LPG and Natural Gas

as Alternative Energy Sources for the Pacific

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The Pacific Region Infrastructure Facility (PRIF) is a multi-development partner coordination, technical assistance and research facility that supports infrastructure development in the Pacific. PRIF members are: Asian Development Bank (ADB), Australian Department of Foreign Affairs and Trade, European Investment Bank, European Union, Japan International Cooperation Agency, New Zealand Ministry of Foreign Affairs and Trade, and the World Bank Group.

The Pacific Power Association (PPA) is an inter-development agency based in Suva, Fiji. It represents 25 electric power utilities in the Pacific and is a member of the Council of Regional Organisations in the Pacific (CROP).

The Secretariat of the Pacific Community (SPC) was represented through its Economic Development Division in Suva, Fiji. This office coordinates the implementation of the regional Framework for Action on Energy in the Pacific: 2010 – 2020; produces Country Energy Security Profiles; and is the host of the Pacific Region Data Repository which contains a range of data on the energy sector.

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Liquefied Petroleum Gas, or 'LPG', refers to a family of light gases called propane and butane, derived from the processing of natural gas liquids and the refining of crude oil. LPG is gaseous at normal temperature and pressure, and becomes liquid when subjected to modest pressure or cooling. LPG is used mainly in cylinders for portable applications, cooking, heating, lighting, refrigeration and transport fuels.

Natural gas is composed primarily of methane (usually over 85% by volume), but it may also contain ethane and propane with small amounts of heavier hydrocarbons (and some impurities which are removed before liquefaction). Liquefied Natural Gas, or 'LNG', is natural gas which has been processed to liquid form for ease of storage or transport, by cooling it to approximately -161°C depending on its exact composition, at which point it becomes a liquid, reducing the volume of the gas by a factor of more than 600 times as it goes from its gaseous state to liquid form.

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Summary of Research and Workshop Outcomes

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List of Key Acronyms

ADB	Asian Development Bank
ADO	Automotive diesel oil
ANP	Autoridade Nacional de Petroleo (Timor-Leste)
ASME	American Society of Mechanical Engineers
Barg	Bar gauge
CEO	Chief Executive Officer
CNG	Compressed natural gas
CNMI	Commonwealth of the Northern Mariana Islands
CP	Contract price
CROP	Council of Regional Organisations in the Pacific
DES	Delivery ex-ship (in relation to LNG pricing)
DFAT	Australian Government Department of Foreign Affairs and Trade
EIB	European Investment Bank
EPA	Environmental Protection Agency
EoI	Expression of Interest
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse gas(es)
HFO	Heavy fuel oil
HPDI	High pressure direct injection
IDO	Industrial diesel oil
FEA	Fiji Electricity Authority
FOB	Free on board
FSM	Federated States of Micronesia
FSU	Floating storage unit
FSRU	Floating storage and regasification unit
IDO	Industrial diesel oil
IPP	Independent Power Producer
IRP	Integrated Resource Plan (Guam Power Authority)
ISO	International Organization for Standardization
JICA	Japan International Cooperation Agency
Kg	Kilogram
Km	Kilometre
L/l	Litre/litre
LCNG	Liquefied compressed natural gas process
LCTs	Local coastal tankers
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
ML	Million litres
MMBTU	One million British thermal units
MR/MRT	Medium range/Medium-range tanker
MT	Metric Tonne
MW	Megawatt
MWe	Megawatt electric
NGOs	Non-government organisations
NZMFAT	New Zealand Ministry of Foreign Affairs and Trade
OEM	Original Equipment Manufacturer
OPEC	Organization of the Petroleum Exporting Countries
opex	Operating Expense
pa	per annum
PCO	PRIF Coordination Office
PICTs	Pacific Island Countries and Territories
PJ	Petajoule (10 to the power of 15) joules
PMC	PRIF Management Committee
PNG	Papua New Guinea
PPA	Pacific Power Association
PPP	Public-private partnership
PRIF	Pacific Region Infrastructure Facility
PV	Photovoltaic
RMI	Republic of the Marshall Islands
SLN	Société Le Nickel (smelter in New Caledonia)
SPC	Secretariat of the Pacific Community
STP	Standard temperature and pressure
T	Tonnes
T/kL	Tonnes per kilolitre
ULP	Unleaded petrol / gasoline
USA	United States of America
USD	United States dollar
USP	University of the South Pacific

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Executive Summary

(i) Introduction

The Pacific Island Countries and Territories (PICTs) face particular energy supply challenges in regard to their small, remote island economies, limited natural resources, and long distances to major markets. Most PICTS are highly dependent on imported petroleum products to meet their energy needs. This dependence means they are heavily impacted by high or volatile global oil prices. In addition, these countries are among the most vulnerable in terms of climate change and natural disasters.

Historically, limited options have been available to displace liquid petroleum fuels such as kerosene, gasoline and diesel. However, recent market developments have changed this situation. Liquefied petroleum gas (LPG) and natural gas, including compressed natural gas (CNG) and liquefied natural gas (LNG), are increasingly offering economical, low-emission interim solutions in the transition from liquid petroleum fuels towards renewable energy. Gas use in stationary power, trucks, cars, buses and ships is now well-established globally and technologies are commercially available.

The study assesses the potential and economic feasibility of LPG, LNG or CNG to meet medium-term energy needs in PICTs. It considers the end-use applications of power generation, process heating, maritime transport, land transport, cooking and water heating. The existing fuels considered for substitution include heavy fuel oil (HFO), diesel, gasoline, kerosene and biomass. International aviation fuel is excluded because gas does not offer a technologically viable alternative to aviation fuel at this stage.

The research phase of the study consisted of desk research; in-country research in Fiji, Papua New Guinea (PNG), New Caledonia, Tonga and Vanuatu; and consultations with government officials and industry representatives. Twenty countries and territories were included[1]. The consultations with government and industry representatives were crucial because they indicated the most likely scenarios or entry points, and the implications of different decisions that have been (or might be) made by individual countries. Data has been aggregated from the best available sources at the time of writing, though there are some data gaps.

Due to the volatility in international fuel markets and the uncertainty of investment by governments, the private sector and others, generalisations can only be made with caution. Therefore, this report presents scenarios and possible situations and reflects the collective understanding at the time the information was being collated. The hypothetical scenarios include one for LPG in air conditioning and two for fuel substitution with LNG or CNG.

(ii) Findings

Overview

Each PICT has unique geographic characteristics, fuel usage patterns and local conditions that affect fuel supply chain costs to varying degrees. As such, their potential role in driving gas uptake across the region varies significantly. For example, PNG and Timor-Leste have substantial, untapped domestic gas reserves while Fiji and New Caledonia have made significant investments in renewable energy resources.

1 The twenty countries and territories included were: American Samoa, Commonwealth of the Northern Mariana Islands (CNMI), Cook Islands, Fiji, French Polynesia, Federated States of Micronesia (FSM), Guam, Kiribati, Nauru, New Caledonia, Niue, Palau, Papua New Guinea (PNG), Republic of the Marshall Islands (RMI), Samoa, the Solomon Islands, Timor-Leste, Tonga, Tuvalu and Vanuatu.

This study has collected data on the size and components of the current energy market in the 20 countries. The total size of the regional energy market (excluding solar, wind and hydropower) is estimated to be more than 216,800,000 MMBTU[2] of diesel, biomass, HFO, gasoline, LPG, coal, kerosene and natural gas. Liquid fossil fuel used in the transport sector (excluding aviation) dominates energy consumption at 31% of fuel demand, with diesel as the main fuel type. Residential and commercial applications represent the next largest user group. Fuel for these applications is predominantly biomass, used mainly in the rural populations of PNG, Timor-Leste, the Solomon Islands and Vanuatu. The power and industrial sectors are of similar size at 20% and 18% of the total market respectively (although some power use is reported in the industrial sector data, notably in New Caledonia's nickel mining).

Market Conditions

The following developments are relevant for PICTs to consider in expanding use of LPG or introducing LNG into their energy markets:

- major LPG and natural gas resources in the wider Pacific region are being progressively commercialised (see Chapter 2)
- new LNG export terminals have been established in Australia, Indonesia, Malaysia, PNG, Singapore and North America (see Chapter 2)
- small-scale LNG transportation is possible through bulk ships, road tankers, and International Organization for Standardization (ISO) containers though at significant cost (see Chapter 5), and
- there is a strong potential that volatility will continue in wholesale fossil fuel markets which could represent an opportunity to reduce energy costs for PICTs under the right circumstances – including in both LPG and LNG markets (see Chapter 5).

Expanding Use of Liquefied Petroleum Gas

All PICTS already use LPG, mainly for household cooking and this study finds significant opportunity for expansion. If use of LPG was expanded to displace all cooking kerosene and biomass in the Pacific region, the current demand could double. The argument for making this change is for health reasons, environmental sustainability and for cost-saving for individual householders. However, the increase in demand could be expected to achieve better economies of scale to different degrees across PICTs. Increased volume could drive some PICTs to move to bulk delivery which could have a significant impact on the delivered price. The addition of LPG use in transport or small piped gas networks would further increase volumes and might be expected to achieve better bulk import economics. Based on commercial technology already available in Australia, experimental work is currently being conducted in Fiji on use of LPG in heavy vehicles and blending of LPG with other fuels in electricity generation.

There are also other ways to stimulate demand for LPG – both in domestic and commercial settings, including:

- providing grants or microfinance initiatives for early market uptake of LPG
- organising information campaigns on LPG use for both domestic and commercial applications
- introducing subsidised cylinder exchange/deposit schemes
- adopting LPG in schools, hospitals, hotels and via other business customers
- developing a niche use for LPG in commercial air conditioning systems, and
- supporting or providing training of installers, contractors and building managers to operate LPG appliances.

2 one million British thermal units

This would not only directly stimulate use of LPG, but it would also grow the capacity of suppliers, agents and depots and expand the secondary market through reduced overall costs for individual domestic customers. It should be noted that LPG is benchmarked to the Saudi Aramco Contract Price (CP) which has recently become more correlated to crude oil prices.

Potential for Liquefied Natural Gas

LNG can be shipped long distances cost-effectively in bulk ships in capacities as small as 10,000m[3]. However, a major drawback is that in most PICTs unloading facilities and storage systems would need to be built. These storage systems could be fixed land-based facilities, floating storage units with land-based regasification, or floating storage and regasification units.

To cost-effectively supply LNG to PICTs, two pre-conditions are required. First, there must be individual or collective points of demand that are large enough to justify bulk LNG shipping and local unloading, storage and regasification facilities. This appears possible in meeting some or all of the power generation demand in Fiji, French Polynesia, Guam and New Caledonia. Second, the market conditions and supply arrangements must be such that the delivered cost of LNG is less than that of diesel or HFO (depending on which fuel is being replaced) on a dollar/MMBTU basis over the life of the contract, which would typically be 15+ years. Clearly, each country would have to undertake its own economic cost-benefit analysis. However, once LNG is established in a country on the back of an 'anchor demand', it could also be expanded to transport, commercial, industrial or pipeline applications. There is also some potential for nearby PICTs to benefit from the existence of storage units and supply, but each case would require careful analysis of the risks, costs and benefits.

PNG is a unique case. Pipeline supply of natural gas to major centres might be feasible in the short-term if supply for local needs can be made available from the well-head or via a branch line from the existing pipeline to the LNG plant in Port Moresby.

Potential for Compressed Natural Gas

CNG cannot be shipped cost-effectively over large distances due to its relatively low energy density. It can, however, be produced if LNG shipments are put through a pressurised vapourisation process within the country – the so-called Liquefied CNG (LCNG) process. However, this technology is very expensive, so it is likely to be less attractive to the PICTs.

