific Island Countries. To ensure our recommendations reflect this diversity, we group the Pacific Island Countries into four broad categories and analyse one country from each in detail, as summarised in the table below.

Grouping of Pacific Island Countries for this report

Category	Countries	Key (relative) characteristics	Likely main types of e-mobility
Large markets	**Fiji** Samoa	Large (in size and population) Wealthy High vehicle ownership Cheap electricity	Electric cars (private, taxis) Electric vans (taxis, commercial)
Intermediate markets	Vanuatu **Solomon Islands** Tonga	Large (in size and population) Less wealthy Low vehicle ownership	Electric cars (taxis) Electric vans (commercial)
Small islands	Kiribati FSM **Marshall Islands** Palau	Small (short distances) Low vehicle ownership	Electric cars (taxis) Electric motorcycles
Very small islands	Nauru **Tuvalu**	Very small (short distances) Very small markets	Electric motorcycles and electric scooters

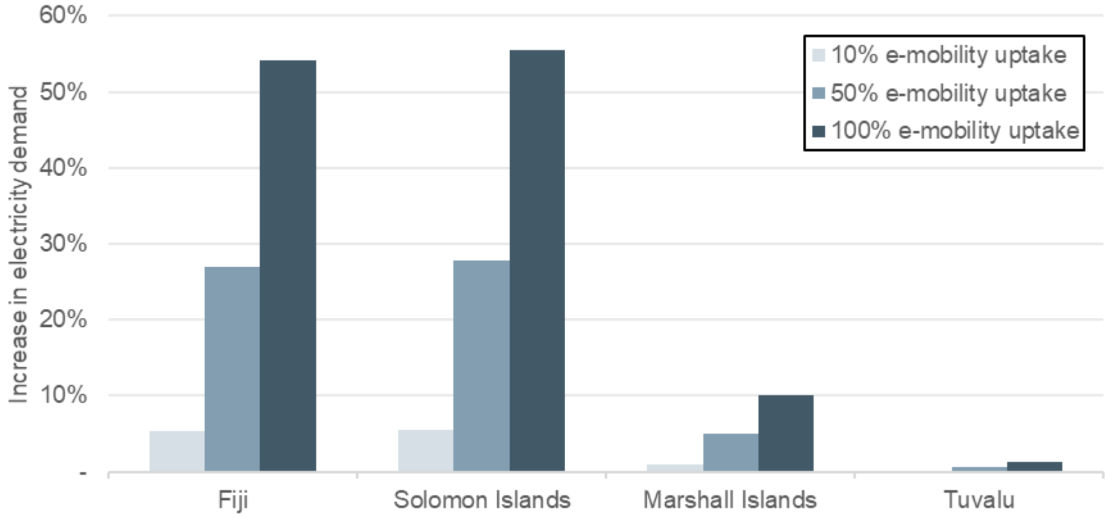
Key: Sample countries that we analyse in detail

Potential impact of e-mobility on electricity systems

The impact of EVs on electricity demand will vary by country, based on car ownership levels and existing electricity demand

Expected impacts of EV uptake on electricity demand in the Pacific Island Countries are expected to vary significantly, as summarised in the figure below.

Increase in total electricity demand due to e-mobility uptake



The figure above shows that:

- Percentage impacts on demand in Fiji (a 'large market') are relatively high due to relatively high car ownership and average distances travelled daily (~30km/car/day).
- Percentage impacts on demand in Solomon Islands (an 'intermediate market') are also high, although in this case it is due to low existing electricity demand per customer counteracting low car ownership compared to Fiji. In other words, household electricity demand is currently low, so the adoption of a relatively small number of EVs will have a large impact on demand.
- Impacts on demand in the Marshall Islands (a 'small island') and Tuvalu (a 'very small island') are very low because car ownership is low. For example, Tuvalu has only 65 registered cars.

As a general rule for the large and intermediate markets (Fiji, Samoa, Solomon Islands, Tonga, and Vanutau), each 1% uptake in e-mobility will lead to approximately a 0.5% increase in electricity demand.

The most efficient way to meet EV demand will be through solar and BESS and to encourage daytime charging

A combination solar PV and Battery Energy Storage Systems (BESS) is currently a more expensive way of meeting electricity demand than a combination of solar and diesel generation, for most of the Pacific Island Countries, although not by much at current fuel prices of around US$80/bbl. We expect this to have changed by 2030, with decreasing technology costs leading to the combination of solar PV and BESS becoming significantly cheaper.

It will therefore be much cheaper to supply EV demand in the Pacific Island Countries during sunshine hours than non-sunshine hours, by a factor of more than two in some cases, as summarised in the table below. This is true even after accounting for the fact that network costs are mostly incurred during weekday business hours.

2030 marginal cost of supplying EV demand efficiently (USc/kWh)

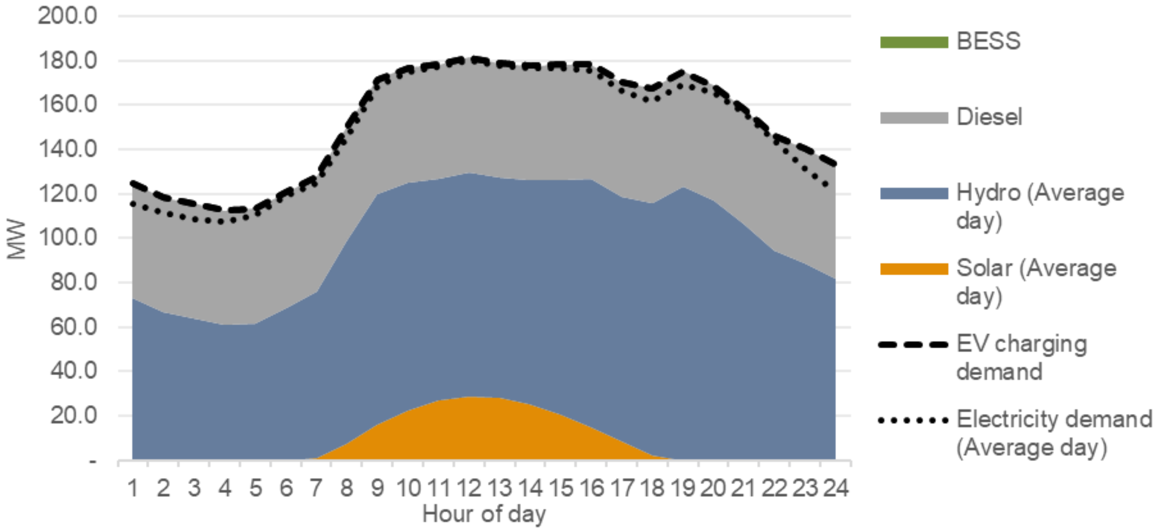
	Fiji	Solomons	Marshall Islands	Tuvalu
Peak (weekday, daytime) + sunshine hours	0.17	0.19	0.26	0.21
Peak + non-sunshine hours	0.30	0.19	0.54	0.43
Off-peak + sunshine hours	0.11	0.13	0.18	0.15
Off-peak + non-sunshine hours	0.25	0.13	0.46	0.38

To improve the business case for EVs, most of the Pacific Island Countries need to add much more solar than currently planned

Most Pacific electricity systems have underbuilt solar PV and therefore diesel generation is currently the marginal generator in most countries and is used to supply any new EV charging demand.

Fiji and Samoa are well placed to displace diesel-fired generation with combination of solar PV and hydro, but only if they invest more heavily in solar PV. For example, Fiji will likely need to add around 300MW of solar capacity by 2030, rather than the approximately 50MW of new solar capacity currently planned, as illustrated in the figure below.

2030 electricity supply curve in Fiji after adding 50MW solar



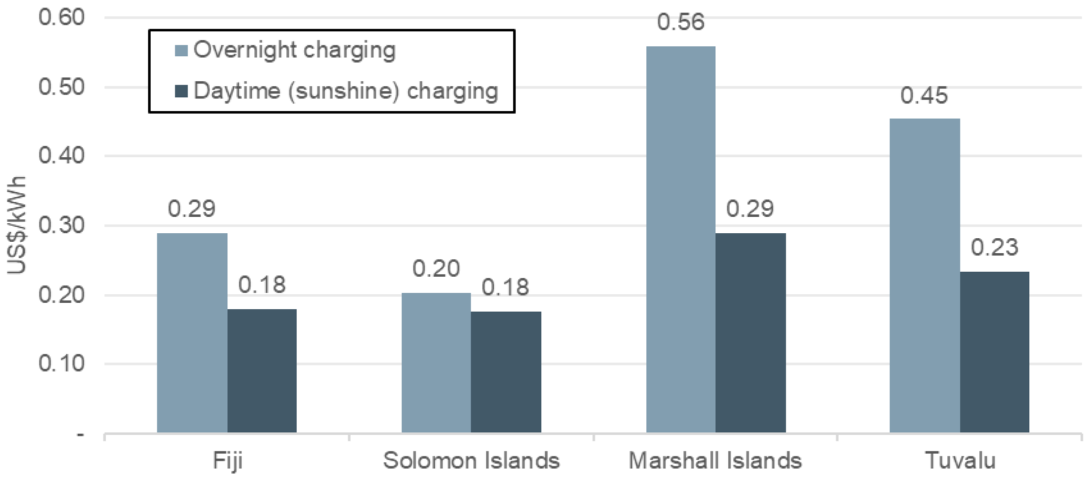
Other Pacific Island Countries will also need to add a lot of solar PV, and BESS, to push diesel generation off the margin and avoid it being used to supply EV demand.

The more that daytime charging can be encouraged, the cheaper the overall cost of supplying EVs

Without incentives encouraging otherwise, consumers in the Pacific Island Countries will likely prefer to charge EVs at home by trickle charging from a standard electrical outlet. This would lead to a predominance of overnight charging, which would ease demands on generation and network capacity in the short term, but would be sub-optimal in the medium to long term once utilities have invested more heavily in solar generation.

Once there is sufficient solar PV and BESS, overnight EV charging will be around 50% more expensive than daytime charging, as summarised in the figure below. Therefore to unlock the benefits of e-mobility, Pacific Island Countries need to invest in solar generation and encourage daytime EV charging through incentives such as time-of-use tariffs and charging infrastructure at workplaces.

2030 marginal costs of supplying EV demand



Economic viability of e-mobility

Government efforts should focus on supporting the EV types that provide the most benefits to society

Governments should encourage the uptake of EV types that are economically viable (including environmental benefits) from a societal perspective. This can be done through policies and incentives that align societal benefits with individual financial incentives, for example providing tax breaks that broadly reflect environmental benefits.

To inform the formulation of e-mobility policies, we assess the viability of EVs in different Pacific Island Countries and under different use cases (low, medium, and high) by comparing the upfront costs, fuel/charging costs, maintenance costs, and environmental costs of electric and Internal Combustion Engine (ICE) vehicles. We also assess viability under three different future scenarios, which are summarised in the figure below.

Overview of economic viability scenarios

Business-as-usual 2022
- Based on status quo
- No new policy interventions beyond status quo

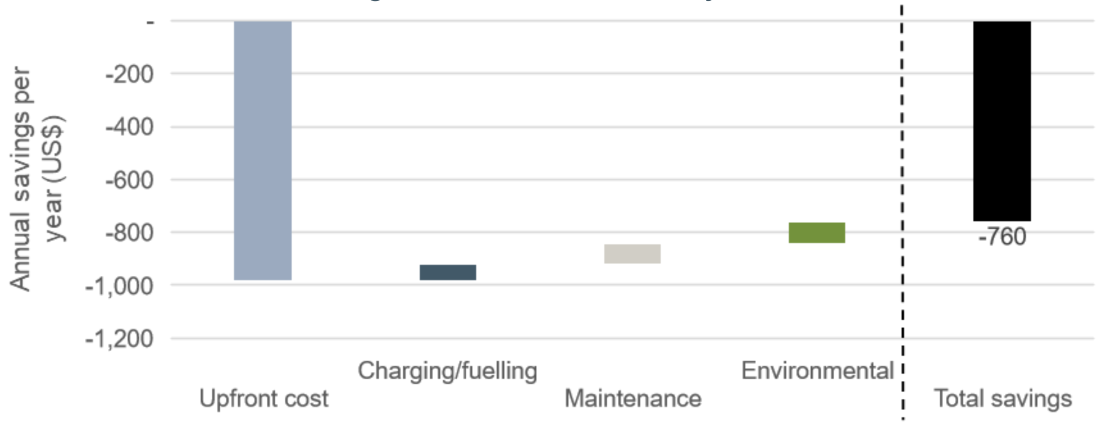
Business-as-usual 2030
- Conservative assumptions reduction in EV upfront costs
- Only 20% of daytime EV charging supplied by solar (diesel used the rest of the time)
- Mostly overnight EV charging

Favourable 2030
- Higher future cost reductions in EV upfront costs
- 100% of daytime EV charging supplied by solar, due to increased RE investment
- Mostly daytime EV charging, due to TOU tariffs and provision of public charging facilities

Currently, EVs are mostly not economically viable in the Pacific Island Countries due to higher upfront costs and limited environmental benefits

Our analysis shows that electric cars, motorbikes, and vans are all not economically viable in the Pacific Island Countries at current costs and under average use cases (‘business-as-usual 2022’ scenario). This is due to EVs having higher EV upfront costs, limited fuel/charging savings, and limited environmental benefits (due to reliance on diesel-fired generation), as illustrated in the figure below for Fiji.

Electric car annual net savings – medium-use case, Fiji – business-as-usual 2022



In general, the smaller the country, the less viable are EVs, due to them having higher EV import costs and shorter daily distances travelled. EVs may be viable in a few exceptional cases, in particular users who regularly travel large distances.

We expect EVs to become viable if Pacific Island Countries increase solar generation and encourage day time charging

Despite expected large reductions in their upfront costs, electric cars, motorbikes, and vans are all likely to remain unviable in 2030 ('business-as-usual 2030' scenario) unless the Pacific Island Countries make significant investments in solar PV capacity.

If the Pacific Island Countries do successfully increase solar penetration and encourage daytime charging ('favourable 2030' scenario), then we expect electric cars, motorbikes, and vans to become viable, except for low use-cases, as summarised in the figure below. Governments should ideally focus most on supporting the medium and high use cases of EVs (ie. commuters and taxis) because these have the greatest expected viability.

In Tuvalu and other very small islands, EVs are unlikely to become viable in the short to medium term, because the short distances travelled do not allow the high upfront costs of EVs to be recouped through lower operating costs.

Viability of EVs under different use cases – favourable 2030 scenario

Modes	Use case	Fiji	Solomon Islands	RMI	Tuvalu
E-cars	Low	✗	✗	✗	✗
	Medium	✓	✓	✓	✗
	High	✓	✓	✓	✗
E-motorbikes	Low	✗	✗	✗	✗
	Medium	✓	?	?	✗
E-vans	Medium	✗	✗	✗	✗
	High	✓	✗	✓	✗

E-mobility policy recommendations

There are significant barriers to e-mobility uptake in the Pacific Island Countries that need to be addressed

In addition to the reliance on diesel-fired generation, e-mobility uptake in the Pacific Island Countries is inhibited by a range of other barriers, including a lack of charging infrastructure, limited EV financing options and subsidies, an absence of EV regulations and standards, and no endorsed regional or national e-mobility strategies.

Not all the barriers can be overcome quickly, especially those that relate to the commercial viability of EVs. But policy makers still need to give most of them some attention, because they are often interrelated and an entire ecosystem of supporting policies needs to be established.

We have identified 26 policy recommendations that will help overcome the key barriers to e-mobility uptake in the Pacific Island Countries

Our policy recommendations as summarised in the table below. They have been designed with the unique characteristics of the Pacific Island Countries in mind and are applicable to both governments (including national, regional, and local administration) and electricity utilities. The utilities in the Pacific Island Countries have a crucial role to play in encouraging e-mobility uptake given the interdependence of decarbonising the transport and electricity sectors, and because the utilities are prominent players in civil society.

Summary of policy recommendations

#	Policy recommendation	Potential impact	Fiscal affordability	Ease of implementation	Target countries	Overall priority
Transport and electricity infrastructure						
1	Develop public electric charging infrastructure	High	Medium	Medium	All, especially large and intermediate markets	High
2	Support the development of in-house EV charging facilities	Medium	Medium	Medium	All	Medium
3	Roll-out electricity smart meters	High	Low	Medium	All	High
4	Require charging facilities in new buildings	Low-Medium	High	High	Large and intermediate markets	Medium
5	Expand RE and BESS capacity	High	Low	Low	All	High
6	Introduce time-of-use tariffs	High	Medium	Medium	All	High
7	Foster development of private PV facilities to charge EVs	Medium	High	Medium	All, especially small and very small islands	Medium
8	Conduct impact assessments of EV uptake on the distribution grids	Medium	Medium	Medium	All	Medium
9	Offer special EV access	Low-medium	Medium	High	Large and intermediate markets	Low
Commercial viability						
10	Provide purchase incentives, such as subsidies or tax breaks	High	Low	Medium	All, especially large and intermediate markets	High
11	Offer targeted financial incentives for private companies to establish EV fleets	Medium-High	Medium	Medium	Large and intermediate markets	Medium
Governance and policy						
12	Create a regional e-mobility council	Medium	High	High	Regional	High
13	Develop a regional e-mobility strategy	Medium	Medium	High	Regional	High
14	Develop national e-mobility strategies	Medium	High	High	All	High

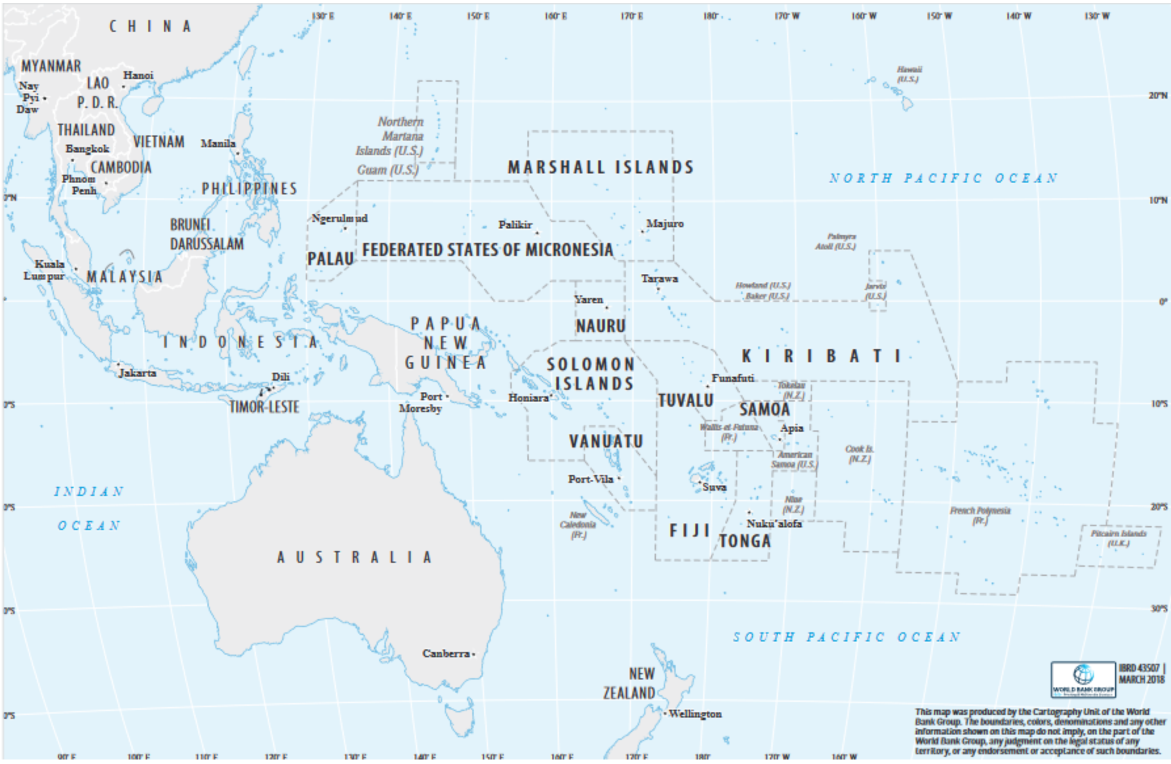
#	Policy recommendation	Potential impact	Fiscal affordability	Ease of implementation	Target countries	Overall priority
15	Monitor progress made on e-mobility	Low	High	High	All	Medium
16	Coordinate planning across public administrations	Low	High	Medium	All, especially large and intermediate markets	Medium
Regulations and standards						
17	Establish regulatory instruments for EVs	Medium	High	Low-medium	All	Medium
18	Develop technical guidelines for EV charging	Low-medium	High	High	All, ideally regional	Medium
19	Establish minimum standards for EVs and charging equipment	Low-medium	High	High	All, ideally regional	High
20	Develop public procurement procedures for EV products	Low-medium	High	High	All, especially large and intermediate markets	Medium
Communication and awareness						
21	Develop an e-mobility communication strategy	Medium	High	Medium	Large and intermediate markets	High
22	Engage with stakeholders	Medium	High	Medium	All	Low
23	Launch EV pilot projects	Medium	Medium	Medium	Large and intermediate markets	Medium
24	Switch public vehicle fleets to e-mobility	Medium	Low	Short term	All	Low
25	Provide training and information on e-mobility	Medium	High	Medium	All	Medium
26	Mainstream gender aspects in EV policy	Low	High	Medium	All	Medium

1 Introduction

1.1 Objectives of this report

The 11 Pacific Island Countries, shown in the map below, face unique challenges related to global climate change and have committed to ambitious goals to decarbonise their economy. Currently, this includes ambitious targets to increase the share of renewable energy in the electricity system, reducing the current reliance on expensive and polluting diesel generation. Increased focus is also being given to the transportation sector, where electrification is expected to play a key role in facilitating its decarbonisation.

Figure 1 Map of Pacific Island Countries



Source: World Bank/IFC

Although e-mobility is rapidly reshaping mobility in many countries around the globe, uptake remains low in emerging economies and outside of large urban agglomerations. Increasing the uptake of e-mobility in the Pacific Island Countries will require coordinated and holistic policies and support. A key focus here will be to ensure that the electrification of transport is aligned with the decarbonisation of the electricity system, and that the electricity system is able to cope with the increased electricity demand.

To support policymakers and utilities in the Pacific Island Countries, the World Bank – with funding from the Korean Green Growth Trust Fund (KGGTF) – has commissioned the design of a regional e-mobility framework and roadmap. The objective of this assignment is to support the development of a comprehensive policy framework on decarbonising the transport sector and aligning the electrification of transport with the decarbonisation of the electricity networks.

1.2 Structure of this report

This roadmap sets out concrete recommendations for policies that can be implemented in the Pacific Island Countries to overcome key barriers and encourage e-mobility uptake. The figure below provides an overview of how it is structured.

Figure 2 Structure of Pacific Island Countries e-mobility roadmap

Section 2	• Status of e-mobility in the Pacific Island Countries and the potential for different modes of e-mobility.
Section 3	• Impact of e-mobility on the electricity grids in the Pacific Island Countries.
Section 4	• Economic viability of e-mobility in the Pacific Island Countries
Section 5	• Key barriers to higher e-mobility uptake in the Pacific Island Countries.
Section 6	• Policy recommendations for e-mobility in the Pacific Island Countries.

Additional details have been included in the Annexes, including:

- Draft technical guidelines for EV charging stations in the Pacific Island Countries (Annex A1).
- Draft minimum standards for EV charging (Annex A2).
- Draft guidelines for EV maintenance procedures (Annex A3).
- The full results of the grid impact assessment covered in Section 3 (Annex A4).
- The full results of the economic viability assessment covered in Section 4 (Annex A5).

Further details are available in our *Interim Report,* which covered the following aspects:

- A detailed analysis of the impacts of increased e-mobility uptake on the Pacific Island Countries' electricity systems.
- An assessment of the economic viability of different modes of e-mobility in the Pacific Island Countries.
- A comprehensive review of business models and policies supporting e-mobility uptake implemented in other jurisdictions.

2 Status of e-mobility

2.1 Introduction to the different types of EVs

There are a wide range of different types of EVs, which are at different levels of technology maturity and viability

Although mainstream discussion is often centred around electric cars, there are many other different types of EVs, which are summarised in the figure below. Note that this figure is a simplification and represents the overarching, main types of EVs. In electrifying their transport sectors, the Pacific Island Countries should take a holistic view to the transport sector and consider the full range of transport modes and EVs which are relevant to the relative countries.

Figure 3 Overview of different types of EVs

Source: Consultant

With respect to electric cars, there is a further distinction between different forms of electrification. These include:

- **Battery-Electric Vehicles (BEVs) –** These are powered solely using a battery which is charged at designated charging points. BEVs do not have another source of power and do not have a traditional internal combustion engine (ICE).
- **Fuel-Cell Electric Vehicles (FCEVs) –** Powered by hydrogen, with fuel cells converting the hydrogen into electricity.
- **Plug-in Hybrid Electric Vehicles (PHEVs)** – Contains both an electric battery and an ICE. The battery is charged from external charging points.
- **Hybrid Electric Vehicles (HEVs) –** Have an electric battery which can selectively power the engine. However, it is not possible to charge this battery from an external source, with charge instead being provided by the ICE.

2.2 Global developments in e-mobility

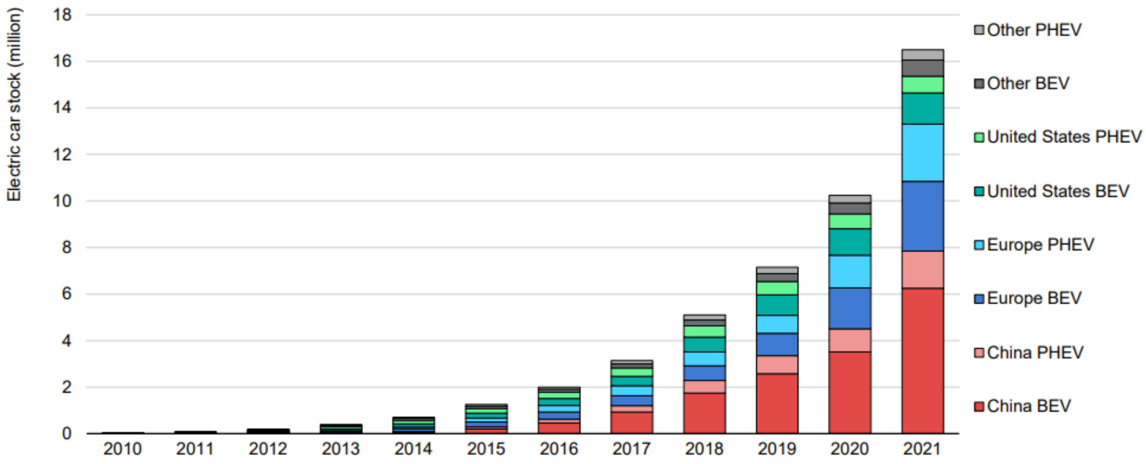
Global uptake of EVs is rapidly accelerating, although emerging economies are trailing behind

As countries around the globe strive to limit their use of fossil fuels and reduce their greenhouse gas emissions, they are increasingly turning their attention to decarbonising the transport sector. E-mobility, paired with low-carbon electricity generation, plays a central role in this. In addition to decarbonisation, the e-mobility is being spurred on by rising fuel costs, concerns over security of fuel supply, and deteriorating air quality in urban centres.

Currently, there are almost 20 million passenger EVs (ie, cars) in service across the globe, along with 1.3 million commercial EVs (ie, buses, delivery vans, and trucks), and over 280 million electric mopeds, scooters, motorcycles, and three-wheelers[1]. The uptake of EVs has accelerated drastically over recent years as the technology becomes mainstream and at-scale manufacturing reduces the cost of the vehicles and makes the commercially competitive. The figure below shows the trend in global electric car uptake.

[1] BloombergNEF. Electric Vehicle Outlook 2022

Figure 4 Global uptake in electric cars, 2010 to 2021



Source: IEA, Global Electric Vehicle Outlook 2022

The increase so far has been accompanied by considerable government efforts to incentivise e-mobility uptake. This has included financial incentives for EV purchases, changes to laws and regulations, and considerable investments in developing adequate charging infrastructure.

As EV technology continues to mature, it is expected that the share of EVs on road will continue to increase, although uptake in low and middle-income countries is expected to be slower.

Global forecasts are that electric cars will reach 10% or higher by 2030

Estimates about EV uptake are highly uncertain, given the rapid pace of developments, the impact of policies in different jurisdictions, as well as issues such as potential shortages in battery supply. The IEA's 2022 Global Electric Vehicle Outlook forecasts uptake by 2030, for the stated policies of the countries surveyed, as follows (expressed as a percentage of the total vehicle stock):

- Cars (light-duty vehicles): 10%
- Motorbikes (electric two and three-wheelers): 35%.
- Trucks (medium and heavy-duty): 2.5%
- Buses: 11%

China is expected to be a leader in uptake, closely followed by other Europe, United States, and Japan. Uptake rates are expected to be lower in low and middle-income countries. The higher rate for electric motorbikes reflects the fact these technologies are easy to implement (they have smaller batteries and therefore charging requirements are less demanding) and are already cost competitive.

Uptake is expected to be slower in low and middle-income countries because:

- Most consumers own second-hand vehicles. For example, in Fiji around three-quarters of the vehicles imported to the country during 2021 were used[2]. As a result, there is a time lag before second-hand EVs, which employ relatively new technologies, become available in these markets.

- There are fewer consumers with high disposable income and are therefore willing to spend more on expensive electric cars.

- There tends to be a lack of targeted EV policies, including financial subsidies, and regulatory frameworks.

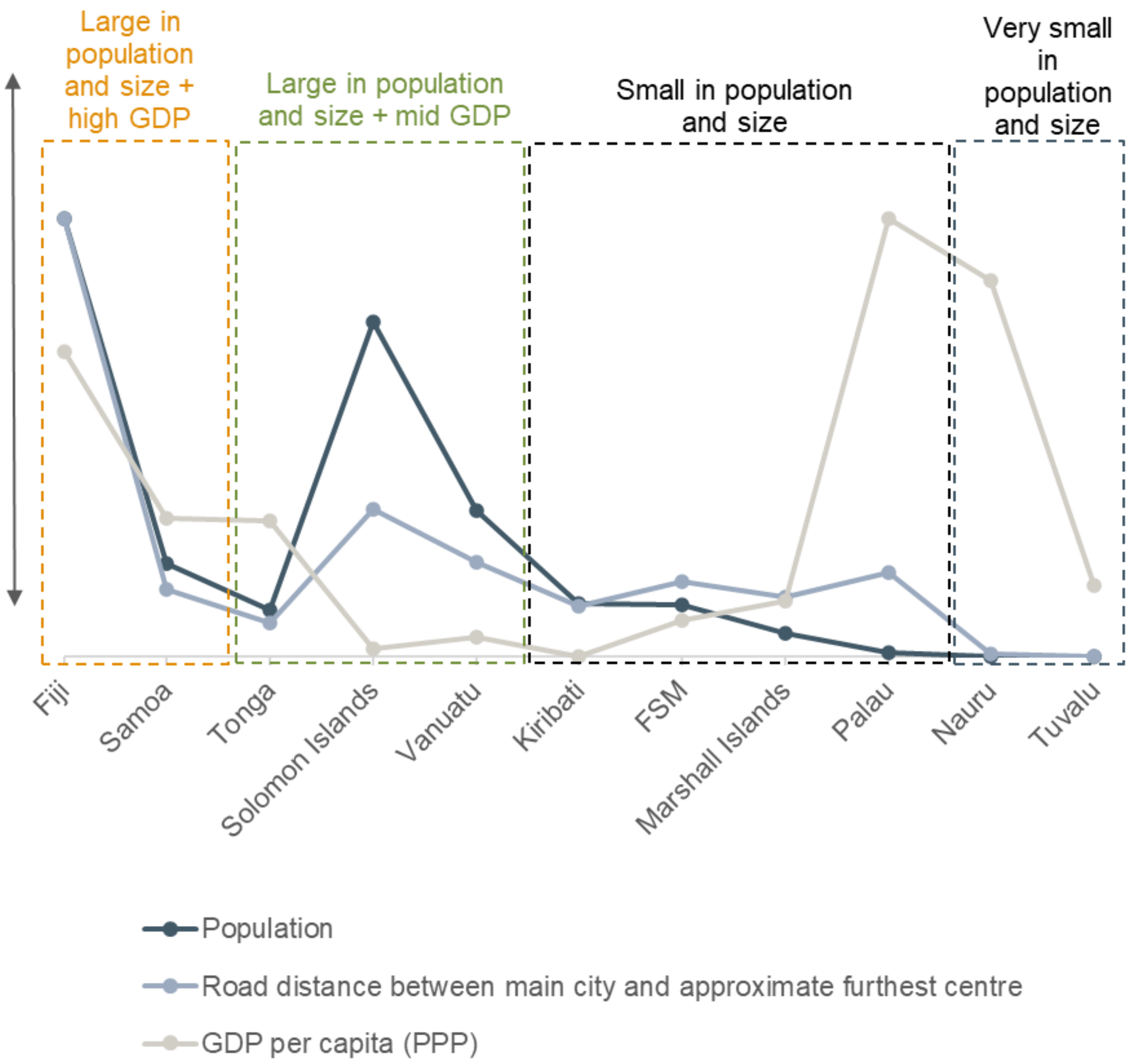
2.3 Current status of mobility and e-mobility in the Pacific Island Countries

There are significant differences between the 11 Pacific Island Countries, which will make differences to e-mobility uptake

These countries share many common characteristics, including their relative remoteness, relatively small size on the global scale, reliance on imports, and their exposure to the adverse effects of climate change. Despite this, the Pacific Island Countries are also heterogenous in many respects. The figure below provides an overview of how they differ along various characterises.

[2] Consultant calculation based on Motor Vehicle Landing Cost data published by Fiji Revenue and Customs Service

Figure 5 Overview of Pacific Island Countries and key characteristics



Source: Consultant analysis. Population and GDP data based on World Bank WDI 2020.

Notably, some islands are considerably larger in both size and population than others. For example, Fiji has a population of nearly 900,000, and its main island, Viti Levu, has a road network of over 11,000 km. This contrasts with Tuvalu which has a population of just over 10,000 mostly located within walking distance of each over in Funafuti.

Most Pacific Island Countries have low rates of vehicle ownership. Trip distances are also typically short

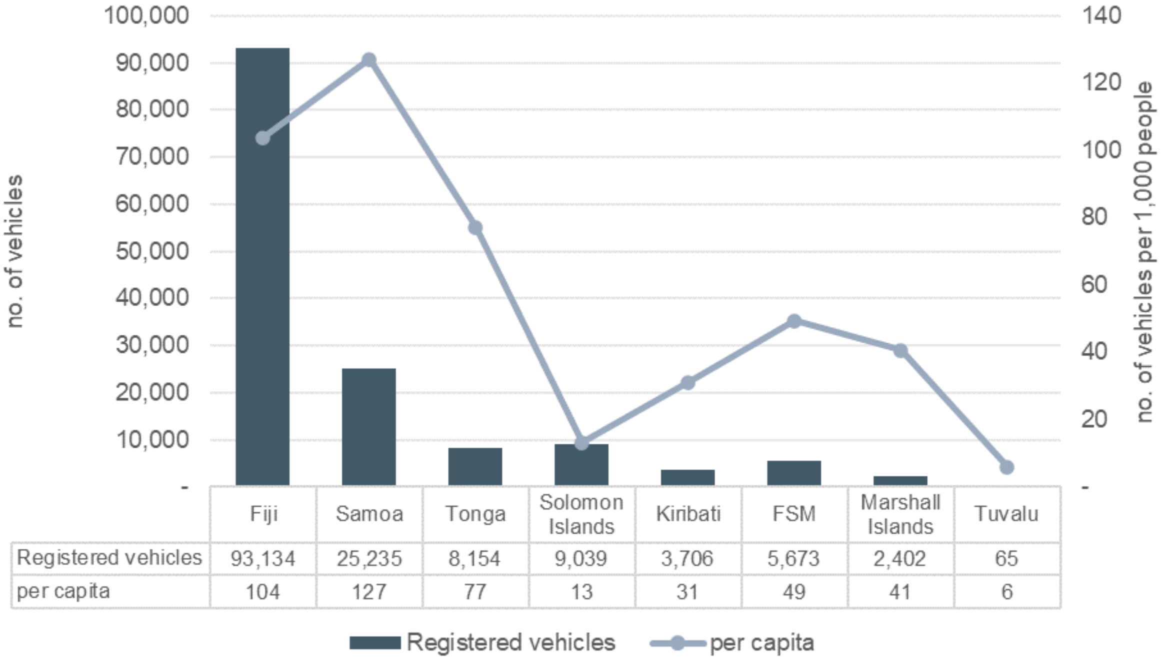
The Pacific Island Countries are characterised by their relatively small size. Indeed, in most countries the distance between the main city and the furthest centre which can be reached by land is less than 50 km.

The relatively small distances travelled do not mean that mobility is not an essential element of life in the Pacific Island Countries. However, the form of mobility varies considerably across the islands. Key characteristics include:

- **Vehicle ownership is limited –** The Pacific Island Countries have relatively low vehicle ownership rates. Only in Fiji and Samoa do vehicle ownership rates exceed 100 vehicles per 1,000 people. In countries like the Solomon Islands, the data suggests that there is one motor vehicle for every 67 people. In terms of sectoral emissions, low vehicle ownership is a clear advantage. Limited existing ownership may also limit inertia and incentives for people to own their own vehicles and facilitate increased use of public and shared transportation.

- **Public transport is underdeveloped in most Pacific Island Countries –** There are limited formal public transport networks in most Pacific Island Countries. Even where public transport exists, it is often organised informally. Combined with low vehicle ownership rates, this explains why there are a significant number of taxis in many of the Pacific Island Countries.

Figure 6 Vehicle ownership rates in Pacific Island Countries



	Fiji	Samoa	Tonga	Solomon Islands	Kiribati	FSM	Marshall Islands	Tuvalu
Registered vehicles	93,134	25,235	8,154	9,039	3,706	5,673	2,402	65
per capita	104	127	77	13	31	49	41	6

Note: Data was not available for Vanuatu, Palau, or Nauru
Source: Consultant based on information from authorities, World Health Organisation (2016) and World Bank WDI (2020)

There has been very little EV uptake in the Pacific Island Countries to-date

Although EV uptake has accelerated greatly in many developed countries, it remains in a nascent stage across the Pacific Island Countries. This is despite these countries, in theory, being well placed for e-mobility due to their small size, meaning that a single charge is sufficient for virtually all possible trips, and relatively high fuel prices.

Some Pacific Island Countries have seen a gradual uptake in HEVs and PHEVs over the past years, in some cases spurred by various incentives. For example, tax credits on environmentally friendly cars in Fiji have stimulated the growth of hybrid vehicles. As shown in the table below, there is an increasing number of pilot projects and studies being undertaken to increase the uptake of e-mobility in the Pacific Island Countries.