Fuel Price Forecasts

Relative future fuel costs are critical to investment decisions on fuel conversion. There is considerable volatility in the global market. End-users should understand the *long-term* price trends for various fuels, as well as future fuel supply and demand scenarios, and make investment decisions on this basis rather than on present-day cost and demand.

(iii) Conclusions

Expanding the Use of LPG

This study shows that there is significant opportunity in a broad range of PICTs to increase LPG utilisation. It is a cleaner burning fuel than biomass and kerosene, therefore providing both health and environmental benefits and increased uptake may improve economies of scale in supply chains. In some cases, the capacity of existing port and storage infrastructure is sufficient but, in others, it would require investment and expansion.

Fiji has demonstrated that the adoption of LPG for land transport can result in developing economies of scale and increased competition to deliver lower prices for household LPG. In other PICTs, there are also opportunities for increased uptake of LPG in transport and other applications in both domestic and commercial settings. These warrant further consideration.

Possible Introduction of LNG

Under current market conditions, LNG might possibly prove to be a viable investment for a few of the PICTs. Any shift to the introduction of LNG requires considerable new capital investment in ports, storage facilities, in-country distribution networks, and equipment conversion. It also requires the development of new skills and regulations, as well as extensive marketing to ensure adequate demand. Whether such investments and reforms are appropriate will depend on the size of the market, the relative cost of alternative energy sources, and the degree to which costs can be amortised over the life of the assets with a reasonable rate of return.

If LNG is introduced to a new market in the Pacific, a possible use could be for a limited number of stationary power applications that are geographically concentrated in a few areas around sites and/or major ports. Other possibilities also discussed in workshops in this study include providing energy via a new gas pipeline network for an economic zone where LNG could be used to displace existing fuels. The projects in this 'economic zone' would need to justify the upfront investments in infrastructure, whereupon secondary markets could be developed over time. This could include LNG and CNG for transport and industrial/commercial uses, which generally require much smaller volumes per individual application.

The most relevant PICTs with sufficient fuel demand (either individually or in aggregate) are Fiji, French Polynesia, Guam and New Caledonia. PICTs with smaller demands could conceivably seek to leverage off any use of LNG in the larger economies, though this would also require comprehensive analysis ahead of any infrastructure investments that would be needed.

In the situation where market conditions make cost-effective supply of LNG possible in a PICT, the following actions could be considered:

- an individual power station, IPP, government, gas importer, or consortium could enter into a long-term contract for LNG supply, and/or
- PICT governments could consider facilitating LNG use in transport or industry once LNG infrastructure is established on the back of an 'anchor demand' in power generation.

PNG and Timor-Leste are special cases: they have indigenous supplies of natural gas and could investigate local use of LNG or piped natural gas.

(iv) Recommendations

Although many further commercial, technical, policy and environmental factors need to align for a significant fuel transition to occur, a number of recommendations can be made at this point in time. These require a relatively low investment of time and resources. It is therefore recommended that:

Expansion of LPG

1 The transition to LPG from biomass and kerosene for cooking be accelerated, given that it has positive documented health and environmental benefits. This could include assessing the need in some PICTS to reduce the import duty and tax for LPG relative to household kerosene (given it is subsidised in some PICTs), supporting subsidised cylinder exchange/

deposit schemes, microfinance initiatives or other initiatives designed to reduce health risks (particularly for women), environmental impacts and overall costs for individual domestic customers and some commercial enterprise as well.

2 PICT governments consider approaches for developing small piped LPG networks in urban areas to supply LPG for cooking and other purposes. This approach would help improve economies of scale and create centres of demand.

3 PICT governments consider developing LPG options for the transport sector. In addition to providing a cleaner burning fuel, the increased demand may improve economics for LPG across the region.

4 PICT governments consider introducing appropriate incentives for private sector and other stakeholders to increase their LPG import and storage capacities to facilitate increased LPG usage.

Potential Introduction of Natural Gas

5 Relevant end-users with an aggregate power-generation capacity of more than 40 Megawatts (MW) assess the economic viability of importing bulk LNG, including using floating storage units (FSUs) or a floating storage and regasification unit (FSRU).

6 Governments develop policy frameworks for LNG import and use in those countries where there is realistic potential for LNG substitution.

For Both LPG and Natural Gas

7 Power-generating utilities and Independent Power Producers (IPPs) consider investing in multi-fuel and gaseous fuel injection capability (LNG/natural gas, diesel, HFO, LPG) when buying new generators in relevant countries. This offers maximum flexibility in future fuel choices with a relatively small incremental cost.

Fuel Pricing

8 Secretariat of the Pacific Community (SPC) and Pacific Power Association (PPA) develop an ongoing 'watching brief' on the world's bulk LPG and LNG markets to identify potential oversupply conditions and price anomalies and keep Governments and private sector groups informed of emerging opportunities.

(v) Next Steps

This report will be distributed to development partners, governments and industry. The recommendations and activities mentioned above provide the 'next steps' towards making decisions about the technical and economic viability of increased gas use in PICTs. They do not represent a barrier to the continued pursuit of sustainable and renewable energy systems for power generation where viable. Rather, they may prepare countries to capitalise on potential price disruptions and technical developments in world fuel markets.

For environmental and health reasons as well as long term energy security, PICTs need to reduce their reliance on imported liquid fossil fuels and develop alternative renewable energy sources. Gas and other new approaches may broaden access to energy for rural and remote areas, and provide cleaner, cheaper and more reliable energy for power generation, industry and households. Such change is vital for the region's long-term future.

1 Introduction

The Pacific Island Countries and Territories (PICTs) face unique energy supply challenges in regard to their small, remote island economies, limited natural resources, and long distances to major markets. Most PICTS are highly dependent on imported petroleum products, including kerosene, gasoline and diesel, to meet their energy needs. The physical characteristics of these fuels (very high energy density, ease of transportation and storage, and for many years, a low cost) have made them the fuels of choice in PICTs. However, high and volatile world oil prices since the 2000s have exposed the vulnerability of PICTs' energy security due to their current dependence on petroleum fuels.

1.1 Background to Study

With the growing global trend towards alternative energy sources, the World Bank proposed a research project to the Pacific Regional Infrastructure Facility (PRIF) with the aim of considering the potential of liquefied petroleum gas (LPG) and liquefied natural gas (LNG) for the Pacific region. The PRIF Management Committee (PMC) approved the study in February 2014, to be carried out in consultation with the Pacific Power Association (PPA) and the Secretariat of the Pacific Community (SPC).

LPG has been imported by PICTs for several decades but, apart from this, there have been limited options for replacing petroleum fuels in most PICTs. Recent developments are altering this situation and warrant review of the possibilities for broadening energy choices in the region. These developments include:

- major new natural gas resources in the region, which are being commercialised with new LNG export terminals in Australia, Indonesia, Malaysia, Papua New Guinea (PNG) and Singapore, and
- small-scale LNG transportation, which is possible by means of bulk ships, road tankers, and International Organization for Standardization (ISO) containers.

Gas use in stationary power, trucks, cars, buses and ships is now well established globally and technologies are commercially available. There is a strong potential for volatility to continue in fossil-fuel markets, which could be exploited to reduce energy costs for PICTs under the right circumstances (including the LPG and LNG markets).

Although most PICTs are reliant on imported fossil fuels, there are exceptions. These are:

- Fiji, which has harnessed significant hydroelectric resources and has more projects planned
- New Caledonia, which uses imported coal and has access to renewable energy resources
- Timor-Leste, which has substantial domestic natural gas and oil resources, and
- Papua New Guinea, which has vast untapped natural gas reserves and hydropower potential.

In addition, almost all PICTS are following varying levels of investment in renewable energy, including both solar and wind power.

1.2 Purpose of Study

The aim of this research study is to assess the potential and economic feasibility of LPG and natural gas – LNG and compressed natural gas (CNG) – in meeting the medium-term energy needs of the Pacific region for power generation, maritime transport, land transport, cooking, water heating and other uses.

1.3 Scope of Study

Twenty PICTs are included in this study and they are generally referred to in this report as the Pacific region or Pacific Islands region[3]. Each PICT has unique fuel usage patterns and geographic characteristics that affect fuel supply chain costs. As such, their potential role in driving gas uptake varies substantially. For the purposes of the study, PICTs are classified as:

- economies with substantial fuel use: e.g. Fiji, French Polynesia, Guam, New Caledonia, PNG
- economies with medium-size fuel use: e.g. Solomon Islands, American Samoa, Vanuatu, and
- small fuel-users and sub-regional locations: e.g. Kiribati, Palau, Tonga.

The fuels and sectors included for the purpose of identifying market potential for either increasing LPG utilisation or introducing LNG/CNG are: heavy fuel oil/industrial fuel oil (HFO) within the power sector; diesel fuel oil (power, industrial and transport sectors); gasoline (transport sector); LPG (industrial, commercial and household sectors); and kerosene and biomass (household sector). International aviation fuels and bunkered fuels for re-export were excluded because gas does not offer a technologically viable alternative to aviation fuel at this stage, and it is not likely that PICT governments or the local private sector have the operational control needed to influence a conversion to gas in international marine vessels. The report provides some hypothetical scenarios – one for LPG in air conditioning and two for fuel substitution with LNG or CNG.

Importantly, the following factors, though relevant for evaluating gaseous fuels, were not studied in detail but are mentioned where appropriate in the report:

- changes to the relative prices between fuels due to prices that reflect their relative greenhouse gas (GHG) intensity
- economic or health benefits from using a gaseous fuel that reduces particulates and improves air quality, or
- any economic or environmental benefits from using a gaseous fuel that reduces impacts of fuel spills in land or water.

It is understood that if any of these externalities are included in an economic analysis, it is likely to favour gaseous fuels such as LPG, LNG or CNG.

1.4 Research Questions

The research study focuses on the following seven research questions:

- Why would expanding use of LPG and introducing natural gas be beneficial for PICTs?
- Is it technically viable to expand LPG and introduce natural gas into PICTs?
- Is it economically feasible to expand LPG and introduce natural gas into PICTs?
- Which PICTs have the highest potential to benefit from the expansion of LPG or the introduction of natural gas?
- What factors need to change in order to realise the potential benefits?
- Given the development of renewable energy, what is the likely scenario for LPG and natural gas in the longer term?
- How can the findings of this study be applied or developed?

[3] American Samoa, Commonwealth of the Northern Mariana Islands (CNMI), Cook Islands, Fiji, French Polynesia, Federated States of Micronesia (FSM), Guam, Kiribati, Nauru, New Caledonia, Niue, Palau, Papua New Guinea (PNG), the Republic of the Marshall Islands (RMI), Samoa, the Solomon Islands, Timor-Leste, Tonga, Tuvalu and Vanuatu.

1.5 Specifications and Assumptions

Fuel specifications vary according to their source and how they are processed. They may also be defined differently by suppliers or within the markets they serve. The definitions in Table 1 have been used to provide consistent and relevant findings throughout the study.