Table 1 Overview of current state of e-mobility in the Pacific Island Countries and planned projects

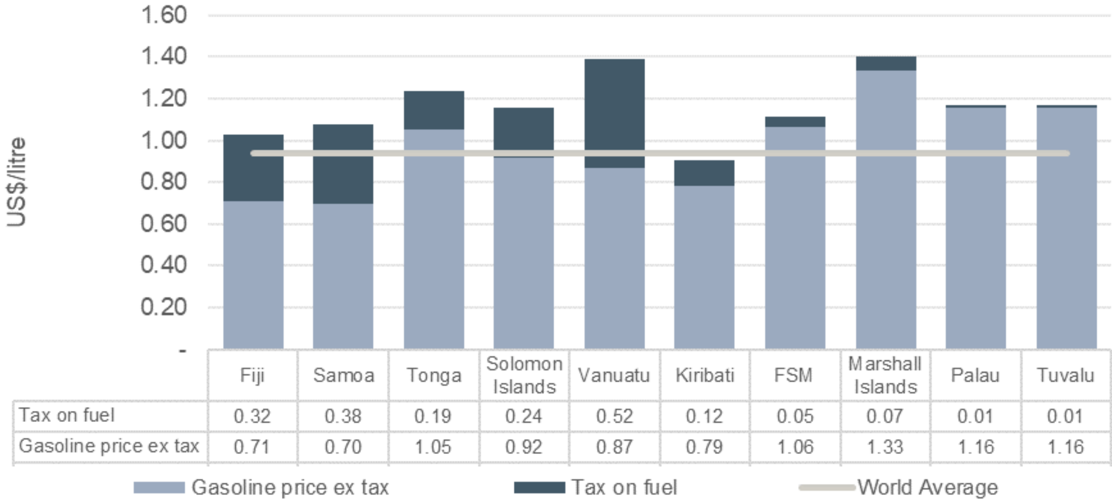
Country	Overview of current state of e-mobility
Fiji	Private firm Leaf Capital Pte Ltd was established in 2021 with a goal of establishing a charging ecosystem across Viti Levu
Samoa	Hyundai Kona EV have been imported by Fore Hyundai Samoa. Electric cars and charging stations are being supplied to EPC. Lotopoa Commercial vehicles
Tonga	Have acquired two Nissan Leaf cars Goal that 10% of new LDVs are electric by 2030
Marshall Islands	World Bank pilot on e-mobility technology
Tuvalu	Electric scooter/motorbike pilot is underway with 12 electric scooters to be deployed.

Source: Consultant based on information from TEC, World Bank, PCREEE/SPCF

High gasoline prices in the Pacific Island Countries should help encourage EV uptake

One of the key barriers to mobility in the Pacific Island Countries is that fuel prices are relatively high. This is similar to the situation with diesel electricity generation, the result of fuel having to be imported. The figure below provides an overview of gasoline prices. Note that this is based on the 2018 Pacific Fuel Price Monitor, and that fuel prices will have been very affected since by global swings in commodity prices.

Figure 7 Gasoline prices in Pacific Island Countries – 2018

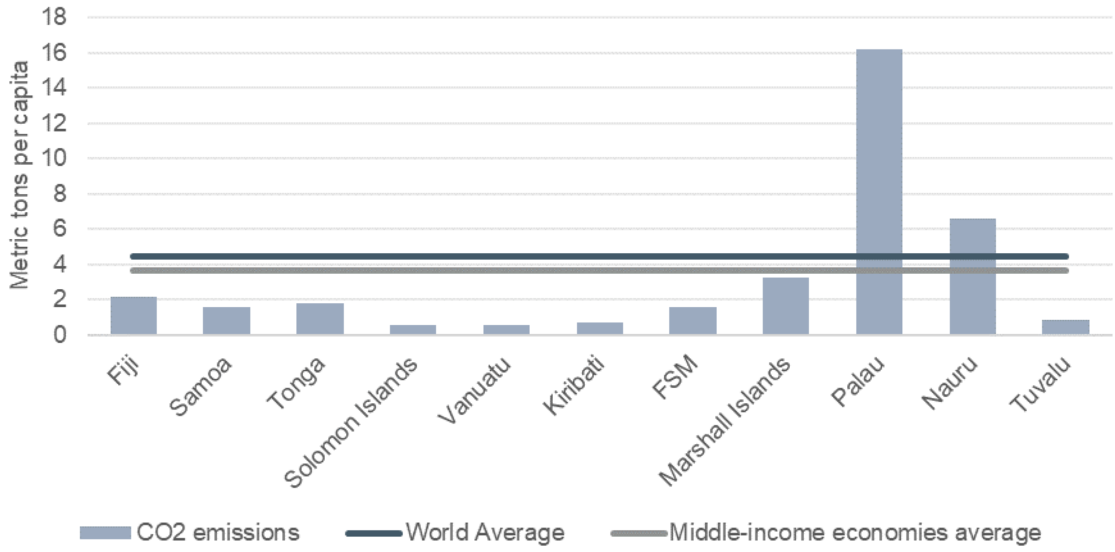


Note: Data for Nauru was not available
Source: Consultant based on Pacific Fuel Price Monitor 2018. World Average from IEA 2019, Global fuel price changes, 2005-2018

The Pacific Island Countries are particularly exposed to climate change impacts and have set ambitious decarbonisation targets

The Pacific Island Countries have relatively low rates of emissions, especially by global standards. The figure below shows CO_2 emissions per capita in the Pacific Island Countries.

Figure 8 CO_2 emissions of Pacific Island Countries



Source: Consultant analysis based on World Bank data (CO_2 emissions – metric tonnes per capita, based on Climate Watch 2020)

Despite this, the Pacific Island Countries face unique challenges in relation to climate change. Many Pacific Island Countries are low-lying atolls, while in other countries major urban settlements tend to be in low-lying costal areas. As a result, they are particularly exposed to the threats of rising sea levels and increased tropical storm activity.

Due to their exposure to the impact of climate change the Pacific Island Countries have committed to ambitious climate goals. This includes both ambitious targets for increasing the share of RE as well as broader efforts as part of their Nationally Determined Contributions (NDCs) and more general policy goals. The table below provides an overview of the NDCs of the Pacific Island Countries.

Table 2 Selected NDC Commitments of Pacific Island Countries

Country	Proposed reduction	Reference year	Further goals/ actions
Fiji	30% reduction of business-as-usual (BAU) CO_2 emissions from the energy sector by 2030	2013	
Samoa	26% reduction in overall greenhouse gas (GHG) emissions by 2030 30% reduction of GHG emissions from the energy sector by 2030	2007	
Tonga	13% reduction in GHG emissions in the energy sector by 2030	2006	Achieved through a transition to 70% RE

Country	Proposed reduction	Reference year	Further goals/ actions
			generation and energy efficiency measures
Solomon Islands	Unconditional 33% reduction in GHG emissions by 2030 compared to BAU projection , conditional 45% reduction in GHG emissions compared to BAU projections	2015	
Vanuatu	• Transition to close to 100% RE in electricity generation by 2030 through RE capacity addition and substitution of fossil fuels with Coconut (Copa) oil • 10% improvement in transport sector energy efficiency • Introduce EVs by 2030, including 10% of the public bus fleet, 10% of the government car fleet, and 1,000 electric two-/three-wheelers		
Kiribati	12.8% reduction in GHG emissions by 2030 compared to BAU projections	2015	
Federated States of Micronesia	Unconditionally reduce GHG emissions by 28% by 2025	2000	
Republic of the Marshall Islands	Economy-wide target to reduce GHG emissions by at least 45% by 2030	2010	
Palau	22% energy sector emissions reductions by 2025	2005	45% RE target by 2025, 35% energy efficiency (EE) target by 2025
Nauru	RE to be 50% of Nauru's power generation and to achieve 30% energy savings (both conditional on access to means of implementation)		
Tuvalu	Reduce GHG emissions from energy sector by 60% by 2025	2010	

Source: UNFCCC, NDC Registry (Accessed May-June 2022)

2.4 Categorisation of Pacific Island Countries for analysis of e-mobility

To ensure our e-mobility roadmap is targeted, we group the Pacific Island Countries into four broad categories

This report sets out a regional e-mobility framework across the 11 Pacific Island Countries, across which there is significant diversity, as summarised in the table below. The entries are colour coded, with characteristics that are generally favourable towards e-mobility shown in green and those that are generally unfavourable shown in red.

Table 3 Overview of Pacific Island Countries and key characteristics

	Land area	Long vehicle journey	Popul-ation	GDP per capita (PPP)	Motor vehicles per capita	Electricity tariff (domestic) [3]	Hydro % of electricity	Total RE % of electricity
	km sq.	*km*	*'000*	*USD/person*	*no. per 1,000 people*	*USD/kWh*	*%*	*%*
Fiji	18,274	190	896.4	12,078	138	0.15	46%	54%
Samoa	2,821	36	198.4	6,768	130	0.34	29%	43%
Tonga	717	22	105.7	6,695	81	0.19	0%	12%
Solomon Islands	27,986	69	686.9	2,619	27	0.23	1%	1%
Vanuatu	12,189	47	307.2	3,010	na	0.58	9%	27%
Kiribati	811	29	119.4	2,383	33	0.28	0%	14%
Federated States of Micronesia (FSM)	702	39	115.0	3,553	51	0.48	2%	7%
Marshall Islands	181	33	59.2	4,147	36	0.35	0%	5%
Palau	459	43	18.1	16,322	na	0.34	0%	3%
Nauru	21	9	11.8	14,340	na	0.19	0%	3%
Tuvalu	26	8	10.8	4,653	na	0.32	0%	23%

Sources: CIA factbook, google maps, World Bank WDI (2020), World Health Organisation (2016), Pacific Power Utilities Benchmarking Report, IRENA market assessments 2019

To ensure that our analysis and recommendations reflect this diversity, we group the Pacific Island Countries into four broad categories, as shown in the table below. We note that the groups are not clear cut in some cases, in particular Samoa which could be argued to fall in the intermediate markets category.

Table 4 Grouping of Pacific Island Countries for this report

Category	Countries	Key (relative) characteristics	Likely main types of e-mobility	Explanation
Large markets	• Fiji • Samoa	• Large (in size and population) • Wealthy • High vehicle ownership • Cheap electricity	Electric cars (private, taxis) Electric vans (taxis, commercial)	• Fiji is the standout country in terms of e-mobility potential, given its size (both population and land area) and relative wealth (GDP per capita). Furthermore, Fiji has low electricity tariffs and a high share of its electricity generation is from hydro sources, which should make charging EVs cheaper.

[3] Based on residential customer consuming 200kWh/month.

Category	Countries	Key (relative) characteristics	Likely main types of e-mobility	Explanation
				• Samoa is likely the second in terms of e-mobility potential, based on its land area (which is spread across two islands, compared to Tonga's four main islands), vehicle ownership (similar to Fiji), wealth (around half that of Fiji) and hydro generation.
Intermediate markets	• Vanuatu • Solomon Islands • Tonga	• Large (in size and population) • Less wealthy • Low vehicle ownership	Electric cars (taxis) Electric vans (commercial)	• Despite relatively large size, Vanuatu and Solomon Islands have noticeably lower wealth and consequently low rates of vehicle ownership. • As a result, we expect the potential for e-mobility, and in particular the widespread use of personal electric cars, to be more limited compared to the first group. • We also include Tonga in this group, although it could arguably have been included in the large markets category. It has similar levels of wealth to Samoa, but is significantly smaller and has low vehicle ownership rates.
Small islands	• Kiribati • FSM • Marshall Islands • Palau	• Small (short distances) • Low vehicle ownership	Electric cars (taxis) Electric motorcycles	• These countries are relatively small, and there is limited need for personal vehicles in some of these countries. • The market size is relatively small and will likely be focussed on electric motorcycles.
Very small islands	• Nauru • **Tuvalu**	• Very small (short distances) • Very small markets	Electric motorcycles and electric scooters	• These countries are very small, with there being few opportunities for journeys over 10 km. Hence the focus will be on electric motorcycles and scooters.

Source: Consultant

For our in-depth analysis of e-mobility impacts and viability we select a sample of countries

To allow for an in-depth assessment of the impact of e-mobility and viability in Sections 3 and 4 of this report, we focus on one country from each of the above four categories:

- **Fiji (Large Market)** – The standout and largest market among the Pacific Island Countries, and therefore has the largest potential for e-mobility.
- **Solomon Islands (Intermediate Market)** –The second most populous Pacific Island Country. But average incomes are significantly lower than in the larger markets of Fiji and Samoa. It currently has a low share of RE electricity generation, but the under-construction Tina River Hydro project will deliver significant hydro output from 2024 or 2025 onwards.
- **Marshall Islands (Small Island)** – Shares similar characteristics to many of the other small Pacific Island Countries, including a small potential market size, short distances travelled, and a generation mix currently dominated by diesel.
- **Tuvalu (Very Small Island) –** Very low population and very short distances travelled. The implications from here will also be relevant for other very small islands within other Pacific Island Countries, such as Kosrae in the FSM.

2.5 Potential uptake of different types of EVs in the Pacific Island Countries

2.5.1 Overview

An overview of the potential uptake of different types of EVs in the Pacific Island Countries is provided in the table below. We discuss each type in more detail in the following sub-sections. Sections 3 and 4 focus on analysing electric cars, motorbikes, and vans in more detail, because they have the most potential.

Table 5 Overview of potential for EV uptake

Type of EV	Potential uptake in the short to medium term future	Brief explanation
Electric cars 	High, particularly for taxis and high-use customers	As cost differentials and charging costs come down, we expect to see many users, particularly commuters and taxis, choosing second-hand electric cars. We estimate that in larger Pacific Island Countries, electric cars could plausibly make up between 6% and 19% of the vehicle fleet by 2030, with the lower end of this range being more likely.

Type of EV	Potential uptake in the short to medium term future	Brief explanation
Electric motorbikes and scooters	High, in countries where motorbikes are already used	Potential for high uptake in Pacific Island Countries that already have high motorbike use. Cost differential to ICE motorbikes is already quite low and much of the uptake can be driven by the private sector with minimal policy intervention.
Electric vans and trucks	High for delivery vans and transport vans, low for trucks	High potential for uptake of electric vans for commercial purposes – in particular small goods delivery vehicles and public transport. Uptake of electric trucks is unlikely given the high cost differentials to second-hand ICE trucks.
Electric buses	Low, unless heavily subsidised	Only a few large cities in the Pacific Island Countries have public transport networks using large buses. Any uptake would likely have to be highly subsidised, given the high upfront costs of electric buses and associated charging infrastructure.
Electric boats	Low	Although usage of small vessels with outboard engines is high, the cost differentials between electric and ICE engines are still high. Perhaps even more importantly, the challenges and costs of carrying spare battery capacity and charging in remote areas will deter uptake.
Micro e-mobility	Moderate to high	Electric bikes and kick scooters are already viable in most countries and need little policy intervention. Barriers to entry are likely to be more cultural/behavioural (biking is uncommon in many Pacific Island Countries) rather than commercial.

Source: Consultant

2.5.2 Electric cars

Electric cars are increasingly competitive with traditional ICE vehicles

The past decade has seen the rapid proliferation of electric cars in many developed markets around the world. This was rooted in the rise of PHEVs and HEVs, but these technologies are now being leap-frogged by BEVs. A notable number of car manufacturers now produce several models of BEVs to cater to different consumer needs. This is leading to a continued decline in the cost of EVs and narrowing the noticeable differential in the upfront cost between EVs and ICE vehicles.

As noted in Section 2.2 estimates suggest that by the end of the decade, 10% of the global passenger car fleet will be compromised of BEVs. Currently the number of BEVs in emerging countries is limited, given the reliance on second-hand vehicles and the still nascent nature of the second-hand BEV market. However, it is expected that as BEV penetration in developed countries continues to progress, and the battery lifetime of these vehicles continues to increase, that they will be more readily available in emerging economies.

The uptake trajectory is difficult to estimate precisely as it will depend heavily on the specific characteristics and contexts of the individual market, as well as global development, such as the change in battery prices. We estimate a range of potential uptake scenarios for the Pacific Island Countries based on the following assumptions:

- **15 year average vehicle lifetime**[4]
- **No EVs currently in the stock of vehicles –** This reflects the current situation - there are currently only a handful of BEVs in operation (mostly in pilot projects).
- **10% annual growth in the total number of vehicles –** The specific characteristics of individual countries and islands (such as distances travelled and the nature of the road network) will play a key factor in determining the growth of vehicle ownership rates. We assume 10% based on the observation that growth in vehicle ownership rates tends to exceed growth in GDP per capita, particularly in emerging countries.
- **Three different scenarios for the percentage of purchased vehicles that are EVs (rather than ICE)**[5] **–** We assume a linear increase rise from 2% in 2022 to

    1. 20% in 2030.
    2. 40% in 2030.
    3. 60% in 2030.

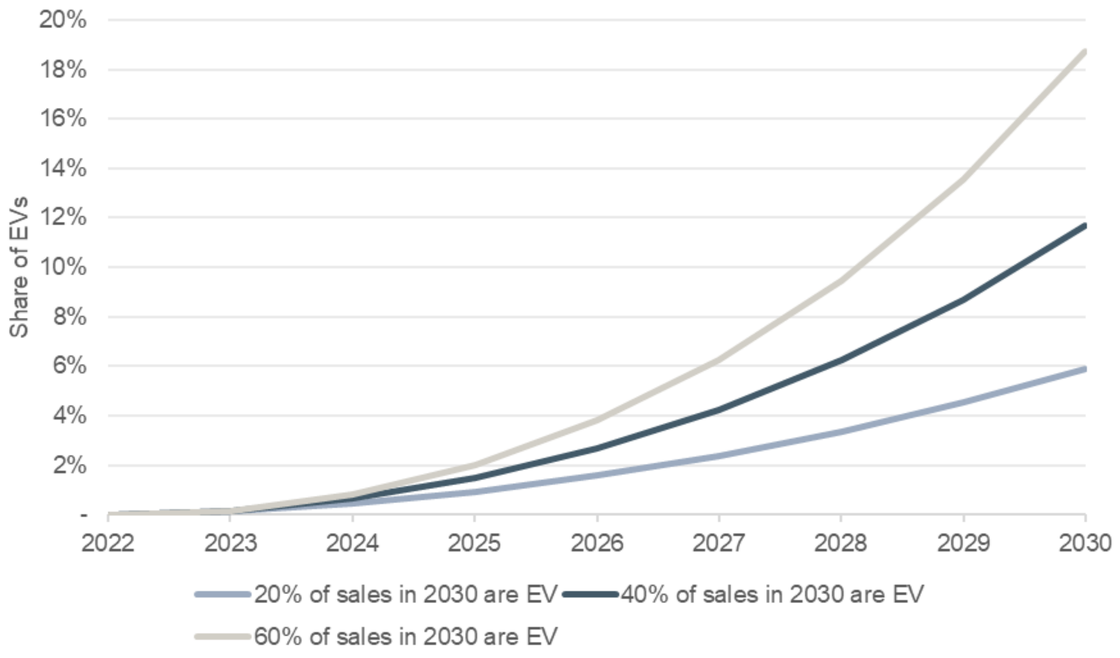
As shown in the figure below, this leads to a result that between 6% and 19% of all passenger vehicles will be EVs in 2030[6]. We suggest that actual uptake is likely to be at the lower end of this range, although if the recommendations in Section 6 are adopted then high values may be possible.

[4] This is higher than the average age of vehicles in Europe (7 years), Australia (10 years) and New Zealand (14 years), reflecting the reliance on second-hand vehicles and the reality that average distances travelled in the Pacific Island Countries tend to be relatively low. We have cross-referenced this figure with an estimate of average vehicle turnover rates in Fiji, based on data on vehicle imports from the Fiji Revenue and Customers Service. This suggests that the average vehicle turnover rate in Fiji is ~8% pa, or ~7% if we account for a 10% annual growth in the total vehicle stock. This corresponds to an average lifetime of 13-15 year.

[5] We assume that second-hand vehicles will continue to play a major role in the Pacific Island Countries. The percentage of purchased vehicles includes both new vehicles and imported second-hand vehicles.

[6] The uptake scenario shows increasing returns to scale because of assumptions regarding the annual growth in the total vehicle stock and retirement of ICE vehicles after 15 years (no EVs are retired before 2030) combined with the increased share of new vehicles which are EVs each year.

Figure 9 Potential electric car uptake in the Pacific Island Countries



Source: Consultant calculations

As is covered later in Section 4.2, the first adopters of electric cars are likely to be with users who travel significant distances each day – such as commuters, taxis, and other commercial vehicles.

2.5.3 Electric motorbikes

Electric motorbikes are relatively affordable and can displace traditional vehicles sooner

Motorcycle and scooters (which are a form of motorcycle, usually with a lower powered engine and a step-through chassis) play an important role in some of the smaller Pacific Island Countries. For example, in Tuvalu there are over 13 times more motorcycles than cars. However, the larger islands tend to have a very limited uptake in two-wheel transport, for a variety of societal, safety, and climate related reasons. For example, in Fiji there are less than 800 registered motorbikes (compared to over 90,000 cars) and in the Marshall Islands there are only 13 registered motorbikes. We do not expect that there will be a major shift from cars to two-wheeled transport. Instead focus should be paid to electrifying the fleets in those countries where they do play a main role.

Globally, electric motorbikes are seeing increasing market shares, driven by relatively high uptake rates in China and South-East Asian countries, which traditionally have high levels of motorbike usage. Notably there have been limited incentives to stimulate the uptake of electric motorbikes, especially when compared to policies applied for cars. The availability of a range of relatively affordable vehicles, particularly from manufacturers in Asia, means that the cost differential to ICE motorbikes is relatively low and that much of the uptake is occurring naturally.

In those Pacific Island Countries where two-wheelers are widely used, electric motorbikes will become prominent in due course. This will be driven by manufacturers producing more electric motorbikes and falling costs, as well as the growth of electric motorbikes in source markets for second-hand vehicles.

2.5.4 Electric vans and trucks

There is potential to decarbonise the freight and logistics sector through electric vans

Comprehensive efforts to decarbonise the transport sector also need to consider the environmental impacts of the freight and logistics sector. This includes exploring the potential role for electric trucks and electric vans.

Electric trucks are unlikely to be a viable option in the near future in the Pacific Island Countries. This technology is still in a nascent stage, and as noted earlier global forecasts estimate that only 2.5% of medium and heavy-duty trucks will be electric by the end of the decade. This limits the potential for second-hand electric trucks in the short to medium term.

In the Pacific Island Countries, most trucks are relatively old, second-hand vehicles and consequently cheap, meaning that new EV trucks are very expensive in relative terms. In any case, the number of large trucks in the Pacific Island Countries is rather small, posing further barriers due to the limited scalability.

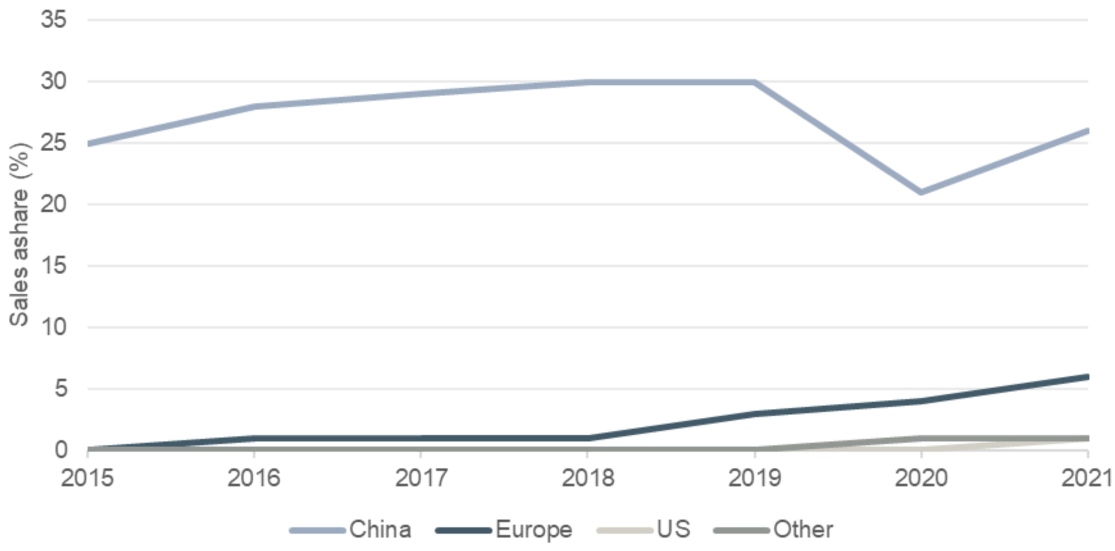
However, there is significant potential to introduce electric vans for commercial purposes. These could be used for local delivery services, last-mile logistics, and for passenger transport (as discussed in the next sub-section). We expect that uptake for such vehicles could be largely led by the private sector, and that this will accelerate once technology costs have come down significantly.

2.5.5 Electric buses

Electric buses are increasingly common in large, global cities, but are unlikely to dominate the public transport industries in the Pacific Island Countries in the near future

Many large cities have begun to adopt electric buses into their public transport fleets. These developments have been driven by the availability of a range of battery powered buses, initially from Chinese manufacturers. As shown in the figure below, in 2021 electric buses constituted 26% of all bus sales in China, compared to 6% in Europe and 1% in the US and other countries. Cities where air pollution plays a major concern have been keen adopters of such buses to mitigate the impact of diesel emissions from buses.

Figure 10 Electric buses sales share in different regions



Source: IEA, 2022, Electric bus registrations and sales shares by region, 2015-2021

However, electric buses are often (highly) subsidised as upfront costs remain high and there are significant costs involved with upgrading depots and adequate charging. In addition, electric buses require a sufficiently sized fleet to be viable, given the need to train mechanics and have adequate replacement parts available.

In the Pacific Island Countries only a few large cities have notable public transport networks with large buses. And although electric buses could play a part here, the economic viability is likely to be limited, given the high upfront costs and limited benefits, particularly if charging is reliant on expensive diesel generated electricity. This is further complicated by the fact that many of the Pacific Island Countries' public transport networks have limited public involvement, and instead rely on private operators. However, there are qualitative benefits to electric bus fleets, including raising awareness about such technologies and in stimulating the development of the local EV industry, which means that electric buses should not be ruled out altogether in the Pacific Island Countries.

In some cases, small mini-buses using electric vans may offer a viable option to develop and advance the public networks on the Pacific Island Countries. These can also offer a way of decarbonising transport required to support the tourism industry in relevant Pacific Island Countries.

Various trials and pilots have been proposed in the Pacific Island Countries

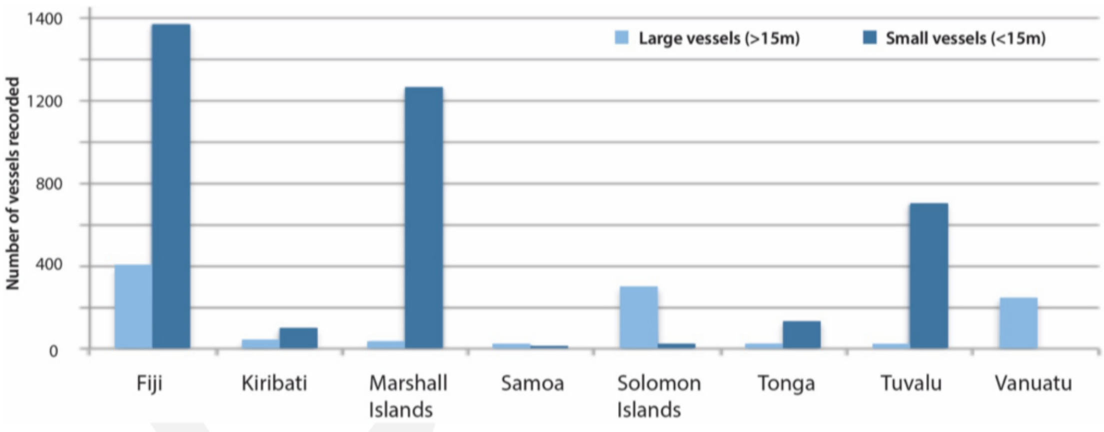
Some Pacific Island Countries have expressed plans to electrify their public bus fleets. For example, Vanuatu plans to electrify 10% of its public transport fleet by 2030, while the Fiji Government announced that it proposed to pilot electric buses in the Nasinu area during its 2021-2022 state budget. Such pilots offer an opportunity to explore the viability of electric buses in real environments and should be undertaken in coordination with other stakeholders, including the utility.

2.5.6 Electric boats

There are many boats in use in the Pacific Island Countries. Decarbonising them is a key challenge of Pacific Island Countries meeting climate goals

Electric boats are a further form of e-mobility relevant to the Pacific Island Countries. Maritime transport is a key aspect of mobility in the Pacific Island Countries. As shown in the figure below, there are known to be around 1,100 vessels that are greater than 15 m in length. But a larger number of smaller vessels that are used to transport people and goods between small islands. Most of these vessels are old.

Figure 11 Number of maritime vessels recorded in government datasets



Note: Data for FSM, Palau, and Nauru was not available as these countries are not members of the Pacific Blue Shipping Partnership
Source: Pacific Blue Shipping Partnership, 2020, Concept Note

Many Pacific Island Countries have noted the need to decarbonise the maritime sector if they want to achieve their NDCs and ambitious goals. There are also concerns about the reliance on imported fuels leading to high costs and reducing self-sufficiency. Eight Pacific Island Countries have recently set up the 'Pacific Blue Shipping Partnership' (PBSP), which aims to completely decarbonise the maritime transport sector by 2050, including reducing emissions from shipping by 40% until 2030. The PBSP aims to develop a blended finance package of at least US$500m over the course of the decade to support the development of low-carbon options in the domestic maritime fleets and investments in related infrastructure.

Moving towards low-carbon boats can be achieved through a range of technologies, including more efficient diesel blends, electric boats, or hydrogen. However, we note that electric boats are still a relatively nascent technology. Although there is increasing traction in this space – one report finds that in 2017 there were over 100 manufacturers of electric boats, and that the market for hybrid and electric boats will rise to over US$20bn by 2027[7] - this has largely been focussed on individual luxury vessels. To the best of our knowledge there have been limited developments regarding electric boat technology for vehicles more applicable in the Pacific, such as small fishing boats.

[7] IDTechEx, Electric Boats and Ships 2017-2027

Electric boats are unlikely to be viable in the Pacific in the short to medium term future. And when they are, their uptake can be private sector led

Even if such technologies were available, we consider that they are unlikely to be economically viable in the short and medium term in most applications. This is because:

- The upfront costs of small electric outboard engines are currently around two times the price of new ICE equivalents. But many Pacific Island Countries rely on second-hand outboards and keep them well beyond their usual service lives, so the price differential becomes much larger.

- Many users of electric outboard engines would need significant battery capacity, which makes them much more expensive than ICE equivalents. The battery capacity would be needed because:

    - The safety implications of running out of battery charge are more significant on the sea than on the road. And battery range is much more sensitive to sea conditions. So boat users will need to ensure they are far from the limits of their battery range.

    - Many boats are used in reasonably remote areas that are quite far from the electricity grid (or strengthened parts of the grid). So fast charging is challenging. And often the destination of these small vessels is cut off from the main grid altogether (so could only be charged after making a return journey).

In addition, similar to our observations drawn for land-based vehicles in the previous sub-section, there are limited economic benefits of electrifying boats so long as charging relies on diesel generation. This is because the cost of charging would remain relatively high (and only represent a small discount relative to diesel fuel prices) and the environmental benefits are limited.

However, we understand that stated policy commitments by the Pacific Island Countries to decarbonise their maritime sector may nonetheless stimulate further developments in this field. In the short term Pacific Island Countries should focus on developing a better understanding of the current state of the maritime sector, including a stock-take of all vessels and the operating costs currently faced by their operators. Governments and donors should also focus on private sector activities in this region, as there is potential for this sector to lead uptake, potentially through the provision of financing instruments as proposed under the PBSP.

2.5.7 Micro e-mobility

The definition of e-mobility includes modes of micro-mobility, such as electric bikes and electric kick scooters. These have become increasingly prominent in many cities around the globe, with a range of councils and private operators offering rental services. These forms of mobility can help overcome certain barriers which prevent active forms of transport otherwise, such as long distances or challenging terrain.

These forms of EVs are already viable in most countries, given the limited upfront costs. As a result, we expect that uptake will be led by the private sector, given the relatively limited barriers to entry. In the Pacific Island Countries, there is a particular role in the larger urban centres (although cycling infrastructure tends to be underdeveloped) and in the tourism sector. In particular in urban centres there is potential for these forms of transport to displace certain trips which may have otherwise been made by cars or motorbike. In smaller countries that rely heavily on two-wheelers, electric bikes may offer a convenient and less energy-intensive solution.

3 Potential impact of e-mobility on electricity grids

3.1 Overview of electricity systems in the Pacific Island Countries

Pacific electricity systems are particularly sensitive to the impacts of e-mobility

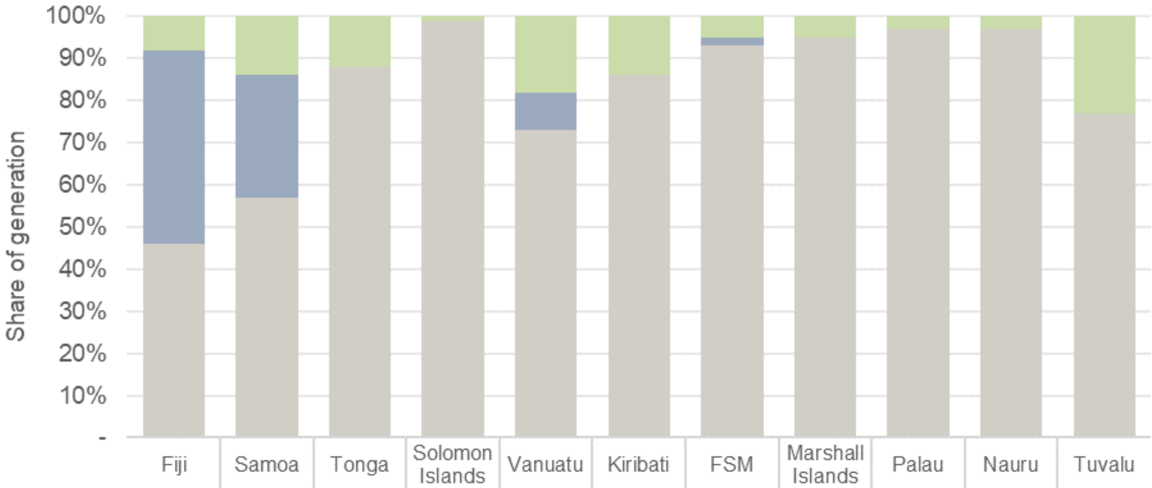
The increased uptake of e-mobility has the potential to dramatically affect electricity systems in the Pacific Island Countries, both in terms of the new generation capacity that needs to be installed to meet the higher demand and the network reinforcement that needs to happen to facilitate charging.

Electricity grids in the Pacific are particularly sensitive to e-mobility uptake because existing demand is relatively low (most Pacific nations do not have large commercial and industrial loads) and because they have traditionally been very reliant on expensive diesel-fuelled generation. In the medium term future, vehicle-to-grid technologies and increased rooftop solar have the potential to further change the nature of electricity provision in the Pacific.

Most of the Pacific Island Countries have diesel-dominated electricity generation, although a few have hydro and all are planning to add solar

The electricity and energy sectors form a crucial part of the Pacific Island Countries' decarbonisation efforts. The figure below shows that most Pacific Island Countries rely on thermal sources for generation, which is predominately in the form of diesel generators.

Figure 12 Share of electricity generation by type in Pacific Island Countries



	Fiji	Samoa	Tonga	Solomon Islands	Vanuatu	Kiribati	FSM	Marshall Islands	Palau	Nauru	Tuvalu
Other RE	8%	14%	12%	1%	18%	14%	5%	5%	3%	3%	23%
Hydro	46%	29%	0%	0%	9%	0%	2%	0%	0%	0%	0%
Thermal	46%	57%	88%	99%	73%	86%	93%	95%	97%	97%	77%

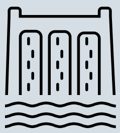
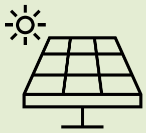
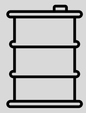
Thermal Hydro Other RE

Source: Consultant based on IRENA 2019 Market Assessment

Only Fiji and Samoa have a considerable share of RE generation, dominated by the availability of hydro in these countries. We expect that Solomon Islands will join these countries upon commissioning of the Tina River Hydro plant.

Some countries have increased their share of RE, predominately in the form of solar PV, although diesel generation is still dominant in these countries. Some other Pacific Island Countries currently have very low levels of RE generation. The table below provide an overview of this categorisation.

Table 6 Implications of different generation mixes on e-mobility generation

Category 1: Significant hydro	Category 2: High RE non-hydro	Category 3: Diesel
Significant level of non-variable RE. Limits the potential impact of load curve variability on EV charging. 	Moderate levels of variable RE (predominately solar PV). 	Generation is almost entirely powered through diesel generation. High solar PV growth potential going forward. 
• Fiji • Samoa • Solomon Islands (post-Tina River)[8]	• Vanuatu • Tuvalu • Tonga • Kiribati	• FSM • Marshall Islands • Palau • Nauru • Solomon Islands (pre-Tina River)
High levels of hydropower mean that excess RE generation during the daytime can be stored and used for night-time charging. If there is excess hydro capacity, this will limit the need to invest in Battery Energy Storage Systems (BESS) to facilitate EV charging.	These systems have significant share of solar PV, with the balance being provided by diesel generation. During times of high solar output, the cost of charging will be approximately equal to the cost of solar, although some backup capacity (eg. diesel generators or BESS) is needed for cloudy days. However, if charging predominantly occurs at night, the cost of charging will be equal to the cost of diesel generation. In such grids, it is likely to be beneficial to encourage charging during daytime hours when solar output is high.	In these systems the cost of charging will be equal to the cost of diesel generation, regardless of the time of day.

Source: Consultant

[8] Solomon Islands will move to the high hydro category when the Tina River Hydro project comes online, which is currently expected to occur in 2024.

The reliance of diesel generation leads to high electricity tariffs, which discourages EV uptake

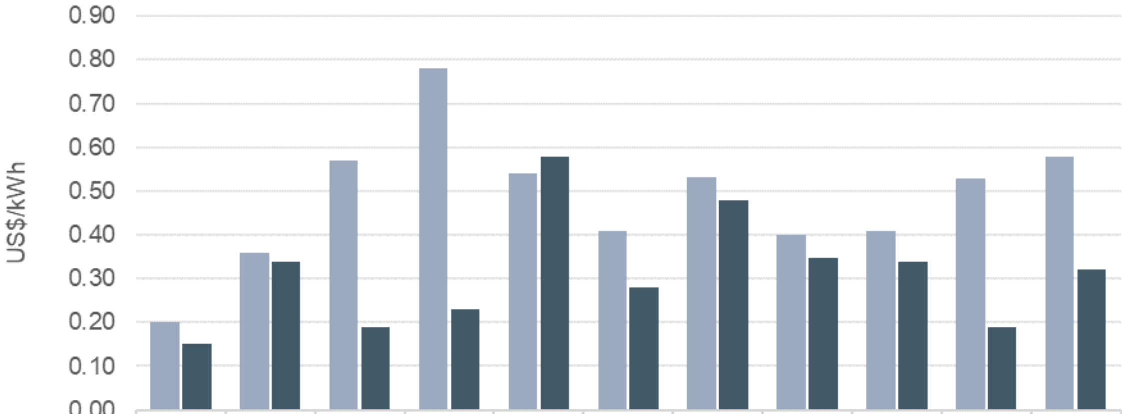
The current generation mix poses several concerns:

- **High levels of emissions –** Diesel generators are relatively inefficient and emit high levels of greenhouse gases into the atmosphere. They can also cause air pollution in the immediate surroundings.

- **Expensive imported diesel leads to high tariffs –** In addition to the environmental impacts of diesel generation, the Pacific Island Countries' rely on imports to fulfil diesel generation. The consequence of this is that the Pacific Island Countries' have among some of the highest tariffs globally. In addition, there are concerns about their independence and security of supply. Tariffs are also exposed considerably to global oil price fluctuations.

The generally high tariff levels, and the considerable heterogeneity in tariff levels between countries is shown in the figure below.

Figure 13 Electricity tariffs in Pacific Island Countries



	Fiji	Samoa	Tonga	Solomon Islands	Vanuatu	Kiribati	FSM	Marshall Islands	Palau	Nauru	Tuvalu
Commerical	0.20	0.36	0.57	0.78	0.54	0.41	0.53	0.40	0.41	0.53	0.58
Residental	0.15	0.34	0.19	0.23	0.58	0.28	0.48	0.35	0.34	0.19	0.32

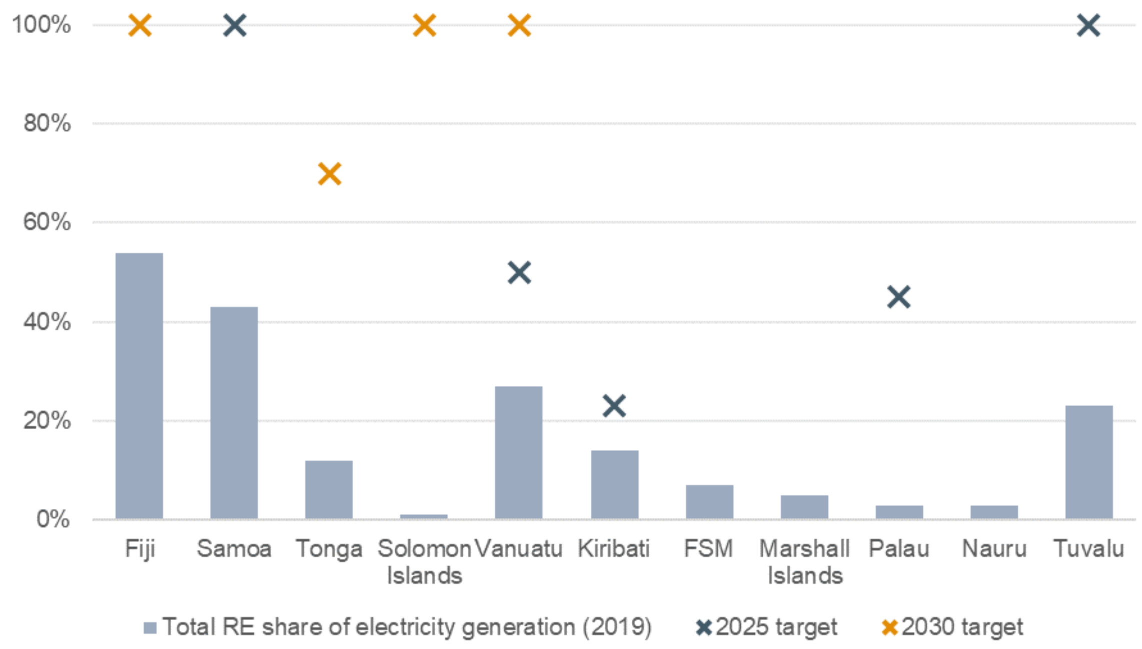
■ Commerical ■ Residental

Source: Consultant based on Utility Websites and IRENA (Commercial tariffs), and Pacific Power Utilities Benchmarking Report 2019 (Residential)

Most Pacific Island Countries have targets to increase their share of renewable generation, but implementation appears to lag behind

Reflecting their overall climate goals and NDCs, many of the Pacific Island Countries have ambitious goals to increase the share of RE. The figure below summarises these targets and shows that many countries are still far below their 2025 targets. As we discuss further there appears to be large gaps between national targets and actual planned renewable investments, which may constrain EV uptake.

Figure 14 RE targets in Pacific Island Countries



Note: Solomon Islands' target relates to Honiara only
Source: Consultant based on IRENA market assessments 2019 and UNFCCC NDC data

Beyond Fiji and Solomon Islands, there is limited potential for further hydropower generation in the Pacific Island Countries. There is good potential for the development of wind power in the Pacific Island Countries, although little has occurred to-date outside of Vanuatu. There is very good to excellent potential for solar generation in all of the Pacific Island Countries, with many countries having a potential of 5-6 kWh/m2/day, and most of the countries are busy adding solar generation.

Due to the potentially significant impact of EVs upon the Pacific Island Countries' electricity systems and the impact of the electricity systems on the viability of EVs, the utilities are likely to have a key role. In many Pacific Island Countries the utilities employ a large share of the available engineering workforce, and are typically in a good financial position due to the relatively high tariffs. As a result, utilities will play a key role in encouraging EV uptake.

3.2 Approach

This assessment focuses on understanding the possible future costs of charging EVs, because it is so critical to future uptake

Due to the fundamental interdependence of the electricity systems and e-mobility, we conduct an assessment of the impact of increased EV uptake on the electricity systems. The focus of this assessment is to answer the following questions:

- What types of investments will electricity utilities need to make to ensure that e-mobility demand is met efficiently?

- What are the approximate future costs of e-mobility charging?

We assess impacts on electricity demand and estimate the costs of supplying that demand, based on the current generation mix versus efficient investments

Our assessment is focussed on the four sample countries, as outlined in Section 2.4. We assess the three aspects of the future impacts of e-mobility uptake in Pacific Island Countries:

- **Impact on electricity demand** – We use assumptions about the future size of the vehicle fleet, average distances travelled, and growth of electricity demand, to show the impacts of EV uptake on electricity demand under different uptake scenarios. We analyse the overall impact as well as the impact by time of day, which is important to the future cost of charging.

- **Supplying e-mobility demand using the current generation mix** – We assess how well placed different Pacific Island Countries are to meet future EV demand, based on their current generation mix and planned investments. We estimate the future costs of supplying EV demand and investigate whether those costs vary for those systems that already have significant hydro and solar capacity.

- **Supplying e-mobility demand through efficient investments –** We determine what the efficient means of supplying EV demand is likely to be for Pacific Island Countries and how that should be charged for through tariffs.

Our assessment is based on a bespoke Excel-based dispatch model. The key inputs and assumptions are included in Annex A4.1.

In addition, we provide some general discussion on the impact of increased e-mobility uptake on local distribution infrastructure. The exact nature of such impacts is highly localised and context-specific, though we have included this to highlight the possible impacts and the potential reinforcements which may be required.

3.3 Impact on electricity demand

3.3.1 Modelled EV uptake scenarios

Uptake in the Pacific Island Countries will depend on policy actions and future charging costs

Global forecasts (of around 10% EV uptake by 2030), as discussed in Section 2.2 are not necessarily a good indication of future uptake in the Pacific Island Countries. Uptake in the Pacific Island Countries will be heavily influenced by local factors, which we will target in our e-mobility roadmap. Key local factors are likely to include:

- The cost differential between purchasing an EV relative to an ICE vehicle

- The future cost of charging EVs.

- The availability of public charging facilities.
- The level of promotion of EV technologies.

In Section 2.5.2 we show that electric car uptake of 6-19% is a potentially reasonable assumption for the Pacific Island Countries based on current vehicle turnover rates and assumptions about the share of new vehicles which are EVs. However, for illustrative purposes, here we use a broader range of different uptake scenarios. They allow us to form a broad picture of the possible impacts that governments and utilities should be prepared for in the coming years, without fixing a time frame to it. The uptake scenarios we use for the year 2030 are as follows:

- 10% uptake
- 50% uptake
- 100% uptake.

50% and 100% uptake are very unlikely to apply by 2030, given how many existing ICE vehicles would need to be prematurely replaced in such a short time. But these scenarios are still instructive in helping governments and utilities understand future impacts.

3.3.2 Overall impact on demand

% impacts on electricity demand will vary by country, based on levels of car ownership and electricity demand

The following table and figure summarise the impact of e-mobility uptake on electricity demand under different uptake scenarios, for the four sample countries we have analysed. It shows that:

- Electricity demand in **Fiji** would increase by **54%** if all cars, motorbikes, and mini-vans were electric. This is high because Fiji has relatively high car ownership and because the average distances travelled daily (and therefore EV charging requirements) are significant (especially when compared to other Pacific Island Countries).
- Electricity demand in the **Solomon Islands** would increase by **56%** if all cars, motorbikes, and mini-vans were electric. This is high because although the Solomon Islands has relatively low car ownership, its existing electricity demand per capita is also quite low, and therefore the proportional impact of e-mobility on electricity demand is high[9]. Said differently, most households in the Solomon Islands currently have low electricity consumption, so if they start charging EVs their consumption will increase by a high percentage.
- Electricity demand in the **Marshall Islands** would only increase by **10%** if all cars, motorbikes, and mini-vans were electric. This is quite low because electricity

[9] The low car ownership and electricity demand per capita rates are partly attributable to the fact that a large proportion of Solomon Islands' population lives outside of Honiara and does not have access to electricity (or good roading infrastructure).

demand per capita is already reasonably high, car ownership rates are relatively low, and average distances travelled daily are also likely to be lower than in Fiji.

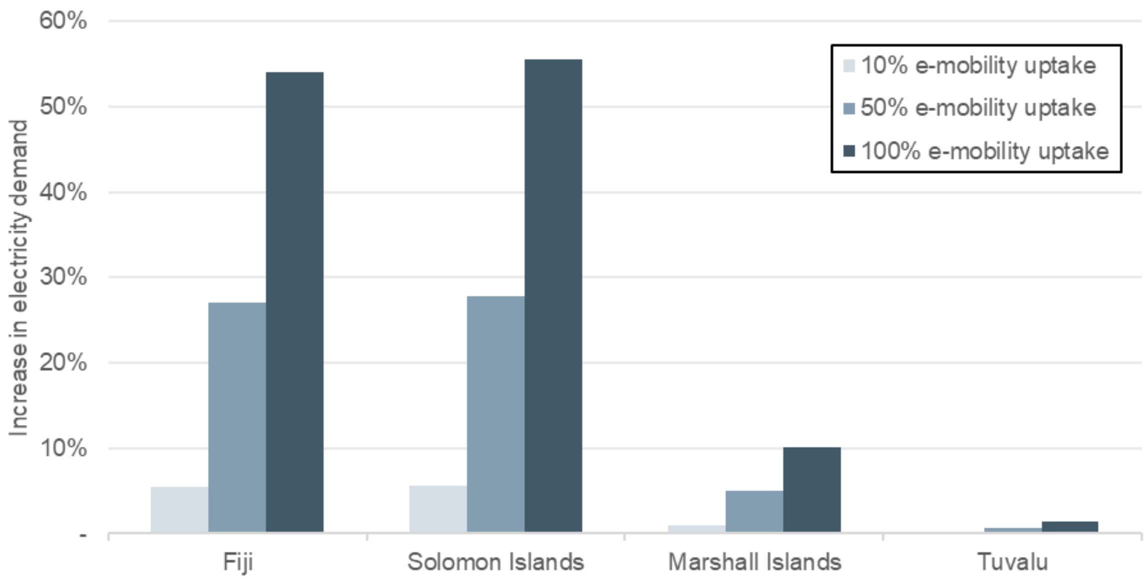
- Electricity demand in **Tuvalu** would only increase by **1%** if all cars, motorbikes, and mini-vans were electric. This is very low because car ownership is so low (there are currently only 65 registered cars) and e-motorbikes do not require much charging, especially in a small island like Tuvalu where average distances travelled daily will be low.

Table 7 Summary of increases in electricity demand due to e-mobility uptake

	10% e-mobility uptake in 2030	50% e-mobility uptake in 2030	100% e-mobility uptake in 2030
% increase in demand			
Fiji	5%	27%	54%
Solomon Islands	6%	28%	56%
Marshall Islands	1.0%	5%	10%
Tuvalu	0.1%	1%	1%
MWh increase in demand			
Fiji	58,231	291,155	582,310
Solomon Islands	4,698	23,488	46,977
Marshall Islands	555	2,774	5,548
Tuvalu	14	72	145

Source: Consultant calculations

Figure 15 Summary of increases in total electricity demand due to e-mobility uptake



Source: Consultant calculations

It is important to emphasise that these impacts are only approximate. They depend on the assumed e-mobility uptake and a range of other factors, including the growth of the vehicle fleet between now and 2030, growth of existing electricity demand, and average distances travelled, as summarised in Annex A4.1.

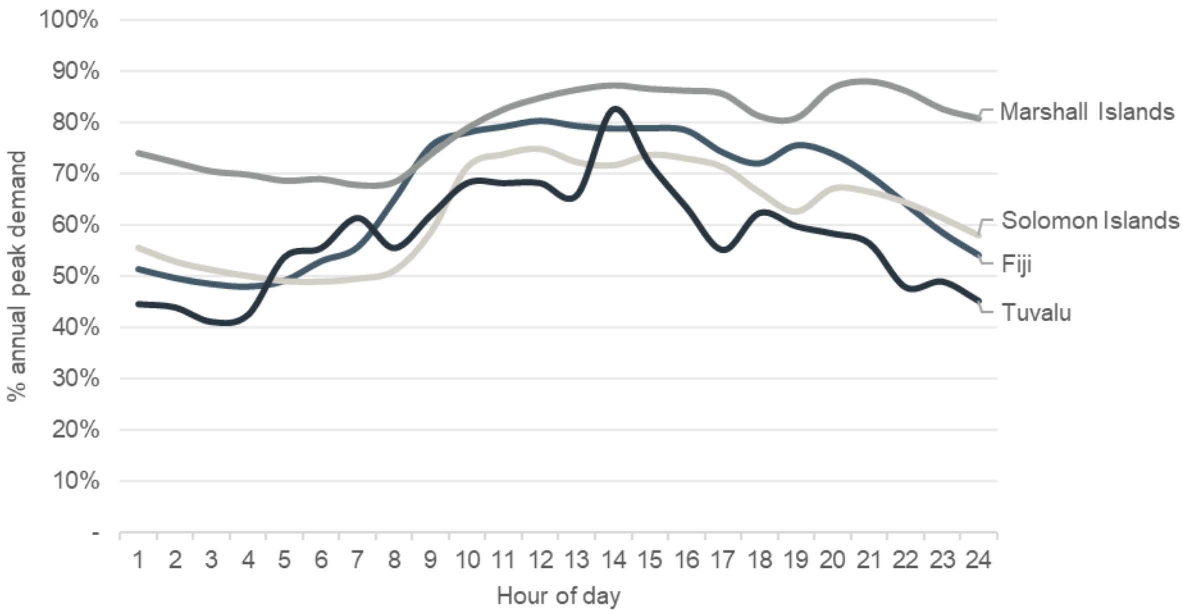
3.3.3 Impacts on the demand profile

The times when e-mobility demand occurs will have important impacts on future costs of supply

The impact of e-mobility uptake on the shape of the Pacific Island Countries' demand curves, ie. the times of day that e-mobility charging occurs, is also very important. This is because, as we discuss in the following sub-sections, the costs of supply vary significantly by the time of the day, especially once Pacific Island Countries invest more heavily in solar.

The shape of the demand curves of the four sample countries analysed are summarised in the figure below. In most of the Pacific Island Countries, demand is highest during the middle of the day, due primarily to businesses running air-conditioners. This is followed by a second peak in the evening hours, attributable to household using appliances once occupants return home from work.

Figure 16 Current electricity demand curves on an 'average' day



Note: The Tuvalu demand curve is based on a sample rather than a full set of annual data, which likely explains why there is such a large peak around 2pm. The average day based on a full set of annual data would likely result in a smoother curve.

Source: Consultant calculations based on data provided by the utilities

Demand impacts will vary depending on when consumers charge their EVs

It is difficult to know exactly what the charging behaviour of EV owners in the Pacific Island Countries will be because there have not been any pilot studies undertaken to-date. We can, however, use data from other countries to make assumptions about the likely impact on demand curves.

Key characteristics of EV charging in the Pacific Island Countries are likely to include:

- Without incentives encouraging otherwise, consumers will likely prefer to **charge at home**. The relatively short distances travelled in the Pacific means that only heavy users would need to charge more than once a day. And without significant investment by Pacific Island Countries governments, widespread installation of fast chargers is unlikely in the short to medium term future.

- Charging at home will typically be from a **standard electrical outlet** which is rated to 8-10 Amp, given that most household connections in the Pacific Island Countries are limited to 20 Amp in total. This will allow charging of approximately 2 kW per hour, and therefore it will take 20 hours to charge a 40kWh battery (which is the size of a 2018 Nissan Leaf battery – the most prevalent second-hand model in New Zealand and Australia at present). An electric car travels approximately 6 kms per kWh of energy and an electric motorbike travels 35 kms, while average distances travelled in Fiji are around 30 km per day[10]. So the daily charging requirement should be 2.5 hours on average, from a standard electrical outlet. This is typically categorised as 'level 1' charging. Many households in high-income countries rely on 'level 2' chargers which are rated to around 16 Amp and output around 3.8 kW per hour. With time, many Pacific Island Countries households may upgrade their household connection, but we expect this will happen slowly given that trickle charging should be sufficient for most users' needs.

The figure below shows three possible EV charging demand curves:

- **Overnight charging** – This is based on a study conducted in New Zealand. Most households that did not face time-of-use (TOU) tariffs chose to trickle charge overnight, when their EVs are not in use. This is likely a reasonable representation of charging behaviour in the Pacific Island Countries, if TOU tariffs do not incentivise different behaviour.

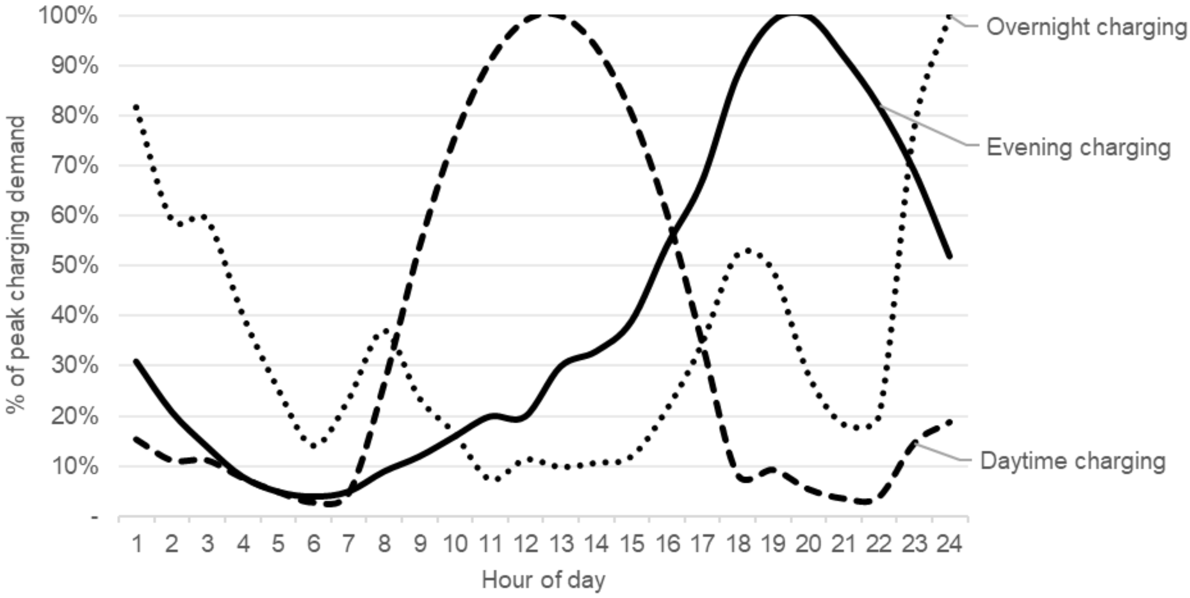
- **Evening charging** – This is based on the profile of EV charging in California, most households chose to use fast chargers to charge when they returned home from work, which led to a peak in the early evening. Again, this is without TOU tariffs encouraging otherwise. This is likely not a good representation of charging behaviour in the Pacific Island Countries, given that fast chargers are unlikely to be prevalent in the short to medium term.

- **Daytime charging** – As we discuss in the following sub-sections, it will be most efficient to meet EV demand in the Pacific Island Countries using solar generation. This daytime charging profile represents the ideal charging behaviour by strongly incentivising households to charge during the day. This could be achieved through much lower electricity tariffs in those hours and the widespread use of public charging stations for example. We created this profile by assuming that charging

[10] For private vehicles, based on the 2015 Fiji Household Travel Survey. Reported distances travelled are lower in the Ba and Rewa provinces (23 km/day and 15 km/day respectively), where Nadi and Suva are located. But distances in the more rural provinces (in particular Naitasiri and Tailevu) are significantly higher.

follows a typical solar output curve in the Pacific, with charging in other hours broadly following the shape of the overnight charging profile.

Figure 17 Possible EV charging demand curves

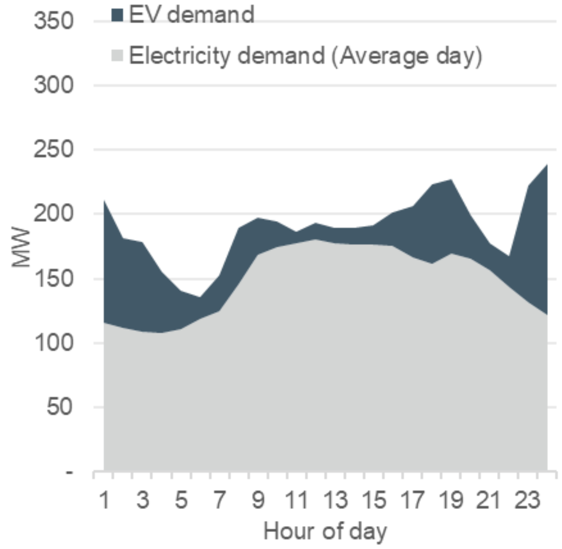
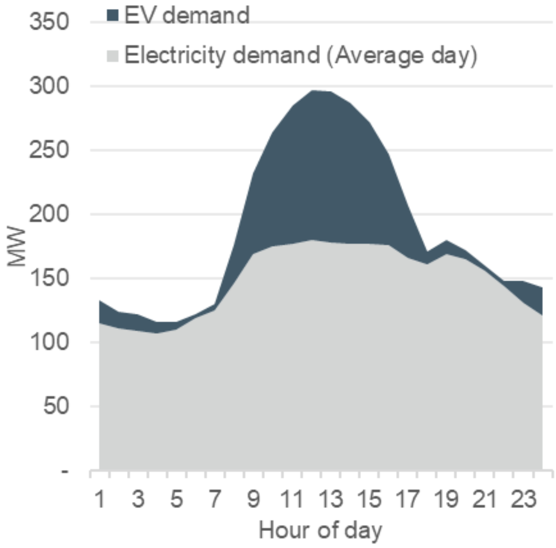
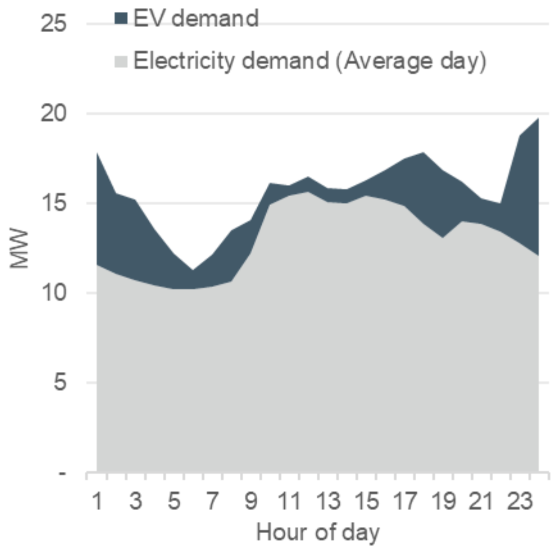
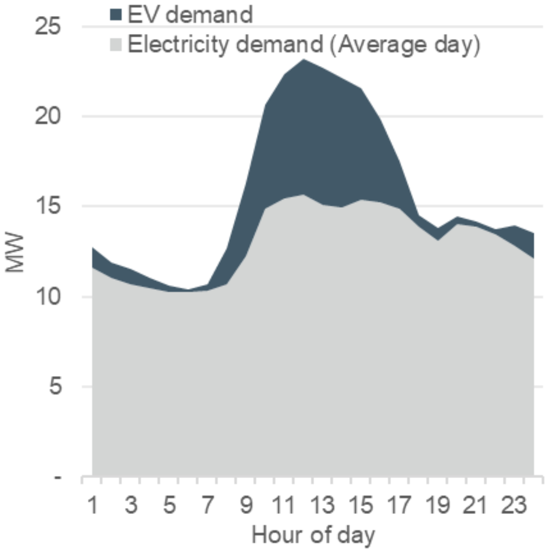


Source: Overnight charging: Wellington Electricity, 2018, Report on Electric Vehicle Charging Trial. Evening charging: NREL, Electric Vehicle Charging Implications for Utility Ratemaking in Colorado. Daytime charging: Consultant assumptions.

The actual demand profile of EV charging in the Pacific Island Countries will probably end up being some combination of overnight charging and daytime charging. Even with strong incentives to charge during sunshine hours, many households will still charge overnight for convenience.

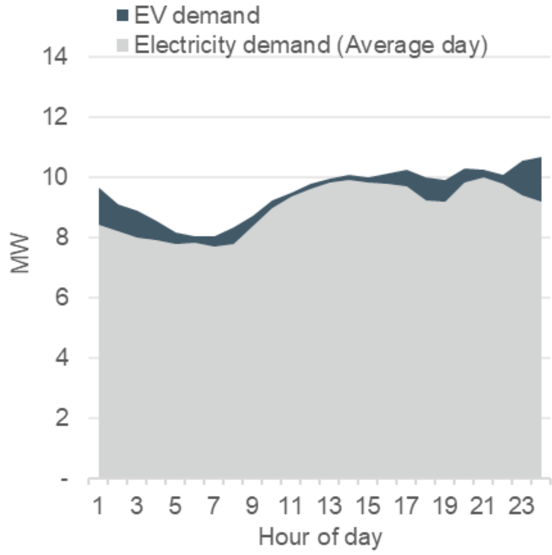
The table below shows the impact of EV demand on the system demand curve under different EV charging profiles, assuming 100% EV uptake in 2030 (which illustrates the impacts most clearly). For lower uptake assumptions the patterns are similar, but less pronounced. For example, with an assumption of 10% EV uptake and daytime charging, peak demand in Fiji would only be 192 MW, compared to 297 MW when 100% EV uptake is assumed. It is tempting to consider that overnight charging is preferable, because it avoids adding demand during peak hours, therefore avoiding needing to add significant network capacity. But, as we describe in the following sub-section, this would be sub-optimal once the Pacific Island Countries electricity utilities invest more heavily in solar generation.

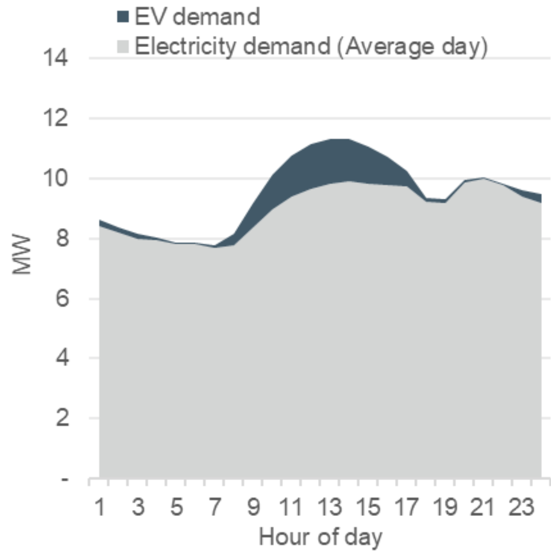
Table 8 2030 system demand curves under different EV charging profiles (100% EV uptake)

Overnight charging	Daytime charging
Fiji	
	
Solomon Islands	
	

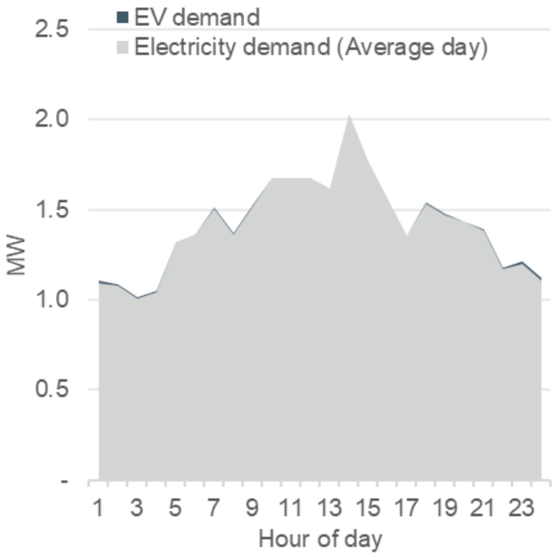
Overnight charging	Daytime charging

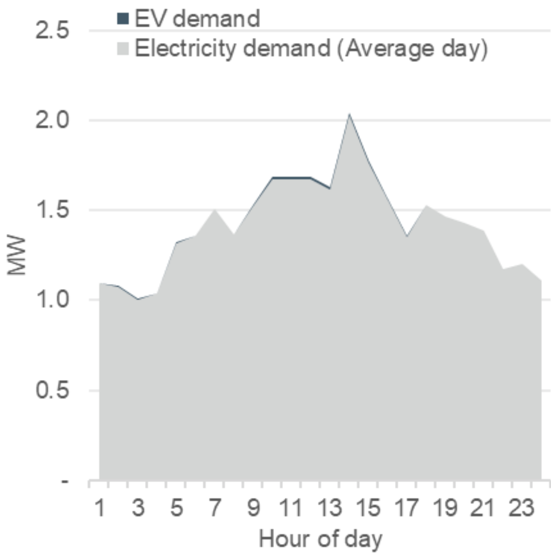
Marshall Islands





Tuvalu





Source: Consultant calculations

3.4 Supplying e-mobility demand

3.4.1 Using the current generation mix

Setting EV tariffs based on the current generation mix would encourage overnight charging (using diesel generation)

The marginal cost of supply is the cost of supplying the increment in demand attributable to EVs. It should reflect not only the marginal fuel cost, but also the incremental costs of adding generation and network capacity. The marginal cost of supply will usually be different to the average cost of supplying total demand, which reflects a whole range of past investment decisions and available resources. Marginal cost-based charging is preferrable because it incentivises efficient consumption decisions – when a consumer is considering when to charge their EV, they fact price signals that reflect the actual cost of supply.

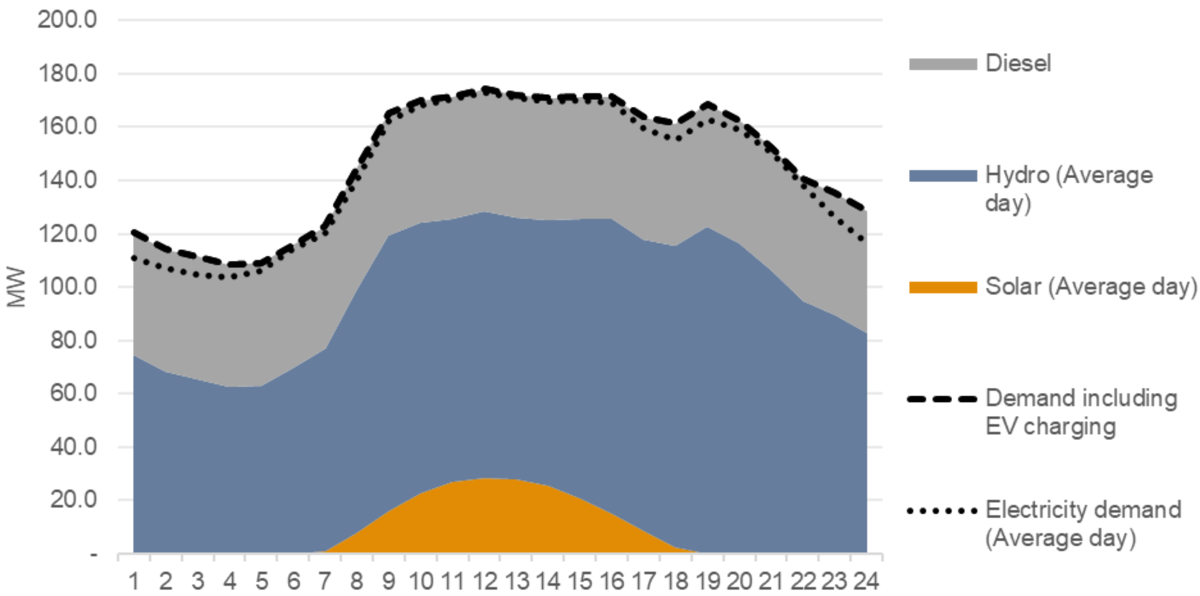
The current generation mix in the Pacific Island Countries is characterised by:

- Diesel generation is the marginal source of supply most of the time.
- Peak demand is during the daytime, and therefore most of the network capacity costs are attributable to daytime demand.

This is likely to persist for the foreseeable future, unless the Pacific Island Countries invest much more heavily in solar (and BESS, for countries without hydro) than is currently planned.

For example, if Fiji were to install 50 MW of new solar capacity by 2030, as assumed in the figure below, it will not be enough (on an average solar output day) to displace diesel generation at the margin. A back-of-the-envelope calculation suggests that Fiji would need to install around 300 MW of new solar capacity by 2030 to displace diesel on an average solar output and average hydro output day, which would enable incremental EV demand to be charged with solar generation.

Figure 18 2030 electricity supply curve (10% EVs) – Fiji



Source: Consultant calculations

We estimate that the marginal cost of supply in the Pacific Island Countries is 15% to 20% higher during the daytime, after allocating most network capacity costs to those hours, as summarised in the table below. Although most of the utilities plan to invest in solar, unless the amount invested is sufficient to shift diesel off the margin, then these marginal costs will continue to apply.

Table 9 2022 marginal cost of supplying EV demand

	Fiji	Solomons	Marshall Islands	Tuvalu
Peak (daytime) hours	0.33	0.44	0.63	0.51
Off-peak hours	0.28	0.38	0.55	0.45
% difference	19%	17%	15%	13%

Notes:

- Assumes a marginal cost of network supply of US$400/kW, based on a 2017 Cost of Service Study for Fiji. This may not be applicable to the other Pacific Island Countries, but gives an approximate indication of the differences.
- For Fiji, this difference ignores the difference between heavy fuel oil and light fuel oil fired generation. Currently light fuel oil (LFO) fired generation is sometimes used during peak hours, but not in off-peak hours. If we were to account for this difference, the difference would be even greater.

Source: Consultant calculations

Cost-reflective EV tariffs would encourage charging during the evening/night-time. Setting flat EV tariffs (non-TOU) would result in similar charging behaviour, because overnight charging is most convenient for households. But this is not a sustainable strategy for Pacific utilities in the long term, because it will entrench consumer behaviour and make it difficult to utilise solar generation once added.

3.4.2 Using efficient investments

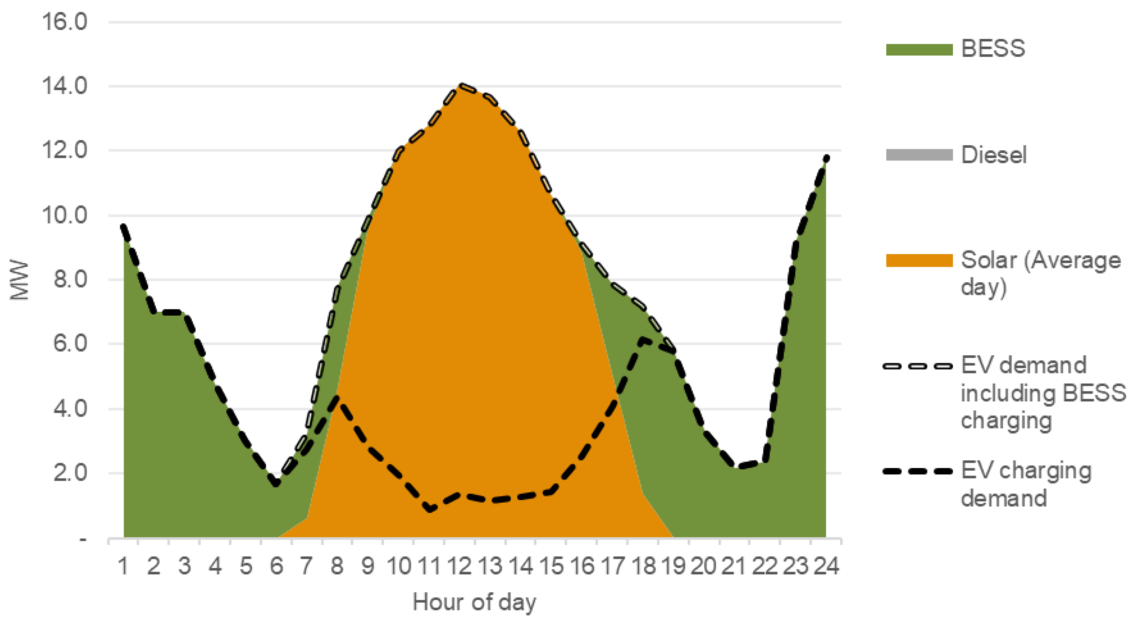
In the future the most efficient way to meet EV demand will usually be through a combination of solar and BESS

In all the Pacific Island Countries, utilities should invest in solar and use BESS capacity to shift the solar generation to the hours when EVs are being charged. A combination solar+BESS is currently more expensive than solar+diesel generation (although not by much at current fuel prices), but we expect that to change by 2030 as the cost of solar and BESS capacity continues to fall. Those countries with excess hydro capacity – likely only Solomon Islands – will need to install less BESS capacity, as the hydro can be effectively used to 'shift' solar generation to off-peak hours.

The more that daytime charging can be encouraged, the lower the cost of supply

The figure below illustrates how EV demand in Fiji (around 60,000 MWh/year, assuming 10% EV uptake in 2030) could be met by a combination of solar and BESS, if most EV charging happens overnight. Note that this figure shows EV demand only and assumes that all the available hydro generation is used meeting non-EV demand. It demonstrates that because the majority of EV demand is overnight, a lot of BESS capacity is needed to store excess solar generation in the daytime. The illustration looks very similar for the other Pacific Island Countries (albeit at different scales).

Figure 19 2030 supply curve of EV demand, based on solar+BESS (overnight charging, 10% EVs) – Fiji



Source: Consultant calculations

If all EV charging occurs during sunshine hours, then the cost of charging will be low – the levelised cost of solar plus network costs. But the sun will not always shine, and many consumers will still want to charge in the evening or overnight, regardless of price incentives. The cost of charging during the non-sunshine hours will be based on some combination of BESS and diesel, depending on how much BESS is installed.

The figure below illustrates how EV demand in Fiji could be met by a combination of solar and BESS, if most EV charging during the sunshine hours. When compared to the previous figure, significantly less BESS capacity is needed. Again, the illustration looks very similar for the other Pacific Island Countries. The notable exception to this is the Solomon Islands, where, once Tina River Hydro is operational, daytime charging is not cheaper until the hydro capacity is exhausted.

Daytime EV charging will be much cheaper than overnight charging

The table below summarises our estimated 2030 marginal costs of supplying EV demand at different times of the day, using a combination of solar, BESS, and diesel which is considered to be efficient. It assumes that during sunshine hours, EV demand is met entirely with solar, while in the non-sunshine hours, it is met 80% with BESS and 20% with diesel, except in the Solomon Islands, which we assume will use spare hydro capacity rather than BESS.

It shows that it is much cheaper to supply EV demand during sunshine hours than non-sunshine hours, by a factor of more than two in some cases. This difference is greater than the difference between peak and off-peak costs, which arises due to network costs being allocated mostly to peak (weekday business hours) periods.

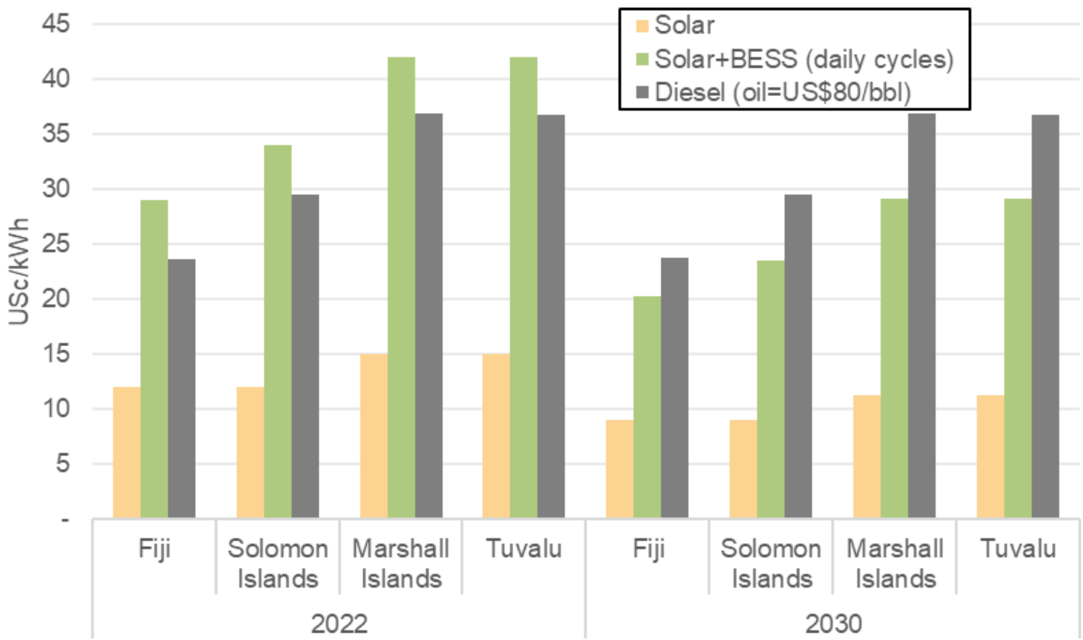
Table 10 2030 marginal cost of supplying EV demand efficiently (USc/kWh)

	Fiji	Solomons	Marshall Islands	Tuvalu
Peak (weekday, daytime) + sunshine hours	0.17	0.19	0.26	0.21
Peak + non-sunshine hours	0.30	0.19	0.54	0.43
Off-peak + sunshine hours	0.11	0.13	0.18	0.15
Off-peak + non-sunshine hours	0.25	0.13	0.46	0.38

Source: Consultant calculations

These costs are based on the following assumed levelised costs for each type of generation (the inputs and assumptions are further described in A4.1).