Table 1. Fuel Specifications in this Study

Item	LPG	ADO	IDO	HFO	LNG	CNG	ULP	Kero-sene
Composition	LPG for automotive use in Australia: 50-100% Propane, 0-50% butane, 5% other hydrocarbons LPG in Fiji: 100% butane LPG in new Caledonia: 100% Propane		Similar to ADO		Varies according to the source, but mostly methane	Varies according to the source, but mostly methane		
Energy Density (MMBTU/T)	44.3	43.6	Similar to ADO	40.5	52.1 (can be up to 55)	52.1		45.0
Energy Density (MMBTU/kL)	24.4	36.6	Similar to ADO	37.6	24.0	10.0 at 251 bar	32.4	37.5
Density (T/kL)	0.55	0.84	Similar to ADO	0.93	0.46			0.79
Atmospheric Boiling Point at Sea Level					-161°C	-161°C		
Sulphur Content		0-500 ppm	0-3.5%				0-500 ppm	
Other	Vapourises in air quickly				Vapourises in air quickly	Disperses in air quickly		
Other Possible Names	Autogas Bottled-gas	Distillate No. 2 Fuel Oil		No. 6 Fuel Oil Bunker Fuel, Residual fuel oil				
Typical Storage Pressure	<23 bar				<18 bar	<300 bar		

Note: ADO Automotive diesel oil; IDO Industrial diesel oil; ULP Unleaded petrol; MMBTU One million British thermal units

In addition this report is based on a number of general assumptions. These include the following:

- most PICTs will be highly dependent on imported petroleum products to meet the vast majority of their medium-term energy needs, the exceptions being Fiji (which uses hydro-power), New Caledonia (which uses imported coal and also has access to renewable energy resources) and PNG and Timor-Leste (which have substantial domestic natural gas resources)
- PICT governments will assess the need for policy decisions about different options as well as the implications of these policy decisions, creating an appropriate enabling environment to support the desired changes in fuel supply and consumer behaviour
- an appropriate supplier will be in a position to make LNG commercially available and supply to the PICTs via small scale bulk ships (from Vancouver and Gladstone) and in ISO containers (from Melbourne)

- any shipping of LNG would be on a rotational basis (i.e. delivered from source to site followed by return to point of origin for refueling) and that local storage tanks would be available in-country
- published tariffs for transport and storage costs are correct and do not change significantly
- any general estimates in developing hypothetical scenarios are correct (or within reasonable approximation), and
- costs for containers for shipping LNG are generally spread over the full lifespan.

In the case of some of the hypothetical scenarios, the proposed situation is that an 'anchor demand' for LNG is established in a country and that CNG is available at an equivalent delivered price. This is based on an understanding that the additional infrastructure for CNG is minimal in comparison to the bulk infrastructure and the shipping and commodity costs associated with delivery of LNG to a country.

Other assumptions may be made in regard to particular tables or figures in the report and those assumptions are explained as part of the table or figure.

Importantly, all assumptions and costings need to be verified by governments, companies or other stakeholders that are considering exploring the options presented in this report.

1.6 Partnership Arrangements

A Project Implementation Committee was formed consisting of the PRIF Coordination Office (PCO), PPA Secretariat, SPC and the World Bank. The PCO recruited and managed the consultants on the project. SPC in Fiji hosted the consultants during the research phase of the project and provided support in the data-collection process and administrative functions. Workshops were held with governments and industry and findings were disseminated by the Committee members. All Committee members reviewed the project documentation and provided guidance to the consultants in finalising the report. The World Bank also organised specialised input on LNG and held discussions with global industry bodies.

1.7 Data Collection and Consultation Process

The research phase of the study was comprised of desk research; in-country research in Fiji, New Caledonia, PNG, Tonga and Vanuatu; and interviews, presentations and workshops with government officials, development partners and industry representatives. The consultations with government officials and industry representatives were particularly important because they indicated the most likely scenarios or entry-points and the implications of different decisions made by individual countries (see Appendix A for a list of persons consulted during the study).[4]

The study evaluated the size of the energy market including electricity, transport, cooking and other uses. Available technologies, infrastructure needs and potential suppliers were then assessed. The following research methodology was used to collect information:

- desk research and direct communications with energy and statistics departments in the PICTs to aggregate all data on energy use and the sectoral breakdown
- desk research to review similar studies that have been completed, identify technology options, and source any relevant case studies
- consultation with industry on budget costs for all aspects of the LNG supply chain and infrastructure costing

4 During workshops with industry, representatives were asked to supply photos that could be used in the report. Various company websites were also used to obtain data, photographs and drawings. These are used for illustrative purposes and should not be taken as an endorsement of any particular company.

- development of a built-up landed cost model using the budget costing from industry and the desktop research
- validation of fuel use quantities, fuel use sectoral breakdowns, and the viability of fuel substitution through visits to representative countries, and
- validation of the built-up cost analysis model and the viability of fuel substitution by holding workshops where draft findings were presented, feedback was discussed and then incorporated into the study.

The data for the study was compiled from material provided by relevant Ministries and other government departments, and from additional non-government organisations (NGOs) and private sector sources, as required. Some data gaps and inconsistencies in reporting of national statistics remained at the time the study was completed. Most critical is that fuel quantities used by Independent Power Producers (IPPs) for public or private power generation were not universally available: some countries report IPP fuel use under the 'industry' sector, while others report it under the 'power' sector. This means that the total fuel demand for all power generation that could be substituted is more than that reported in the 'power' sector alone. In addition, at the time of the research phase of the study, it was understood that Hawaii may have been going to expand use of natural gas, but then it was subsequently decided to move comprehensively to renewable energy – so reference in this report to the situation in Hawaii must be understood within this changing context.

1.8 Structure of Report

In addition to the introductory sections of the report, there are 10 other parts, as follows:

- Chapter 2 provides a detailed overview of the current energy market in PICTs and presents data on fuel use, energy prices and the existing fuel supply chains
- Chapter 3 explains the benefits of expanding LPG and introducing natural gas to PICTs
- Chapter 4 addresses the technical issues related to the introduction of LNG and the expansion of LPG in the region, and analyses the technical viability of displacing liquid petroleum fuels with LPG and natural gas
- Chapter 5 further considers the costs of LPG and LNG, including fuel pricing and the economics of shipping and storing the gases
- Chapter 6 looks at which PICTs could benefit the most from the use of LPG and LNG
- Chapter 7 evaluates the factors that need to change in order for PICTs to realise the benefits of using LPG and LNG
- Chapter 8 briefly considers the long-term scenario of LPG and LNG in the broader context of transitioning towards renewable energies
- Chapter 9 explains how the findings of this study can be progressed
- Chapter 10 provides an overall conclusion and addresses the issues of cost-effective delivery of LNG, the viability of LPG, and their potential use in the power, transport, commercial, industrial and residential sectors, and
- Chapter 11 provides a list of recommendations for governments, power utilities and industry if they decide to pursue LPG and/or LNG as alternative energy sources. A comprehensive set of appendices supports the issues raised in the body of the report.

2 Pacific Context

2.1 Introduction

PICTs vary substantially in many ways. They have widely varying populations, different political systems, and different levels of economic development and urbanisation. Some are more remote than others, government institutional strength varies, as does the vibrancy of the private sector and its contribution to PICTs' development. However, one feature that most PICTs have in common is that they are highly dependent on imported petroleum products to meet their energy needs. The exceptions to this are Fiji, New Caledonia, PNG and Timor-Leste (as mentioned earlier). The move towards developing renewable energy is also significant in considering the context over the short-to-medium term.

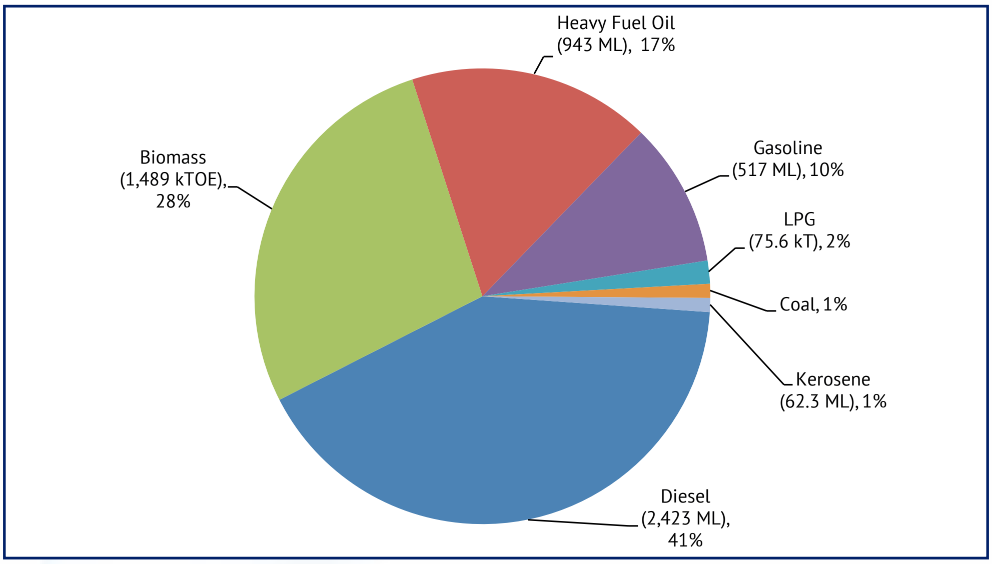
2.2 Current Fuel Consumption

2.2.1 Total Market Size

It was not possible to develop a consistent baseline year for data analysis due to regional variations in availability of information and reporting. Therefore, while the following volume data provides a good indication in terms of overall market size, annual fluctuations in demand or more recent changes in energy activity are not included and actual figures may vary from those contained within this report. All volume data is derived from detailed breakdown of volumes and references listed in Appendix Tables D.1 and D.2, unless otherwise noted.

The total size of the regional energy market – as considered relevant for displacement by LPG or LNG (i.e. fuel sources that exclude renewable resources, aviation fuels and maritime bunkering) – is estimated at approximately 220 million MMBTU of diesel, biomass, HFO, gasoline, LPG, coal, kerosene and natural gas. Diesel is the largest fuel source at 41% of energy consumption, while biomass is second at 28% (noting that the majority of biomass volume is in PNG where there are significantly higher populations than in other PICTs). This is followed by HFO (17%) and gasoline (10%), with only minor use of LPG, coal and kerosene.[5] Even so, LPG has been used as an energy source in Pacific countries for over 50 years and utilisation continues to grow (see Figure 1.)

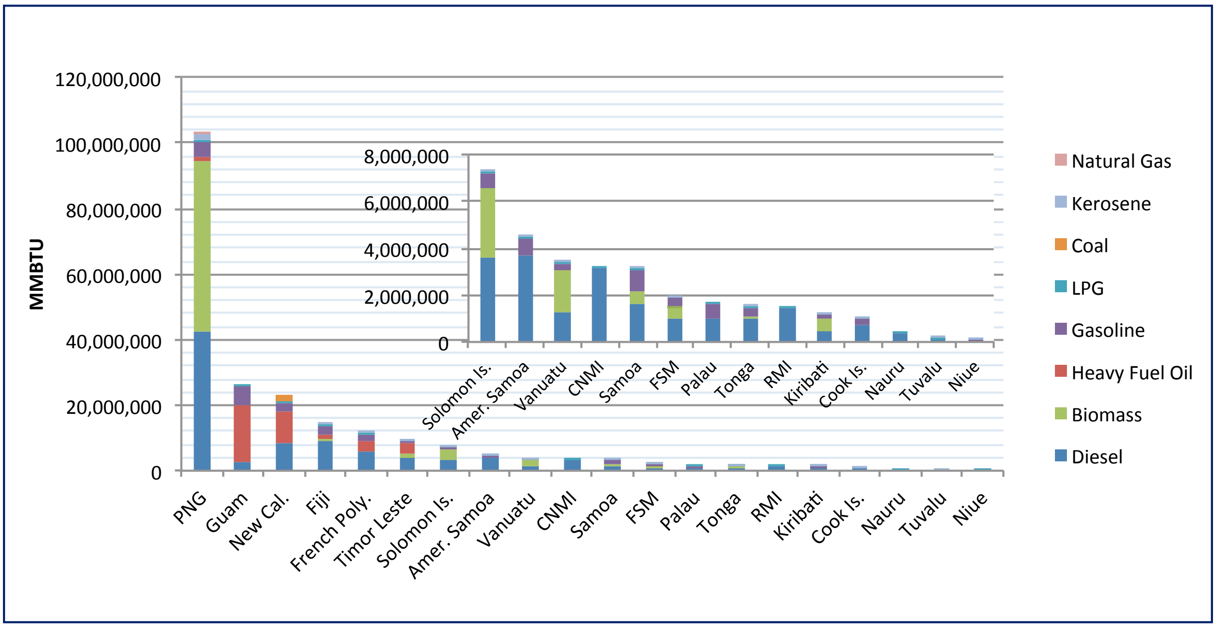
Figure 1. Overall Energy Profile of Individual Countries



5 excluding aviation fuels

As Figure 2 shows, fuel demand profiles vary significantly among countries.