Table 11 Assumed levelised costs of different generation types

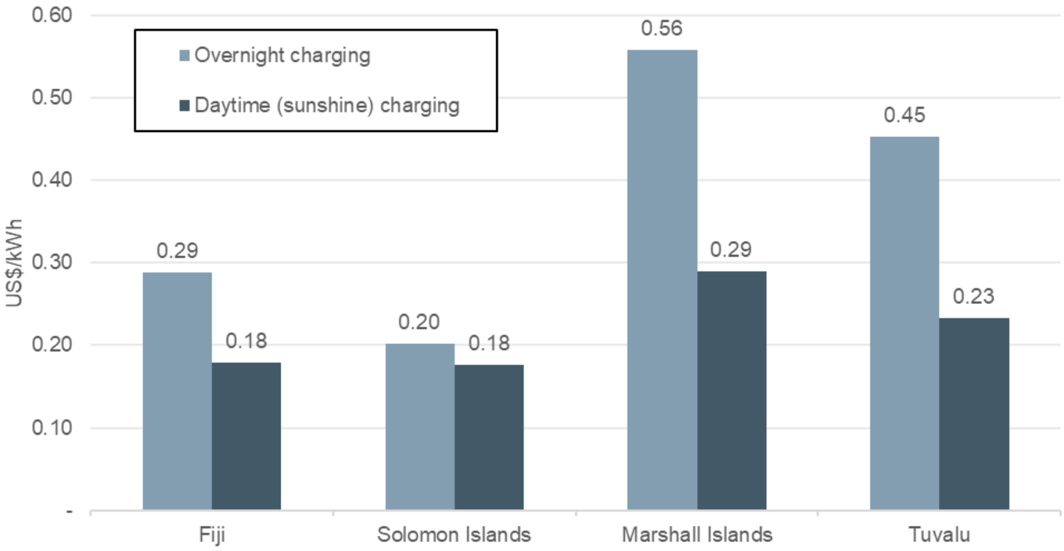


Source: Consultant calculations

The more that daytime charging can be encouraged, the cheaper the overall cost of supply

The figure below summarises the overall (average) costs of supplying EV demand in 2030, assuming an optimal mix of solar and BESS (or hydro in the case of Solomon Islands) is used. It shows that if most EV charging occurs overnight, the average cost of supply is around 50% more expensive than if consumers are encouraged to do most of their charging during sunshine hours, This can be achieved through TOU tariffs and by installing public charging facilities.

Table 12 2030 marginal costs of supplying EV demand under different EV charging profiles



Source: Consultant calculations

3.5 Impact on distribution networks

Increased e-mobility uptake will also have impacts on local distribution infrastructure

In addition to impacts on total demand, and hence requirements for generation capacity additions, increased e-mobility uptake will also have impacts on the local distribution network and necessitate network upgrades. The nature of such impacts will depend on the charging approach (ie. whether regular or fast chargers are used, and how many vehicles are being charged at the same time), and the location of the charging infrastructure within the grid.

Household charging is unlikely to require significant impacts to local distribution infrastructure

Common chargers used for household applications have capacities up to 7 kW in a single-phase AC layout. In the Pacific, most houses have 20-amp connections, which limits charging to around 2 kW. In this case, EV charging may be possible without network upgrades, as slow charging, particularly if it does not coincide with existing peak household demand, is unlikely to require a change in the subscribed capacity. For example, if EVs are charged overnight, when other relatively electricity-intensive household appliances are not being used, the impact of slow charging will not require an upgrade to the network. And slow charging (and long overnight charging times) is likely sufficient for most EV uses in the Pacific Island Countries, given the short distances travelled. However, if there is a high level of EV uptake in a concentrated area, this could require some grid strengthening at low voltage levels, up to and inclusive of the step-down transformers.

At the household level, those households which have sufficient wiring for medium to high loads (for example those households whose electrical installations could support an air condition system) are unlikely to require further upgrades. However, households with older indoor wiring may require some retrofits. The cost for such an upgrade can range from US$500 to US$2,000.

Public charging stations require careful consideration of their impacts on the local distribution network

Public charging stations that can be used in public buildings, parking lots, supermarkets, normally seek faster charging times and in consequence capacities might range from 20 to 50 kW for light vehicles. Typically, three-phased chargers are utilised, and these can use either AC or DC. Even in the case of using lower charging capacities, the charging station will likely offer more than one charging point and, in consequence, these types of applications draw much higher capacity requirements than household applications. The costs associated to semi-fast or fast charging infrastructure in these applications can range from US$2,000 to US$30,000.

The network capacity needs will be determined by the number of charging stations and their individual capacity. The load of small stations can be analogous to those of commercial or small industrial applications and therefore the distribution network needs are no different. On the contrary, large charging stations with many spots can be more demanding and require network strengthening. In these cases, the selection of candidate locations for the chargers should incorporate the grid capacity as one of the main criteria. In this sense, power utilities should be prepared to respond to increasing requests from prospective EV charger developers as EV takes over. Alternatively, power utilities can also take the lead in identifying and/or planning the best locations for public charging infrastructure.

Fast charging infrastructure for buses will require considerable investments in the local grid, but is unlikely to play a significant role in the Pacific Island Countries

Fast charging applications for buses typically require very high capacities that can range from 100-150 kW and even reach to 300 kW and use DC. The cost per charging unit can be well above US$100,000. Fast charging applications will typically require upgrades in the distribution network, especially in the case of having multiple charging stations that can operate simultaneously.

Given the current stage of EV market development in the Pacific Island Countries and the nature of the public transport systems in, it is not envisioned that these types of stations will be required in a generalised manner. In most Pacific Island Countries, no more than a few such charging stations will be required to satisfy the demand.

In such cases, it is recommended to locate the charging stations around the power generators and their main feeders. That will minimise the energy distribution losses and will benefit from larger capacities of power infrastructure around the plants, thus minimising the need for upgrades. Furthermore, it is recommended that the deployment of this type of infrastructure involves the power utilities, given not only their impact on the grid but also the demand side management opportunities for the utility.

4 Economic viability of e-mobility

4.1 Approach

4.1.1 Introduction

Knowing which types of e-mobility provide net benefits to society will help governments know where to focus their efforts

E-mobility roadmaps should encourage e-mobility uptake, but only if the various types of EVs and their use cases are economically viable from a societal perspective. Said differently, governments should not encourage EV uptake if it does not provide net benefits to society. These net benefits factor in both financial and non-financial costs and benefits and provide an assessment of viability.

In this analysis we assess the viability from a societal perspective, meaning that we quantify the costs and benefits incurred by society, including factors such as the economic cost of carbon emissions and ignoring taxes (which are a transfer from one group in society to another). This societal cost-benefit analysis is different to a financial viability analysis at the individual level, which is sometimes referred to as a comparison of 'Total Cost of Ownership'. Once governments know which types of e-mobility are beneficial to society, they can focus their policy interventions on aligning personal incentives with societal incentives (to unlock the benefits), for example giving tax breaks on EVs to reflect their lower environmental impacts.

4.1.2 Types of vehicles

We assume that most electric cars and vans in the Pacific Islands will be purchased second-hand and have relatively small battery sizes

As discussed in Section 2.5, our assessment focuses on three types of EVs which are the most promising and relevant in the Pacific Island Countries:

- **Electric cars**
- **Electric motorbikes**
- **Electric vans**

There is a lot of variation in the different types of EVs on the market. To conduct our analysis, we select a representative vehicle for each type.

We note that the main source of vehicles in the Pacific Island Countries is Asia, with secondary market links also existing to Australia and New Zealand[11]. Given the proximity we

[11] Source markets for second-hand vehicles will also be determined by the handedness of road traffic in the respective countries. In the Pacific Island Countries, Fiji, Solomon Islands, Tuvalu, Tonga, Samoa, Nauru, and Kiribati drive on the left-hand side, while Marshall Islands, Micronesia, Palau, and Vanuatu drive on the right-hand side.

expect that most EVs would continue to come from Asian manufacturers. An existing study in Fiji suggests the ratio of new vs used imported EVs is likely to follow the patterns observed in Australia and New Zealand, where there is a preference to purchasing second-hand vehicles relative to new vehicles[12]. The table below shows the vehicles we have proposed to use in our analysis. Note that for all vehicles we assume that second-hand vehicles will be purchased and used. These representative vehicles all have relatively small battery sizes, but they should be more than adequate for most use cases in the Pacific Island Countries, given the short distances travelled by most users.

Table 13 Selected vehicles for assessment

	EV	ICE comparator
Cars	Nissan leaf 2018	Toyota Corolla
Motorcycles	Gesits (new)	Honda PCX
Vans	Nissan E-NV200 2018	Nissan Caravan

Source: Consultant

We examine the viability of EVs under low, medium, and high-use cases

Given that the viability of EVs is largely a question of trading off increased upfront costs with reduced operating costs, we anticipate that viability will vary based on the amount vehicles are used – ie, the average daily distance travelled. We therefore assess the net benefits under a range of use cases, as summarised in the figure below. For the avoidance of doubt, the use cases refer to the distance travelled by the average vehicle users (and not the level of EV uptake).

Table 14 Vehicle use cases for cost-benefit analysis

Types	Use case (distances travelled)	Example
Electric cars	Low	Occasional journey
	Medium	Daily work commute
	High	Taxi, public vehicle
Electric motorbikes	Low	Occasional journey
	Medium	Daily work commute
Electric vans	Medium	Commercial
	High	Public transport

Source: Consultant

We assume changes in EV costs between now and 2030, as described further below.

[12] GGGI, 2019, *Fiji: An Analysis of the Power Sector Infrastructure Requirements on Electric Vehicles for Viti Levu*

4.1.3 Scenarios

We assess the current net benefits of EVs, and the net benefits in 2030 under ‘business-as-usual’ conditions and under favourable conditions

In assessing the viability of e-mobility in the Pacific Island Countries we have developed three market scenarios, which are summarised in the table below. The first scenario examines viability under present day conditions, while the other two scenarios focus on the medium term future in 2030.

Table 15 Market scenarios for cost-benefit analysis

Scenario	Description	Key assumptions
BAU 2022	Assessment of e-mobility under current conditions	• Based on status quo • No further policy interventions beyond status quo
BAU 2030	Assessment of e-mobility under conditions and assumptions which are likely to be prevalent in 2030 without extra government interventions	• Conservative assumptions about future reductions in EV upfront costs • Only 20% of daytime EV charging supplied by solar. Use of diesel outside of sunshine hours • Mostly overnight EV charging
Favourable 2030	Assessment of e-mobility under conditions and assumptions which are either an optimistic, upside estimate for 2030 and/or which are induced by additional policy interventions	• Higher future cost reductions in EV upfront costs • 100% of daytime EV charging supplied by solar, thanks to increased RE investment. And 80% use of BESS (charged by solar) outside of sunshine hours • Mostly daytime EV charging, thanks to TOU tariffs and provision of public charging facilities

Source: Consultant

4.1.4 Costs compared

We calculate the net benefit by comparing annual ICE costs with EV costs

For each of the following categories of costs, we calculate the annual cost savings (which may be negative in some cases) of an EV versus an ICE equivalent vehicle. We convert any one-off costs, for example the upfront purchase costs, by annuitising them over the life of the vehicle. The cost categories we consider include:

- **Upfront costs** include the costs related to acquiring a vehicle and associated private charging infrastructure
- **Charging/fuelling costs** includes the costs related to fuel for ICE vehicle, and electricity costs for EVs. The cost of electricity incorporates costs related to network strengthening and public charging infrastructure.

- **Maintenance costs** includes the costs of maintenance for vehicles. Note that we do not consider the cost of battery replacement, as we expect batteries to last for the lifetime of the vehicle. This is an increasingly common assumption for EVs. Even if this were to be considered, we do not anticipate battery replacement to be viable in the Pacific Island Countries in the short to medium term future given the small and remote markets, and the dominance of second-hand vehicles.

- **Environmental costs** include the costs of carbon emissions resulting from ICE vehicles and carbon emissions resulting from the electricity generated for EV charging.

In addition to the quantitative assessment of e-mobility described above, we examine a range of qualitative factors in Section 4.3. These are considered in a qualitative nature because their impacts are either secondary, and a result unlikely to materially impact the outcome of the analysis, and/or are difficult to quantify. These impacts include concerns about lifecycle emissions and battery disposal, air pollution, and fuel security.

The full assumptions are included in Annex A5.1. Although assumptions underlying cost-benefit analyses are inherently associated with a degree of uncertainty, we believe that the results provide a reasonable and plausible assessment of the viability of EVs in the selected countries.

4.2 Quantitative viability of different types of EVs

Currently, EVs are not economically viable in the Pacific Island Countries due to high upfront costs and reliance on diesel-fired electricity generation

In general, we found that none of the three types of e-mobility considered are viable under the current BAU 2022 scenario in any country, regardless of the use case. This reflects that the upfront costs of EVs remain higher than comparable ICE vehicles. And the potential savings from lower fuel costs and environmental benefits are limited given charging in most countries remains reliant on diesel generation.

If Pacific Island Countries successfully increase solar penetration and encourage daytime charging, then electric cars, electric motorbikes, and electric vans are all viable (except when usage is low)

The table below summarises which types of EVs and use cases are viable under the Favourable 2030 scenario.

Table 16 Viability of EVs under certain use cases in selected Pacific Island Countries – Favourable 2030 scenario

Types	Use case	Fiji	Solomon Islands	Marshall Islands	Tuvalu
Electric cars	Low	✗	✗	✗	✗
	Medium	✓	✓	✓	✗
	High	✓	✓	✓	✗
Electric motorbikes	Low	✗	✗	✗	✗
	Medium	✓	?	?	✗
Electric vans	Medium	✗	✗	✗	✗
	High	✓	✗	✓	✗

Legend:

✓	*Economically viable*
?	*Marginal/potentially economically viable*
✗	*Not economically viable*

Source: Consultant

The table above shows that:

- **All types of EVs are generally unlikely to be economically viable in Tuvalu**. This is because the very short distances travelled in the country do not allow the higher upfront costs of EVs to be recouped through lower operating costs. Some EVs may still be viable in Tuvalu, but only if their usage is very high (more than the high-use case assumed in our modelling).

In the other countries:

- **Electric cars are viable under the medium- and high-use case scenarios.** This suggests that under the assumptions incorporated in the Favourable 2030 scenario – which includes further reductions in the upfront costs of the EV compared to BAU scenario, as well as significant investments in RE generation to reduce the cost and emissions from charging – there are societal benefits of increased EV uptake. However, policies to encourage EV uptake should be focussed on medium and high-use cases, such as taxis and regular commuters.

- **Electric motorbikes may be viable for medium-use cases.** The comparatively small distances travelled by motorbikes – and their limited fuel/electricity consumption, limit the potential benefits of EVs which would offset the higher upfront costs. Nonetheless, there is potential to achieve societal benefits by encouraging the uptake of electric motorbikes among users who travel larger distances on a regular basis.

- **Electric vans are viable in Fiji and the Marshall Islands** for high-use cases. As a result, focus should be given to the public transport sector and delivery operators, as well as other users of vans which travel considerable distances. They are not viable in the Solomon Islands due to the higher assumed upfront cost of vans relative to the other Pacific Island Countries.

Large investments in solar generation and BESS are critical to EV uptake. Without them, EVs are unlikely to be viable, even in 2030

The table below summarises which types of EVs and use cases are viable under the BAU 2030 scenario, which differs from the Favourable scenario in that not nearly as much solar generation is added and EVs are mostly charged overnight, and as a result EVs are mostly charged using diesel-fired electricity generation.

Table 17 Viability of EVs under certain use cases in selected Pacific Island Countries – BAU 2030 scenario

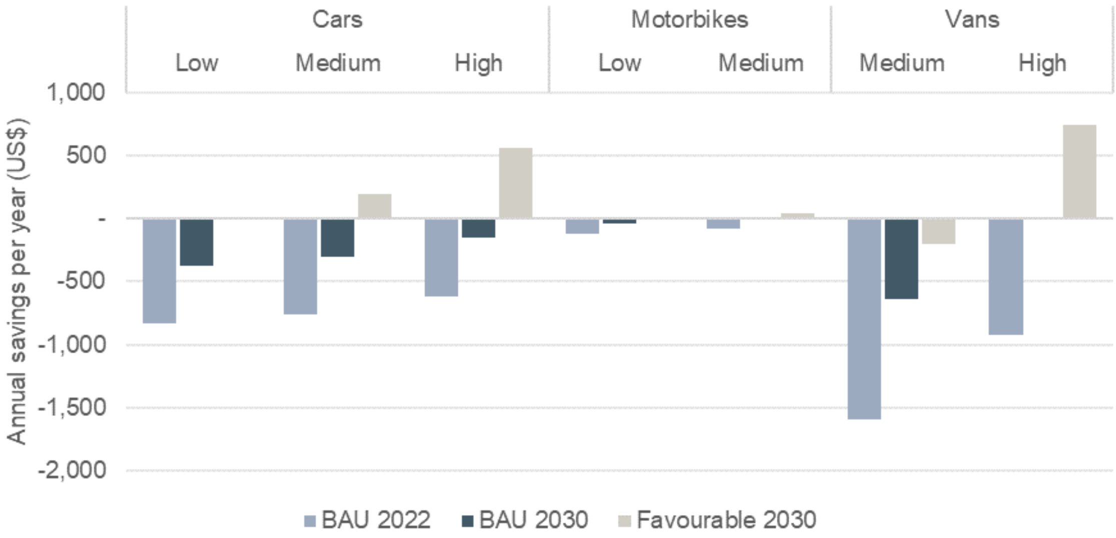
Types	Use case	Fiji	Solomon Islands	Marshall Islands	Tuvalu
Electric cars	Low	✗	✗	✗	✗
	Medium	✗	✗	✗	✗
	High	✗	✗	✗	✗
Electric motorbikes	Low	✗	✗	✗	✗
	Medium	?	✗	✗	✗
Electric vans	Medium	✗	✗	✗	✗
	High	✗	✗	✗	✗

Source: Consultant

The table above shows that the only mode which may be viable is e-motorbikes under the medium-use case in Fiji (and even here the viability is marginal).

A summary comparison of annual net benefits under the different scenarios is provided in the figure below for Fiji. The results are broadly similar to those observed for Solomon Islands and Marshall Islands.

Figure 20 Overview of annual savings of EVs, comparison of types under different scenarios and uses cases – Fiji



Source: Consultant calculations

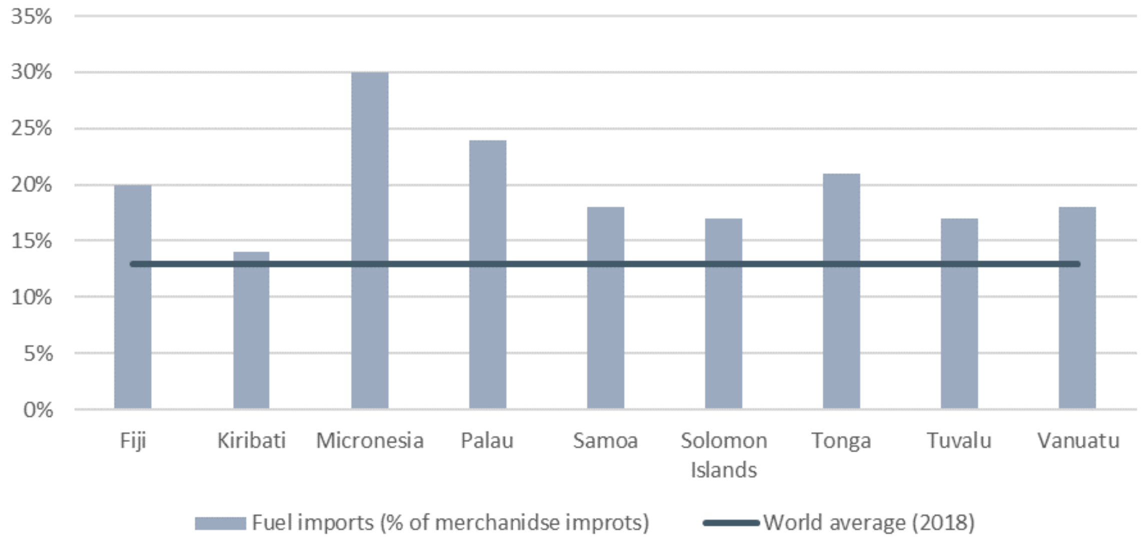
4.3 Qualitative factors to also consider

4.3.1 In favour of EVs

Increased e-mobility usage can increase the Pacific Island Countries' fuel security, if it is accompanied by significant investments in RE generation

The Pacific Island Countries currently rely on imports for their fuel supply, for both transport and electricity generation. As shown in the figure below, fuel imports make up a significant share of total imports in these countries.

Figure 21 Fuel imports as share of total merchandise imports in selected Pacific Island Countries



Note: 2018 data is used for all countries, except Tonga (2014), Micronesia (2013), Vanuatu (2011), and Tuvalu (2008)

Source: Consultant based on World Bank data (Fuel imports - % of merchandise imports)

The reliance on imported fuel has negative consequences for the Pacific Island Countries' current account balances. It also limits their fuel security, as they are reliant on other countries.

Increased e-mobility uptake could reduce the dependency on imported fuel. However, this is contingent on the share of electricity being provided by RE increasing enough to meet the increased electricity demand from EV charging. If this is not the case, e-mobility will not have a considerable impact on reducing the Pacific Island Countries' reliance on fuel imports.

E-mobility can reduce air pollution in urban centres

Globally, one of the key rationales for e-mobility is to reduce the impact of vehicle emissions in densely populated urban centres. However, urban air pollution is less of an issue in the Pacific Island Countries. This is due to relatively low car ownership rates, low distances travelled, and the presence of sea breezes.

Nonetheless, an increase in EV usage would reduce air pollution in the Pacific Island Countries' urban centres. Although this pollution may simply be displaced elsewhere if electricity continues to be generated using diesel generators.

V2G services will be able to help with grid stability

While EV charging during peak hours will add significant network costs, EVs will also bring some network benefits. EVs can provide utilities with a mechanism for managing demand in particular hours of the day (through automated demand management). And vehicle-to-grid (V2G) services can be used to stabilise distribution networks, although these technologies are unlikely to be implemented in the short term future.

4.3.2 Against EVs

The development of EVs is associated with higher lifecycle emissions

Contingent on the share of RE generation in the electricity mix, EVs will generally have lower operating emissions than comparable ICE vehicles. However, the production of EVs is associated with considerable emissions. The exact scale of these emissions depends on the model and location of manufacture. BloombergNEF estimates that CO_2 emissions from battery manufacturing in China are around 60% to 85% higher than those in Europe and the US[13]. In addition, there are also concerns about the practices involved with the mining of rare metals needed for the batteries in EVs.

In our cost-benefit analysis we assume that all vehicles in the Pacific will be second-hand. This means that the issue of lifecycle emissions plays a secondary role.

There is potential for unwanted costs related to battery disposal and recycling if these issues are not addressed

We have assumed that there will be no replacement of batteries for EVs. This reflects the modern EV market, where most vehicles are built with batteries which last for prolonged periods of times. And even where batteries deteriorate to the extent that they would require replacement, this is unlikely to be feasible in the Pacific Island Countries in the short term given the small market sizes and high costs.

However, consideration should be given to the potential impact of what happens to these batteries at the end of the EV's lifetime. Efforts to repurpose them as BESS are promising but are not at a point of commercial maturity. While recycling is likely to be unviable due to the remote and small markets of the Pacific Island Countries. As a result, consideration needs to be given on how to deal with battery disposal to avoid externalities associated with dumped batteries and consequent pollution.

4.4 Aggregate benefits to society of 10% EV uptake

For viable EVs, we multiply the net benefits by their assumed uptake to calculate the total net benefits to society

In the preceding section we examined the viability of an individual EV from the societal perspective. In this section, we use these estimates and combine them with forecast EV uptake rates across the country to estimate the potential aggregate annual savings from increased e-mobility uptake. Our analysis focuses on the Favourable 2030 scenario.

We calculate forecast uptake rates based on the current number of vehicles in each country[14], an assumed 10% annual growth rate in the number of vehicles, and an assumed EV share of 10%, which aligns with figure used in the electricity system impact assessment.

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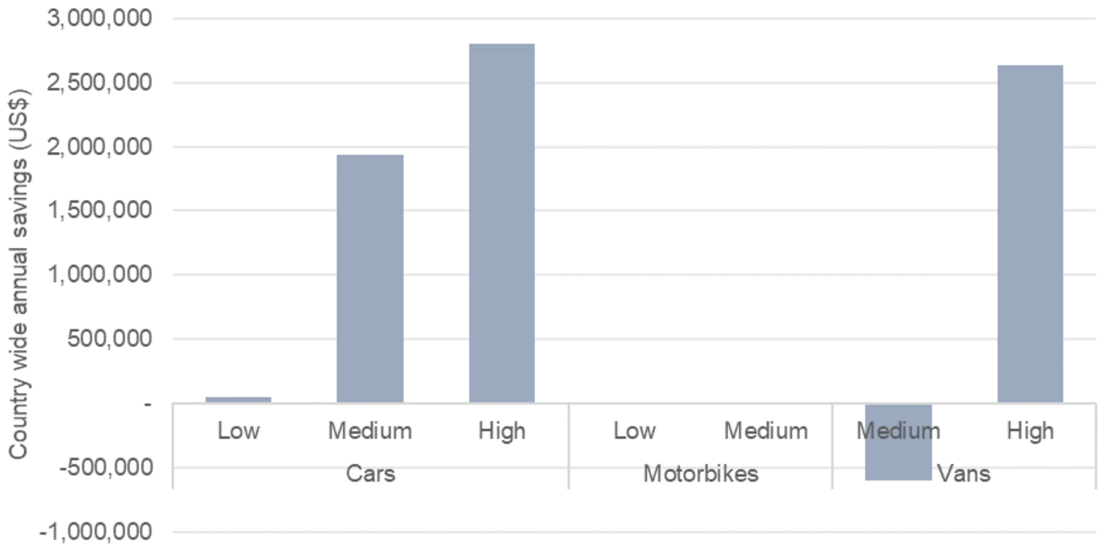
[13] Bloomberg NEF, 2021, The Lifecycle Emissions of Electric Vehicles
[14] We assume that for cars, 25% fall under the high and low-use cases and 50% fall under the medium-use case. For motorbikes and vans we assume a 50:50 split between the use cases.

Electric cars are likely to bring large total net benefits to Pacific Island Countries and their uptake should be encouraged

As shown in the figure below, increased electric car and van uptake amongst those who fall into the medium and high-use cases, could bring considerable benefits to the countries. For example, if 10% of cars which fall in the high-use category were switched to EVs, Fiji would benefit from annual savings in the region of US$2.4m per year.

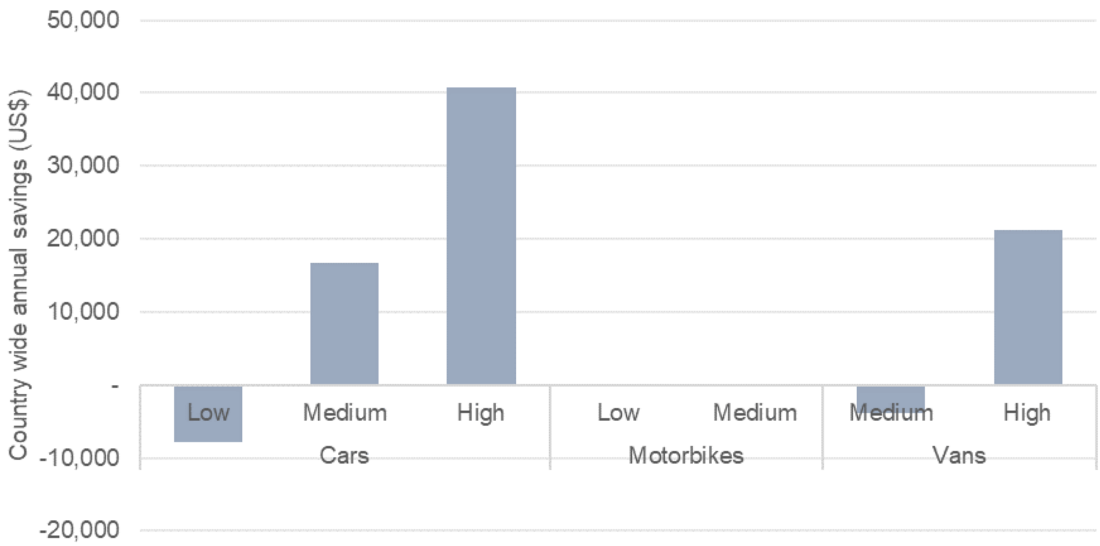
Figure 22 Aggregate annual net benefit of EV use – Comparison of types and use cases, Favourable 2030 scenario – Fiji



Source: Consultant

A very similar pattern holds for the Marshall Islands, with noticeable social benefits from encouraging electric car and van usage among high-use cases.

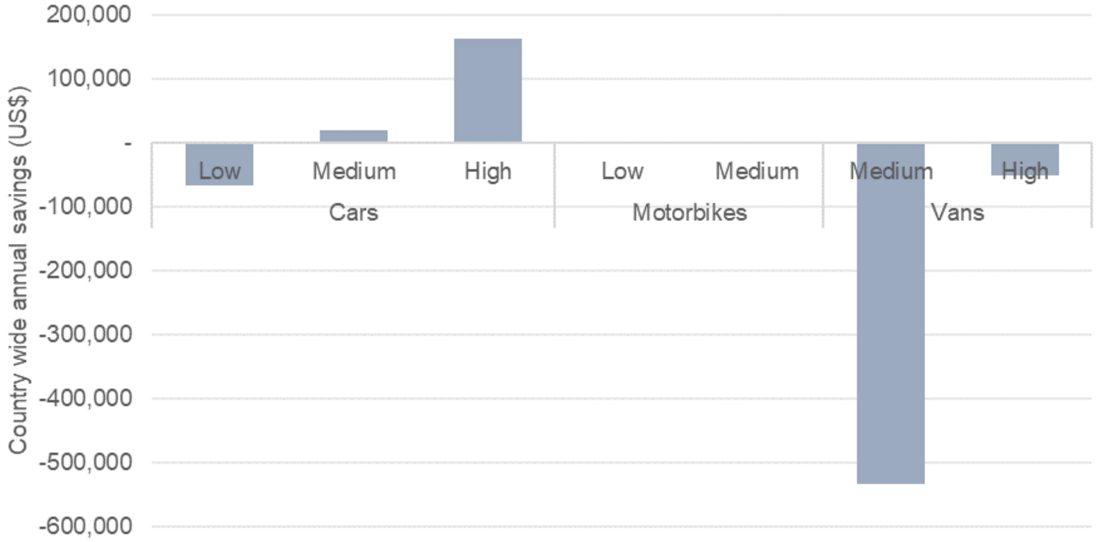
Figure 23 Aggregate annual net benefit of EV use – Comparison of types and use cases, Favourable 2030 scenario –Marshall Islands



Source: Consultant

For the Solomon Islands, a similar pattern holds, with considerable benefits gained from encouraging electric cars for high-use cases. However, there are no benefits from encouraging electric van usage.

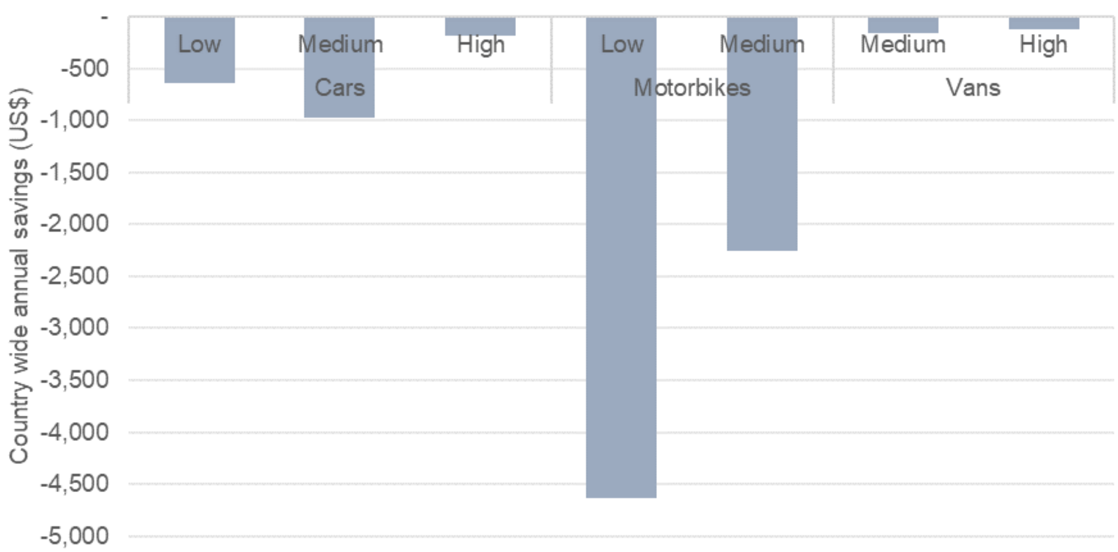
Figure 24 Aggregate annual net benefit of EV use – Comparison of types and use cases, Favourable 2030 scenario – Solomon Islands



Source: Consultant

Finally, in Tuvalu the short distances mean that under the assumptions applied in the analysis EVs will not bring social benefits. This is because the higher upfront costs cannot be balanced out with lower operating costs and higher environmental benefits.

Figure 25 Aggregate annual net benefit of EV use – Comparison of types and use cases, Favourable 2030 scenario – Tuvalu



Source: Consultant

5 Barriers to e-mobility uptake

5.1 Overview of barriers

There are currently a range of barriers to e-mobility uptake in the Pacific Island Countries

The table below summarises our assessment of the key barriers to e-mobility uptake in the Pacific Island Countries, which is informed by our analysis in the previous sections of this report. Some of these barriers are the result of the unique characteristics of the Pacific Island Countries, while others are a function of policy decisions (or indecision).

Table 18 Overview of barriers to e-mobility uptake in the Pacific Island Countries

#	Barrier
Transport and electricity infrastructure	
A	Lack of electricity charging infrastructure
B	Dependency on imported fuel for electricity production and consequently high electricity tariffs
C	Lack of technical support and adequate maintenance services for EVs
D	Limited environmental benefits given reliance on diesel generation for electricity
E	Electricity grid has limited available capacity for the deployment of electricity charging infrastructure
Commercial viability	
F	Price gap between the upfront cost of EVs and ICE, with demand in the Pacific Island Countries very sensitive to price
G	Small trip distances limit the potential for lower operating costs to outweigh the price gap in upfront costs
H	Reliance on second-hand vehicles and the limited second-hand EV market
I	Limited financing options for investment in infrastructure and EV fleets
J	Limited fiscal capability to subsidise EV uptake
Governance and policy	
K	No clear e-mobility strategy or roadmap
L	Limited coordinated efforts between the Pacific Island Countries
Regulation and standards	
M	Absence of regulations and standards relating to EVs, both within country and across the Pacific Island Countries
Communication and awareness	
N	Limited experience and training with EVs
O	Limited understanding of quality standards of EVs and associated products

Source: Consultant

5.2 Evaluation of barriers

5.2.1 Criteria

We evaluate the barriers based on their impact and potential for mitigation

For each category of Pacific Island Countries, as described in Section 2.4, we evaluate the barriers described above based on:

- **Magnitude of impact –** The extent to which the specific barrier burdens e-mobility uptake in the selected country. The higher the score, the more significant the impact of the barrier in preventing progress on e-mobility uptake in that country

- **Potential for mitigation –** The capacity of policymakers to mitigate the barrier or influence the evolution of the barrier through the implementation of various policies to support EV uptake. The higher the score the higher is the capacity of the government to reduce the impact of the barrier.

Our evaluation assigns scores between zero and 10 to each barrier, where zero represents very low and 10 represents very high. Barriers that scores greater than 7 with respect to both the magnitude of impact and potential for mitigation deserve the most attention from policy makers.

Our scoring is informed by a range of information, including:

- A review of common barriers to e-mobility uptake in other jurisdictions, as presented in the Interim Report

- A review and our understanding of the specific characteristics of the Pacific Island Countries and the implications of these on the relevant barrier. For example, some barriers are more applicable to very small islands, while others are only applicable to the larger markets.

Although any evaluation inevitably involves some judgement, it provides value in highlighting the *relative* importance of different barriers and the degree to which they can be mitigated.

5.2.2 Large markets

Fiji and Samoa have good potential to mitigate key barriers, due largely to economies of scale and cheaper electricity

The large markets of Fiji and Samoa (which have a relatively large population, size, and GDP) are likely to have the highest viability for e-mobility and key barriers are more limited than in other markets. For example, their large size should mean lower EV costs and greater provision of support services. In addition, the presence of hydro in Fiji and Samoa means that electricity generation is lower cost and less polluting than in other countries. Our evaluation of the barriers is summarised below.

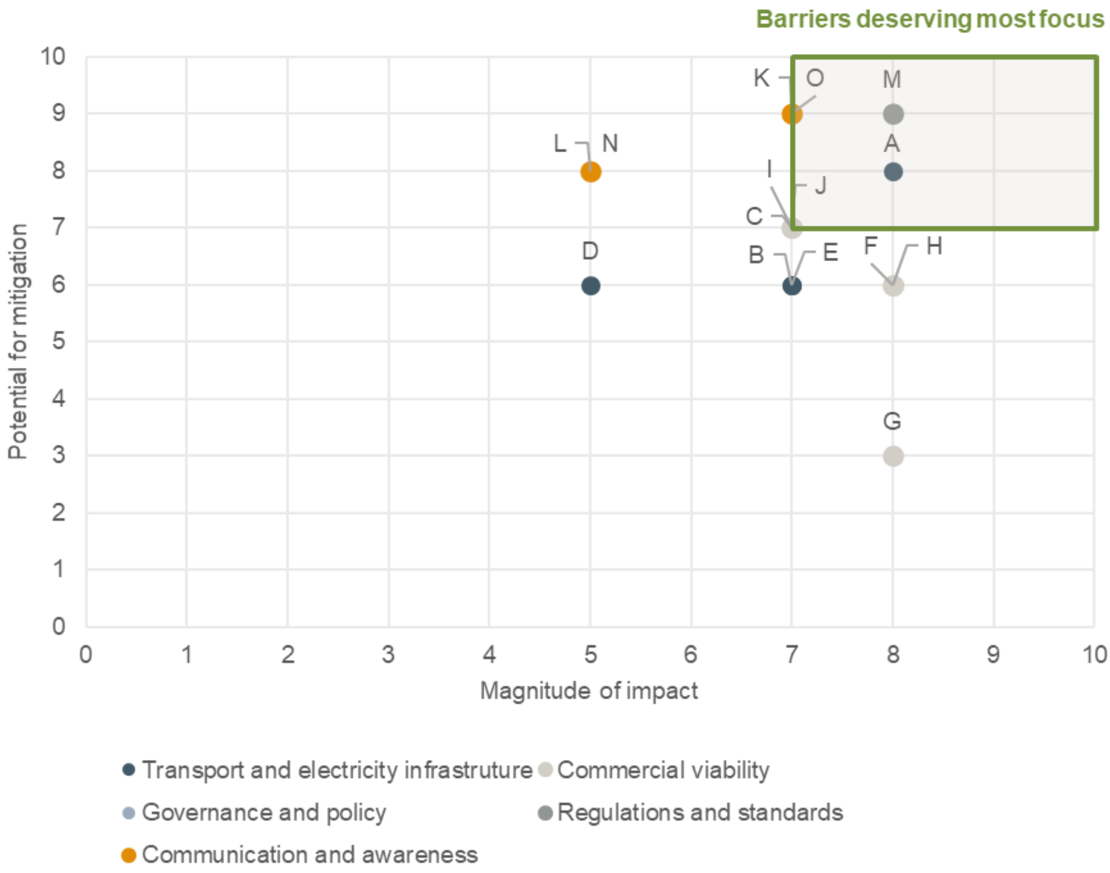
Table 19 Barriers – Large markets (Fiji and Samoa)

#	Barrier	Magnitude of impact	Potential for mitigation
Transport and electricity infrastructure			
A	Lack of electricity charging infrastructure	8	8
B	Dependency on imported fuel for electricity production and consequently high electricity tariffs	7	6
C	Lack of technical support and adequate maintenance services for EVs	7	7
D	Limited environmental benefits given reliance on diesel generation for electricity	5	6
E	Electricity grid has limited available capacity for the deployment of electricity charging infrastructure	7	6
Commercial viability			
F	Price gap between the upfront cost of EVs and ICE, with demand in the Pacific Island Countries very sensitive to price	8	6
G	Small trip distances limit the potential for lower operating costs to outweigh the price gap in upfront costs	8	3
H	Reliance on second-hand vehicles and the limited second-hand EV market	8	6
I	Limited financing options for investment in infrastructure and EV fleets	7	7
J	Limited fiscal capability to subsidise EV uptake	7	7
Governance and policy			
K	No clear e-mobility strategy or roadmap	7	9
L	Limited coordinated efforts between the Pacific Island Countries	5	8
Regulation and standards			
M	Absence of regulations and standards relating to EVs, both within country and across the Pacific Island Countries	8	9
Communication and awareness			
N	Limited experience and training with EVs	5	8
O	Limited understanding of quality standards of EVs and associated products	7	9

Source: Consultant

The figure below plots the above barriers based on their ranking. The barriers in the upper right quadrant – those which have the highest impact in inhibiting e-mobility uptake but for which there is greater scope to mitigate – include those related to financing options and the capability to support EV uptake, as well as the lack of charging infrastructure, support services and the lack of regulations and standards.

Figure 26 Barriers – Large markets (Fiji, Samoa)



Source: Consultant

5.2.3 Intermediate markets

The barriers in the Solomon Islands, Vanuatu, and Tonga are similar, but it will be more difficult to mitigate them

The barriers for e-mobility uptake in the Solomon Islands, Vanuatu, and Tonga are largely the same as those in the larger markets. However, we expect them to have slightly less capability to mitigate them because of their smaller market size and fiscal budgets.

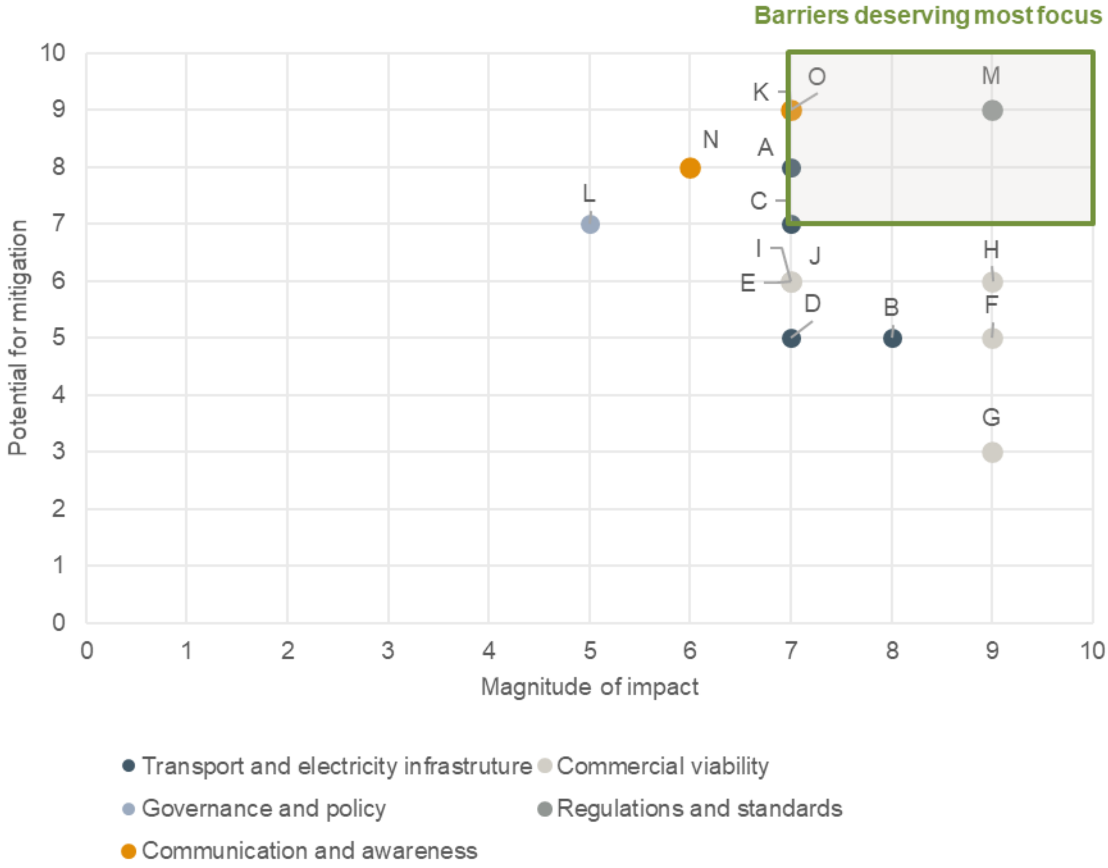
Table 20 Barriers – Intermediate markets (Solomon Islands, Vanuatu, and Tonga)

#	Barrier	Magnitude of impact	Potential for mitigation
Transport and electricity infrastructure			
A	Lack of electricity charging infrastructure	7	8
B	Dependency on imported fuel for electricity production and consequently high electricity tariffs	8	5
C	Lack of technical support and adequate maintenance services for EVs	7	7

#	Barrier	Magnitude of impact	Potential for mitigation
D	Limited environmental benefits given reliance on diesel generation for electricity	7	5
E	Electricity grid has limited available capacity for the deployment of electricity charging infrastructure	7	6
Commercial viability			
F	Price gap between the upfront cost of EVs and ICE, with demand in the Pacific Island Countries very sensitive to price	9	5
G	Small trip distances limit the potential for lower operating costs to outweigh the price gap in upfront costs	9	3
H	Reliance on second-hand vehicles and the limited second-hand EV market	9	6
I	Limited financing options for investment in infrastructure and EV fleets	7	6
J	Limited fiscal capability to subsidise EV uptake	7	6
Governance and policy			
K	No clear e-mobility strategy or roadmap	7	9
L	Limited coordinated efforts between the Pacific Island Countries	5	7
Regulation and standards			
M	Absence of regulations and standards relating to EVs, both within country and across the Pacific Island Countries	8	9
Communication and awareness			
N	Limited experience and training with EVs	6	8
O	Limited understanding of quality standards of EVs and associated products	7	9

Source: Consultant

Figure 27 Barriers – Intermediate markets (Solomon Islands, Vanuatu, and Tonga)



Source: Consultant

5.2.4 Small islands

Small Pacific Island Countries have less potential to improve the commercial viability of e-mobility, but can focus on reducing the reliance of diesel generation

The smaller Pacific Island Countries have less potential to mitigate the key e-mobility barriers, particularly those that relating to commercial viability. This is due primarily to the short distances travelled, which makes the upfront cost of EVs harder to justify. Most effort should be invested in increasing the share of solar (and BESS) to reduce dependency on diesel fuels.

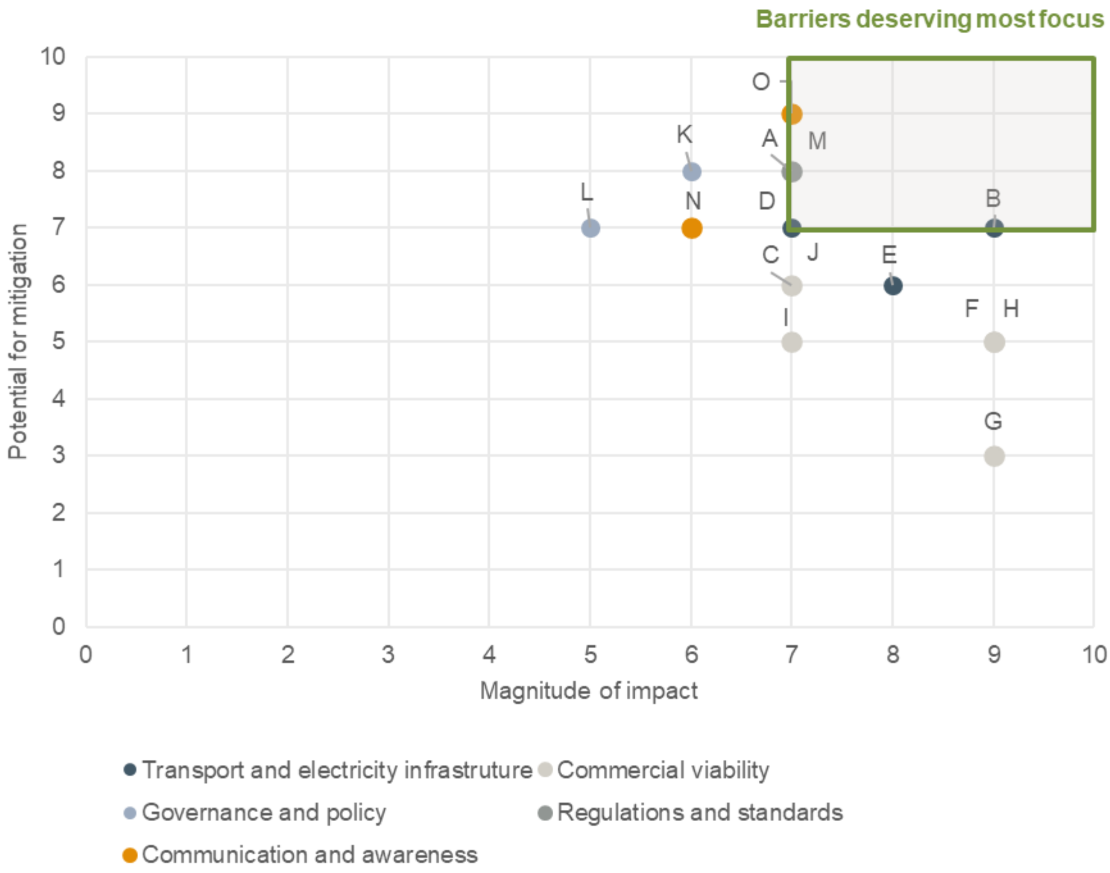
Table 21 Barriers – Small islands (Kiribati, FSM, Marshall Islands, Palau)

#	Barrier	Magnitude of impact	Potential for mitigation
Transport and electricity infrastructure			
A	Lack of electricity charging infrastructure	7	8
B	Dependency on imported fuel for electricity production and consequently high electricity tariffs	9	7
C	Lack of technical support and adequate maintenance services for EVs	7	6

#	Barrier	Magnitude of impact	Potential for mitigation
D	Limited environmental benefits given reliance on diesel generation for electricity	7	7
E	Electricity grid has limited available capacity for the deployment of electricity charging infrastructure	8	6
Commercial viability			
F	Price gap between the upfront cost of EVs and ICE, with demand in the Pacific Island Countries very sensitive to price	9	5
G	Small trip distances limit the potential for lower operating costs to outweigh the price gap in upfront costs	9	3
H	Reliance on second-hand vehicles and the limited second-hand EV market	9	5
I	Limited financing options for investment in infrastructure and EV fleets	7	5
J	Limited fiscal capability to subsidise EV uptake	7	6
Governance and policy			
K	No clear e-mobility strategy or roadmap	6	8
L	Limited coordinated efforts between the Pacific Island Countries	5	7
Regulation and standards			
M	Absence of regulations and standards relating to EVs, both within country and across the Pacific Island Countries	7	8
Communication and awareness			
N	Limited experience and training with EVs	6	7
O	Limited understanding of quality standards of EVs and associated products	7	9

Source: Consultant

Figure 28 Barriers – Small islands (Kiribati, FSM, Marshall Islands, Palau)



Source: Consultant

5.2.5 Very small islands

In the very small Pacific Island Countries, large EVs are unlikely to be commercially viable in the short to medium term future

Nauru and Tuvalu have very small vehicle fleets, which obviously limits the potential market for e-mobility. The short distances travelled on these islands act as a further barrier and renders most electric cars and vans commercially unviable (as explained in Section 4). Like the small islands discussed above, efforts are best spent on increasing the share of solar (and BESS) to reduce dependency on diesel fuels, which will help make electric motorbikes and micro-mobility viable.

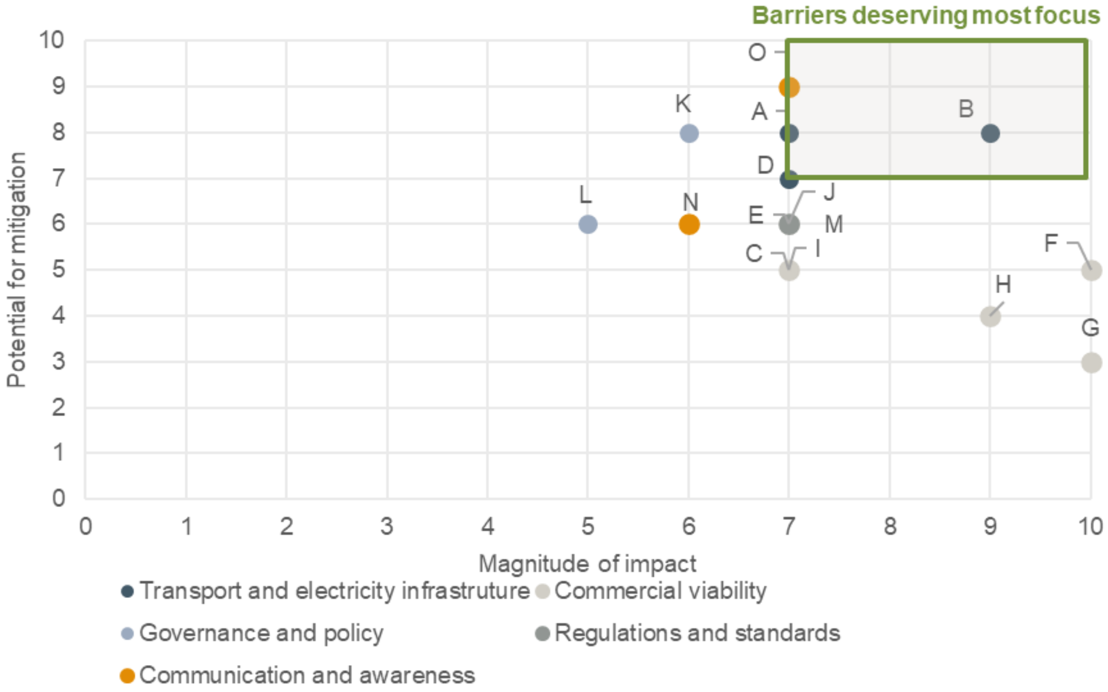
Table 22 Barriers – Very small islands (Nauru and Tuvalu)

#	Barrier	Magnitude of impact	Potential for mitigation
Transport and electricity infrastructure			
A	Lack of electricity charging infrastructure	7	8
B	Dependency on imported fuel for electricity production and consequently high electricity tariffs	9	8

#	Barrier	Magnitude of impact	Potential for mitigation
C	Lack of technical support and adequate maintenance services for EVs	7	5
D	Limited environmental benefits given reliance on diesel generation for electricity	7	7
E	Electricity grid has limited available capacity for the deployment of electricity charging infrastructure	7	6
Commercial viability			
F	Price gap between the upfront cost of EVs and ICE, with demand in the Pacific Island Countries very sensitive to price	10	5
G	Small trip distances limit the potential for lower operating costs to outweigh the price gap in upfront costs	10	3
H	Reliance on second-hand vehicles and the limited second-hand EV market	9	4
I	Limited financing options for investment in infrastructure and EV fleets	7	5
J	Limited fiscal capability to subsidise EV uptake	7	6
Governance and policy			
K	No clear e-mobility strategy or roadmap	6	8
L	Limited coordinated efforts between the Pacific Island Countries	5	6
Regulation and standards			
M	Absence of regulations and standards relating to EVs, both within country and across the Pacific Island Countries	7	6
Communication and awareness			
N	Limited experience and training with EVs	6	6
O	Limited understanding of quality standards of EVs and associated products	7	9

Source: Consultant

Figure 29 Barriers – Very small islands (Nauru and Tuvalu)



Source: Consultant

5.2.6 Key barriers

Many different barriers need to be addressed to encourage e-mobility uptake, although some particularly notable

Most barriers have at least a medium-sized impact on hindering e-mobility uptake. It is the varying potential to mitigate the barriers which impacts how much focus they deserve. Most barriers should not be viewed in isolation, because most are interrelated and need to be overcome to create an ecosystem that encourages e-mobility uptake.

The above analysis shows that there are two barriers that have both a high impact and high potential to mitigate across all types of Pacific Island Countries:

- **A: Lack of electricity charging infrastructure**
- **O: Limited understanding of quality standards of EVs and associated products**

Adequate charging infrastructure is a necessary pre-requisite for a more widespread roll-out of EVs, particularly given the importance of day time charging in the Pacific Island Countries. And improving awareness of EVs will be relatively low effort and cost, while having a large impact (particularly when paired with our policy initiatives).

The barrier **B: Dependency on imported fuel for electricity production and consequently high electricity tariffs** has a very high impact in almost all countries and therefore needs a lot of attention, although policy makers should be realistic about how quickly change (ie. the transition to widespread use of renewables) can be realised.

In medium and large markets specifically, the following barriers deserve a lot of focus:

- **I: Limited financing options for investment in infrastructure and EV fleets**
- **J: Limited fiscal capability to subsidise EV uptake**
- **K: No clear e-mobility strategy or roadmap**
- **M: Absence of regulations and standards relating to EVs, both within country and across the Pacific Island Countries**

Small and very small islands have limited potential to mitigate barriers I and J without large external assistance. And are likely just to adopt the strategies (K) and regulations (M) of larger countries - the small market size limits the benefits that of tailor-made strategies/regulations.

6 Policy recommendations for e-mobility

6.1 Introduction

In this section we propose targeted policies that remove or mitigate the key barriers to e-mobility uptake, which we identified in the previous section. In developing these policy recommendations, we have been careful to ensure that they suit the unique characteristics of the Pacific Island Countries.

Our recommendations are not just applicable to governments, but also to electricity utilities and regulators. We believe that in the Pacific Island Countries, electricity utilities have a crucial role to play in encouraging e-mobility uptake. This is because:

- Most Pacific Island Countries are still heavily reliant on diesel-fired generation. Without a transition to renewable energy, EV charging will be expensive and environmentally harmful.
- Most of the Pacific Island Countries have vertically integrated utilities that are major employers and already have strong communication channels with the general population.
- Existing levels of per capita electricity demand are relatively low, compared to developed economies, and therefore the impacts of e-mobility uptake on electricity systems are magnified. And increasing e-mobility will require significant upgrades to household and distribution network infrastructure.

As described in Section 6.4, we encourage countries to develop their own national e-mobility strategies, which can borrow heavily from this regional roadmap.

In the sub-sections below, we group our recommendations into the following categories:

- **Transport and electricity infrastructure –** Ensuring that there is adequate charging infrastructure to facilitate EV charging and that the Pacific Island Countries' electricity systems are able to efficiently meet the extra demand.
- **Commercial viability –** Providing support to reduce the upfront cost of EVs.
- **Governance and policy –** Ensuring that institutional arrangements can meet the challenges and opportunities provided by e-mobility.
- **Regulations and standards –** Changes to regulations and standards to facilitate the safe and controlled uptake of e-mobility.
- **Communication and awareness –** Promoting uptake of e-mobility and ensuring that stakeholders are able to navigate the new technologies.

For each policy recommendation we provide a ranking of low-medium-high across four different criteria. These are shown in the table below. This is based on an assessment of the relevant policy recommendations in conjunction with the specific context in the Pacific Island

Countries and the analysis of barriers presented in Section 5. These rankings provide a high-level overview of the *relative* characteristic of a certain recommendation.

Table 23 Ranking criteria used to evaluate policy recommendations

Criteria	Low	Medium	High
Potential impact	Limited impact on overcoming barriers and encouraging e-mobility uptake	Moderate impact on overcoming barriers and encouraging e-mobility uptake	Significant impact on overcoming barriers and encouraging e-mobility uptake
Fiscal affordability	High costs to implement policy	Moderate costs to implement policy	Low costs to implement policy
Ease of implementation	Difficult to implement, requiring significant efforts and/or hampered by various barriers and bottlenecks. May require a long time-period to implement	Requires moderate effort to implement and may be hampered by a few barriers and bottlenecks	Relatively simple to implement, with limited efforts. May be able to be implemented in a short time-period
Overall priority	**Although policy may have merits, it is not a priority as it has limited impacts on e-mobility uptake and may require significant resources which are best used on higher priority policy recommendations**	**Policy has potential to encourage e-mobility uptake but requires a moderate amount of resources to implement**	**Policy should be prioritised as it has a potentially significant impact on facilitating e-mobility uptake and can be implemented with limited resources**

Source: Consultant

6.2 Transport and electricity infrastructure

6.2.1 Develop public electric charging infrastructure

Table 24 Policy recommendation – Develop public electric charging infrastructure

#1	Develop public electric charging infrastructure
Barriers addressed	– Limited financing options for investment in infrastructure and EV fleets – Lack of electricity charging infrastructure
Potential impact	High
Fiscal affordability	Medium
Ease of implementation	Medium
Overall priority	High

Source: Consultant

Limited electric charging infrastructure is one of the key barriers to EV uptake internationally. A study in the Caribbean Islands found that a lack of charging infrastructure was the second biggest reservation of potential users about switching to EVs, after the higher upfront cost of EVs[15]. The development and roll-out of electric charging infrastructure is typically a key feature of e-mobility strategies.

The short distances travelled in the Pacific Island Countries means that, in theory, most charging can be done at home and there is not an essential need for large scale fast charging infrastructure (except for a few unique use cases, such as large buses or high-use commercial vehicles).

However, no public charging facilities would mean that most charging occurs during evening or night-time hours, when there is no solar generation. We therefore recommend that Pacific Island Countries roll-out charging facilities at workplaces and public places to allow users to charge EVs during daytime hours. The exception is in very small islands, where only electric motorbikes and micro-mobility are likely to be viable in the short to medium term future, and therefore there will be very little demand for public charging facilities.

We recommend that electricity utilities, who have the most technical expertise, play a major role in rolling out electric charging facilities. Governments may choose to directly subsidise the installation costs or instruct the utilities to pass through the costs to electricity tariffs.

We also recommend that governments and utilities explore the scope for public-private collaborations to install and maintain electric charging stations. This can limit the amount of upfront capital investment that needs to be deployed. A typical scheme to provide e-charging follows the 'build-operate-transfer' (BOT) model, which involves granting a permit to a private operator to occupy the public space with the purpose of providing the e-charging service for a certain period of time. The private operator sets an access tariff to the system, which can involve 'pay as you go' charging for individual customers and bi-lateral contracts between the operator and the operators of larger fleets, and oversees the operation and maintenance of these facilities. A few private operators may manage to generate enough demand to be financially self-sustaining, for example by signing contracts with taxi companies or companies with large vehicle fleets, but in most cases they will require government support such as tax exemptions, capital subsidies, or public sector generated demand (such as public sector EV fleets or pilot projects).

Governments and utilities should ensure that the location of public charging stations is documented and easily accessible. In addition to clearly signing the location of charging stations, the provision of an app which maps all charging stations could help users easily identify where there nearest charging station is and provide real-time updates on current availability of charging points.

6.2.2 Support development of in-house EV charging facilities

Table 25 Policy recommendation – Support the development of in-house EV charging facilities

#2	Support the development of in-house EV charging facilities
Barriers addressed	– Lack of electricity charging infrastructure

[15] Viscidi et al,2020, Electrified Islands; The Road to E-Mobility in the Caribbean.

#2	Support the development of in-house EV charging facilities
	– Lack of technical support and adequate maintenance services for EVs – Limited experience and training with EVs
Potential impact	Medium
Fiscal affordability	Medium
Ease of implementation	Medium
Overall priority	Medium

Source: Consultant

To encourage EV uptake, some support needs to be provided to households and businesses regarding EV charging facilities within their houses. Fortunately, most households in the Pacific Island Countries will not need to upgrade their electrical connections as slow charging up to 3.75 kW will be sufficient for most needs. But the public need to be educated on this and to understand the costs and advantages of upgrading to faster household chargers. The existing uncertainty inhibits the transition to EVs.

We recommend that electric contractors be trained on the use of EV charging equipment, so that they can support households in understanding, and if necessary, upgrading their charging points.

6.2.3 Roll-out electricity smart meters

#3	Roll-out electricity smart meters
Barriers addressed	– Dependency on imported fuel for electricity production and consequently high electricity tariffs – Lack of electricity charging infrastructure
Potential impact	High
Fiscal affordability	Low
Ease of implementation	Medium
Overall priority	High

Source: Consultant

Another associated aspect of in-home charging is the roll-out of smart meters, which enables time-of-use (TOU) tariffs (Section 6.2.6 below) and therefore incentivises charging during the day through cheap solar generation. Many countries are already rolling out smart meters, but these do come at a cost to the utility, and ultimately electricity consumers.

In many countries, evaluations have shown that it is unclear whether upgrading residential customers to smart meters is cost-benefit positive. But in the Pacific Island Countries, our view is that wide scale roll-out of smart meters is essential and inevitable. Once the penetration of solar PV increases, the cost of electricity generation will vary widely between day and night-time and without smart meters utilities will be unable to send the appropriate price signals to consumers.

The appropriate timing and cost-recovery of smart meter rollouts will vary from country to country. The timing should be aligned with the roll-out of solar generation (Section 6.2.5) and TOU tariffs (Section 6.2.6). But in the meantime, electricity utilities should be gaining experience with smart meter technologies, if they are not already doing so.

Some countries may consider widescale roll-out of smart meters appropriate, with the costs being socialised, while others may consider user-pays models more appropriate. We caution against requiring customers to pay for smart meter upgrades upfront, as it will deter e-mobility uptake. Other user-pay models exist, for example utilities covering the upfront costs of smart meter upgrades and recovering them over time through EV/TOU tariffs.

6.2.4 Require charging facilities in new buildings

Table 26 Policy recommendation – Require charging facilities in new buildings

#4	Require charging facilities in new buildings
Barriers addressed	– Limited financing options for investment in infrastructure and EV fleets – Lack of electricity charging infrastructure
Potential impact	Low-Medium
Fiscal affordability	High
Ease of implementation	High
Overall priority	Medium

Source: Consultant

Many countries now stipulate that when new commercial, administrative, or large residential buildings are developed, it is compulsory to pre-install EV charging points. The threshold for this requirement can be specified based on the square meterage of the development and can use a ratio of chargers per square meter or per number of households.

Applying such a regulation to new developments in the Pacific Island Countries will ensure that new developments are EV-ready and limits the need for more expensive retrofits at a later stage.

6.2.5 Expand RE and BESS capacity

Table 27 Policy recommendation – Expand RE and BESS capacity

#5	Expand RE and BESS capacity
Barriers addressed	– Dependency on imported fuel for electricity production and consequently high electricity tariffs – Limited environmental benefits given reliance on diesel generation for electricity
Potential impact	High
Fiscal affordability	Low
Ease of implementation	Low

#5	Expand RE and BESS capacity
Overall priority	High

Source: Consultant

The Pacific Island Countries' current reliance on diesel generation leads to high electricity tariffs, which limits the commercial viability of e-mobility. And limits the environmental benefits of EV uptake. This currently is the biggest barrier to e-mobility uptake in the Pacific Island Countries.

All the Pacific Island Countries are already undertaking efforts to expand RE capacity, but these efforts need to be accelerated. We strongly recommend that Pacific Island Countries quickly expand their solar and Battery Energy Storage System (BESS) capacity, to reduce their cost of electricity supply and efficiently meet EV demand. As discussed in Section 3.4, increased solar generation, coupled with TOU tariffs that incentivise daytime charging, can lead to low EV tariffs and make EVs commercially viable for many users.

BESS investments are necessary to allow excess solar generation to be used for night-time charging. The optimal amount of BESS investment will vary based on future BESS costs, fuel prices, electricity demand curves, and the amount of hydro capacity. But in the medium term future, only Solomon Islands is expected to have enough spare hydro capacity such that little BESS investment is required.

This policy recommendation extends beyond the scope of e-mobility and is fundamental to the decarbonisation of both the energy and transport sectors. It will require significant upfront investment but will reduce the lifecycle costs of energy and transport in the long-run. Private sector involvement in generation projects can help reduce the financing burden on utilities and governments.

6.2.6 Introduce time-of-use tariffs

Table 28 Policy recommendation – Introduce time-of-use tariffs

#6	Introduce time-of-use tariffs
Barriers addressed	– Dependency on imported fuel for electricity production and consequently high electricity tariffs – Limited environmental benefits given reliance on diesel generation for electricity – Electricity grid has limited available capacity for the deployment of electric charging infrastructure
Potential impact	High
Fiscal affordability	Medium
Ease of implementation	Medium
Overall priority	High

Source: Consultant

As Pacific Island Countries invest heavily in solar capacity (Section 6.2.5), the cost of charging EVs during the day will be much lower than during the evening and night-time hours (when either diesel generators or BESS is used). TOU tariffs should be introduced to encourage daytime charging, because without it EVs are far less likely to be commercially viable. This will require the roll-out of smart meters to households and premises where EV charging takes place (Section 6.2.3).

Because most of the Pacific Island Countries still run their diesel-fired generators throughout the day, there is currently minimal difference between daytime and night-time costs and therefore little value in introducing TOU tariffs. But utilities need to be ready to introduce TOU tariffs on a wide scale as soon as solar displaces diesel entirely during some hours.

Some developed countries have trialled EV tariffs that provide either free or subsidised charging at public charging stations. While these undoubtedly encourage EV uptake, we do not recommend them for the Pacific Island Countries because they come at a significant cost and often only benefit segments of society who are already well-off. We instead recommend that Pacific Island Countries focus on reducing the underlying cost of EV charging and fairly reflecting those costs through TOU tariffs.

6.2.7 Foster development of private solar PV to charge EVs

Table 29 Policy recommendation – Foster development of private PV facilities to charge EVs

#7	Foster development of private PV facilities to charge EVs
Barriers addressed	– Limited financing options for investment in infrastructure and EV fleets – Electricity grid has limited available capacity for the deployment of electric charging infrastructure
Potential impact	Medium
Fiscal affordability	High
Ease of implementation	Medium
Overall priority	Medium

Source: Consultant

We recommend that, in addition to electricity utilities investing in grid-scale solar and BESS to decarbonise the energy sector and reduce the cost of EV charging (Section 6.2.5), utilities should facilitate and encourage households and businesses to install their own rooftop solar generation.

Some, but not all, Pacific Island Countries already have net-metering (or net-billing) arrangements in place that allow electricity consumers to install their own rooftop solar and feed any excess generation back into the grid. By publishing the terms and conditions of such schemes, utilities can ensure that consumers make optimal decisions about pairing own-use generation with EV charging. Key features of net-metering arrangements include smart meters (Section 6.2.3), TOU tariffs (Section 6.2.6), feed-in tariffs, and technical standards.

In some jurisdictions, commercial enterprises have emerged that co-locate charging stations with several solar PV panels, and in some cases even localised BESS. We recommend that electricity utilities and regulators ensure that the appropriate terms and conditions / regulations are in place to facilitate such arrangements. We note that a new enterprise, Leaf Capital, is planning to develop such a model in Fiji.

6.2.8 Conduct impact assessments of EV uptake on the distribution grids

Table 30 Policy recommendation – Foster development of private PV facilities to charge EVs

#8	Conduct impact assessments of EV uptake on the distribution grids
Barriers addressed	– Electricity grid has limited available capacity for the deployment of electric charging infrastructure
Potential impact	Medium
Fiscal affordability	Medium
Ease of implementation	Medium
Overall priority	Medium

Source: Consultant

To ensure that the local distribution grids can meet the demand posed by EV charging, utilities should conduct assessments of the impact of EV charging on distribution grids. This will be a crucial pre-requisite in cases where fast charging infrastructure is to be deployed or where large clusters of charging is expected. This might include public charging stations, large commercial complexes, commercial vehicle depots, or in more affluent residential areas with high EV ownership rates.

While these impact assessments will be very important once EV uptake becomes significant or fast charging infrastructure is installed, current EV uptake in the Pacific Island Countries is so low that grid impact assessments can likely wait a few years.

6.2.9 Offer special EV access

Table 31 Policy recommendation – Offer non-financial incentives for EV operation

#9	Offer non-financial incentives for EV operation
Barriers addressed	– Small trip distances limit the potential for lower operating costs to outweigh the price gap in upfront costs – Lack of awareness about EVs
Potential impact	Low-medium
Fiscal affordability	Medium
Ease of implementation	High
Overall priority	Low

Source: Consultant

We recommend that non-financial incentives be used to promote EV uptake, by giving them preferential access to public spaces. Such incentives may include:

- Providing dedicated car parking spaces for EVs in central and in-demand locations.

- Allowing EVs to use restricted roads in urban centres or other restricted areas.

These incentives raise awareness of EVs in addition to directly benefiting EV owners.

The scope for providing such incentives in the Pacific Island Countries is lower than in many other countries, because of the comparative lack of large urban centres. For example, few, if any, cities in the Pacific Island Countries have dedicated bus lanes that could allow EV access. But local municipalities should keep an eye out for special access opportunities, particularly pairing EV parking spaces with public charging facilities.

6.3 Commercial viability

6.3.1 Provide purchase incentives, such as subsidies or tax breaks

Table 32 Policy recommendation – Provide purchase incentives

#10	Provide purchase incentives, such as subsidies or tax breaks
Barriers addressed	– Price gap between upfront cost of EVs and ICE vehicles – Reliance on second-hand vehicle markets
Potential impact	High
Fiscal affordability	Low
Ease of implementation	Medium
Overall priority	High

Source: Consultant

The high upfront cost differential between EVs and ICE vehicles is one of the main barriers to the uptake of e-mobility in the Pacific Island Countries. In other jurisdictions, financial incentives have played a major role in reducing this upfront cost differential and encouraging EV uptake.

Purchase incentives can include:

- **Tax breaks –** Tax reductions or tax exemptions on the cost of EV purchases.
- **Direct subsidies (rebates) –** Payable to consumers on the purchase of a new or second-hand EV.
- **Scrappage schemes –** Subsidies or tax breaks provided conditional on the scrappage of older, more polluting ICE vehicles.

As well as improving commercial viability, purchase incentives would also underline the governments' commitments to EVs and increase awareness of EVs among the population.

A recent example of purchase incentives is in Fiji, where in 2014 the Government implemented tax breaks for imported environmentally friendly cars[16] not older than eight years.

[16] This includes BEVs, HEVs, gas-operated cars (LPG and CNG) and solar-powdered vehicles

It led to a sharp rise in the number of new car registrations and eventually to second-hand HEVs (mostly Toyota Prius') becoming among the most popular vehicles in the country.

Purchase incentives can be expensive and therefore should be carefully designed and implemented. This is a particular concern for the Pacific Island Countries because they have limited fiscal budgets and competing needs for public investment. We therefore recommend limiting purchase incentives to 10% of the vehicle purchase cost.

We also recommend that policy makers largely hold off introducing purchase incentives until increased solar capacity (Section 6.2.5) results in EVs being charged from RE sources.

Ideally, policy makers would target EVs that will be used for commercial purposes and other medium and high-use cases (for example regular long-distance commuters), because our viability assessment (Section 4) indicates that these bring the most societal net benefits. However, it will likely be difficult to provide incentives in such a targeted way, and consumer incentives should result in those who get the most value from EVs being the ones to purchase them.

In other jurisdictions, purchase incentives support has often been limited to the purchase of new vehicles. However, given the reliance on second-hand vehicles in the Pacific Island Countries, we recommend that such incentives are also extended to second-hand imported vehicles, possibly at a lower rate, as applied in the New Zealand EV rebate scheme.

6.3.2 Offer targeted financial incentives for private companies to establish EV fleets

Table 33 Policy recommendation – Offer financial incentives for private companies

#11	Offer financial incentives for private companies to establish EV fleets
Barriers addressed	– Price gap between upfront cost of EVs and ICE vehicles – Limited financing options to invest in infrastructure and EV fleets – Limited fiscal capability to subsidise EV uptake
Potential impact	Medium-High
Fiscal affordability	Medium
Ease of implementation	Medium
Overall priority	Medium

Source: Consultant

As highlighted in our assessment of EV viability in Section 4, the highest benefits from EV uptake are likely to be from EVs that are highly utilised, such taxis, tourism vehicles, and small goods transport.

To encourage private enterprises to electrify their fleets, we recommend that governments consider offering financial incentives that target key industries, for example through exemptions from taxes, fees, and/or administrative charges. The magnitude of these incentives can vary depending on the number of EVs purchased and their purpose.

By providing targeted incentives, governments can maximise the effectiveness of their expenditure and leverage financial contributions from private sector beneficiaries.

Key industries that could be targeted include:

- **Taxis –** Public hire vehicles tend to travel considerable distances each day, which means that they can recover the higher upfront costs through savings in operating costs more quickly. Through electrifying the taxi fleet, the benefits of e-mobility are also put on display to the wider population.

- **Tourism –** In many Pacific Island Countries, the tourism industry is a pivotal component of the economy, and electric cars or scooters could be offered as rental vehicles for tourists. This could help support the wider tourism industry and build on efforts to be a 'green' tourism destination.

6.4 Governance and policy

6.4.1 Create a regional e-mobility council

Table 34 Policy recommendation – Create a regional e-mobility council

#12	Create a regional e-mobility council
Barriers addressed	– Limited coordinated efforts between the Pacific Island Countries – Absence of regulations and standards relating to EVs
Potential impact	Medium
Fiscal affordability	High
Ease of implementation	High
Overall priority	High

Source: Consultant

We recommend the establishment of a 'regional e-mobility council' to coordinate efforts to increase e-mobility uptake across the Pacific Island Countries. This could be situated within existing inter-regional institutions.

This body would bring together relevant stakeholders from all Pacific Island Countries. Its objectives would include:

- Reinforcing the mandate towards a decarbonised transport sector in the Pacific Island Countries.

- Boosting public-private partnerships, including by attracting private partners to engage across the Pacific Island Countries.

- Supporting the building of local capacity, including by sharing lessons between Pacific Island Countries.
- Raising and administering funding to support EV uptake, including from international donors.
- Designing common regulations, guidelines and technical standards

Such regional council has particular importance for the smaller Pacific Island Countries, as it provides them with an opportunity to draw on lessons from the larger countries and leverage joint policy actions.

Subject-specific collaborations are common within policy making among the Pacific Island Countries. For example, eight Pacific Island Countries have established the 'Pacific Blue Shipping Partnership' to decarbonise maritime transport, as discussed in more detail in Section 2.5.6.

6.4.2 Develop a regional e-mobility strategy

Table 35 Policy recommendation – Develop a regional e-mobility strategy

#13	Develop a regional e-mobility strategy
Barriers addressed	– No clear e-mobility strategy or roadmap – Limited coordinated efforts between the Pacific Island Countries
Potential impact	Medium
Fiscal affordability	High
Ease of implementation	High
Overall priority	High

Source: Consultant

The first task of the regional e-mobility council (Section 6.4.1) would be to develop a common and comprehensive e-mobility strategy.