Figure 2. Total Annual Fuel Demands of PICTs by Fuel Type



Note: Data was not available for CNMI (for transport and industry demand for all fuels), Guam (for maritime and industry demand for all fuels), and RMI (for gasoline demand).

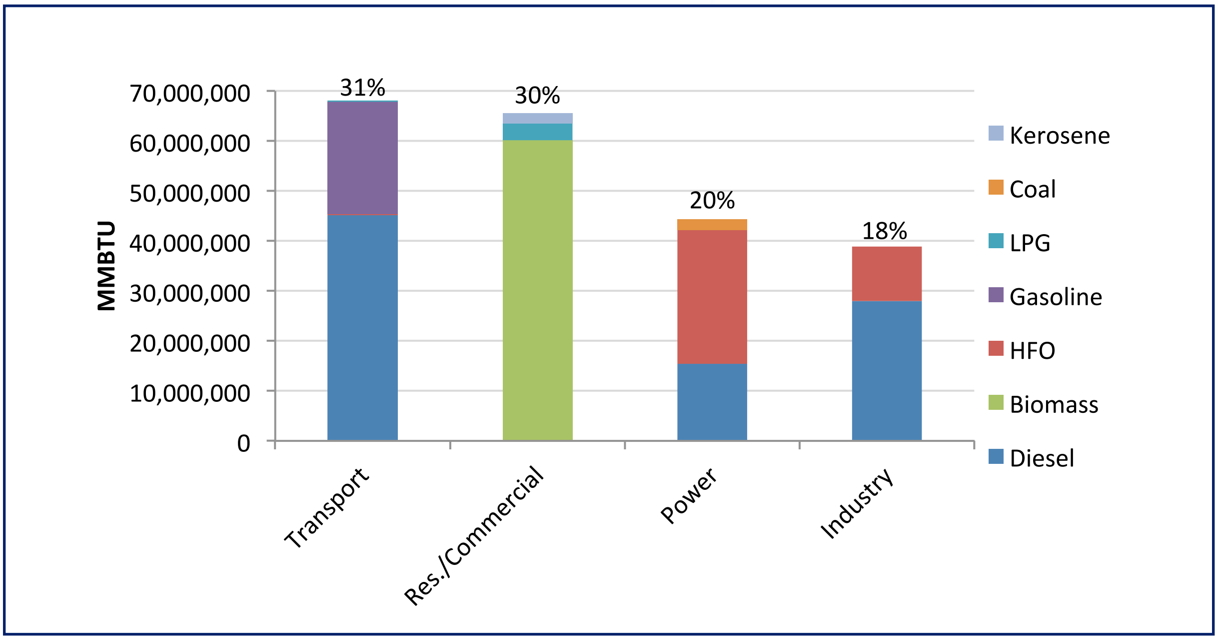
PNG has the largest energy demand among PICTs, principally driven by its significant industrial activity and larger population. It is also the only country in this study that uses natural gas as an energy resource (within private mining operations). Unfortunately, due to the availability of information, consumption of natural gas within PNG could not be calculated and installed generating capacities for major mining projects are detailed within the power sector breakdown. Guam and New Caledonia also have high energy demands. Both are countries at the upper end of development within the region, they have large tourist industries, there is a military presence in Guam, and there is a significant nickel-mining industry in New Caledonia. New Caledonia is also the only PICT that uses coal for thermal power generation. The next most sizable markets are Fiji, French Polynesia and Timor-Leste. Notably, HFO is a significant fuel source in the larger markets where it is used as a lower-cost fuel for the power sector.

Available data indicate a significant variance in sectoral demands for energy resources among the PICTs. Key influences on these demands are urbanisation rates, use of hydropower (e.g. Fiji), and whether or not there is any significant industrial activity.

2.2.2 Regional Sectoral Profile

Available data for the region shows that fuel demand is greatest in the transport sector, accounting for 31% of estimated regional energy demand – noting that if aviation fuels were included in this study it would make the sector even larger – with diesel being the most dominant fuel (see Figure 3). The second highest area of demand is for residential and commercial use, a sector that is dominated by biomass consumption, especially in the rural areas of PNG, Timor-Leste, the Solomon Islands and Vanuatu. The power and industrial sectors are of similar size at 20% and 18% of the total market, respectively. However, it should be noted that some discrepancies can exist across the region in terms of how fuel is reported. A considerable amount of HFO and diesel used in independent power production is reported in 'industry' rather than in 'power' statistics, most notably data on the nickel mining industry of New Caledonia. These figures have been reconciled where appropriate and feasible.

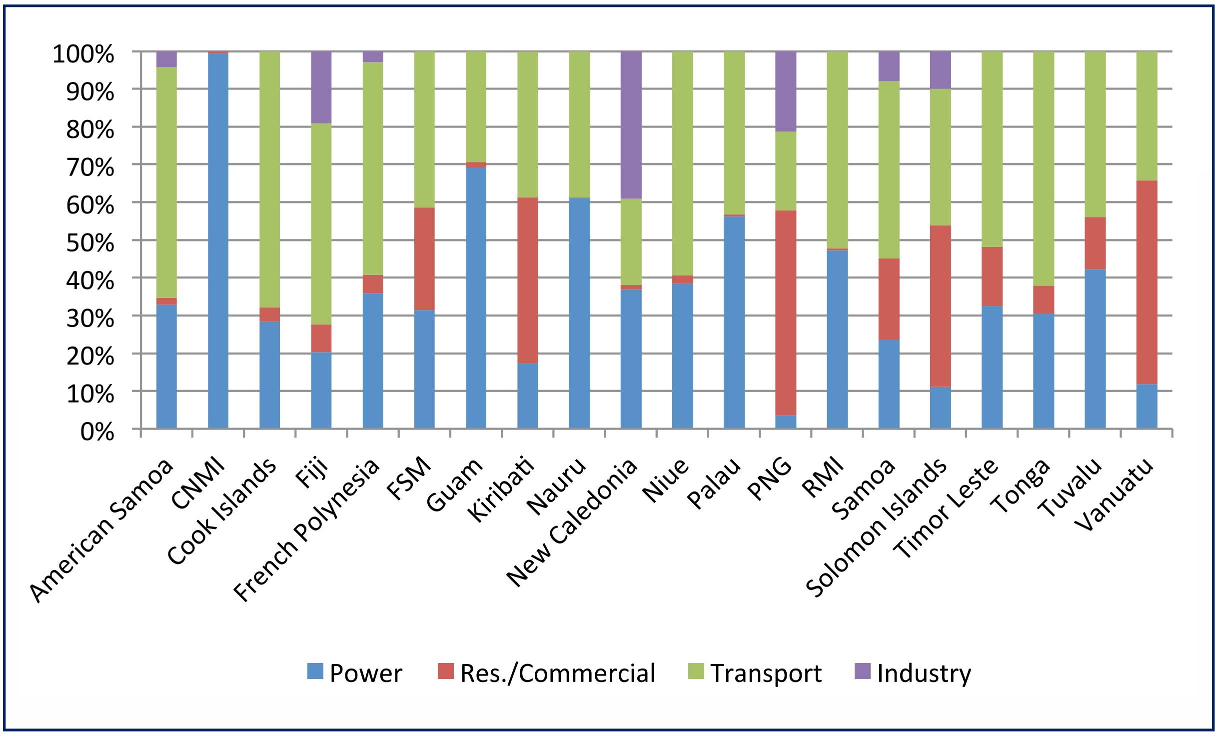
Figure 3. Sectoral Fuel Use (MMBTU) in PICTs by Fuel Type



The following sections of the report present some additional information on usage for transport, residential and commercial applications, the power sector and industrial use.

Figure 4 shows sectoral fuel use within different countries in the Pacific.

Figure 4. Sectoral Fuel Use (% breakdown) in PICTs by Fuel Type

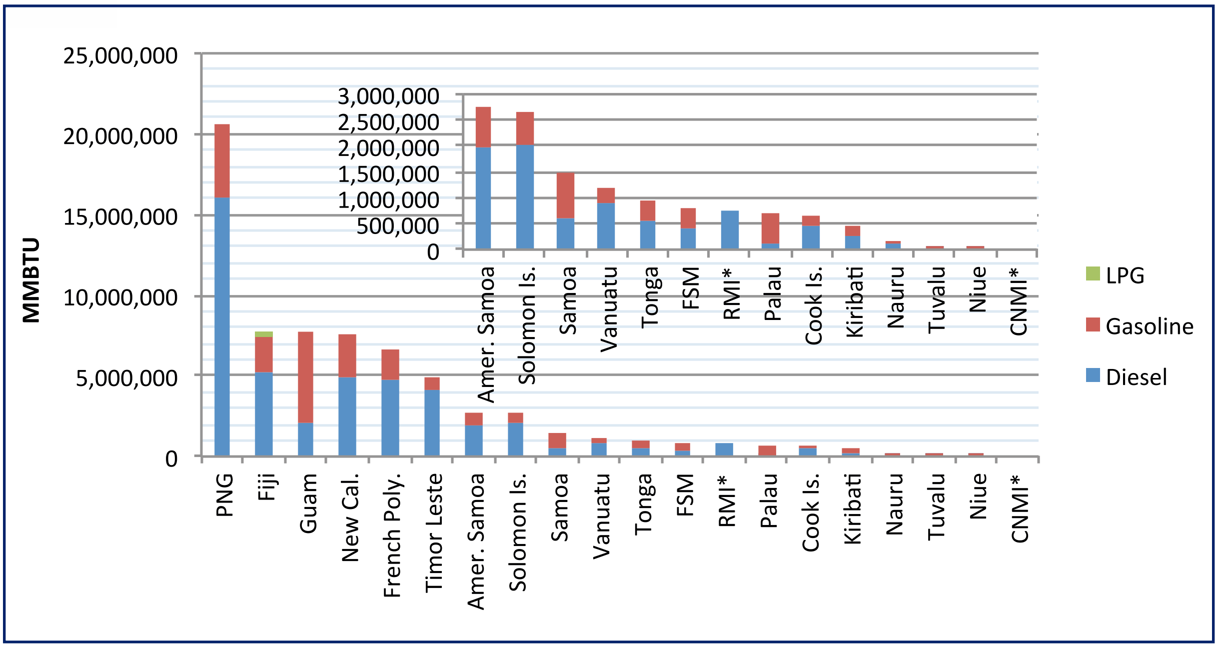


Note: Data gaps remained at time of writing for the following countries: Guam's marine and industry demand for all fuels; CNMI's transport and industry demand for all fuels; RMI's gasoline demand in the transport sector

2.2.3 Fuel Use in the Transport Sector

As mentioned above, the available data show that the transport sector accounts for nearly one-third of fuel use across the region.[6] This is largely associated with the more highly populated, more highly urbanised and/or most developed of the PICTs: Fiji, French Polynesia, Guam, New Caledonia and Timor-Leste (see Figure 5).

Figure 5. Transport Sector Energy Profile by Country



Note: Diesel/Gasoline volume for transport sector was unavailable at time of report writing

Diesel is the most common fuel, with some use of gasoline and only a minor penetration of LPG into the transport sector, solely in Fiji, which totals approximately 4% of Fiji's transport fuel demands. LPG, generally a more expensive fuel for transport for most PICTs, is influenced by low demand and high supply-chain costs. Therefore, it is mainly viable only in markets where tax or excise subsidies exist (such as in Fiji) or where air-quality standards drive interest. It is interesting to note that within Fiji, most of the LPG market is for taxi fleets, and that in Fiji, Guam and Vanuatu, there are significant bus fleets, although these run on diesel, not LPG.