This document provides a useful starting point for the e-mobility strategy but should be further developed by the local stakeholders so that they have ownership over it. It would include the definition of a regional vision, objectives, and specific targets for the decarbonisation of transport. It would also highlight key policy actions to be taken by different actors within the council under specific timeframes.

The regional strategy should be embedded in a comprehensive vision, which includes the key requirements set out in the table below.

Table 36 Key requirements of a regional e-mobility vision

Inspiring	Contain messages which inspires current and future decision-makers, companies and other stakeholders, and the general population towards achieving the objectives

General	The vision is not a specific goal in itself and should cover the topic holistically
Ambitious	The vision should be reasonably challenging and require time, effort, and energy, but one to which stakeholders can commit to and support
Realistic	The vision should not be impossible to reach, nor should it be so far out of reach that is appears disconnected from reality and purpose
Strategic	The vision must be aligned and connected with the long term strategic policies of the country, otherwise it will not be achievable

Example visions for e-mobility uptake across the Pacific Island Countries are provided in the boxes below.

Box 1 Proposed regional e-mobility vision for 2025

"In 2025 the Pacific Island Countries have cemented the urgency of the shift to e-mobility in policy making and conveyed it to the population and business. All the countries have worked closely to develop and share common regulation and technical standards on e-mobility that have led to a seamless penetration of EV in the automotive market. Residents and companies have access to an increasingly wider offer of EVs that is being supported with proper charging infrastructures both on street and off street. People are familiar with electric cars, electric motorbikes and micro-mobility as their operating cost has become competitive thanks to the increased share of renewables in the electricity system"

Box 2 Proposed regional e-mobility vision for 2030

"In 2030 e-mobility uptake in the Pacific Island Countries has strongly contributed to reducing the fuel dependency of these countries, leading to a more prosperous society and a future proof economy. The presence of EVs is common in public administration and households. There is a proper balance in the production of renewables and capacity from the grid and the demand for energy from the EVs in a context where energy management technologies and v2h (vehicle to home) systems are widespread"

The e-mobility vision(s) should be translated into clear, strategic objectives. At the regional level, such objectives may include:

- Design and agree on specific regulations and standards for e-mobility.
- Establish an ecosystem of public-private collaboration which acts as a catalyst for the adoption of e-mobility.
- Develop the appropriate infrastructure for e-mobility.
- Support the development of local technical capacities and capabilities.
- Familiarise the population with e-mobility.

6.4.3 Develop national e-mobility strategies

Table 37 Policy recommendation – Develop national e-mobility strategies

#14	Develop national e-mobility strategies
Barriers addressed	– No clear e-mobility strategy or roadmap
Potential impact	Medium
Fiscal affordability	High
Ease of implementation	High
Overall priority	High

Source: Consultant

The Pacific Island Countries are all unique, with different needs, as well as social, environmental, and economic circumstances. Consequently, the regional e-mobility strategy (Section 6.4.2) will need to be adapted to the local context through national and/or local e-mobility strategies. In some cases, these strategies will cover the entire country, while in others they may be localised to specific islands or urban centres.

These strategies should be developed in a joint effort between the public administration and key stakeholders, such as the electricity utilities, transport agencies, key commercial and industrial stakeholders, and representatives of the public. Focus should be given that proper support and tailored guidance is provided to the Pacific Island Countries in supporting them to develop these strategies and that the strategy includes a clearly defined action plan.

The key steps involved in designing a national e-mobility strategy are summarised in the figure below, which are further described in the context of a regional e-mobility strategy in the sub-section above.

Figure 30 Steps to designing a national e-mobility strategy

Source: Consultant

6.4.4 Monitor the progress made on e-mobility

Table 38 Policy recommendation – Monitor the progress made on e-mobility

#15	Monitor the progress made on e-mobility
Barriers addressed	– No clear e-mobility strategy or roadmap
Potential impact	Low
Fiscal affordability	High
Ease of implementation	High
Overall priority	Medium

Source: Consultant

To provide credibility to the e-mobility strategies and action plans, it is crucial that the Pacific Island Countries monitor the progress they are making in achieving their stated goals and targets. This requires the development of suitable mechanisms and digital tools to monitor e-mobility uptake and progress in the region. For some goals the monitoring of progress will involve the design of bespoke key performance indicators (KPIs).

In collecting data, focus needs to be paid to ensure that it is collected from reliable sources and using a robust approach. The table below provides an overview of potential targets and indicators which could be measured.

Table 39 Example of e-mobility KPIs and targets

#	Indicator	2025 target	2030 target	Comments
1	Number of EVs in service			Disaggregated by type of EVs. Ideally information should also be collated on specific models, etc. to ensure that there is good understanding of prevailing market dynamics
2	Market shares of EVs	At least 2%	At least 10%	Disaggregated by type of EVs
3	Number of public charging points	5 per 100,000 population (at least five per country)	75 per 100,000 population (at least 50 per country)	
4	Number of public fast charging points	1 per 100,000 population (at least two per country)	15 per 100,000 population	In markets where fast charging markets are required
5	EVs in public fleets	At least one pilot project	National fleets are 100% electric	

Regular progress reports should be published in the interest of transparency, which should also be shared with the regional e-mobility council so that other jurisdictions can develop an understanding of how other countries are progressing in achieving their e-mobility goals. As part of this, the council may wish to create a central store or database containing such information. This will support decision-makers to identify how effective the implemented measures have been and if changes need to be made to the overall strategy.

6.4.5 Coordinate planning across public administrations

Table 40 Policy recommendation – Coordinate planning across public administrations

#16	Coordinate planning across public administrations
Barriers addressed	– No clear e-mobility strategy or roadmap – Limited experience and training with EVs
Potential impact	Low
Fiscal affordability	High
Ease of implementation	Medium
Overall priority	Medium

Source: Consultant

The shift to e-mobility requires the involvement of a range of stakeholders, including those who have previously not been heavily involved in transport issues (for example electricity utilities). Coordination between relevant departments in public administration is crucial to ensure meaningful shared responsibility for e-mobility strategies and relevant results. This also includes coordinating responsibility between levels of government.

We recommend establishing delivery partnerships between government organisations, non-governmental organisations, and the private sector. This such include establishing clear competencies and responsibilities from the onset to avoid potential conflicts and confusion at later stages.

6.5 Regulation and standards

6.5.1 Establish regulatory instruments for EVs

Table 41 Policy recommendation – Establish regulatory instruments for EVs

#17	Establish regulatory instruments for EVs
Barriers addressed	– Absence of regulations and standards relating to EVs, both within country and across the Pacific Island Countries – Limited experience and training with EVs
Potential impact	Medium
Fiscal affordability	High
Ease of implementation	Low-medium
Overall priority	Medium

Source: Consultant

To facilitate e-mobility uptake, local and national administrations need to establish the relevant regulatory instruments. These regulations should be aligned with the corresponding national regulations and with any region-wide policy commitments made by the Pacific Island Countries e-mobility council (Section 6.4.1).

Aspects that need to be covered by such regulation includes:

- How electric charging infrastructure can or must be offered.
- How electric charging infrastructure must be operated and maintained.
- The obligations of the charging point operators.
- Procedures for battery disposal and end-of-life recycling.

Particular attention needs to be paid to regulating battery disposal, given the potential environmental impacts if this is left unregulated. The small market sizes in the Pacific Island Countries may limit the potential for commercial solutions, such as battery reuse, in the short to medium term.

6.5.2 Develop technical guidelines for EV charging

Table 42 Policy recommendation – Adopt technical guidelines for EV charging

#18	Adopt technical guidelines for EV charging
Barriers addressed	– Lack of electricity charging infrastructure – Absence of regulations and standards relating to EVs, both within country and across the Pacific Island Countries
Potential impact	Low-medium
Fiscal affordability	High
Ease of implementation	High
Overall priority	Medium

Source: Consultant

The regional e-mobility council should develop and agree on regional technical guidelines for electric charging. As part of this assignment, we have developed draft guidelines, which are attached as Annex A1.

Such regulations cover:

- The minimum requirements for electric charging points.
- The type of chargers to be deployed.
- The type of connectors.
- Safety procedures for the installation and usage of the equipment.

We recommend that these guidelines are region-wide to encourage the development of a regional market and facilitate compatibility across the Pacific Island Countries. However, due to peculiarities in the electricity systems across the countries, there may need to be some differences/flexibility allowed for.

6.5.3 Establish minimum standards for EVs and charging equipment

Table 43 Policy recommendation – Establish minimum standards

#19	Establish minimum standards for EVs and charging equipment
Barriers addressed	– Absence of regulations and standards relating to EVs, both within country and across the Pacific Island Countries – Lack of awareness about EVs, including benefits and quality standards of EVs
Potential impact	Low-medium
Fiscal affordability	High
Ease of implementation	High
Overall priority	High

Source: Consultant

To ensure that increased e-mobility uptake does not pose safety concerns, there is a need to establish minimum standards on EVs and associated equipment (eg. charging infrastructure). The objective of these standards is to ensure that the equipment meets standards applied to other electrical appliances and prevent the import of products which pose potential health and safety risks.

Such standards could be based on those established in other jurisdictions, adapted to the local regulatory framework. The provision of standards at an early stage will also provide confidence to stakeholders in the ecosystem, such as car dealers and importers, at an early stage.

Our recommended international standards for EV charging are provided in Annex A2.

6.5.4 Develop public procurement procedures for EV products

Table 44 Policy recommendation – Develop public procurement procedures for EV products

#20	Develop public procurement procedures for EV products
Barriers addressed	– Limited financing options to invest in infrastructure and EV fleets – Lack of electricity charging infrastructure
Potential impact	Low-medium
Fiscal affordability	High
Ease of implementation	High

#20	Develop public procurement procedures for EV products
Overall priority	Medium

Source: Consultant

The development of public charging infrastructure networks and the establishment of public EV fleets will require robust EV procurement processes. We recommend that governments address the following to improve the robustness of EV procurement:

- **Standardisation –** Procurement procedures benefit from the adoption of unified technical standards across the region. Regional standardisation (even if not adopted fully by all the Pacific Island Countries) will help ensure minimum levels of quality and provide clear guidance to suppliers and operators on the technical requirements. This will ultimately narrow down the number of compliant products present in the market, thus favouring scalability. A limited number of products being used will also simplify the operation and maintenance for both users and operators.

- **Confidence –** The establishment of a credible regional e-mobility strategy, which includes a clear regional vision, concrete actions, and realistic timelines, will provide confidence to potential private sector suppliers.

- **Scalability –** Pacific Island Countries can scale up procurement processes by centralising them through a regional entity, such as the regional e-mobility council. Combining the procurement procedures that would otherwise be tendered individually by each country will enable economies of scale. In addition to achieving competitive prices, other benefits can arise, including improved warranty terms or after-sale services. Furthermore, the promotion of large scale procurement will reduce the spare-part inventory needs for operators at regional or national level.

6.6 Communication and awareness

6.6.1 Develop an e-mobility communication strategy

Table 45 Policy recommendation – Develop public procurement procedures for EV products

#21	Develop an e-mobility communications strategy
Barriers addressed	– Lack of awareness about EVs, including benefits and quality standards of EVs
Potential impact	Medium
Fiscal affordability	High
Ease of implementation	Medium
Overall priority	High

Source: Consultant

We recommend that regional and national e-mobility strategies be accompanied by a holistic communication strategy. It should promote the strategy and raise awareness about e-mobility potential benefits and any upcoming incentives to be introduced.

The communication strategy should:

- Establish clear target groups which are relevant to e-mobility uptake.
- Be tailored to different potential users and customers for different types of EVs.
- Be specific to the needs and characteristics of the specific territory (ie. it should not be a generic e-mobility campaign but one specific to each country).
- Use a range of channels, making sure they are relevant to the target groups and the key communication channels in the relevant countries.
- Continue to evolve by adapting to regular evaluations which assess the impact of the campaigns.

In developing the communication strategy, a crucial pre-requisite is to conduct a baseline assessment of the perceptions the population currently has on e-mobility and different types of EVs. This should include the current understanding of the public on e-mobility, their concerns, their willingness and openness to EV technologies, and any perceived barriers to personal and societal e-mobility uptake. Such research can be conducted with assistance, or in association of universities, local associations, and consumer groups.

6.6.2 Engage with stakeholders

Table 46 Policy recommendation – Engage with stakeholders

#22	Engage and consult with stakeholders
Barriers addressed	– No clear e-mobility strategy or roadmap – Lack of awareness about EVs, including benefits and quality standards of EVs
Potential impact	Medium
Fiscal affordability	High
Ease of implementation	Medium
Overall priority	Low

Source: Consultant

In implementing e-mobility communication strategies, policy makers should ensure that communication activities are bidirectional. This will maximise the outreach of communication and dissemination actions and strengthen the relationship with them and get valuable feedback.

This feedback should be used to better understand the needs of potential EV users and identify ways in which the administration can address them properly. Organising seminars, workshops and other engagement activities is helpful to allow stakeholders to discuss how to eliminate barriers of EV adoption at both local and national level, share information, disseminate information about e-mobility, launch joint initiatives and explore synergies.

6.6.3 Launch EV pilot projects

Table 47 Policy recommendation – Launch EV pilot projects

#23	Launch EV pilot projects
Barriers addressed	– Price gap between the upfront cost of EVs and ICE – Reliance on second-hand vehicles and limited second-hand market – Lack of technical support and adequate maintenance services for EVs – Lack of awareness about EVs, including benefits and quality standards of EVs
Potential impact	Medium
Fiscal affordability	Medium
Ease of implementation	Medium
Overall priority	Medium

Source: Consultant

Many countries have raised awareness about e-mobility through pilot projects. They can encourage e-mobility uptake by:

- Offering an opportunity to assess the real-world viability of different EV types and deciding whether they have a large potential.
- Raising awareness about e-mobility among the population by increasing the visibility of EVs.
- Supporting the development of the e-mobility ecosystem, such as adequate maintenance facilities and spare parts markets.

Pilot projects can take different forms, including:

- Incorporating EVs in the municipal fleet. This allows direct access to real-world results and offers a route through which multilateral organisations and donors can provide financing. This is covered in more detail in the next recommendation.
- Providing key institutions or corporations, such as universities or utilities, with EV fleets.
- Providing direct support (for example through soft loans and financial guarantees) to taxi drivers and taxi companies to implement pilot projects for electric taxis.
- Supporting the establishment of companies or cooperatives who offer sharing (eg. car-sharing or the sharing of electric bikes).

- Providing forms of micro-mobility (such as electric bikes and scooters) in tourist hotspots.

Supporting the establishment of e-mobility sharing companies deserves particular emphasis – such models are increasingly common in many countries around the globe and, if successful, provide the most effective way for occasional users to electrify their journeys.

6.6.4 Switch public vehicle fleets to e-mobility

Table 48 Policy recommendation – Switch public vehicle fleets to e-mobility

#24	Switch public vehicle fleets to e-mobility
Barriers addressed	– Price gap between the upfront cost of EVs and ICE – Reliance on second-hand vehicles and limited second-hand market – Lack of technical support and adequate maintenance services for EVs – Lack of awareness about EVs, including benefits and quality standards of EVs
Potential impact	Medium
Fiscal affordability	Low
Ease of implementation	Medium
Overall priority	Low

Source: Consultant

There are limited incentives to be an 'early adopter' of e-mobility given the absence of required infrastructure (in particular public charging infrastructure) and associated support services (eg. trained mechanics and adequate spare parts). This limits the appeal of EVs in their early stage, especially when the upfront cost is significantly higher. In addition, due to the absence of keen early adopters, there may be limited interest by dealers and manufacturers to serve the market at an early stage.

To overcome this barrier, public authorities and agencies can take a leading role by replacing their own conventional public vehicle fleets with EVs. For example, electric cars and motorcycles can be used by municipalities to conduct technical and administrative vehicles, while utilities could use electric cars for patrols. This will help develop the relevant support services and will act as a starting point for the establishment of a local/regional second-hand EV market. The development of this market over time will lead to a reduction in prices and ensure that EVs become more price competitive. It will also increase the visibility of e-mobility in the population.

6.6.5 Provide training and information on e-mobility

Table 49 Policy recommendation – Provide training and information on e-mobility

#25	Provide training and information on e-mobility
Barriers addressed	– Lack of technical support and adequate maintenance services for EVs – Limited experience and training with EVs – Lack of awareness about EVs, including benefits and quality standards of EVs
Potential impact	Medium
Fiscal affordability	High
Ease of implementation	Medium
Overall priority	Medium

Source: Consultant

A key element of an e-mobility communications strategy should be informing and training the potential users about the basics of e-mobility, such as EV charging. This will help overcome misconceptions, including that charging an EV at home requires a lot of effort and investments (which is not the case for trickle charging through household sockets, as would likely be the case in the Pacific Island Countries).

In addition to potential users, training should also be provided to mechanics and other technical staff to ensure that they are able to provide EV services. This also extends to other stakeholders, such as technical approval organisations, public administrations, but also organisations such as the fire brigade (given specific safety requirements relating to EVs in accidents).

Collaborative agreements between public administrations, educational institutions and technical/research centres can be established to develop a framework in which the e-mobility capacity training programme can be implemented.

6.6.6 Mainstream gender aspects in EV policy

Table 50 Policy recommendation – Mainstream gender aspects in EV policy

#26	Mainstream gender aspects in EV policy
Barriers addressed	– Limited experience and training with EVs – Lack of awareness about EVs, including benefits and quality standards of EVs
Potential impact	Low
Fiscal affordability	High
Ease of implementation	Medium
Overall priority	Medium

Source: Consultant

E-Mobility policies, planning, and practices should address the gender sensitive aspects of transport. Women's travel patterns differ from men's in numerous ways. For example, it has been observed in other countries that women are likely to travel shorter distances than men and are more likely to use public transportation[17].

Involving women in consultation, planning and decision-making processes ensures that this gender dimension in mobility patterns, including journey frequency and distance travelled, are taken into account. And therefore that e-mobility uptake is maximised across society. Producing gender-based statistical data and research – including gender impact assessments – can improve understanding of women's needs and for appropriate policy responses. The gender sensitive considerations also need to be incorporated in the e-mobility communication strategy.

6.7 Summary of recommendations

The table below summarises our policy recommendations. Note that, as detailed in the preceding sub-sections, some of the recommendations are contingent on others and should not necessarily be implemented immediately – for example TOU tariffs should not be implemented until RE and BESS capacity has been expanded.

Table 51 Summary of policy recommendations

#	Policy recommendation	Potential impact	Fiscal affordability	Ease of implementation	Target countries	Overall priority
Transport and electricity infrastructure						
1	Develop public electric charging infrastructure	High	Medium	Medium	All, especially large and intermediate markets	High
2	Support the development of in-house EV charging facilities	Medium	Medium	Medium	All	Medium
3	Roll-out electricity smart meters	High	Low	Medium	All	High
4	Require charging facilities in new buildings	Low-Medium	High	High	Large and intermediate markets	Medium
5	Expand RE and BESS capacity	High	Low	Low	All	High
6	Introduce time-of-use tariffs	High	Medium	Medium	All	High
7	Foster development of private PV facilities to charge EVs	Medium	High	Medium	All, especially small and very small islands	Medium
8	Conduct impact assessments of EV	Medium	Medium	Medium	All	Medium

[17] Civitas Policy Note 2020, Gender equality and mobility: mind the gap!

#	Policy recommendation	Potential impact	Fiscal affordability	Ease of implementation	Target countries	Overall priority
	uptake on the distribution grids					
9	Offer special EV access	Low-medium	Medium	High	Large and intermediate markets	Low
Commercial viability						
10	Provide purchase incentives, such as subsidies or tax breaks	High	Low	Medium	All, especially large and intermediate markets	High
11	Offer targeted financial incentives for private companies to establish EV fleets	Medium-High	Medium	Medium	Large and intermediate markets	Medium
Governance and policy						
12	Create a regional e-mobility council	Medium	High	High	Regional	High
13	Develop a regional e-mobility strategy	Medium	Medium	High	Regional	High
14	Develop national e-mobility strategies	Medium	High	High	All	High
15	Monitor progress made on e-mobility	Low	High	High	All	Medium
16	Coordinate planning across public administrations	Low	High	Medium	All, especially large and intermediate markets	Medium
Regulations and standards						
17	Establish regulatory instruments for EVs	Medium	High	Low-medium	All	Medium
18	Develop technical guidelines for EV charging	Low-medium	High	High	All, ideally regional	Medium
19	Establish minimum standards for EVs and charging equipment	Low-medium	High	High	All, ideally regional	High
20	Develop public procurement procedures for EV products	Low-medium	High	High	All, especially large and intermediate markets	Medium
Communication and awareness						
21	Develop an e-mobility communication strategy	Medium	High	Medium	Large and intermediate markets	High
22	Engage with stakeholders	Medium	High	Medium	All	Low

#	Policy recommendation	Potential impact	Fiscal affordability	Ease of implementation	Target countries	Overall priority
23	Launch EV pilot projects	Medium	Medium	Medium	Large and intermediate markets	Medium
24	Switch public vehicle fleets to e-mobility	Medium	Low	Short term	All	Low
25	Provide training and information on e-mobility	Medium	High	Medium	All	Medium
26	Mainstream gender aspects in EV policy	Low	High	Medium	All	Medium

Source: Consultant

Annexes

A1 Technical guidelines for charging stations

A1.1 Introduction

Charging infrastructure has a decisive influence on the reliable charging of EVs. Making e-mobility simple and easy for final users requires following special considerations compared to the installation of traditional electric equipment, to make the charging infrastructure safe for everyone.

These guidelines should direct the planning, construction, and operation of charging infrastructure in the Pacific Island Countries. It provides an overview of international norms, standards, and regulations which should be followed in the Pacific Island Countries[18]. It has been developed continuing the work that Andrew Campbell prepared in March 2022 for PCREEE titled “Safe Charging – A Template for PICs Introducing Electric Vehicle Charging Guidelines”.

A1.2 EV Charging essentials

Rechargeable batteries used by EVs work on DC while mains work on AC. For this reason, the AC power coming from the grid needs to be converted to a DC supply of a certain voltage level to charge a battery using an AC-to-DC converter.

Charging a battery, which is an electrochemical element, is a non-linear process. It goes through different stages depending on the current battery pack state-of-charge (SOC), requiring different charging voltages and currents throughout the process. For this reason, the AC-to-DC converter also has charge controller capabilities, which means, it can adapt the output voltage and current needed by these different charging stages.

The charging process of the battery is also monitored by the battery management system (BMS) to ensure the safety of the whole process and the lifespan of the battery pack. The BMS is an electronic device sensing the current, voltage, and temperature of each battery cell inside the battery pack. It communicates with the charger to guarantee the correct charging (and discharging) process, triggering alarms, or even stopping the whole process in case something is not working properly. The BMS also has self-controlled features, such as active and passive cell SOC balancing.

While the BMS is always found onboard the EV because it is attached to the battery pack, the charger can be onboard or off-board the EV, generating different charging modes, that could be classified as AC or DC charging.

[18] To ensure consistency in recommendations to the Pacific Island Countries, these guidelines have built upon the work conducted by PCREE and UNIDO, and their Consultant Andrew Campbell in March 2022. See *PCREEE, Safe Charging – A Template for PICs Introducing Electric Vehicle Charging Guidelines*

A1.2.1 EV chargers

AC charging means the electrical energy is transferred to the EV using a cable designed to work in one or three phases. The charging process is performed by the onboard AC-to-DC converter/charger.

DC charging, on the other hand, means the AC-to-DC converter/charger is located off-board the EV. The connection between the EV and the charger is therefore DC using a permanently connected (tethered) cable at the “charging station” side. The cable also allows proper communication between the charger and the BMS of the battery.

Commonly known as “charging cables”, IC-CPD (in-cable control and protection device) is erroneously considered an EV charger. They do not incorporate an AC-to-DC converter but only some equipment with the sole function of controlling the flow of electricity from the grid to the EV onboard charger for the safety of the whole process. They are usually provided by the manufacturer of the EV as a standard accessory at the time of the purchase.

However, there are portable charging cables intended for charging small EVs such as scooters. In contrast to IC-CPD, these cables do include a low-power AC-to-DC converter/charger and look like an overgrown laptop charger.

Figure 31 Wall-mounted AC charger

Source: CIRCUTOR, SAU, https://circutor.com/

Figure 32 DC fast charger (user unit)

Source: Source: CIRCUTOR, SAU, https://circutor.com/

Figure 33 In-cable control and protection device (IC-CPD)

Source: MENNEKES Elektrotechnik GmbH & Co. KG, http://www.mennek.es/

Figure 34 Charging cable for small EVs (e-scooters, small e-motorbikes)

Source: NIU Canada, http://www.niucanada.com

The IEC 61851-1 (Electric Vehicle conductive charging systems – Part 1: General requirements) describes three connection types between the EV and the source of energy, as shown in Table 52.

Table 52 Connection cases between EVs and the source of energy, IEC 61851-1.

Case	Description	Example
A	Cable permanently attached to the vehicle Not very common	
B	Both sides of the cable are detachable	
C	Cable permanently attached to the EVSE (Electric Vehicle Supply Equipment)	

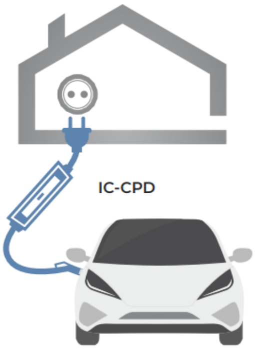
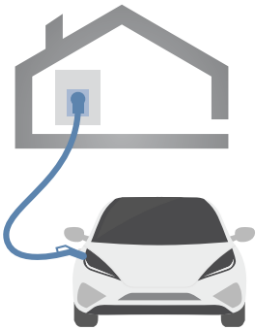
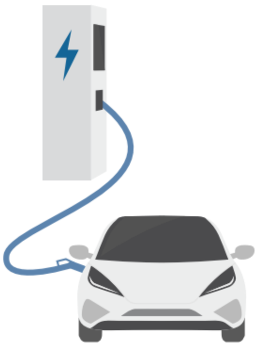
Source: Faculty of Electrical Engineering and Computing University of Zagreb, http://www.hrvojepandzic.com/wp-content/uploads/2019/09/Lecture_4_EVs.pdf

A1.2.2 Charging modes

According to IEC 61851-1, there are four modes of charging EVs. Three modes are AC and one of them is DC, as shown in Table 53.

Table 53 EVs charging modes according to IEC 61851-1

Charging mode	Description
Mode 1: 	AC charging directly from a domestic socket to the EV's onboard converter using a simple cable with no protection or in-cable charge controller. Therefore, this mode allows Case B connection. In many countries, this mode is only allowed to charge low-power EVs such as e-bikes, e-scooters, and small e-motorbikes. It is forbidden for larger vehicles like cars and vans because of safety concerns due to the high power flowing through the charging cable and the lack of communications and control over the process.
Mode 2:	It is similar to Mode 1 but the cable used for the connection between the mains and the EV has an "In-Cable Control and Protection Device" (IC-CPD). This mode also allows Case B connection.

Charging mode	Description
	The IC-CPD provides pilot control and can check the existence of earthing in the electrical wiring. The vehicle's onboard converter converts the AC supply to DC to charge the battery pack. Mode 2 can operate in 1-phase (most common) and 3-phase for more power.
Mode 3: 	This AC charging mode utilises a dedicated, permanently wired circuit to supply AC power to the onboard converter. Connection cases 2 and 3 are allowed in this mode. In this case, the EV is connected to the EVSE, typically a wall-mounted or pedestal device, which provides pilot control and safety functions such as a non-energised connector when not in use, earthing, and residual current device (RCD), among others. Because of these characteristics, Mode 3 chargers can usually deliver more power to the EV than Mode 2 chargers. It can deliver up to 7.36 kW if one-phase, and up to 22 kW if three-phase power is available
Mode 4: 	DC charging where the AC-to-DC converter is off-board the EV thus the onboard converter is bypassed. In this mode, only Case 3 connection is allowed. The EVSE, typically a pedestal from the point of view of the user, provides pilot control and safety functions. Because the converter is located off-board, it can be physically bigger to manage a larger amount of power, charging the EV faster than any other mode if the EV allows it. It can deliver up to 350 kW.

Source: Consultant (content), «Technischer Leitfaden: Ladeinfrastruktur Elektromobilität, version 4», DKE et al., http://www.dke.de (diagrams).[19]

In terms of the power for charging, the IEC 61851-1 states the maximum current and voltage of each mode. The available power depends on the voltage level of the mains and the number of phases used for the connection. For residential charging, the available power is restricted by the household connection, outlet-socket rated power, and by the power that other appliances use at the same time.

[19] https://www.dke.de/resource/blob/988408/87ed1f99814536d66c99797a4545ad5d/technischer-leitfaden-ladeinfrastruktur-elektromobilitaet---version-4-data.pdf

Table 54 Charging modes characteristics and recommended use

Charging Mode	Voltage	Power	Communication	Safety	Recommended use
Mode 1	230 V (1phase)	1.38 kW (6Amp) 2.30 kW (10Amp) 3.68 kW (16Amp)	None	Depends on the electrical wiring where the EV is connected.	At home only for scooters and small motorbikes
Mode 2	230 V (1phase)	1.38 kW (6Amp) 2.30 kW (10Amp) 3.68 kW (16Amp) 7.36 kW (32Amp)[20]	Pilot Control	Basic.	At home only.
Mode 3	230 V (1phase) 400 V (3phase)	3.68 kW (16Amp) 7.36 kW (32Amp) 11 kW (16Amp) 22 kW (32Amp)	Power line OCPP 1.6 or ISO 151181	High.	Domestic, commercial, and public charging
Mode 4	400 V (3phase)	25 kW 50 kW Up to 350 kW	Power line DIN SPEC 70121 or ISO 151181	High.	Commercial and public charging

Source: Consultant

A1.2.3 Charging levels (USA market)

While most Pacific Island Countries use similar grid voltage levels as New Zealand and Australia (230 V or 240 V and 50 Hz), some use 120 V and 60 Hz as domestic voltage level and frequency, comparable to the USA standard. For this reason, the Society of Automotive Engineering (SAE) standard for chargers is described in Table 55.

In contrast to IEC 61851-1, SAE J1772 set charging levels according to the AC connection voltage level and the number of phases. For this reason, charging level 2 can take the power from a household socket (like IEC Mode 2) or an EVSE (like IEC Mode 3).

On the other hand, SAE J1772 does not allow direct charging from a household socket as IEC61851-1 Mode 1. The utilisation of IC-CPD is mandatory for both charging levels 1 and 2.

Table 55 Charging levels according to SAE J1772

Charging Level	Charger	Voltage	Power	Communication	Safety
Level 1 AC	Onboard	120 V (1phase)	1.44 kW (12Amp) 1.80 kW (15Amp)	Pilot Control	Basic. IC-CPD mandatory
Level 2 AC	Onboard	208 V (1phase)	2.5 kW (12Amp) 3.12 kW (15Amp)	Pilot control or Power line	Basic (IC-CPD) or high (EVSE)

[20] Available only where industrial sockets are installed.

Charging Level	Charger	Voltage	Power	Communication	Safety
		240 V (1phase)	6.24 kW (30Amp) 19.2 kW (80Amp)		
Level 3 DC	Off-board	208-600 V (3phase)	25 kW 50 kW Up to 240 kW	Power line	High. DC fast charging

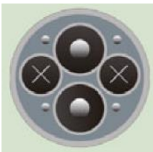
Source: Consultant

A1.2.4 Charging connectors (EV side)

There are several connector types on the EV side, allowing AC charge, DC charge, or both, depending on the world region the EVs are sold. DC and combined AC/DC connectors have developed more recently because DC fast charge became a necessity as battery packs, and therefore autonomy of EVs has increased.

AC connectors are defined by IEC 62196-2 and DC connectors are defined by IEC 62196-3.

Table 56 AC and DC connectors

	North America	Japan	EU and other markets	China
AC				
	J1772 (Type 1)		Mennekes (Type 2)	GB/T AC 20234.2
	Only 1-phase Up to 7.4 kW		Allows 3-phase Up to 43.6 kW (3phase)	Allows 3-phase Up to 48 kW (3phase)
DC				
	CCS1 (combined charging system 1)	CHAdeMO	CCS2 (combined charging system 2)	GB/T DC 20234.3
	AC+DC combo AC only 1-phase Up to 350 kW (DC)	DC only Up to 62.5 kW (1st generation) Up to 400 kW (2nd generation)	AC+DC combo[21] Up to 350 kW (DC)	DC only Up to 250 kW

[21] If DC only, the upper part of the connector only has three pins for communication and earthing.

Source: JIA Qing-Shan; LONG, Teng; "A review on charging behaviour of electric vehicles: data, model, and control". Control Theory and Technology, Vol. 18, N°3, pp. 217-230, August 2020

The most common connectors on the market are the ones used in North America, Japan, and the EU.

Although the number of connectors available on the market can be seen as a disadvantage in terms of interoperability, this is not a major issue. At home charging using IC-CPD is not affected by the type of connector because the final user has the proper connection cable provided by the EV seller. At home charging using a dedicated EVSE will be installed considering the connector in the EV, the problem could arise only if changing the EV, leading to changing the EVSE if it has the cable permanently attached. Finally, the manufacturers of public chargers (AC and DC) can provide EVSEs with two different connectors at the same panel.

A1.2.5 Charging speed and EV autonomy

The range an EV can reach starting with a fully-charged battery depends on the size of the battery pack, EV characteristics, and driving conditions. On average, an electric car travels approximately 6 km per kWh of energy and an electric motorbike travels 35 km per kWh. Table 57 summarizes typical charging times for a 40 kWh battery size and autonomy gained per 1 hour of charging at a certain power level.

Table 57 Estimated charging times

Charging Speed category	Power used	Range added per hour	Total charge time for 40 kWh	Typical charging mode
Very slow	1.38 kW 2.3 kW	~ 8 km ~ 14 km	~ 29 hours ~ 17 hours	Mode 1 and 2
Slow	3.68 kW 7.36 kW	~ 22 km ~ 44 km	~ 11 hours ~ 5.4 hours	Mode 2 and 3
Moderate	11 kW 22 kW	~ 66 km ~ 132 km	~ 3.6 hours ~ 1.8 hours	Mode 3
Fast	25 kW 50 kW	~ 150 km ~ 190 km[22]	~ 1.6 hours ~ 36 min (up to 80% SoC)	Mode 4

Source: Consultant

As stated before, charging a battery is not a linear process, depends on many factors such as current weather conditions, the initial SoC of the battery, and the charging capacity of the onboard converter, among others. The charging times shown in the table are rough estimations, but they can help to decide which charger use depending on the intended EV utilisation. Although moderate and fast charging can be perceived as the ideal charging mode if available, this kind of charging should be used only when needed to preserve the health of the battery. Moreover, fast (and higher speed) chargers usually charge only up to 80% of the total capacity of the battery for the same reason. Slow charging should be used for every day to preserve the lifespan of the battery.

[22] Related to the charge time in minutes up to 80% SoC.

A1.2.6 Special notes on charging electric scooters and motorbikes

Within the EV market, there is a growing interest in the use of e-scooters and e-motorbikes. The names can be confused even for the manufacturers.

Scooters typically have small battery packs of about 2kWh of total capacity. In terms of autonomy, this means about 70 km per full charge. This kind of vehicle does not have an onboard charger but uses a cable charger as depicted in Figure 31. The power managed for those chargers does not go beyond 300 W, so they can be used in almost any household socket properly wired without major safety concerns.

On the other hand, bigger motorbikes are equipped with 10 kWh up to 20 kWh battery packs. From the point of view of the charging process, these motorbikes are similar to electric cars thus the same safety considerations have to be taken into account when charging. They implement an onboard AC-to-DC converter/charger and can use the same AC connectors as a car. Some of the larger motorbikes also allow fast DC charging.

A1.3 Planning and installing

Charging EVs can present some challenges and stress the electrical wiring where the charging process is performed. For this reason, this section presents some considerations and requirements to guarantee the safety and reliability of the charging facilities. The technologies listed below are not covered in this document because they are not considered relevant for most PICs, at least in the initial stages of market development:

- Ultrafast charging (ie, involving charging rates above 150 kW – these tend to require site-specific and specialist input into its design and installation).
- Non-standard charging of EVs, including that carried out during testing and repair of EVs or during research and development.
- Wireless charging (also known as inductive charging).

Mode 1 and 2 should be allowed for at home charging under the considerations listed below. At home charging will request no further planning because it will be limited by the power rating of a standard socket outlet which is rated to 8-10 Amp. In other words, the charging power rate would not be higher than 2.3 kW, ie, similar to some appliances.

On the other hand, modes 3 and 4 request more power. The decision on the location and the installation itself will require careful planning considering:

- The type and number of EVs to be expected to charge at the location.
- Charging capacity of the EVs.
- Expected parking time.
- The charging behaviour of the owner.

A1.3.1 General requirements when charging EVs

This section summarises the general and basic requirements that should be followed when deciding about charging and EV in any charging mode.

a) National wiring rules and regulations concerning electricity installations, including for the installation and use of charging equipment, must be complied with.
b) The installation of EVSE and the use of EVSE must be safe.
c) Only EVSE shall be used to charge an EV.
d) All EVSE must be fit for purpose:
    i. The EVSE must be labelled by the manufacturer with its electricity supply requirements and must not be used with electricity supplies that do not match.
    ii. The EVSE must be labelled by the manufacturer with its rating and must not be used at a higher rating. Protection devices must also be used to prevent excessive loading of the electricity supply and EVSE.
    iii. EVSE shall be either compliant with relevant IEC standards or relevant UL standards, and be labelled as such, and a supplier shall provide proof of compliance if requested by a government Authority charged with performing such checks. In this respect:
        - Electricity supply cables used for Mode 1 charging should be compliant with the national wiring rules and regulations.
        - Mode 2 EVSE should be additionally compliant with IEC 61851-1, IEC 62752 or UL 2251, as applicable.
        - Mode 3 EVSE should be additionally compliant with IEC 61851-1 or UL 2251, as applicable.
        - Mode 4 EVSE should be additionally compliant with IEC 61851-1 and IEC 61851-23 or UL 2202, as applicable.
    iv. EVSE must be selected, designed, built and installed to withstand normal use. This includes ensuring that EVSE has appropriate weather and dampness protection for the specific application. The use of bollards or other means may also be required to avoid impact from vehicles.
e) Any installation, use, testing, verification, maintenance and repair of EVSE, or parts thereof, shall only be carried out by people who are competent to carry out such tasks.
f) EVSE shall only be used if all connectors and plugs between the electricity supply and the vehicle match.
    i. No socket outlet adaptors are permitted to be used.
    ii. No charging-type adaptors are permitted to be used unless approved by the manufacturer of the EV.
    iii. No connectors or plugs are to be changed unless this work is carried out by a competent technician who is authorised to carry out such work.
g) Each supply circuit from the switchboard shall charge no more than one EV at a time.
    i. No multi-plug outlet arrangements shall be used.
    ii. As an exception, an arrangement that has been specifically designed for the purpose of charging multiple EVs from the same power supply can be used if the arrangement robustly and automatically limits the total current draw so that the rating of the electricity supply circuit is never exceeded.
h) Do not use charging equipment that is damaged.

i. Damage may show itself either as physical damage or as an electric shock to a user.
ii. If a public charger, the damage must be reported to the contact named on the charger's notices (on the side of the charger), or the supplier if a private charger. The charger must not be used until it has been tested and verified to be safe.
iii. Some degree of superficial damage can be accepted – there is no need to throw away a vehicle because it is dented, or a charging cable if it is scratched. But if any connectors are cracked, cables have cuts in them, there are loose components, or potentially live components are visible, then do not use the charging equipment.

A1.3.2 Charging at home

Mode 1: scooters and small motorbikes

Although this charging mode is not advised under any circumstance for the charging of electric cars, vans, or motorbikes because it is inherently less safe than other charging modes, it can be allowed for charging small EVs with battery packs of a total capacity of about 2 to 3 kWh. Moreover, the decision about allowing or not this kind of charging should be based on the external charger capacity.

Considering that most household's connections in the PICs are limited to 20 Amp (~4.6 kW), scooters provided with an external charger up to 500 W would have a minor impact on the electric wiring of a household, and therefore safe to use given the current conditions of the electric wiring.

Nevertheless, users should be advised to adhere to the following:

- Charge the EV through a socket outlet that is not exposed to rain, water, or direct sunlight.
- The charger cable should not be exposed to rain, water, or direct sunlight either.
- The socket outlet should be part of a circuit that is not shared with other high-consumption appliances such as washing machines, and hairdryers, among others.
- The socket outlet should be part of a circuit that implements an RCD with at least Type A performance (tripping at not greater than 30mA residual AC or 6mA residual pulsing DC and isolating all live conductors, including the neutral).
- An extension cord must not be used.
- The EV must not be parked in a public area while charged.

Mode 2: cars, vans, and large motorbikes

As stated in section A1.2.2, in Mode 2 the utilisation of an IC-CPD is mandatory.

For safety reasons, Mode 2 should not be permitted for public charging or for charging in a public area. Some other considerations are:

- A Mode 2 charger must not be plugged into a socket outlet of a site that is only supplied a low-power mains connection unless that socket outlet and its supply circuit has been inspected by a competent electrical inspector, verified as rated for the application, and the socket outlet is clearly marked as suitable for EV charging.

- A Mode 2 charger must have earth continuity monitoring (where a break in the earth connection of an EV to the earth of the electricity supply circuit's earth protection circuit stops the operation of the charger). This requires the Mode 2 charger to have a three-pin plug, the supply socket outlet to be three-pin, and the earth circuit to be complete between vehicle and electricity supply.

- An extension cord must not be used.

- The socket outlet used must not be exposed to rain, water or direct sunlight unless it is an IEC60309-2 socket outlet (see below).

- Mode 2 charging device must receive supply through an RCD with at least Type A performance. Preference is to supply Mode 2 EVSE through protection that also trips with smooth residual DC (eg, through the use of a Residual Direct Current Detecting Device (RDC-DD) alongside the use of a Type A RCD, or through the use of a Type B RCD as described for Mode 1 charging above).

- The IC-CPD should not be exposed to rain, water, or direct sunlight even if it has an IP rating that allows it.

- The plug at the electricity supply to the IC-CPD must be rated for the application. For domestic applications:

    - An AS/NZS 3112 (three flat pin, 10 A rated) plug can be used for an IC-CPD rated up to 8 A unless fitted with temperature sensing in the plug, in which case it can be used with an IC-CPD rated up to 10 A.

    - An IEC 60309-2 (three round pin, 16 A rated 'caravan') plug can be used for an IC-CPD rated up to 12 A unless fitted with temperature sensing in the plug, in which case it can be used with an IC-CPD rated up to 16 A.

- If there is no suitable socket outlet and capacity on the circuit, the owner of the house should engage a registered and licensed electrical practitioner to install a socket outlet or upgrade the circuit or household connection.

Mode 3: cars, vans, and large motorbikes

It is expected that charging with Mode 3 chargers at home will not exceed a demand of 16 Amp due to the household connection limit of 20 Amp. At this rate, a 40kWh battery like the one of the 2018 Nissan Leaf – one of the most prevalent second-hand models in New Zealand and Australia – will need about 11 hours to fully charge (see Table 57).

It is more likely that a residential user who wants to install a wall-box charger will need to ask for a secondary, independent connection to the local grid with a new energy meter or upgrade the capacity of the household connection if allowed by the local distribution company. In the last case, the whole installation should be checked by the registered electrical practitioner who is going to install the EVSE. It is important to avoid overloads and the malfunction of existing RCDs. For this reason, it is highly recommended to install a dynamic load management (DLM) system, that will avoid any risk of blackout when using the appliances and charging the EV at the same time. This device will reduce the power flowing to the EVSE according to real-time demand of the house and the connection capacity to the grid.

Other considerations are:

- Mode 3 EVSE must not be able to operate unless it has earth continuity.
- Mode 3 charging must be provided through an independent circuit that includes an RCD with at least Type A performance (ie, trips on detection of AC residual leakage). In addition, it is recommended to supply Mode 3 EVSE through protection that also trips with smooth residual DC leakage (eg, using 6mA RDC-DD alongside the use of a Type A RCD, or using a Type B RCD).
- Mode 3 EVSE should be placed at least 800 mm above ground level.
- For safety reasons, it is preferred that the connection between the EVSE and the EV lies in case C (tethered cable).

A1.3.3 Public charging

Public charging stations that can be used in public buildings, parking lots, and supermarkets, normally seek faster charging times and in consequence, capacities might range from 7.36 to 150 kW for light vehicles. Typically, three-phased chargers are utilised, and these can use either AC or DC. Even in the case of using lower charging capacities, the charging station will likely offer more than one charging point and, in consequence, these types of applications draw much higher capacity requirements than household applications.

The network capacity needs will be determined by the number of charging stations and their individual capacity. The load of small stations can be analogous to those of commercial or small industrial applications and therefore the distribution network needs are no different. On the contrary, large charging stations with many spots can be more demanding and require network strengthening. In these cases, the selection of candidate locations for the chargers should incorporate the grid capacity as one of the main criteria. In this sense, power utilities should be prepared to respond to increasing requests from prospective EV charger developers as EV takes over. Alternatively, power utilities can also take the lead in identifying and/or planning the best locations for public charging infrastructure. In any case, DLM systems should be used to avoid local-power black-outs

Mode 3: cars, vans, and big motorbikes

A Mode 3 public charger should be rated 7.36 kW at least (32 Amp, 1-phase connection). If a three-phase grid is available, the recommended power is 11 kW (16 Amp) to allow faster charging of EVs in a short period of time (see Table 57). In this way, the public infrastructure could be used for more than one EV during the day.

- Mode 3 EVSE must not be able to operate unless it has earth continuity.
- Mode 3 charging must be provided through an RCD that trips with smooth residual DC leakage (eg, through the use of 6mA RDC-DD alongside the use of a Type A RCD, or through the use of a Type B RCD).

- Public charging stations must be provided with an isolating switch, lockable in the isolated position, that isolates the EVSE from all live conductors including the neutral.
- Preference is for Mode 3 EVSE to possess functions that will allow remote management of the charging event.
- Must have clear safety and operating instructions for the charging equipment
- Mode 3 EVSE should be placed at least 800 mm above ground level.

In order to provide interoperability and greater certainty to users, it is recommended that Mode 3 (AC) charging stations consider case B connection (both sides detachable) and have a Type 2 female socket (Mennekes AC socket outlet). This allows an EV operator to provide their own flexible charging cable that has a Type 2 charging connector at one end and a connector that matches their EV at the other.

Public charging – Mode 4

The installation of a Mode 4 DC fast charger needs a deep study of the grid conditions at the desired location. Manufacturers of this kind of charging stations may also provide installation service. For this reason, only general recommendations are listed below.

- A Mode 4 charger must have short circuit protection, overvoltage protection, undervoltage protection, isolation monitoring, and earth continuity monitoring.
- The height that an EV charging connector is held when stored should be at least 800 mm above the ground level.
- Must have clear safety and operating instructions for the charging equipment
- For interoperability, Mode 4 (DC) charging stations provide both the CHAdeMO DC and DC CCS Type 2 connector types with charging cable holders.
- It is highly recommended that user units of DC fast charging station are provided with touch screen with easy messages to improve the user experience and prevent any misuse.

A2 Minimum standards for EV charging equipment

A2.1 International standards

Standard	Year	Fields covered
IEC 61851-1	2017	EV conductive charging system - Part 1: General requirements.
IEC 61851-21-2	2018	Electric vehicle conductive charging system - Part 21-2: EV requirements for conductive connection to an AC/DC supply - EMC requirements for off-board EV charging systems
IEC 61851-23	2014	EV conductive charging system - Part 23: DC EV charging station
IEC 61851-24	2014	EV conductive charging system - Part 24: Digital communication between a d.c EV charging station and an EV for control of d.c. charging
IEC 62196-1	2014	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of EVs - Part 1: General requirements
IEC 62196-2	2016	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of EVs - Part 2: Dimensional compatibility and interchangeability requirements for a.c. pin and contact-tube accessories
IEC 62196-3	2014	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of EVs - Part 3: Dimensional compatibility and interchangeability requirements for d.c. and a.c./d.c. pin and contact-tube vehicle couplers
IEC 61851-21-2	2018	EV requirements for conductive connection to an AC/DC supply-EMC requirements for off-board EV charging systems
IEC 62752	2018	In-cable control and protection device for Mode 2 charging of electric road vehicles (IC-CPD)
IEC 60309-2	2021	Plugs, fixed or portable socket-outlets and appliance inlets for industrial purposes - Part 2: Dimensional compatibility requirements for pin and contact-tube accessories
ISO 15118-2	2019	Road vehicles – Vehicle-to-Grid Communication Interface – Part 2: Network and application protocol requirements
DIN SPEC 70121	2014	Electromobility - Digital communication between a d.c. EV charging station and an EV for control of d.c. charging in the Combined Charging System
AS/NZS 3820		Essential Safety Requirements for Electrical Equipment
AS/NZS 3112		Approval and test specification – Plugs and socket-outlets
AS/NZS 603335.1		Household and similar electrical appliances - Safety - Part 1: General requirements
AS/NZS 3000	2018	Electrical Installations “Wiring Rules”
SAE J1772	2017	EV and Plug-in Hybrid EV Conductive Charge Coupler

A2.2 Reference circuit wiring for charging modes

The following wiring and protection devices have been taken and adapted from the RIC N°15, Electric Vehicle Charging Infrastructure, Superintendencia de Electricidad y Combustibles, Ministry of Energy, Chile.

Figure 35 Mode 1

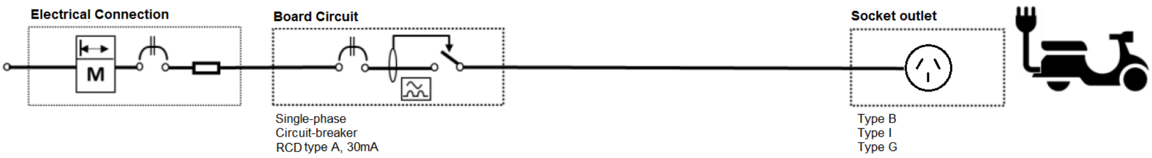


Figure 36 Mode 2

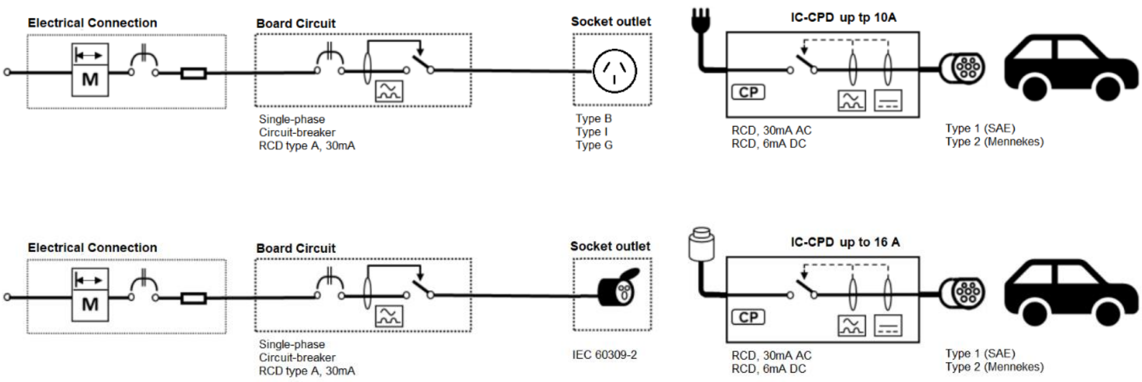
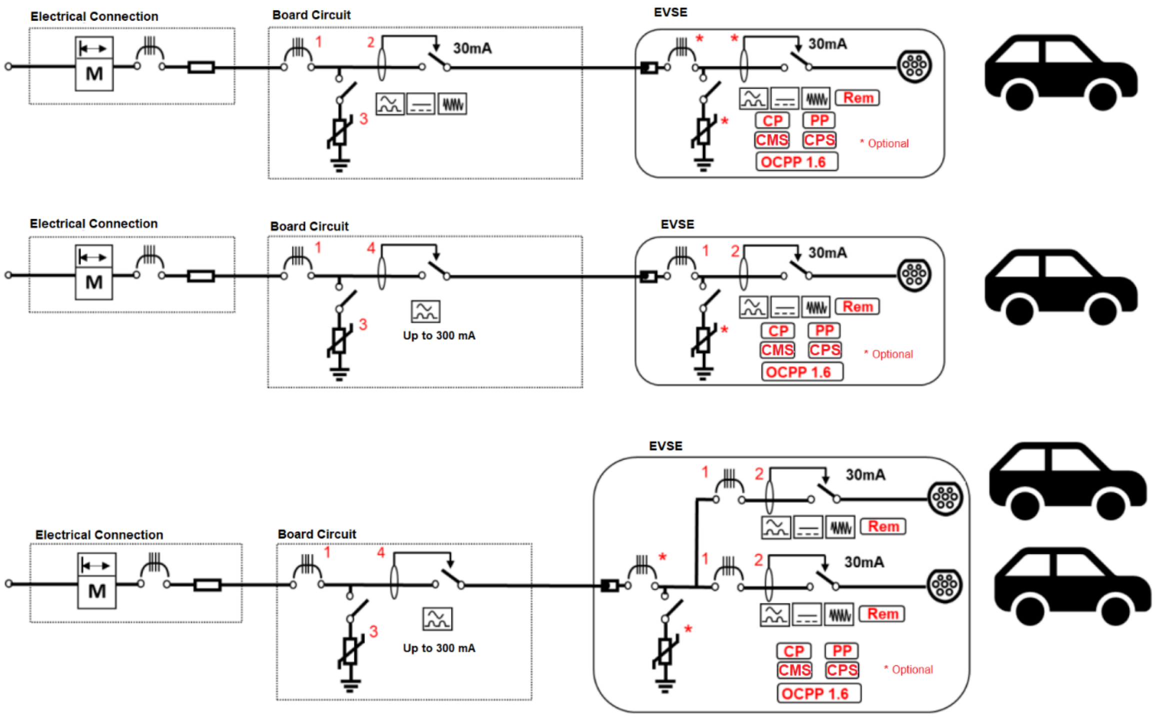


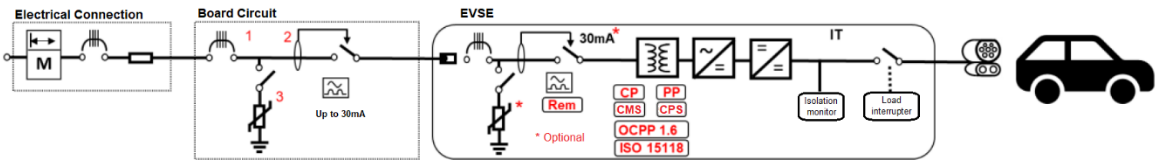
Figure 37 Mode 3



Notes for charging Mode 3:

1. Bipolar or four-polar protection accordingly.
2. RCD Type B of 30 mA by connector in circuit or EVSE. Or RCD Type A of 30mA + 6mA RDC-CC
3. Protection against overvoltage Type 2.
4. RCD Type A up to 300 mA if in the connector the EVSE has a RCD Type B.

Figure 38 Mode 4



Notes for charging Mode 4:

5. Bipolar or four-polar protection accordingly.
6. RCP Type A of 30 mA ac per EVSE up to 100 kW or Type A up to 300 mA per EVSE over 100 kW.
7. Protection against overvoltage Type 2.

EVSE Characteristics (Mode 3 and 4):

CP: Control Pilot Function.
PP: Proximity Pilot Function.
CMS: EVSE allows load management.
CPS: EVSE allows to operate with a cabling protection system.
OCPP 1.6: Communication protocol
REM: RCD with monitor and remote control.

Table 58 Voltage and frequency levels from the mains in the Pacific Island Countries

Country	Domestic plug type	Residential voltage	Three-phase voltage (L-L)	Frequency
Fiji	I	240 V	415 V	50 Hz
Kiribati	I	240 V	Unavailable	50 Hz
Marshall Islands	A, B	120 V	Unavailable	60 Hz
FSM	A, B	120 V	Unavailable	60 Hz
Nauru	I	240 V	415 V	50 Hz
Palau	A, B	120 V	208 V	60 Hz
Samoa	I	230 V	400 V	50 Hz
Solomon Islands	G, I	230 V	Unavailable	50 Hz
Tonga	I	240 V	415 V	50 Hz
Tuvalu	I	230 V	400 V	50 Hz
Vanuatu	I	230 V	400 V	50 Hz

Source: worldstandars.eu and generatorsource.com

A3 Guidelines for EV maintenance procedures

A3.1 Maintenance checks

There are no international standards for maintenance procedures of EVs but there is consensus about the reduced maintenance needs compared to conventional vehicles.

In an EV, there is no manual gearbox or clutch, an electric motor delivers direct drive. All the maintenance works of a traditional transmission system are therefore avoided. However, there are a few fluids that are used by an EV that require regular checking, refilling, or replacement:

- Brake fluid
- Coolant
- Windshield Wiper

Other regular maintenance services like the ones needed by a conventional car have to be performed according to the manufacturer's recommendation. These include checking tyre pressure, tyre rotation, suspension system, maintenance work on the chassis, bodywork, tyres, and steering system, among others.

A3.2 Battery health

There is also needed to check the auxiliary battery health and replace it every 3 to 4 years. This battery is used to power some auxiliary elements like lighting and electronics, similar to one on a conventional car.

The most expensive component of an EV is the battery pack. The lifespan of a traction battery can easily be above 10 years and therefore manufacturers of EVs offer long warranty periods between 5 to 8 years. After that time, the overall capacity of the battery pack may be reduced to 80% of the original capacity.

There are some measures that the users can take in order to maintain the health of the traction battery:

- Do not expose the EV to extreme temperatures for long periods of time.
- Do not keep the EV exposed to temperatures lower than -20°C for more than 7 days (unlikely in PICs climate).
- Do not keep the EV at low levels of charge for periods longer than 2 weeks.
- Do not use fast charging as a regular charging method. Prioritise slow and moderate speed of charge instead.
- Try to keep the SoC between 20% and 80%, or what the manufacturer recommends.

- Optimise the driving style:
    - Keep speed and accelerating down
    - Adopt a more relaxed, smooth driving style
    - Drive at a constant speed as much as possible:
    - Adjust speed by controlling your acceleration, including going downhill
    - Use the regenerative braking: when you need to stop the vehicle, first release the accelerator pedal to slow down, then brake the vehicle

A3.3 Example maintenance schedule

As an example, the Nissan Leaf maintenance schedule for the first 3 years is shown in Table 59. In the table, the elements related to the electric motor are highlighted. Coolant replacement is recommended after the first 200.000 km (125.000 miles), subsequent replacements should be done every 120.000 km (75.000 miles, or 5 years).

Table 59 Nissan Leaf maintenance schedule

Period	Normal use maintenance	Severe use maintenance
Every 12.000 km, 7.500 miles, or 6 months	Inspections: • Horn, lights, signals, wipers, rear hatch/hood lift supports • Battery terminals and cables, battery test • Tyre pressure, treadwear and depth • Suspension components (shocks, subframe, tie rods) Essential: • Tyre rotation	Inspections: • Axle & suspension parts • Brake pads & rotors • Drive shaft boots • Front suspension ball joints • Steering gear and linkage • Steering linkage ball joints
Every 24.000 km, 15.000 miles, or 12 months	Inspections: • Brake lines & cables • Brake pads & rotors • Charging port • Drive shaft boots • EV Battery Usage Report (required for warranty purposes) • Reduction gear oil Essential: • Replace in-cabin microfilter	Essential: • Replace brake fluid
Every 36.000 km, 22.500 miles, or 18 months	Inspections: • Inspect Intelligent Key battery	
Every 48.000 km, 30.000 miles, or 24 months	Inspections: • Axle & suspension parts • Charging port sealing cap	

Period	Normal use maintenance	Severe use maintenance
	• Front suspension ball joints • Steering gear and linkage • Steering linkage ball joints Essential: • Replace brake fluid	
Every 72.000 km, 45.000 miles, or 36 months	Essential: • Replace intelligent key battery	

Source: 2022 Owner's manual and maintenance information

A4 Grid impact analysis – Detailed results

A4.1 Assumptions

Table 60 Summary of inputs and assumptions – electricity systems

Item	Unit	Fiji		Solomon Islands		Marshall Islands		Tuvalu	
		2022	2030	2022	2030	2022	2030	2022	2030
Demand									
Peak demand	MW	163.9	224.3	16.8	20.9	9.8	11.4	1.6	2.5
Energy sent out	MWh/year	950,712	1,301,115	91,276	113,355	67,654	78,715	8,074	12,386
Load factor	%	66%	66%	62%	62%	79%	79%	58%	58%
Energy sales	MWh/year	862,160	1,179,925	74,603	92,648	47,020	54,707	6,870	10,539
Network losses	%	9%	9%	18%	18%	30%	30%	15%	15%
Annual growth in demand	%	4%	4%	3%	3%	2%	2%	5%	5%
Generating capacity									
Solar	MW	5.0	50.0	1.0	20.0	-	14.5	1.7	3.1
Hydro	MW	116.1	148.1	-	15.0	-	-	-	
BESS	MW	-				-	12.0	2.8	5.6
Diesel	MW	137.5	137.5	23.4	12.8	14.3	21.2	1.2	1.2
Total	MW	258.6	335.6	24.4	47.8	14.3	47.7	5.7	9.9
Hydro capacity factor									
Average day	%	62%	62%	57%	57%	-	-	-	-
BESS capacity factor									

Item	Unit	Fiji		Solomon Islands		Marshall Islands		Tuvalu	
Medium	Hours/MW /day	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Diesel costs									
Diesel fuel price	$/l	1.0	1.0	1.1	1.1	1.3	1.3	1.2	1.2
Diesel efficiency	l/kWh	0.21	0.21	0.25	0.25	0.26	0.26	0.29	0.29
Diesel variable cost	$/MWh	213	213	272	272	346	346	344	344

Source: Data provided by utilities and consultant assumptions

Table Summary of inputs and assumptions – EV demand

Item	Unit	Fiji		Solomon Islands		Marshall Islands		Tuvalu	
		2022	2030	2022	2030	2022	2030	2022	2030
Cars									
Number of vehicles	#	93,134	199,641	9,039	19,376	2,402	5,149	65	139
Population	#	908,710	959,477	723,303	889,373	59,943	63,038	11,019	11,634
Vehicle growth rate[23]	%	10%	10%	10%	10%	10%	10%	10%	10%
EV %	%	-	10%	-	10%	-	10%	-	10%
Number of EVs	#	-	19,964	-	1,938	-	515	-	14
Average distance	km/day/ vehicle	30	30	20	20	15	15	5	5
Battery size	kWh	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0
Range	km	225	225	225	225	225	225	225	225
Energy efficiency	km/kWh	6	6	6	6	6	6	6	6
Per EV annual demand	kWh/ vehicle/year	1,801	1,801	1,200	1,200	900	900	300	300

[23] Over the last 10 years vehicle growth rates in Fiji have averaged around 7%. We assume a higher rate of growth to reflect growing household incomes and the relatively low current vehicle ownership rates in the Pacific.

Item	Unit	Fiji		Solomon Islands		Marshall Islands		Tuvalu	
		2022	2030	2022	2030	2022	2030	2022	2030
Motorbikes									
Number of vehicles	#	791	1,696	375	804	13	28	897	1,923
Vehicle growth rate	%	10%	10%	10%	10%	10%	10%	10%	10%
EV %	%	-	10%	-	10%	-	10%	-	10%
Number of EVs	#	-	170	-	80	-	3	-	192
Average distance	km/day/ vehicle	15	15	10	10	8	8	5	5
Battery size	kWh	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Range	km	50	50	50	50	50	50	50	50
Energy efficiency	km/kWh	35	35	35	35	35	35	35	35
Per EV annual demand	kWh/ vehicle/year	158	158	105	105	84	84	53	53
Vans									
Number of vehicles	#	27,152	58,203	3,604	7,725	185	397	1	2
Vehicle growth rate	%	10%	10%	10%	10%	10%	10%	10%	10%
EV %	%	-	10%	-	10%	-	10%	-	10%
Number of EVs	#	-	5,820	-	773	-	40	-	0
Average distance	km/day /vehicle	50	50	40	40	30	30	10	10
Battery size	kWh	37	37	37	37	37	37	37	37
Range	km	180	180	180	180	180	180	180	180
Energy efficiency	km/kWh	5	5	5	5	5	5	5	5
Per EV annual demand	kWh/ vehicle/year	3,824	3,824	3,059	3,059	2,294	2,294	765	765
EV demand profile									
EV charging profile	type	Overnight	Overnight	Overnight	Overnight	Overnight	Overnight	Overnight	Overnight

Item	Unit	Fiji		Solomon Islands		Marshall Islands		Tuvalu	
		2022	2030	2022	2030	2022	2030	2022	2030
Daily load factor	%	35%	35%	35%	35%	35%	35%	35%	35%
Daily peak EV load	MW	-	19.1	-	1.5	-	0.2	-	0.0

Source: Transport data provided by governments and consultant assumptions

Table 61 Summary of inputs and assumptions – supply costs

Item	Unit	Fiji			Solomons			Marshall Islands			Tuvalu		
		2022	2030 BAU	2030 Favourable	2022	2030 BAU	2030 Favourable	2022	2030 BAU	2030 Favourable	2022	2030 BAU	2030 Favourable
Network costs													
Network capacity costs													
Network incremental capacity cost	$/kW/y	400	400	400	400	400	400	400	400	400	400	400	400
% of demand in peak hours	%	67%	67%	67%	64%	64%	64%	61%	61%	61%	65%	65%	65%
Allocation of capacity costs to peak hours	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Allocated network costs													
Peak hours	$/kWh	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.06	0.06	0.06
Off-peak hours	$/kWh	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Network losses	%	9%	9%	9%	18%	18%	18%	30%	30%	30%	15%	15%	15%
Network cost per unit sold													
Peak hours	$/kWh sold	0.07	0.07	0.07	0.08	0.08	0.08	0.10	0.10	0.10	0.07	0.07	0.07
Off-peak hours	$/kWh sold	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Generation costs													

Item	Unit	Fiji			Solomons			Marshall Islands			Tuvalu		
		2022	2030 BAU	2030 Favourable	2022	2030 BAU	2030 Favourable	2022	2030 BAU	2030 Favourable	2022	2030 BAU	2030 Favourable
Solar													
Levelised cost	$/kWh	0.12	0.09	0.09	0.12	0.09	0.09	0.15	0.11	0.11	0.15	0.11	0.11
BESS													
Investment cost	$/kWh	500	329	329	500	329	329	800	526	526	800	526	526
Discount rate	%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Life	years	20	20	20	20	20	20	20	20	20	20	20	20
Annual capacity cost	$/kWh/y	59	39	39	59	39	39	94	62	62	94	62	62
Fixed O&M costs	$/kWh/y	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Capacity factor	%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Levelised cost	$/kWh	0.17	0.11	0.11	0.17	0.11	0.11	0.27	0.18	0.18	0.27	0.18	0.18
Diesel													
Investment cost	$/kW	800	900	900	800	800	800	800	800	800	800	800	800
Discount rate	%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Life	years	25	25	25	25	25	25	25	25	25	25	25	25
Annual capacity cost	$/kW/y	88	99	99	88	88	88	88	88	88	88	88	88
Capacity factor	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Levelised capacity cost	$/kWh	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Fuel price	$/MT	1,014	1,014	1,014	1,089	1,089	1,089	1,315	1,315	1,315	1,207	1,207	1,207
Fuel efficiency	MWh/MT	4.75	4.75	4.75	4.00	4.00	4.00	3.80	3.80	3.80	3.50	3.50	3.50
Fuel cost	$/kWh	0.21	0.21	0.21	0.27	0.27	0.27	0.35	0.35	0.35	0.34	0.34	0.34
Non-fuel O&M costs	$/kWh	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Item	Unit	Fiji			Solomons			Marshall Islands			Tuvalu		
		2022	2030 BAU	2030 Favourable	2022	2030 BAU	2030 Favourable	2022	2030 BAU	2030 Favourable	2022	2030 BAU	2030 Favourable
Levelised cost	$/kWh	0.24	0.24	0.24	0.30	0.30	0.30	0.37	0.37	0.37	0.37	0.37	0.37
Generation share - sunshine hours													
Solar	%	-	20%	100%	-	20%	100%	-	20%	100%	-	20%	100%
Hydro (spare capacity)	%	-	-	-	-	-	-	-	-	-	-	-	-
Diesel	%	100%	80%	-	100%	80%	-	100%	80%	-	100%	80%	-
Generation share - non-sunshine hours													
BESS	%	-	-	80%	-	-	-	-	-	80%	-	-	80%
Hydro (spare capacity)	%	-	-	-	-	100%	100%	-	-	-	-	-	-
Diesel	%	100%	100%	20%	100%	-	-	100%	100%	20%	100%	100%	20%
Resulting generation costs													
Generation costs													
Sunshine hours	$/kWh	0.24	0.21	0.09	0.30	0.25	0.09	0.37	0.32	0.11	0.37	0.32	0.11
Non-sunshine hours	$/kWh	0.24	0.24	0.21	0.30	0.09	0.09	0.37	0.37	0.31	0.37	0.37	0.31
Network losses	%	9%	9%	9%	18%	18%	18%	30%	30%	30%	15%	15%	15%
Generation costs per unit sold													
Sunshine hours	$/kWh sold	0.26	0.23	0.10	0.36	0.31	0.11	0.53	0.46	0.16	0.43	0.37	0.13
Non-sunshine hours	$/kWh sold	0.26	0.26	0.23	0.36	0.11	0.11	0.53	0.53	0.44	0.43	0.43	0.36

Source: Consultant assumption

A4.2 Full results – Fiji

A4.2.1 Supply

Table 62 Demand and supply on average day (2022) – Fiji

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Demand (MW)																								
Electricity demand	84.2	81.4	79.5	78.7	80.6	86.8	91.3	106.4	123.4	127.7	129.7	131.5	129.8	129.0	129.2	128.4	121.4	118.0	123.7	121.0	114.1	105.0	95.9	88.7
EV demand	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BESS charging	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total demand	84.2	81.4	79.5	78.7	80.6	86.8	91.3	106.4	123.4	127.7	129.7	131.5	129.8	129.0	129.2	128.4	121.4	118.0	123.7	121.0	114.1	105.0	95.9	88.7
Supply (MW)																								
Solar	-	-	-	-	-	0.0	0.1	0.7	1.6	2.3	2.7	2.9	2.8	2.5	2.1	1.5	0.9	0.2	0.0	-	-	-	-	-
BESS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydro	49.1	46.2	44.3	43.5	45.4	51.6	56.0	70.5	86.6	90.3	91.8	93.5	91.8	91.3	91.9	91.8	85.3	82.6	88.5	85.8	79.0	69.8	60.8	53.6
Diesel	35.2	35.2	35.2	35.2	35.2	35.2	35.2	35.2	35.2	35.2	35.2	35.2	35.2	35.2	35.2	35.2	35.2	35.2	35.2	35.2	35.2	35.2	35.2	35.2
Total	84.2	81.4	79.5	78.7	80.6	86.8	91.3	106.4	123.4	127.7	129.7	131.5	129.8	129.0	129.2	128.4	121.4	118.0	123.7	121.0	114.1	105.0	95.9	88.7
Solar spill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Source: Consultant

Table 63 Demand and supply on average day (2030, overnight charging) – Fiji

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Demand (MW)																								
Electricity demand	115.3	111.4	108.8	107.7	110.3	118.8	124.9	145.7	168.9	174.8	177.5	180.0	177.7	176.5	176.8	175.7	166.1	161.4	169.3	165.5	156.2	143.7	131.3	121.4
EV demand	48.2	35.0	35.0	23.9	15.1	8.4	13.8	21.9	14.0	9.8	4.4	6.7	5.9	6.3	7.1	12.6	20.4	30.8	29.0	16.8	10.9	11.8	45.7	59.0
BESS charging	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total demand	163.5	146.4	143.8	131.6	125.4	127.1	138.7	167.6	182.9	184.6	181.9	186.7	183.5	182.9	183.9	188.3	186.5	192.3	198.3	182.3	167.1	155.6	177.0	180.4
Supply (MW)																								
Solar	-	-	-	-	-	0.0	1.0	7.5	15.8	22.5	26.7	28.6	28.0	25.4	20.7	14.8	8.5	2.3	0.1	-	-	-	-	-
BESS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydro	95.3	78.2	75.6	63.4	57.3	59.0	69.5	91.9	98.9	94.0	87.0	90.0	87.4	89.4	95.0	105.4	109.8	121.9	130.1	114.2	98.9	87.4	108.9	112.3
Diesel	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1
Total	163.5	146.4	143.8	131.6	125.4	127.1	138.7	167.6	182.9	184.6	181.9	186.7	183.5	182.9	183.9	188.3	186.5	192.3	198.3	182.3	167.1	155.6	177.0	180.4
Solar spill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Source: Consultant

Table 64 Demand and supply on average day (2030, daytime charging) – Fiji

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Demand (MW)																								
Electricity demand	115.3	111.4	108.8	107.7	110.3	118.8	124.9	145.7	168.9	174.8	177.5	180.0	177.7	176.5	176.8	175.7	166.1	161.4	169.3	165.5	156.2	143.7	131.3	121.4
EV demand	9.0	6.5	6.5	4.5	2.8	1.6	2.6	15.4	31.6	44.5	53.6	58.4	59.0	55.3	47.5	35.8	20.5	4.9	5.4	3.1	2.0	2.2	8.5	11.0
BESS charging	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total demand	124.3	117.9	115.3	112.1	113.1	120.4	127.5	161.1	200.4	219.4	231.1	238.4	236.7	231.9	224.3	211.5	186.6	166.3	174.7	168.7	158.3	145.9	139.8	132.5
Supply (MW)																								
Solar	-	-	-	-	-	0.0	6.3	44.8	95.0	135.3	160.4	171.3	168.3	152.3	124.3	88.6	51.2	13.6	0.3	-	-	-	-	-
BESS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydro	98.2	91.9	89.3	86.1	87.0	94.3	95.2	90.2	79.4	58.0	44.6	41.0	42.3	53.6	74.0	96.8	109.3	126.7	148.1	142.6	132.2	119.9	113.8	106.4
Diesel	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.3	26.1	26.1	26.1	26.1	26.1
Total	124.3	117.9	115.3	112.1	113.1	120.4	127.5	161.1	200.4	219.4	231.1	238.4	236.7	231.9	224.3	211.5	186.6	166.3	174.7	168.7	158.3	145.9	139.8	132.5
Solar spill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Source: Consultant

A4.2.2 Marginal costs of supply

Table 65 Marginal costs of supply - Fiji

Item	Unit	2022	2030 Overnight	2030 Daytime
TOU cost-reflective tariffs				
Peak + Sunshine hours				
Generation	$/kWh sold	0.26	0.23	0.10
Network	$/kWh sold	0.07	0.07	0.07
Total	$/kWh sold	0.33	0.30	0.17
Peak + Non-sunshine hours				
Generation	$/kWh sold	0.26	0.26	0.23
Network	$/kWh sold	0.07	0.07	0.07
Total	$/kWh sold	0.33	0.33	0.30
Off-peak + Sunshine hours				
Generation	$/kWh sold	0.26	0.23	0.10
Network	$/kWh sold	0.02	0.02	0.02
Total	$/kWh sold	0.28	0.24	0.11
Off-peak + Non-sunshine hours				
Generation	$/kWh sold	0.26	0.26	0.23
Network	$/kWh sold	0.02	0.02	0.02
Total	$/kWh sold	0.28	0.28	0.25
Summary				

Peak + Sunshine hours	$/kWh sold	0.33	0.30	0.17
Peak + Non-sunshine hours	$/kWh sold	0.33	0.33	0.30
Off-peak + Sunshine hours	$/kWh sold	0.28	0.24	0.11
Off-peak + Non-sunshine hours	$/kWh sold	0.28	0.28	0.25
Average cost-reflective tariffs				
EV consumption				
Peak + Sunshine hours	%	16%	16%	73%
Peak + Non-sunshine hours	%	22%	22%	7%
Off-peak + Sunshine hours	%	10%	10%	10%
Off-peak + Non-sunshine hours	%	52%	52%	10%
Total	%	100%	100%	100%
Average tariff				
Average cost-reflective tariff	$/kWh sold	0.30	0.29	0.18

Source: Consultant

A4.3 Full results – Solomon Islands

A4.3.1 Supply

Table 66 Demand and supply on average day (2022) – Solomon Islands

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Demand (MW)																								
Electricity demand	10.5	9.3	8.9	8.6	8.4	8.3	8.2	8.3	8.6	9.9	12.0	12.4	12.6	12.2	12.1	12.4	12.3	12.0	11.2	10.5	11.3	11.2	10.8	10.3
EV demand	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BESS charging	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total demand	10.5	9.3	8.9	8.6	8.4	8.3	8.2	8.3	8.6	9.9	12.0	12.4	12.6	12.2	12.1	12.4	12.3	12.0	11.2	10.5	11.3	11.2	10.8	10.3
Supply (MW)																								
Solar	0.2	-	-	-	-	-	-	0.0	0.1	0.3	0.4	0.5	0.5	0.5	0.5	0.4	0.3	0.2	0.1	0.0	-	-	-	-
BESS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydro	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diesel	10.3	9.3	8.9	8.6	8.4	8.3	8.2	8.3	8.5	9.6	11.6	11.9	12.1	11.6	11.6	12.0	12.0	11.8	11.1	10.5	11.3	11.2	10.8	10.3
Total	10.5	9.3	8.9	8.6	8.4	8.3	8.2	8.3	8.6	9.9	12.0	12.4	12.6	12.2	12.1	12.4	12.3	12.0	11.2	10.5	11.3	11.2	10.8	10.3
Solar spill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Source: Consultant

Table 67 Demand and supply on average day (2030, overnight charging) – Solomon Islands

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Demand (MW)																								
Electricity demand	11.6	11.1	10.7	10.5	10.2	10.2	10.3	10.7	12.2	14.9	15.4	15.6	15.1	15.0	15.4	15.2	14.9	13.9	13.1	14.0	13.9	13.5	12.8	12.1
EV demand	3.1	2.3	2.3	1.5	1.0	0.5	0.9	1.4	0.9	0.6	0.3	0.4	0.4	0.4	0.5	0.8	1.3	2.0	1.9	1.1	0.7	0.8	3.0	3.8
BESS charging	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total demand	14.7	13.3	13.0	12.0	11.2	10.8	11.2	12.1	13.1	15.5	15.7	16.1	15.5	15.4	15.8	16.1	16.2	15.9	15.0	15.1	14.6	14.2	15.8	15.9
Supply (MW)																								
Solar	-	-	-	-	-	-	0.2	2.3	5.4	7.9	9.5	10.4	10.5	9.7	7.8	5.8	3.5	1.2	0.0	-	-	-	-	-
BESS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydro	12.0	10.6	10.3	9.3	8.5	8.1	8.4	7.1	5.0	5.0	3.5	3.0	2.3	3.0	5.3	7.6	10.0	12.0	12.2	12.4	11.9	11.5	13.1	13.2
Diesel	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Total	14.7	13.3	13.0	12.0	11.2	10.8	11.2	12.1	13.1	15.5	15.7	16.1	15.5	15.4	15.8	16.1	16.2	15.9	15.0	15.1	14.6	14.2	15.8	15.9
Solar spill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Source: Consultant

Table 68 Demand and supply on average day (2030, daytime charging) – Solomon Islands