The determination of specific market sizes between land and maritime transport consumption has proved to be a difficult exercise during this study: energy statistics normally group transport figures or fuel types collectively across both land and maritime transport.[7] However, the size of the overall transport energy sector does demonstrate that technical potential exists to expand the use of LPG or to introduce natural gas as either LNG or CNG.

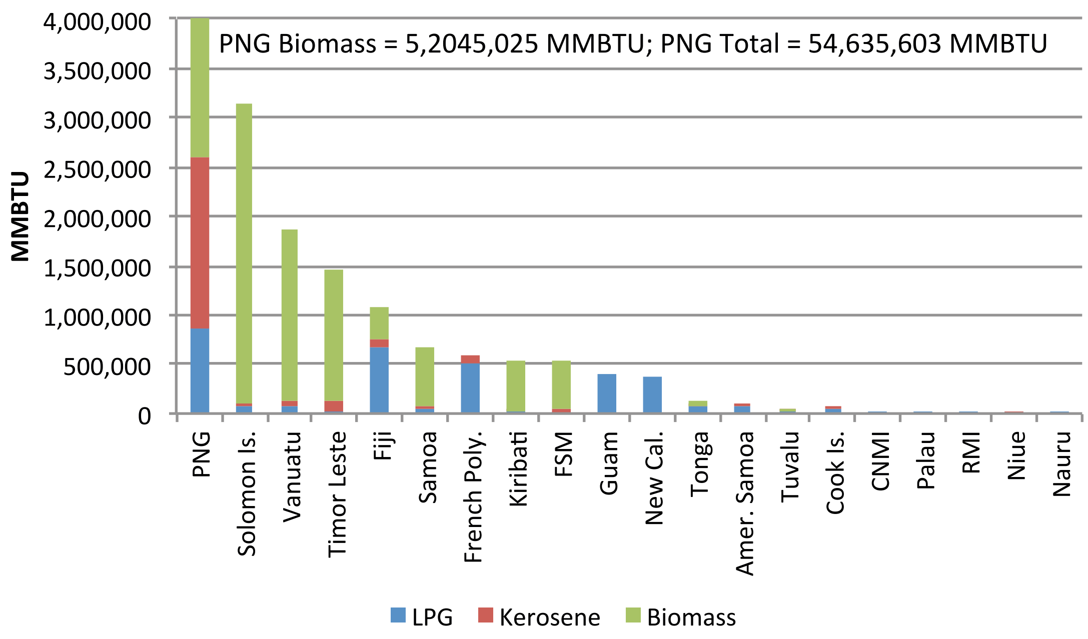
For the maritime sector, natural gas is emerging as a promising fuel option for large, newly-built international tanker and cargo vessels.[8] Although comprehensive data are unavailable, the approximately 2,250 marine vessels registered within the Pacific islands encompass around 20 different classes of vessels. Of these, fishing fleets represent the largest proportion at 30% and cargo vessels account for 14%; the majority are registered in Fiji, FSM, RMI and Samoa (see Appendix E for a detailed breakdown).

6 As mentioned earlier, no data were available on the aviation sub-sector.
7 The University of the South Pacific (USP) commenced a research project during the course of this study to address data gaps in fuel consumption for Pacific GHG reporting of the marine sector, however, preliminary results from this work were not available at the time of writing. The breakdown that could be discerned is represented within the detailed energy table in Appendix D.
8 Case studies are available which demonstrate opportunities for long-range vessels.

2.2.4 Residential and Commercial Use

Figure 6 shows the fuel usage across the region for residential and commercial applications, with Appendix D providing a more detailed breakdown of the data.

Figure 6. Total Energy Demand by PICT for Residential and Commercial Sectors by Country



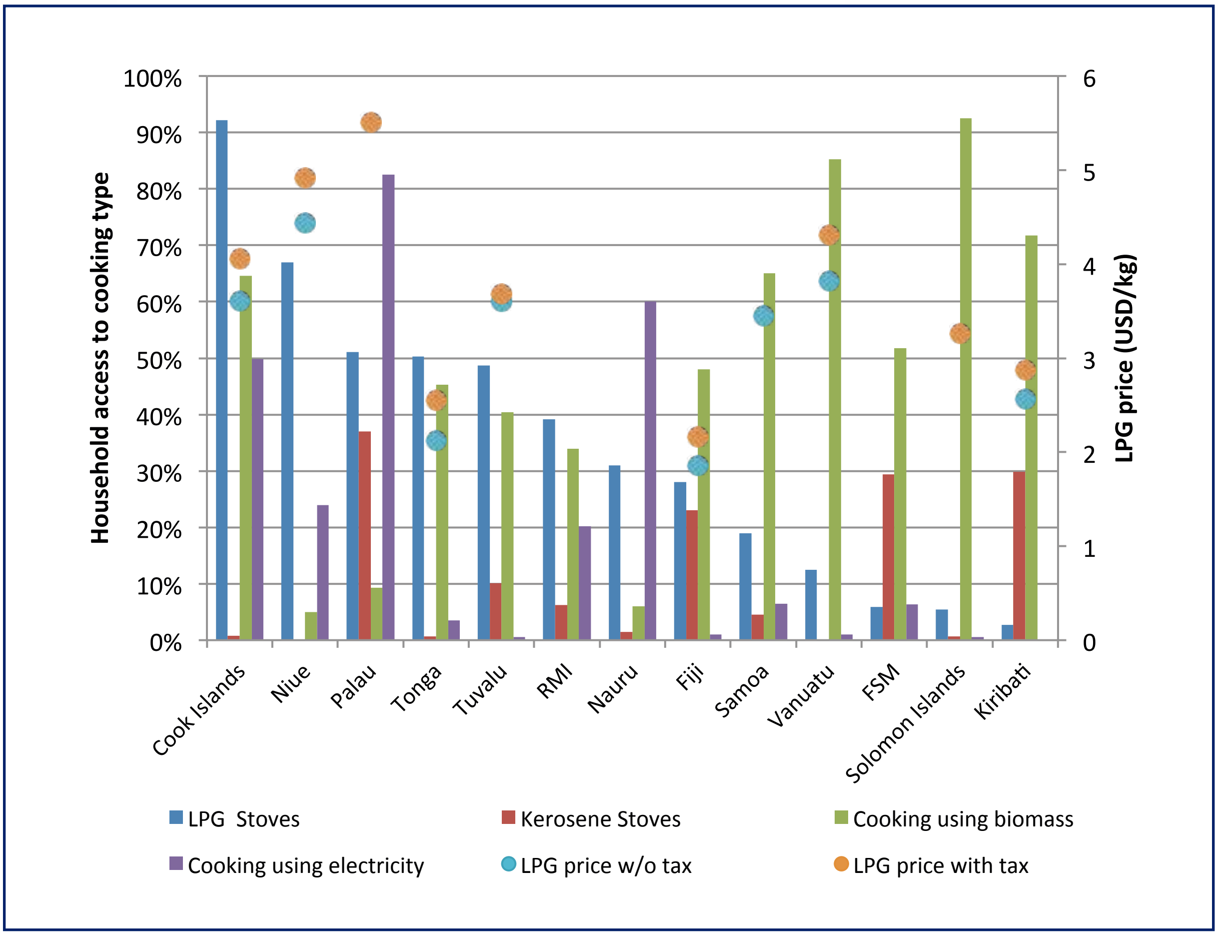
As previously mentioned, biomass has a large market in many of the countries and kerosene is significant, particularly in PNG. LPG is used mostly for cooking and hot water (in both residential and commercial settings). It has also been introduced for new commercial applications in the last decade, notably for air conditioning in Fiji, Tonga and Vanuatu.[9]

Although separate data on residential and commercial use of fuels are not widely available, national household surveys do give some indication of patterns in different countries. What this tends to show is that households may use a diversity of energy fuels, depending on a range of factors such as price, accessibility, personal preferences and cultural influences.[10] This is an important point to remember when one considers the substitution potential for LPG over fuels such as kerosene and biomass. Households use both high- and low-cost fuels, depending on access, budget and personal preferences and/or needs. Figure 7 provides a breakdown of available household energy access and pricing data.

9 Hale & Twomey (2013) Pacific Islands: LPG Supply and Pricing

10 Thomas Lynge Jensen, Environment and Energy Specialist (2011), "Selected Findings including Socio-Economic from recent UNDP-supported Household Energy Surveys in Pacific Island Countries", Environmental and Social Impact Assessment of Renewable Energy Projects Training Workshop, Novotel Hotel, Nadi, Fiji, 11–15 April 2011.

Figure 7. Household Cooking by Fuel Type, including LPG Prices, First Quarter 2014

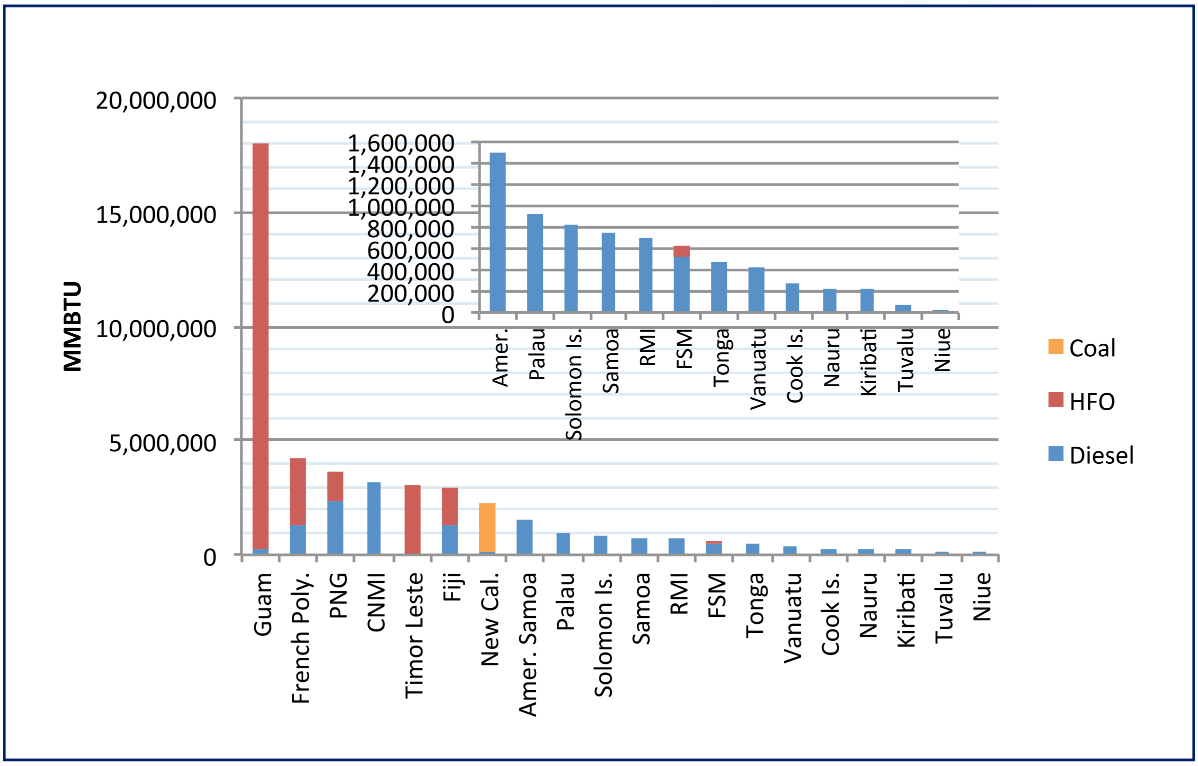


(Source: SPC Development Indicators and Pacific Fuel Price Monitor)

2.3 Public Power-Sector Fuel Use Profile

There is considerable diversity in fuel used for power generation, as illustrated in Figure 8. This variance is strongly influenced by four factors: the status of the country's development, its population size, its industrial activity, and whether or not significant hydropower resources are available. Both Guam and New Caledonia have considerably larger fuel use than that of the other countries. Guam's large electricity demand is due to significant commercial and tourism sectors, high energy use per household, and a large permanent military establishment. In New Caledonia, the nickel mining industry is a major driver of electricity generation and consumption. However, these volumes are recorded within the 'industry' profiles; domestic demand for power is much smaller by comparison. Both Fiji and PNG also have significant hydropower resources available for power generation, which are not shown here.