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Demand (MW)																								
Electricity demand	11.6	11.1	10.7	10.5	10.2	10.2	10.3	10.7	12.2	14.9	15.4	15.6	15.1	15.0	15.4	15.2	14.9	13.9	13.1	14.0	13.9	13.5	12.8	12.1
EV demand	0.6	0.4	0.4	0.3	0.2	0.1	0.2	1.0	2.0	2.9	3.5	3.8	3.8	3.6	3.1	2.3	1.3	0.3	0.4	0.2	0.1	0.1	0.6	0.7
BESS charging	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total demand	12.2	11.5	11.1	10.7	10.4	10.3	10.5	11.7	14.3	17.8	18.9	19.4	18.9	18.5	18.5	17.6	16.2	14.2	13.4	14.2	14.0	13.6	13.4	12.8
Supply (MW)																								
Solar	-	-	-	-	-	-	0.3	3.5	8.1	11.8	14.3	15.5	15.8	14.5	11.7	8.6	5.3	1.8	0.0	-	-	-	-	-
BESS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydro	12.2	11.5	11.1	10.7	10.4	10.3	10.2	8.2	6.2	6.0	4.6	3.9	3.2	4.1	6.7	8.9	11.0	12.4	13.4	14.2	14.0	13.6	13.4	12.8
Diesel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	12.2	11.5	11.1	10.7	10.4	10.3	10.5	11.7	14.3	17.8	18.9	19.4	18.9	18.5	18.5	17.6	16.2	14.2	13.4	14.2	14.0	13.6	13.4	12.8
Solar spill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Source: Consultant

A4.3.2 Marginal costs of supply

Table 69 Marginal costs of supply – Solomon Islands

Item	Unit	2022	2030 Overnight	2030 Daytime
TOU cost-reflective tariffs				
Peak + Sunshine hours				
Generation	$/kWh sold	0.36	0.31	0.11
Network	$/kWh sold	0.08	0.08	0.08
Total	$/kWh sold	0.44	0.39	0.19
Peak + Non-sunshine hours				
Generation	$/kWh sold	0.36	0.11	0.11
Network	$/kWh sold	0.08	0.08	0.08
Total	$/kWh sold	0.44	0.19	0.19
Off-peak + Sunshine hours				
Generation	$/kWh sold	0.36	0.31	0.11
Network	$/kWh sold	0.02	0.02	0.02
Total	$/kWh sold	0.38	0.33	0.13
Off-peak + Non-sunshine hours				
Generation	$/kWh sold	0.36	0.11	0.11
Network	$/kWh sold	0.02	0.02	0.02
Total	$/kWh sold	0.38	0.13	0.13
Summary				

Peak + Sunshine hours	$/kWh sold	0.44	0.39	0.19
Peak + Non-sunshine hours	$/kWh sold	0.44	0.19	0.19
Off-peak + Sunshine hours	$/kWh sold	0.38	0.33	0.13
Off-peak + Non-sunshine hours	$/kWh sold	0.38	0.13	0.13
Average cost-reflective tariffs				
EV consumption				
Peak + Sunshine hours	%	16%	16%	73%
Peak + Non-sunshine hours	%	22%	22%	7%
Off-peak + Sunshine hours	%	10%	10%	10%
Off-peak + Non-sunshine hours	%	52%	52%	10%
Total	%	100%	100%	100%
Average tariff				
Average cost-reflective tariff	$/kWh sold	0.40	0.20	0.18

Source: Consultant

A4.4 Full results – Marshall Islands

A4.4.1 Supply

Table 70 Demand and supply on average day (2022) – Marshall Islands

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Demand (MW)																								
Electricity demand	7.2	7.1	6.9	6.8	6.7	6.7	6.6	6.7	7.2	7.7	8.1	8.3	8.4	8.5	8.5	8.4	8.4	7.9	7.9	8.5	8.6	8.4	8.1	7.9
EV demand	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BESS charging	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total demand	7.2	7.1	6.9	6.8	6.7	6.7	6.6	6.7	7.2	7.7	8.1	8.3	8.4	8.5	8.5	8.4	8.4	7.9	7.9	8.5	8.6	8.4	8.1	7.9
Supply (MW)																								
Solar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BESS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydro	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diesel	7.2	7.1	6.9	6.8	6.7	6.7	6.6	6.7	7.2	7.7	8.1	8.3	8.4	8.5	8.5	8.4	8.4	7.9	7.9	8.5	8.6	8.4	8.1	7.9
Total	7.2	7.1	6.9	6.8	6.7	6.7	6.6	6.7	7.2	7.7	8.1	8.3	8.4	8.5	8.5	8.4	8.4	7.9	7.9	8.5	8.6	8.4	8.1	7.9
Solar spill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Source: Consultant

Table 71 Demand and supply on average day (2030, overnight charging) – Marshall Islands

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Demand (MW)																								
Electricity demand	8.4	8.2	8.0	7.9	7.8	7.8	7.7	7.8	8.4	9.0	9.4	9.6	9.8	9.9	9.8	9.8	9.7	9.2	9.2	9.9	10.0	9.8	9.4	9.2
EV demand	0.6	0.5	0.5	0.3	0.2	0.1	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.4	0.2	0.1	0.2	0.6	0.8
BESS charging	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total demand	9.0	8.7	8.5	8.2	8.0	7.9	7.9	8.0	8.6	9.1	9.4	9.7	9.9	10.0	9.9	10.0	10.0	9.6	9.6	10.1	10.1	9.9	10.0	9.9
Supply (MW)																								
Solar	-	-	-	-	-	-	0.0	1.0	3.1	4.9	6.5	7.5	7.8	7.6	6.8	5.3	3.4	1.4	0.1	-	-	-	-	-
BESS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	-	-	-
Hydro	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diesel	9.0	8.7	8.5	8.2	8.0	7.9	7.9	7.0	5.5	4.2	2.9	2.2	2.1	2.4	3.1	4.6	6.6	8.2	9.5	10.1	10.1	9.9	10.0	9.9
Total	9.0	8.7	8.5	8.2	8.0	7.9	7.9	8.0	8.6	9.1	9.4	9.7	9.9	10.0	9.9	10.0	10.0	9.6	9.6	10.1	10.1	9.9	10.0	9.9
Solar spill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Source: Consultant

Table 72 Demand and supply on average day (2030, daytime charging) – Marshall Islands

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Demand (MW)																								
Electricity demand	8.4	8.2	8.0	7.9	7.8	7.8	7.7	7.8	8.4	9.0	9.4	9.6	9.8	9.9	9.8	9.8	9.7	9.2	9.2	9.9	10.0	9.8	9.4	9.2
EV demand	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.2	0.4	0.6	0.7	0.8	0.8	0.7	0.6	0.5	0.3	0.1	0.1	0.0	0.0	0.0	0.1	0.1
BESS charging	-	-	-	-	-	-	0.0	1.1	3.4	5.4	7.1	8.2	8.5	8.3	7.4	5.8	3.7	1.5	0.1	-	-	-	-	-
Total demand	8.5	8.3	8.1	8.0	7.8	7.9	7.8	9.1	12.1	14.9	17.2	18.6	19.1	18.9	17.9	16.0	13.6	10.8	9.4	9.9	10.0	9.8	9.5	9.3
Supply (MW)																								
Solar	-	-	-	-	-	-	0.1	2.9	8.5	13.6	17.2	18.6	19.1	18.9	17.9	14.6	9.2	3.8	0.3	-	-	-	-	-
BESS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydro	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diesel	8.5	8.3	8.1	8.0	7.8	7.9	7.7	6.2	3.7	1.4	-	-	-	-	-	1.5	4.4	7.0	9.1	9.9	10.0	9.8	9.5	9.3
Total	8.5	8.3	8.1	8.0	7.8	7.9	7.8	9.1	12.1	14.9	17.2	18.6	19.1	18.9	17.9	16.0	13.6	10.8	9.4	9.9	10.0	9.8	9.5	9.3
Solar spill	-	-	-	-	-	-	-	-	-	-	0.7	2.1	2.4	1.9	0.8	-	-	-	-	-	-	-	-	-

Source: Consultant

A4.4.2 Marginal costs of supply

Table 73 Marginal costs of supply – Marshall Islands

Item	Unit	2022	2030 Overnight	2030 Daytime
TOU cost-reflective tariffs				
Peak + Sunshine hours				
Generation	$/kWh sold	0.53	0.46	0.16
Network	$/kWh sold	0.10	0.10	0.10
Total	$/kWh sold	0.63	0.55	0.26
Peak + Non-sunshine hours				
Generation	$/kWh sold	0.53	0.53	0.44
Network	$/kWh sold	0.10	0.10	0.10
Total	$/kWh sold	0.63	0.63	0.54
Off-peak + Sunshine hours				
Generation	$/kWh sold	0.53	0.46	0.16
Network	$/kWh sold	0.02	0.02	0.02
Total	$/kWh sold	0.55	0.47	0.18
Off-peak + Non-sunshine hours				
Generation	$/kWh sold	0.53	0.53	0.44
Network	$/kWh sold	0.02	0.02	0.02
Total	$/kWh sold	0.55	0.55	0.46

Summary				
Peak + Sunshine hours	$/kWh sold	0.63	0.55	0.26
Peak + Non-sunshine hours	$/kWh sold	0.63	0.63	0.54
Off-peak + Sunshine hours	$/kWh sold	0.55	0.47	0.18
Off-peak + Non-sunshine hours	$/kWh sold	0.55	0.55	0.46
Average cost-reflective tariffs				
EV consumption				
Peak + Sunshine hours	%	16%	16%	73%
Peak + Non-sunshine hours	%	22%	22%	7%
Off-peak + Sunshine hours	%	10%	10%	10%
Off-peak + Non-sunshine hours	%	52%	52%	10%
Total	%	100%	100%	100%
Average tariff				
Average cost-reflective tariff	$/kWh sold	0.58	0.56	0.29

Source: Consultant

A4.5 Full results – Tuvalu

A4.5.1 Supply

Table 74 Demand and supply on average day (2022) – Tuvalu

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Demand (MW)																								
Electricity demand	0.7	0.7	0.7	0.7	0.9	0.9	1.0	0.9	1.0	1.1	1.1	1.1	1.1	1.3	1.2	1.0	0.9	1.0	1.0	0.9	0.9	0.8	0.8	0.7
EV demand	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BESS charging	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total demand	0.7	0.7	0.7	0.7	0.9	0.9	1.0	0.9	1.0	1.1	1.1	1.1	1.1	1.3	1.2	1.0	0.9	1.0	1.0	0.9	0.9	0.8	0.8	0.7
Supply (MW)																								
Solar	-	-	-	-	-	-	0.0	0.2	0.5	0.7	0.9	1.0	1.0	0.9	0.7	0.6	0.3	0.1	-	-	-	-	-	-
BESS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-
Hydro	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diesel	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.6	0.5	0.4	0.2	0.1	0.1	0.4	0.4	0.5	0.6	0.9	0.9	0.9	0.9	0.8	0.8	0.7
Total	0.7	0.7	0.7	0.7	0.9	0.9	1.0	0.9	1.0	1.1	1.1	1.1	1.1	1.3	1.2	1.0	0.9	1.0	1.0	0.9	0.9	0.8	0.8	0.7
Solar spill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Source: Consultant

Table 75 Demand and supply on average day (2030, overnight charging) – Tuvalu

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Demand (MW)																								
Electricity demand	1.1	1.1	1.0	1.0	1.3	1.4	1.5	1.4	1.5	1.7	1.7	1.7	1.6	2.0	1.8	1.6	1.4	1.5	1.5	1.4	1.4	1.2	1.2	1.1
EV demand	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BESS charging	-	-	-	-	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-	-	-
Total demand	1.1	1.1	1.0	1.0	1.3	1.4	1.5	1.4	1.5	1.7	1.7	1.7	1.6	2.1	1.8	1.6	1.4	1.5	1.5	1.4	1.4	1.2	1.2	1.1
Supply (MW)																								
Solar	-	-	-	-	-	-	0.1	0.4	0.9	1.3	1.6	1.7	1.6	1.6	1.3	1.0	0.6	0.1	-	-	-	-	-	-
BESS	-	-	-	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-	0.0	0.1	0.0	-	-	-	-
Hydro	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diesel	1.1	1.1	1.0	1.0	1.3	1.4	1.4	0.9	0.6	0.4	0.1	-	-	0.5	0.5	0.6	0.8	1.4	1.4	1.4	1.4	1.2	1.2	1.1
Total	1.1	1.1	1.0	1.0	1.3	1.4	1.5	1.4	1.5	1.7	1.7	1.7	1.6	2.1	1.8	1.6	1.4	1.5	1.5	1.4	1.4	1.2	1.2	1.1
Solar spill	-	-	-	-	-	-	-	-	-	-	-	0.0	0.1	-	-	-	-	-	-	-	-	-	-	-

Source: Consultant

Table 76 Demand and supply on average day (2030, daytime charging) – Tuvalu

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Demand (MW)																								
Electricity demand	1.1	1.1	1.0	1.0	1.3	1.4	1.5	1.4	1.5	1.7	1.7	1.7	1.6	2.0	1.8	1.6	1.4	1.5	1.5	1.4	1.4	1.2	1.2	1.1
EV demand	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BESS charging	-	-	-	-	-	-	0.1	0.7	1.4	2.0	2.5	2.8	2.8	2.6	2.1	1.6	0.9	0.2	-	-	-	-	-	-
Total demand	1.1	1.1	1.0	1.0	1.3	1.4	1.6	2.1	2.9	3.7	4.2	4.5	4.4	4.6	3.9	3.1	2.3	1.8	1.5	1.4	1.4	1.2	1.2	1.1
Supply (MW)																								
Solar	-	-	-	-	-	-	0.2	1.4	2.9	3.7	4.2	4.5	4.4	4.6	3.9	3.1	1.8	0.5	-	-	-	-	-	-
BESS	1.1	1.1	1.0	1.0	1.3	1.4	1.4	0.7	0.1	-	-	-	-	-	-	-	0.4	1.3	1.5	1.4	1.4	1.2	1.2	1.1
Hydro	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diesel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.1	1.1	1.0	1.0	1.3	1.4	1.6	2.1	2.9	3.7	4.2	4.5	4.4	4.6	3.9	3.1	2.3	1.8	1.5	1.4	1.4	1.2	1.2	1.1
Solar spill	-	-	-	-	-	-	-	-	-	0.4	0.9	1.2	1.2	0.6	0.4	0.1	-	-	-	-	-	-	-	-

Source: Consultant

A4.5.2 Marginal costs of supply

Table 77 Marginal costs of supply - Tuvalu

Item	Unit	2022	2030 Overnight	2030 Daytime
TOU cost-reflective tariffs				
Peak + Sunshine hours				
Generation	$/kWh sold	0.43	0.37	0.13
Network	$/kWh sold	0.07	0.07	0.07
Total	$/kWh sold	0.51	0.45	0.21
Peak + Non-sunshine hours				
Generation	$/kWh sold	0.43	0.43	0.36
Network	$/kWh sold	0.07	0.07	0.07
Total	$/kWh sold	0.51	0.51	0.43
Off-peak + Sunshine hours				
Generation	$/kWh sold	0.43	0.37	0.13
Network	$/kWh sold	0.02	0.02	0.02
Total	$/kWh sold	0.45	0.39	0.15
Off-peak + Non-sunshine hours				
Generation	$/kWh sold	0.43	0.43	0.36
Network	$/kWh sold	0.02	0.02	0.02
Total	$/kWh sold	0.45	0.45	0.38
Summary				

Peak + Sunshine hours	$/kWh sold	0.51	0.45	0.21
Peak + Non-sunshine hours	$/kWh sold	0.51	0.51	0.43
Off-peak + Sunshine hours	$/kWh sold	0.45	0.39	0.15
Off-peak + Non-sunshine hours	$/kWh sold	0.45	0.45	0.38
Average cost-reflective tariffs				
EV consumption				
Peak + Sunshine hours	%	16%	16%	73%
Peak + Non-sunshine hours	%	22%	22%	7%
Off-peak + Sunshine hours	%	10%	10%	10%
Off-peak + Non-sunshine hours	%	52%	52%	10%
Total	%	100%	100%	100%
Average tariff				
Average cost-reflective tariff	$/kWh sold	0.47	0.45	0.23

Source: Consultant

A5 Cost-benefit analysis – Detailed results

A5.1 Assumptions

Upfront costs

The dominant upfront cost relates to the cost of vehicle purchase. We assume the following vehicles and costs for our study of Fiji. We have selected common ICE vehicles in the Pacific Island Countries, as well as likely EV models. For cars and vans we assume that all vehicles, both ICE and EVs will be second-hand, in line with the existing patterns of vehicle ownership observed in the Pacific Island Countries. For motorbikes, we assume new EVs, given the availability of affordable, new electric motorbikes from East and South-East Asian Markets. For example, the proposed pilot projects in Tuvalu will rely on new electric motorbikes sourced from a Chinese manufacturer.

Fiji Revenue and Customs Services publishes the Cost, Insurance and Freight (CIF) value (ie pre-tax and duty) of all imported vehicles on a quarterly basis. This provides the basis for most of our assumptions, given the cost-benefit analysis does not consider the impact of taxation.

The table below provides an overview of the chosen vehicles, including the assumed cost for Fiji, and the relevant technical specifications.

Table 78 Assumed vehicle parameters and costs

	Cars		Motorbikes		Vans	
	ICE	EV	ICE	EV	ICE	EV
Assumed vehicle	Toyota Corolla 2015	Nissan Leaf 2018	Honda PCX	Gesists (New)	Nissan Caravan	Nissan E-NV200 2018
Cost (US$)	3,700	10,000	800	2,000	6,000	20,000
Assumed residual lifetime (years)	10	10	10	10	10	10
Efficiency (l or kWh per 100 km)	5.6 l	16.3 kWh	2.31	2.9 kWh	9.8 l	21.0 kWh
Emissions (kg Co2 per 100 km)	12.9		5.36		16.6	

Note: The cost of motorbikes has been obtained from a range of sources, given the absence of data on recently imported motorbikes from Fiji Revenue and Customs Services. The cost of a used Nissan-ENV200 is based on the Japanese second-hand market and adjusted using ratios between other vehicles which are available in both the Japanese and Fiji market. Source: Consultant based on various sources

In our cost-benefit analysis, we annuitise the costs based on the total upfront, assumed lifetime, and the social discount rate of 6%[24].

A further adjustment is made for the purchase of ICE vehicles, to reflect that an individual is likely to already possess an ICE vehicle, and as a result if they were to purchase an EV they would be replacing this vehicle prematurely. We incorporate a five-year adjustment, discounted at the social discount rate, to reflect this.

For cars and motorbikes, we assume no additional costs for a private household charger or electricity connection upgrade. This is because, as outlined in Section 3.3.3 we assume charging will occur via trickle charging. And most EVs come with a charger that facilitate such charging.

For vans, we assume that a household charger and an electricity connection upgrade will be required. The assumed costs, for Fiji, are summarised in the table below. We annuitised the cost based on an assumed lifetime of 10 years.

Table 79 Assumptions for cost of household charger for electric vans

	Assumptions under BAU 2022 scenario
Cost of Level 2 charger (US$)	1,000
Cost of household electricity connection upgrade (US$)	600
Assumed lifetime (years)	10

Source: Consultant

Charging and fuel costs

The key operating cost is the cost of fuel, for ICE vehicles, and the cost of electricity for EVs.

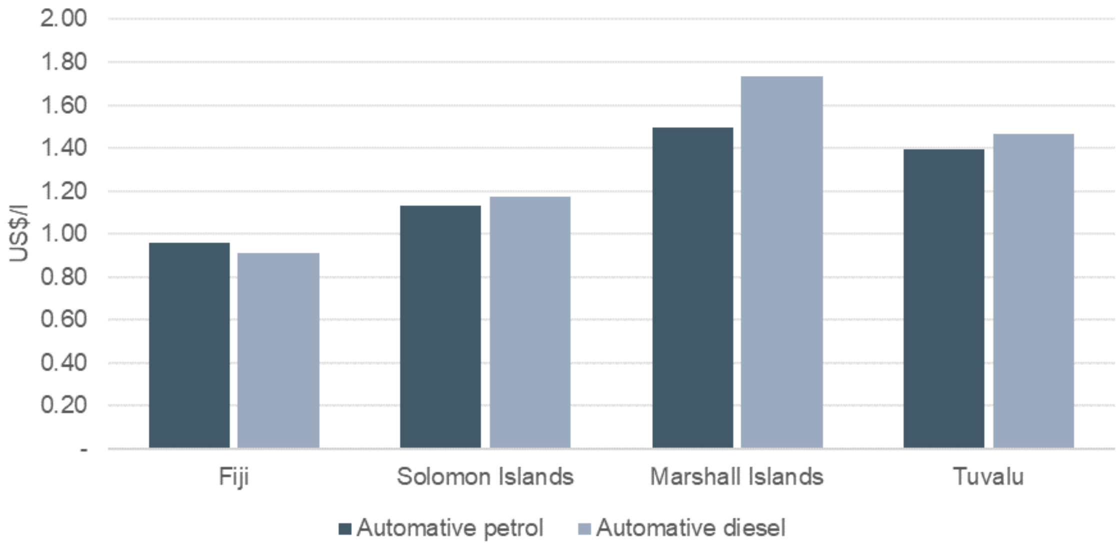
For ICE vehicles, we calculated the cost of fuel as follows:

- **Determine the price of automotive petrol or diesel –** The cost of fuel is associated with considerable uncertainty, particularly given current rises in global commodity prices. We rely on the World Bank's forecast crude oil prices for 2024. We assume that cars and motorbikes use petrol while vans use diesel fuel.

  To calculate specific fuel prices for the Pacific Island Countries we calculate the ratio between the historic fuel prices for each of the four sample countries from the Pacific Fuel Price Monitor and the historical prices from the World Bank. The resulting prices are summarised in the figure below.

[24] This is the default social discount rate used by the World Bank

Figure 39 Forecast automotive fuel prices (without tax) in Pacific Island Countries



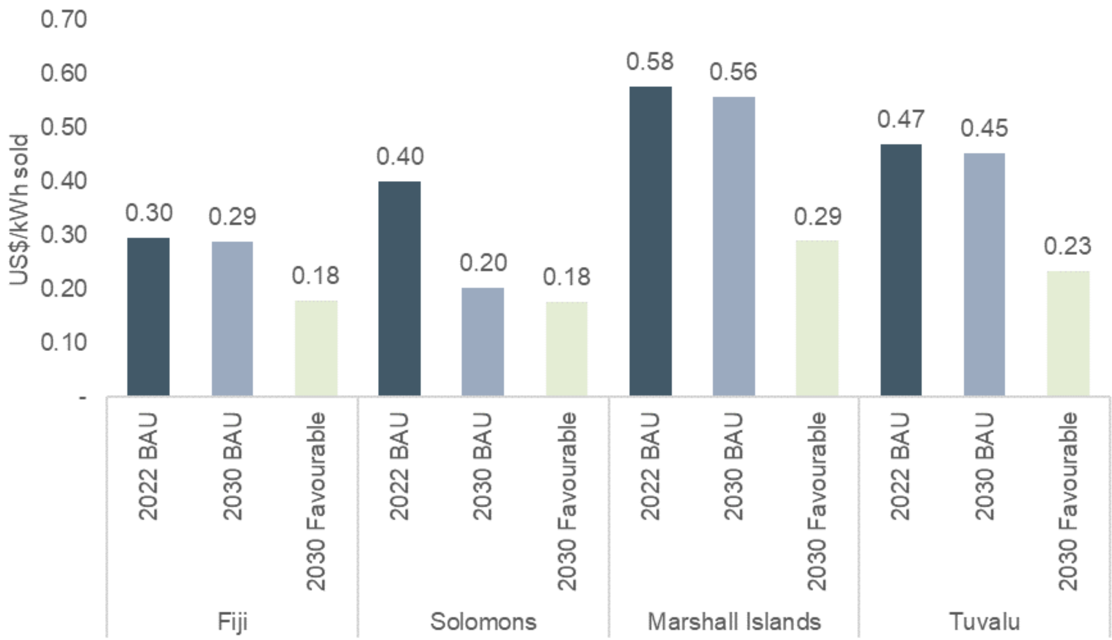
Source: Consultant analysis

- **Calculate fuel consumption –** We use the average fuel consumption based on the specifications of the assumed ICE vehicles. Along with the assumed distances travelled under each use case, we calculate fuel consumption.

- **Calculate fuel cost –** The product of fuel cost and fuel consumption provides the fuel cost.

For EVs we calculate fuel costs based on the grid impact analysis provided in Section A4.1 These tariffs are based on the assumed cost -reflective tariff at different times (combinations of peak and off-peak and sunshine and non-shine hours) and assumed EV charging profiles. The figure below provides an overview of the cost-reflective tariffs assumed under the different scenarios and countries. Note that as this cost already includes a network charge, which reflects the cost of maintaining and investing in the distribution networks, we do not apply an additional cost of network strengthening.

Figure 40 Assumed cost-reflective tariffs under different scenarios



Source: Consultant analysis

In addition, we assume costs related to the use of public charging stations. This reflects the societal cost incurred from the investments in installing public charging stations, which covers both the material cost of the charger and associated materials, and the relevant labour cost. We assume a cost of US$8,000 per public charging station, with an assumed lifetime of ten years, and each charging station supporting ten EVs. This reflects a relatively high density compared to more mature markets; however we believe this is reasonable given the relatively small market size for EVs in the Pacific Island Countries and likely slow rate of EV uptake (at least in absolute terms) in the short to medium term.

We assume that there is no public charging under the BAU 2022 scenario, given the current absence of public charging stations in the Pacific Island Countries. In the BAU 2030 scenario we assume that 25% of charging occurs in public charging stations, while in the Favourable 2030 scenario, 40% of charging occurs in public charging stations.

Maintenance costs

The absence of an ICE mean that EVs have considerably fewer moveable parts. As a result, it is generally assumed that the maintenance costs of EVs is considerably lower than that of ICE vehicles. Estimates in the US suggest that EV maintenance costs are 40% lower than comparable ICE vehicles[25].

We note that assumptions about maintenance costs for vehicles vary considerably, with some expressed as a share of vehicle value and others on a distance basis. In particular, there is a relative lack of robust information on the cost of vehicle maintenance in developing countries where labour costs tend to be cheaper.

[25] OSTI, 2021, Comprehensive Total Cost of Ownership Quantification for Vehicles with Different Size Classes and Powertrains

Due to this lack of information on the cost of vehicle maintenance, and the absence of specific information for the Pacific Island Countries, we have used values from a study in Bhutan as a roughly comparable developing country with low labour costs[26]. This study provides a base maintenance cost of 1% of the vehicle value for EVs and 5% for ICE. As the maintenance cost is expressed a percentage, and the vehicle value of EVs is typically higher than that of an ICE the differential is somewhat less pronounced. We assume that these values are reasonable assumptions given that despite the comparably small distances travelled in the Pacific Island Countries, the climatic conditions (eg. saltwater exposure) balance out the maintenance requirements. In addition, we assume that the vehicles being operated are five years old, and that due to the scarcity of spare parts for EVs in the Pacific Island Countries we apply a 0.5% uplift to the value for EVs. The resulting maintenance cost values are summarised in the table below.

Table 80 Assumed maintenance costs – Fiji, BAU 2022 scenario

	ICE	EV
Base maintenance cost	5% of vehicle value	1% of vehicle value
Increase due to vehicle age	Uplift of 1.4% - calculated as 5% per annum and a vehicle age of five years	Uplift of 0.1% - calculated as 1% per annum and a vehicle age of five years
Remote market uplift	0	0.5%
Total maintenance cost	6.4% of vehicle value	1.6% of vehicle value

Source: Consultant analysis

Environmental costs

A key component of this societal cost-benefit analysis relates to the cost of emissions. This includes both CO_2 emissions from ICEs, as well as the emissions arising from electricity generation related to the charging of EVs. Our assumptions are:

- **ICE Vehicles -** Calculate emissions based on the published emissions factors of the assumed vehicles and the assumed distance travelled.
- **EVs –** Calculate emissions based on generic emissions factors for diesel generators and the assumed share of electricity for EV charging provided by diesel generators.

We quantify the cost of these emissions using the high-end estimate of the World Bank's shadow price of carbon set out by the High-Level Commission on Carbon Prices. This value is currently US$80/MT, which is more than the carbon price on voluntary carbon credit markets, but less than that currently observed in many emissions trading scheme markets.

Cost adjustments outside of Fiji

The values expressed above are based on assumptions for Fiji. However, we note that Fiji is a major shipping hub for the region. It is also, by far, the largest of the Pacific Island Countries, and as a result it has some opportunity to benefit from scale economies.

[26] Norbu, 2015, A Cost Benefit Analysis of introducing Electric Vehicles in Bhutan

To reflect the higher costs incurred in other Pacific Island Countries, we use a cost multiplier. This applies to the cost of the vehicles (ICE and EV), and, where applicable, any charging infrastructure and household electricity upgrades. Given maintenance costs are expressed as a percentage of vehicle value we do not escalate this. This approach has been taken given the absence of robust data, particularly for countries with smaller markets.

For the Marshall Islands and Tuvalu we calculate the multiplier based on Purchasing Power Parity conversion factors provided by the World Bank. For the Solomon Islands, the conversion factor based on these conversion factors is unreasonably high, so we assume a factor of two (noting that average cost levels in the Solomon Island tend to be considerably higher than many other Pacific Island Countries). The values are summarised in the table below.

Table 81 Cost level conversion factors

Country	Conversion Factor
Fiji	1.00
Solomon Islands	2.00
Marshall Islands	1.10
Tuvalu	1.42

Source: Consultant analysis based on World Bank PPP conversion factors

Difference in assumptions between scenarios

The table below describes the key differences between the assumptions made in the three different scenarios. These mostly reflect the assumption that the costs of EVs and associated infrastructure are expected to decrease over time. These assumptions are based on a general survey of literature and expert opinion. However, we stress that there is considerably uncertainty about the development of the cost of these technologies in the future. Note that our assumed reduction in cost is likely a conservative estimate when compared to the generally forecast reduction in the cost of EVs over the next decade. Our assumption reflects the expected continued reliance on second-hand vehicles.

Table 82 Differences in assumptions between scenarios

	BAU 2022	BAU 2030	Favourable 2030
Upfront costs			
Cost of vehicle purchase		Assume 30% reduction in cost of EV	Assume 50% reduction in cost of ICE EV
Cost of charging infrastructure		Assume 20% reduction in cost of relevant infrastructure	Assume 30% reduction in cost of relevant infrastructure
Fuel/charging costs			
Fuel consumption		Assume 10% reduction in ICE consumption Assume 10% reduction in EV usage	Assume 10% reduction in ICE consumption Assume 20% reduction in EV usage

	BAU 2022	BAU 2030	Favourable 2030
Cost of electricity *(More details in Section **Error! Reference source not found.**)*	100% use of diesel to meet EV demand	Only 20% of daytime EV charging supplied by solar. 100% use of diesel outside of sunshine hours	100% of daytime EV charging supplied by solar, thanks to increase RE investment. 80% use of BESS (charged by solar) outside of sunshine hours
Charging behaviour *(More details in Section **Error! Reference source not found.**)*	Mostly overnight EV charging	Mostly overnight EV charging	Mostly daytime EV charging, thanks to TOU tariffs and provision of public charging facilities
Cost of public charging station		Assume 10% reduction in cost	Assume 20% reduction in cost
Maintenance costs			
Maintenance cost as share of vehicle cost			Assume 0.5 percentage point reduction in maintenance cost of EV
Environmental cost			
Emissions factors		Assume 10% reduction in emissions of ICE vehicle	Assume 10% reduction in emissions of ICE vehicle

Source: Consultant

A5.2 Full results – Fiji

A5.2.1 Electric cars

Table 83 Annual net savings of electric car use, comparison of scenarios and use cases – Fiji (US$ per year)

Use case	Low			Medium			High		
Scenario	BAU 2022	BAU 2030	Favourable 2030	BAU 2022	BAU 2030	Favourable 2030	BAU 2022	BAU 2030	Favourable 2030
Reduction in upfront cost	-983	-575	-356	-983	-575	-356	-983	-575	-356
Reduction in charging/ fuelling cost	32	34	138	63	68	276	127	137	553
Reduction in maintenance cost	77	125	182	77	125	182	77	125	182
Reduction in environmental costs	41	40	46	82	80	92	165	159	183
Total costs	**-833**	**-377**	**10**	**-760**	**-303**	**194**	**-615**	**-155**	**562**

Source: Consultant

A5.2.2 Electric motorbikes

Table 84 Annual net savings of electric motorbike use, comparison of scenarios and use cases – Fiji (US$ per year)

Use case	Low			Medium		
Scenario	BAU 2022	BAU 2030	Favourable 2030	BAU 2022	BAU 2030	Favourable 2030
Reduction in upfront cost	-191	-109	-107	-191	-109	-107
Reduction in charging/ fuelling cost	37	34	43	75	68	87
Reduction in maintenance cost	19	29	40	19	29	40
Reduction in environmental costs	10	10	10	21	19	20
Total costs	**-124**	**-36**	**-13**	**-76**	**7**	**40**

Source: Consultant

6.7.1 Electric vans

Table 85 Annual net savings of electric van use, comparison of scenarios and use cases – Fiji (US$ per year)

Use case	Medium			High		
Scenario	BAU 2022	BAU 2030	Favourable 2030	BAU 2022	BAU 2030	Favourable 2030
Reduction in upfront cost	-2,326	-1,444	-1,591	-2,326	-1,444	-1,591
Reduction in charging/ fuelling cost	494	468	915	987	937	1,830
Reduction in maintenance cost	64	160	274	64	160	274
Reduction in environmental costs	177	171	196	353	342	393
Total costs	**-1,591**	**-644**	**-206**	**-921**	**-5**	**906**

Source: Consultant

A5.3 Full results – Solomon Islands

A5.3.1 Electric cars

Table 86 Annual net savings of electric car use, comparison of scenarios and use cases – Solomon Islands (US$ per year)

Use case	Low			Medium			High		
Scenario	BAU 2022	BAU 2030	Favourable 2030	BAU 2022	BAU 2030	Favourable 2030	BAU 2022	BAU 2030	Favourable 2030
Reduction in upfront cost	-1,966	-1,151	-660	-1,966	-1,151	-660	-1,966	-1,151	-660
Reduction in charging/ fuelling cost	-7	100	124	-14	200	248	-28	399	497
Reduction in maintenance cost	154	250	364	154	250	364	154	250	364
Reduction in environmental costs	26	25	34	51	50	68	102	101	136
Total savings	**-1,794**	**-776**	**-138**	**-1,775**	**-651**	**20**	**-1,738**	**-401**	**336**

Source: Consultant

A5.3.2 Electric motorbikes

Table 87 Annual net savings of electric motorbike use, comparison of scenarios and use cases – Solomon Islands (US$ per year)

Use case	Low			Medium		
Scenario	BAU 2022	BAU 2030	Favourable 2030	BAU 2022	BAU 2030	Favourable 2030
Reduction in upfront cost	-381	-218	-162	-381	-218	-162
Reduction in charging/ fuelling cost	26	33	35	53	66	71
Reduction in maintenance cost	38	58	80	38	58	80
Reduction in environmental costs	7	6	7	13	13	14
Total savings	**-309**	**-121**	**-39**	**-276**	**-81**	**4**

Source: Consultant

A5.3.3 Electric vans

Table 88 Annual net savings of electric van use, comparison of scenarios and use cases – Solomon Islands (US$ per year)

Use case	Medium			High		
Scenario	BAU 2022	BAU 2030	Favourable 2030	BAU 2022	BAU 2030	Favourable 2030
Reduction in upfront cost	-4,854	-3,096	-3,182	-4,854	-3,096	-3,182
Reduction in charging/ fuelling cost	450	951	1,077	900	1,903	2,154
Reduction in maintenance cost	128	320	548	128	320	548
Reduction in environmental costs	131	129	174	263	259	349
Total savings	**-4,145**	**-1,695**	**-1,383**	**-3,564**	**-615**	**-132**

Source: Consultant

A5.4 Full results – Marshall Islands

A5.4.1 Electric cars

Table 89 Annual net savings of electric car use, comparison of scenarios and use cases – Marshall Islands (US$ per year)

Use case	Low			Medium			High		
Scenario	BAU 2022	BAU 2030	Favourable 2030	BAU 2022	BAU 2030	Favourable 2030	BAU 2022	BAU 2030	Favourable 2030
Reduction in upfront cost	-1,081	-633	-386	-1,081	-633	-386	-1,081	-633	-386
Reduction in charging/ fuelling cost	-28	-17	103	-55	-34	207	-111	-69	414
Reduction in maintenance cost	84	137	200	84	137	200	84	137	200
Reduction in environmental costs	19	19	22	37	37	45	75	74	89
Total savings	**-1,006**	**-494**	**-61**	**-1,015**	**-493**	**65**	**-1,033**	**-490**	**317**

Source: Consultant

A5.4.2 Electric motorbikes

Table 90 Annual net savings of electric motorbike use, comparison of scenarios and use cases – Marshall Islands (US$ per year)

Use case	Low			Medium		
Scenario	BAU 2022	BAU 2030	Favourable 2030	BAU 2022	BAU 2030	Favourable 2030
Reduction in upfront cost	-210	-120	-112	-210	-120	-112
Reduction in charging/ fuelling cost	26	24	36	52	48	71
Reduction in maintenance cost	21	32	44	21	32	44
Reduction in environmental costs	5	5	5	11	10	11
Total savings	**-157**	**-59**	**-27**	**-126**	**-30**	**14**

Source: Consultant

A5.4.3 Electric vans

Table 91 Annual net savings of electric van use, comparison of scenarios and use cases – Marshall Islands (US$ per year)

Use case	Medium			High		
Scenario	BAU 2022	BAU 2030	Favourable 2030	BAU 2022	BAU 2030	Favourable 2030
Reduction in upfront cost	-2,670	-1,703	-1,750	-2,670	-1,703	-1,750
Reduction in charging/ fuelling cost	536	522	1,144	1,071	1,044	2,287
Reduction in maintenance cost	70	176	301	70	176	301
Reduction in environmental costs	96	95	115	192	191	201
Total savings	**-1,968**	**-910**	**-191**	**-1,336**	**-292**	**1,067**

Source: Consultant

A5.5 Full results – Tuvalu

A5.5.1 Electric cars

Table 92 Annual net savings of electric car use, comparison of scenarios and use cases – Tuvalu (US$ per year)

Use case	Low			Medium			High		
Scenario	BAU 2022	BAU 2030	Favourable 2030	BAU 2022	BAU 2030	Favourable 2030	BAU 2022	BAU 2030	Favourable 2030
Reduction in upfront cost	-1,396	-817	-484	-1,396	-817	-484	-1,396	-817	-484
Reduction in charging/ fuelling cost	2	4	37	3	7	73	7	14	146
Reduction in maintenance cost	109	177	258	109	177	258	109	177	258
Reduction in environmental costs	6	6	6	12	12	13	24	24	25
Total savings	**-1,279**	**-630**	**-182**	**-1,272**	**-621**	**-140**	**-1,256**	**-601**	**-54**

Source: Consultant

A5.5.2 Electric motorbikes

Table 93 Annual net savings of electric motorbike use, comparison of scenarios and use cases – Tuvalu (US$ per year)

Use case	Low			Medium		
Scenario	BAU 2022	BAU 2030	Favourable 2030	BAU 2022	BAU 2030	Favourable 2030
Reduction in upfront cost	-271	-155	-130	-271	-155	-130
Reduction in charging/ fuelling cost	17	16	22	34	31	43
Reduction in maintenance cost	27	41	57	27	41	57
Reduction in environmental costs	3	3	3	7	6	6
Total savings	**-223**	**-95**	**-48**	**-203**	**-76**	**-23**

Source: Consultant

A5.5.3 Electric vans

Table 94 Annual net savings of electric van use, comparison of scenarios and use cases – Tuvalu (US$ per year)

Use case	Medium			High		
Scenario	BAU 2022	BAU 2030	Favourable 2030	BAU 2022	BAU 2030	Favourable 2030
Reduction in upfront cost	-3,446	-2,198	-2,260	-3,446	-2,198	-2,260
Reduction in charging/ fuelling cost	164	158	328	328	317	657
Reduction in maintenance cost	91	227	389	91	227	389
Reduction in environmental costs	31	31	32	61	62	65
Total savings	**-3,161**	**-1,782**	**-1,510**	**-2,966**	**-1,593**	**-1,149**

Source: Consultant

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