Figure 8. Public Power-Sector Fuel Use (MMBTU) in PICTs[11]



(Note: This Figure does not include renewables)

Many PICTs are dependent on imported diesel or HFO for most of their power generation, with renewables supplementing supply to varying degrees. Only New Caledonia and PNG use additional fuel sources, as previously mentioned. In PNG, there is a joint venture (Porgera Joint Venture) which generates its power from a 62 MW gas-fired plant at the Hides gas field. However, detailed data on natural gas consumed at this power plant were not available to this study.

Renewable energy is expanding in the Pacific countries. It currently totals around 25% of the annual electricity generated by public utilities (see Table 2). For the purpose of this study, renewables are not quantified with a view to replacing them with either LNG or LPG. However, their existing and growing capacity needs to be taken into consideration as competing alternative fuel options. The most significant impact of renewables has been for those utilities where access to reliable hydropower is available (e.g. Fiji, New Caledonia and PNG). Some Pacific countries have made significant wind-power investments: Tahiti (French Polynesia) generated over 25% of its electricity needs in 2011.

11 excludes renewables and IPPs

Table 2. Gross Generation by Source in PICTs, 2011

PICT	Utility	ADO/IDO	HFO	Coal	Hydro	Wind	Solar PV[12]	Total	% RE+
A. Samoa	ASPA	153,910	-		-	-	1,081	154,991	0.7%
Cook Islands	TAU	28,870	-		-	-	-	28,870	
Fiji	FEA	256,220	83,540		456,469	4,977	35,978	837,184	59.4%
Guam	GPA	29,872	1,801,036		-	-	-	1,830,908	
French Poly.	EDT (Tahiti)	132,034	352,264			181,313	489	666,100	27.3%
FSM	CPUC (Chuuk)	-	7,701		-	-	-	7,701	
FSM	KUA (Kosrae)	6,504	-		-	-	-	6,504	
FSM	PUC (Pohnpei)	33,241	-		-	-	-	33,241	
FSM	YSPSC (Yap)	13,430	-		-	-	16	13,446	0.1%
Kiribati	PUB	21,826	-		-	-	-	21,826	
Nauru	NUC	22,026	-		-	-	51	22,077	0.2%
New Cal.*	EEC, ENERCAL	28,369	1,123,554	635,694	455,211	52,312	4,056	2,299,196	22.3%
NMI	CUC (Saipan)	186,685	-		-	-	-	186,685	
Palau	PPUC	76,677	-		-	-	334	77,011	0.4%
PNG	PNGP	221,064	141,111	-	766,480	-	-	1,128,655	67.9%
RMI	KAJUR (Ebeye)	14,022	-		-	-	-	14,022	
RMI	MEC (Majuro)	61,730	-		-	-	-	61,730	
Samoa	EPC	73,773			35,248	8		109,029	32.3%
Solomon Is.	SIEA	83,810	-		-	-	-	83,810	
Timor-Leste*			318,000					318,000	
Tonga	TPL	52,391	-		-	-	-	52,391	
Tuvalu	TEC	6,531	-		-	-	41	6,572	0.6%
Vanuatu	UNELCO	55463	-		-	4,295	67	59,825	7.3%
	Total	*1,530,091*	*2,703,652*	*483,398*	*1,439,510*	*33,476*	*38,069*	*6,228,196*	
	% of total	*24.6%*	*43.4%*	*7.8%*	*23.1%*	*0.5%*	*0.6%*	*100.0%*	*24.3%*

** All generation data shown for 2011, except New Caledonia and Timor-Leste (data for 2013).*

All data sourced from PPA Benchmarking Report 2012, except for Fiji (Fiji Electricity Authority 2013), New Caledonia (ENERCAL 2012), PNG (PNG Power 2013), and Electricidade de Timor-Leste (Guterres, 2013).Excludes IPPs (MWh) and Biomass. Biomass was removed because the raw data did not distinguish between biomass used for heating, cooking and power generation.

12 photovoltaic

IPPs also play an important role for some utilities. The Guam Power Authority receives around 40% of its electricity supply from three suppliers (Marianas Energy Company, Taiwan Electrical and Mechanical Engineering Services, and Tanguisson Power Plant). Public distribution for the main grid of Noumea in New Caledonia is also mostly reliant upon purchases from the Prony power plant operated by ENERCAL. In PNG, the main grid of Port Moresby receives around 30% of supply from the independently operated Kanudi thermal power station.

Heavy fuel oil (HFO) is a dominant fuel option in the larger power-producing countries due to cost savings where volumes are sufficient to justify the more difficult fuel handling and logistics. In Fiji, for example, HFO is currently around US 20 cents per litre less than diesel for power generation.[13] Fiji also plans to expand HFO capacity since its initial uptake in 2007. The Fiji Electricity Authority purchased 36 MW of additional HFO power generation capacity in four Wartsila generator sets that will be installed at the existing Kinoya Power Station and delivered in 2015.

Despite these movements towards greater utilisation of HFO, LNG is still being considered as a competitive fuel alternative. Guam, for example, is undertaking feasibility studies of the use of LNG as an alternative fuel to HFO in power generation, with a goal to reduce costs and help comply with new Environmental Protection Agency (EPA) air emissions requirements. Timor-Leste is also a large user of HFO in its power sector but is expecting to convert to local supplies of piped natural gas for power-generating purposes within the next few years. New engines that were procured in the recent development and expansion of the power sector in Timor-Leste were purchased with this fuel-switching capacity in mind.[14] Some trials of LPG in generation applications have occurred; however, price competitiveness to conventional fuels has proven an obstacle.

Across the Pacific countries, considerable varieties of electricity generator types are in operation, with varying ages and potential for conversion to gas fuels. Table 3 provides a more detailed profile of electricity generation and associated petroleum fuel consumption for each of the utilities at a country level. Despite the small size of the power sector in the majority of the countries, there remains potential to introduce alternative fuels into these sectors. In an attempt to ground the practicalities of the various challenges for substituting alternative fuels in the power sector, available data on specific engine types in operation within each of the countries covered within the study have been collated (see Appendix J for complete list).

13 Fiji Electricity Authority (FEA) Annual Report 2013.
14 Presentation by Virgilio F. Guterres (General Director of Electricity), Asia-Pacific Energy Forum 2013.

Table 3. Electricity Utilities' Installed Capacity, Fuel Consumption and Tariffs

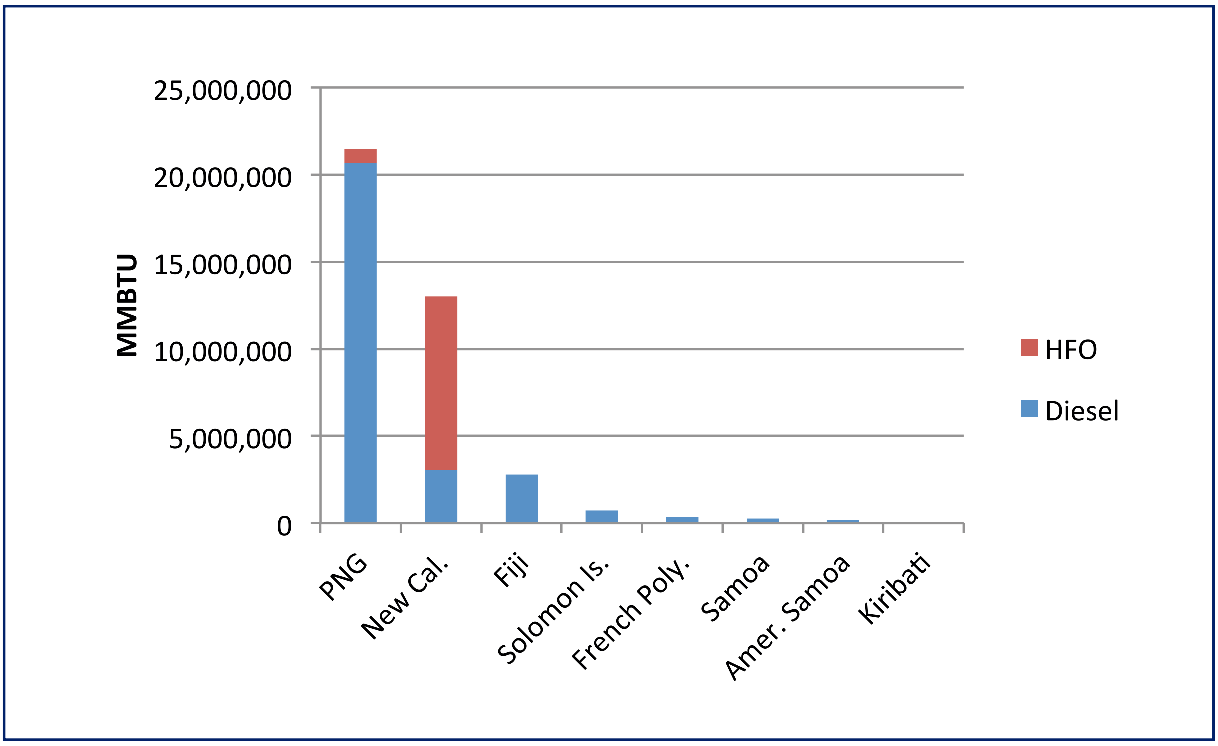
PICT	Installed capacity (MW)	Gross generation ex. IPP (MWh)	Gross generation by petroleum products (MWh)		Fuel consumption (ML)		Energy equivalent (MBTU)		Tariff Structure (USD/kWh)			
			ADO/IDO	HFO	ADO/IDO	HFO	ADO/IDO	HFO	Res.	Comm.	Ind.	Gov.
American Samoa*	41.8	154,991	153,910	-	40.6	-	1,483,811	-				
CNMI	126	186,685	186,685	-	87.1	-	3,185,261	-				
Cook Islands	10.1	28,870	28,870	-	7.7	-	281,656	-	0.60	0.66	0.66	0.66
Fiji*	218	801,206	141,397	183,358	35.7	41.1	1,306,610	1,634,788	0.19	0.24	0.24	0.24
French Polynesia	271	666,137	132,034	352,264	23.5	73.4	860,683	2,922,047				
FSM	25.7	60,892	53,175	77,01	13.4	2.3	488,613	90,164	0.39	0.47	0.48	0.49
Guam	553	1,059,094	29,872	1,801,036	7.3	447.0	266,554	17,793,347				
Kiribati	5.5	21,826	21,826	-	5.7	-	210,133	-	0.41	0.57	0.72	0.72
Nauru	4.45	22,077	22,026	-	6.2	-	226,992	-	0.16	0.26	0.52	0.21
New Caledonia*^	359	2,264,341	28,369	1,120,874	4.2	266.6	152,288	10,612,385				
Niue	2.1	3,000	3,000	-	0.7	-	26,132	-	0.49	0.49	0.49	0.49
Palau	30.3	77,011	76,677	-	25.0	-	914,627	-				
PNG*	122.1	362,175	221,064	141,111	65.8	30.0	2,406,608	1,192,285				
RMI	22.2	75,752	75,752	-	18.7		684,295	-				
Samoa	35.6	109,029	73,773		20.5		748,707	-	0.43	0.43	0.43	0.43
Solomon Islands	20.6	83,810	83,810	-	22.1		810,156	-	0.82	0.88	0.88	0.88
Timor-Leste*	286	318,000	318,000			76.6	-	3,050,317				
Tonga	13.8	52,391	52,391	-	12.8		467,429	-	0.52	0.52	0.52	0.52
Tuvalu	3.2	6,572	6,531	-	1.8		66,371	-	0.43	0.58	0.58	0.58
Vanuatu	23.9	60,632	55,463	-	12.4		453,751	-	0.91	0.52	0.52	0.52

All data derived from Pacific Power Benchmarking Report (2012), unless otherwise noted.
Excludes Renewables and Coal Power Generation
**American Samoa Power Authority (2013); Fiji Electricity Authority (2013); ENERCAL (2013); Electricidade De Timor-Leste (Guterres, 2013); PNG Power (2013)*

2.4 Industry Sector Profile

As mentioned previously, industrial demand for energy accounts for approximately 18% of the total demand in PICTs. Figure 9 provides information on the demand by country.

Figure 9. Fuel Used in Industrial Sector by Country



Note: Information on the Guam IPP fuel use was not available at time of writing.

The largest demand is in PNG, which has multiple, significant existing and proposed mining projects that use various energy resources for independent power generating purposes, such as hydro-electric, geothermal, diesel and natural gas. Available data regarding power generation for the mining sector in PNG are detailed in Table 4.

Table 4. Selection of Mines and Associated Power Sources Operating in PNG

Project	Project Status	Power production
Frieda River	Proposed	Proposed 160 MW hydroelectric scheme for the copper-gold project.
Lihir	Operating	Independent power currently produced by a 52.8 MW geothermal plant.
Ok Tedi	Operating	The Ok Menga hydroelectric run-of-river scheme supplies about 75% of the project's energy requirements. Maximum power output from Ok Menga is 57 MW. A 45 MW diesel power station and two diesel-fired gas turbine generators with a combined capacity of 16 MW at Tabubil, and a two MW hydroelectric power station at Yuk Creek, meet any additional power.
Porgera JV	Operating	Porgera generates power from a 62 MW gas-fired plant at the Hides gas field. Total energy consumption for overall mine operation in 2013 was 7,668,516 GJ (Barrick 2013 Responsibility Report).
Tolukuma	Operating	The mine's power source is a group of hydro and diesel units with capacities of 1.5 MW and 3.2 MW, respectively.
Wafi-Golpu	Proposed	Proposed 150 MW hydro scheme with either heavy fuel oil or LNG backup for the gold-copper project.

Significant developments such as these mine sites, where demand is localised and intensified for a significant time period, are of particular interest: they present an opportunity to initiate an alternative energy market, such as natural gas. In this case, PNG is expanding its use of domestic natural gas reserves. At such levels of demand, the associated costs of infrastructure might be justified if an overall saving is possible in terms of fuel commodity pricing. Other sectors within these locations would then be able to benefit from access to these energy infrastructure investments that may not otherwise be justified for smaller demands.

However, as noted earlier, there is some ambiguity in reporting among industry uses, power production and transport. Specific industrial applications for energy fuels in PICTs are mostly for independent power production. A key example of this is New Caledonia's nickel mining industry, which currently accounts for around 67% of the country's annual electricity use, mostly derived from HFO. A coal-fired power plant also generates electricity for the Noumea grid.

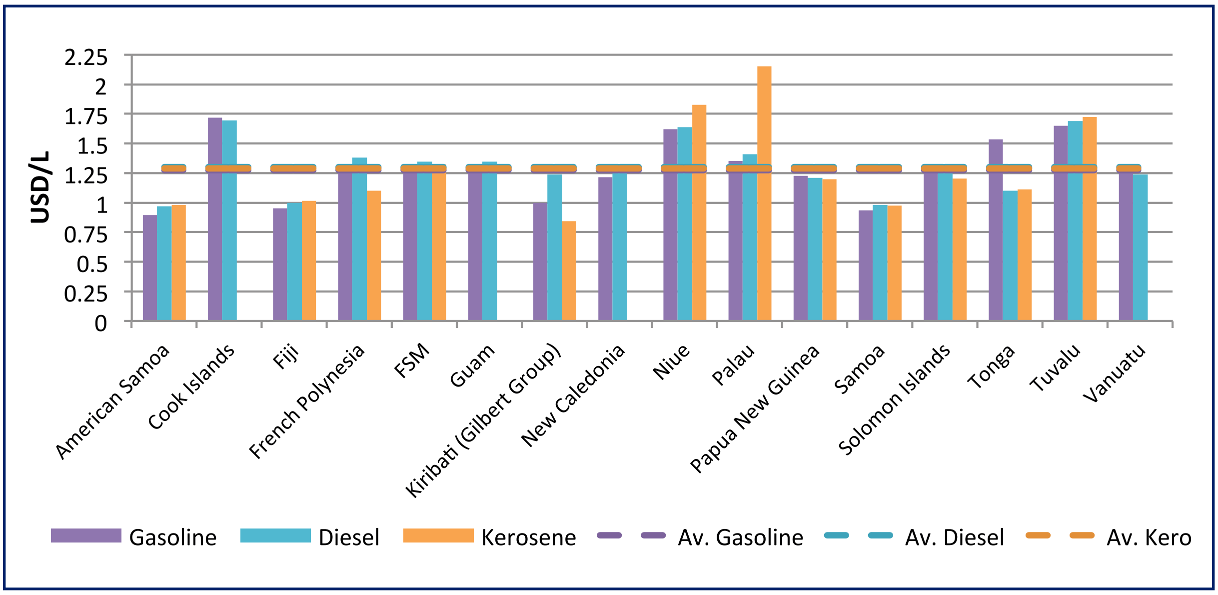
Fiji also has a large industrial demand—most notably with the existing gold mine—which has an annual fuel demand of over 23 million litres (ML) of diesel as an independent power producer. Additional and larger industrial demand is also forecasted for Fiji with the proposed copper mine to be located approximately 30 kilometres west of Suva in Viti Levu. This development presents a major opportunity to establish an LNG-demand anchor point because the project will require an independent power production capacity of around 100MW.

2.5 Energy Prices

The relative competition among fuel suppliers and procurement strategies varies across PICTs. In some remote and smaller markets, there is limited competition in the supply of fuels. This, together with vast transportation distances, adds to the unit costs.

Figure 10 provides a snapshot of average wholesale fuel pricing for the first quarter of 2014 in PICTs, minus domestic duties and taxes. Although the chart compares fuels on a USD/L basis, this does not equate to the specific cost per unit of energy contained in the fuels since the energy density differs. This is, in fact, a contributing factor to end-users' misunderstanding of the value of each fuel.

Figure 10. Retail Diesel, Gasoline and Kerosene Prices: Excluding Taxes and Duties, First Quarter 2014

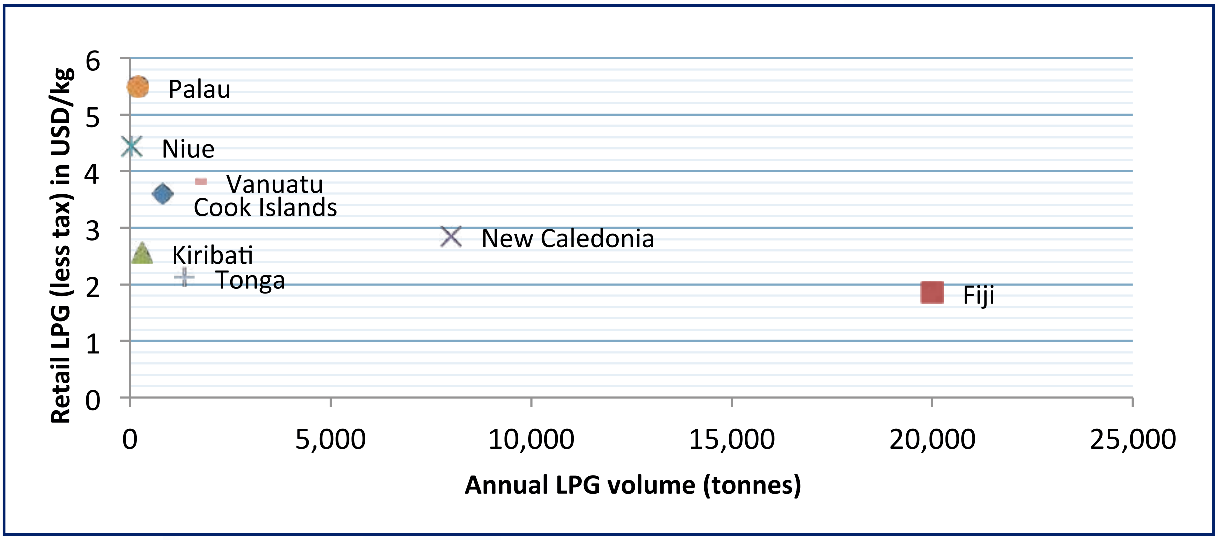


(Source: SPC Pacific Fuel Price Monitor)

The base price of LPG as delivered to PICTs is generally benchmarked to the Saudi Aramco CP (CP) which recently became more correlated to crude oil prices. Distribution and retailing costs and margins are then added. Bulk LPG pricing is not currently monitored by regional bodies such as the SPC and is therefore not readily available at present for each PICT. Anecdotal evidence suggests that the distribution in small-scale bulk ships to PICTs would cost around USD350–500/ tonne (or US 0.35–0.50 cents/kilogram [kg]) in places such as Fiji or Tonga, and more for islands further from the supply sources.

In general, LPG distribution and retailing costs are relatively high due to the low volumes delivered to most PICTs. This is demonstrated in Figure 11 which compares annual volumes to retail pricing. Fiji and New Caledonia have comparatively lower pricing at higher volumes, as does Tonga, which benefits from being on linked shipments with Fiji.

Figure 11. Retail LPG Prices in Comparison to Volumes



Note: Based on available data

Compared to LPG, kerosene benefits significantly from economies of scale because domestic kerosene is generally shipped to the islands as a proportion of bulk jet-fuel deliveries—typically in the range of 5 to 15%—but this differs depending on commercial flight needs in and out of each island. A contradiction to this pricing trend is also found in examples such as Fiji, which is known to have one of the region's larger and more tightly regulated and competitive energy markets.

HFO is generally considered to be much cheaper than other fuels. The Fiji Electricity Authority publishes fuel pricing in its annual reports. As an indication of pricing, the 2013 report listed the annual mean price at approximately US 0.75 cents/litre, which is around US 0.43 cents/litre cheaper than the average regional diesel price, and US 0.21 cents/litre cheaper than the wholesale price of diesel in Fiji. Because the fuels have similar energy content per litre, this price difference is the rationale behind movements towards greater utilisation of HFO in the power sector, despite the higher levels of particulate emissions (as per the Fiji example).

2.6 Existing LNG Use in the Asia–Pacific Region

LNG has a strong presence and is already being used in the broader Asia–Pacific region in a variety of ways, as the following examples demonstrate:

- Indonesia: in 2014 Hoeghe LNG supplied a Floating Storage and Regasification Unit (FSRU) linked to the internal gas distribution system for Lampung, and sold the gas to Perusahaan Gas Negara (PGN)
- Singapore: British Gas imports LNG to supply natural gas to Singapore through a hub operated by Singapore LNG (SLNG)
- Australia: EVOL (Western Australia) supplies several IPPs that operate engine-based power generation for mining companies
- Australia: EVOL supplies a Tasmanian dairy factory for use in an industrial boiler
- Australia: a Victorian dairy company is supplied LNG for a fleet of large milk supply trucks.

Importantly for this study, the availability, technology, awareness and experience in using LNG in small volumes is increasing. Numerous studies have already been undertaken to determine its applicability to remote-area power generation and use. Some public commitments have also been made, which include the following countries:

- Indonesia: Pertamina has committed to powering multiple remote-area power supplies with shipped LNG. An engine-based power plant in Bali was due for commissioning in Q4 2014.
- Hawaii: Hawaii Gas is investigating the use of LNG for power generation and substitution for Syngas. It has undertaken a trial import using ISO containers, and has now called for tenders to supply bulk LNG.
- Guam: The Guam Power Authority (GPA) appears to have committed to a medium-term strategy to use LNG for power generation. The 2013 Annual Report of the GPA indicated a seven-year program to replace all baseload power-generating units with combined-cycle gas turbines: "GPA is currently exploring the number of new plants to install. The range of costs for the generation facilities and the LNG regasification plant are estimated to be between [USD] 500 and [USD]800 million, depending on the number of generators to be installed. However, nearly a billion dollars in net present value savings will be achieved over a 30-year period despite the enormous capital infrastructure cost associated with implementation plans in the Integrated Resource Plan (IRP)."[15] LNG use is estimated to save 13% of fuel costs, or USD30 million or more, with implementation beginning in 2021.

15 GPA. (2013). Taking the right steps: 2013 GPA Annual Report. http://guampowerauthority.com/gpa_authority/investors/gpa_annual_reports/php, p.24.

- The Caribbean: Crowley Maritime Corp has signed an agreement to supply two bottling plants in Puerto Rico with LNG in ISO containers from the US.
- Table 5 summarises information about LNG and CNG power-generation projects in the region (based on available information).

Table 5. Example LNG and CNG Power-Generation Projects Operating or Planned in the Region

Country	Operator	Location	Capacity/Fuel	Status
Australia	Energy Developments	Sunrise Dam	28 MegaWatt electric (MWe) LNG/Diesel	Operating
Australia	Energy Developments	Darlot	12 MWe LNG/diesel	Operating
Australia	Energy Developments	Yulara	4.5 MWe CNG	Operating
Indonesia	Pertamina	Bali, Pesanggaran	200 MWe	Start Q4 2014
Indonesia (Pertamina)	Pertamina	East Kalimantan, Sulawesi, North Maluku (6 in total)	Unknown	2015
Hawaii Gas	Hawaii Gas/ HECO	Oahu	Unknown	Planned. Trial import of LNG complete.
Planned	Guam Power Authority	Guam	HFO	Planned

2.7 Existing Fuel Supply Chains

2.7.1 Diesel, Kerosene, ULP, Fuel Oil

Singapore is the main regional market for the Pacific region, although the source of supply for refined petroleum fuels can be from any of a number of regional refining centres including Korea, Japan, Taiwan, India and most recently Russia. A number of petroleum supply-chain models are used in the Pacific region. These include:

- medium-range tankers (MRTs) from supply centres such as Singapore to supply PICTs including Guam, Fiji, French Polynesia, New Caledonia, American Samoa, Samoa, Solomon Islands, which have significant storage capacity and often have multiple drops per voyage
- onward transport by means of smaller local coastal tankers to smaller markets such as Kiribati, Tuvalu, Tonga and Cook Islands
- ISO containers (and in some cases containers filled with 200-litre drums) from New Zealand and other secondary supply points to some small markets such as Rarotonga, Aitutaki, Tuvalu and various outer island groups, and
- high-seas fuel supply for the fishing fleet, with mother ships sailing directly from regional refining centres to refill a multi-vessel fleet of small supply ships, which in turn supply fuel directly to fishing vessels on the high seas, thus saving them from the need to pause their fishing activities to re-fuel.

Although only a snapshot of regional supply arrangements that can be subject to change, these existing supply chains demonstrate the capacities for bulk supply options to PICTs as well as further redistribution options.

Figure 12 shows the supply routes used in the northern part of the region.

Figure 12. PetroCorpVITAL Supply Chain

Northern supply chain cluster

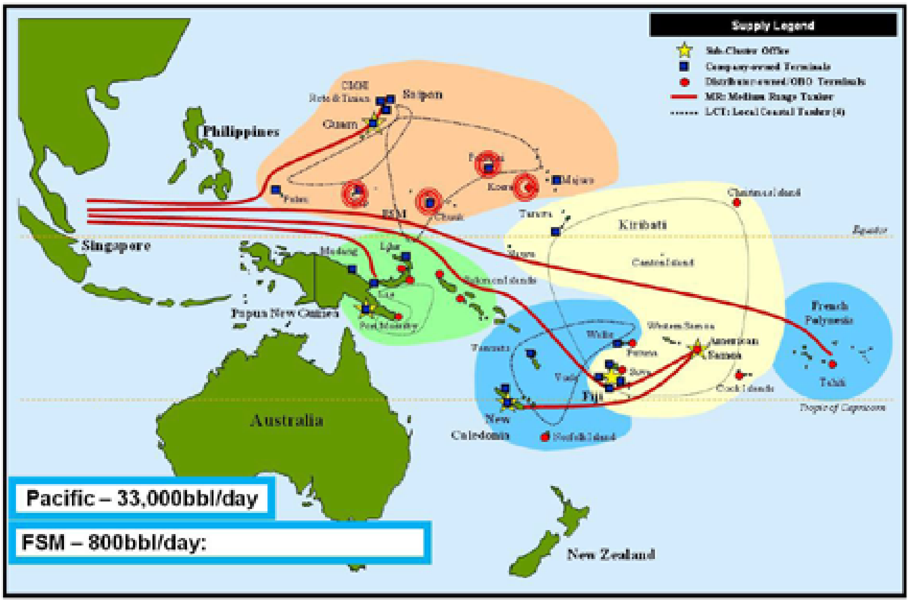
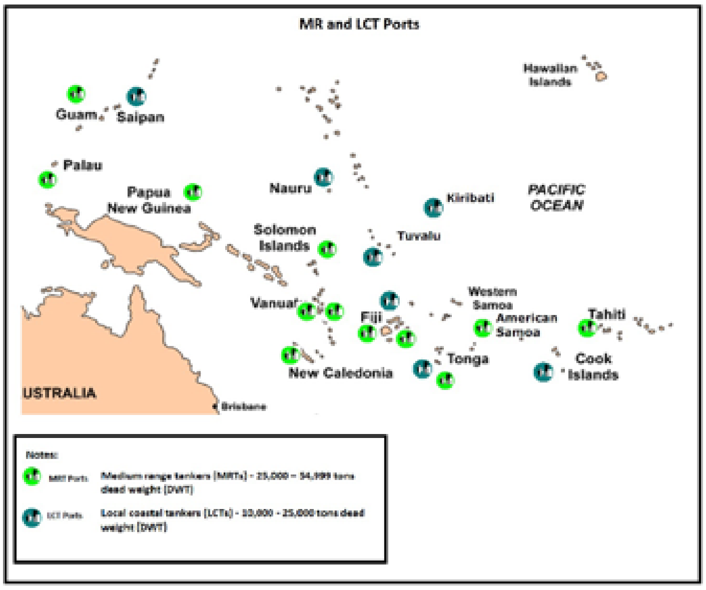


Figure 13 shows the location of ports in the region.

Figure 13. Local Coastal Tankers/Medium-Range Tanker Port Terminal in PICTs



(Source: SPC)

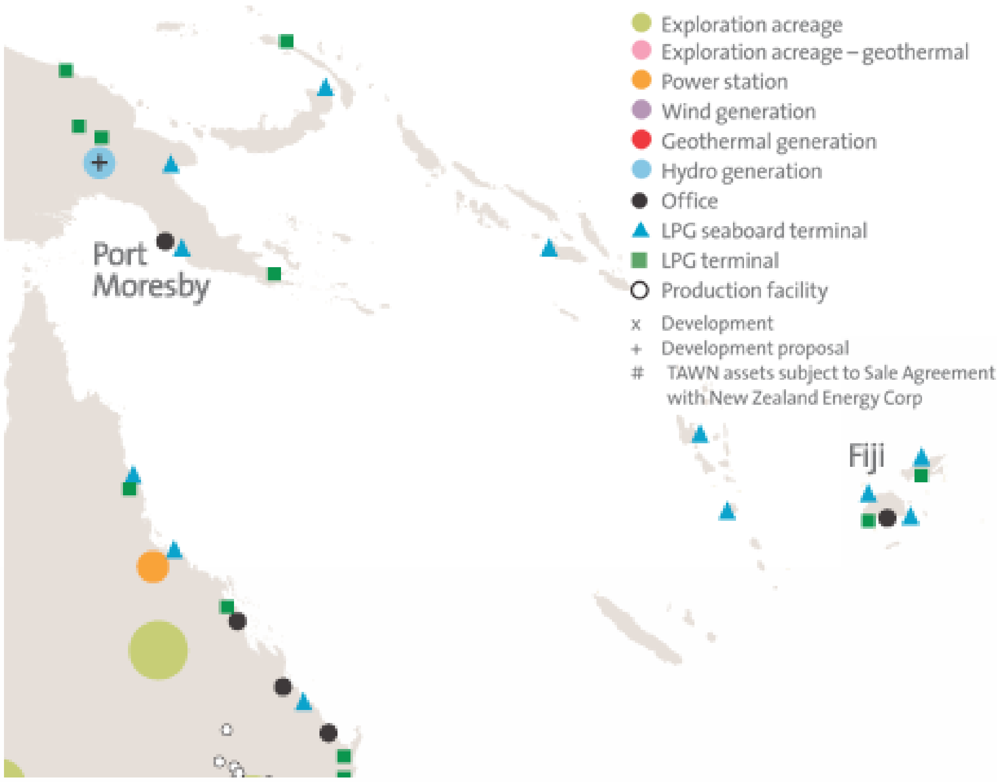
2.7.2 Current LPG Supplies

Current gas supply to PICTs is limited to LPG in the form of either butane or propane, or propane/butane blends, which are transported in bulk on purpose-built LPG tankers, in ISO containers or in filled cylinders, directly to small, more remote island groups.

The transport of liquid petroleum products to smaller islands (using local coastal tankers, ISO containers or 200-litre drums) increases fuel costs substantially, albeit in relatively small volumes. Some PICTs achieve fuel prices similar to those of Australia (through government-controlled tenders and/or fuel-price regulation). Therefore, it could be argued that they do not suffer any particular disadvantage from their remoteness or low volumes. However, two important points should still be considered in these instances: (i) the share of Gross Domestic Product (GDP) that fuel imports represent is much higher in the PICTs in general than in more developed economies; and (ii) the use of these imported fuels in power generation presents a significant disadvantage for PICTs when compared to larger economies where other, lower-cost fuel options are more readily available.

Geogas Trading is the major wholesale supplier in the Pacific region. Origin Energy Australia is the major importer for the majority of PICTs, and the South Pacific Petroleum Corporation (SPPCorp) is a major importer in the northern islands. Origin Energy operates in American Samoa, the Cook Islands, PNG, Samoa, the Solomon Islands, and Vanuatu, and is a major shareholder (51%) in Fiji and Tonga, trading as Fiji Gas and Tonga Gas, respectively (Figure 14). Smaller distributors are also present in the southern islands, such as Blue Gas in Fiji (30% market share), as well as Kiribati Oil Company Limited (KOIL), the sole distributor in these islands. SPPCorp imports LPG for Guam, Micronesia, the Northern Marianas and Palau, within which various additional distributors operate.

Figure 14. Origin Energy Australia's LPG Supply to PICTs



(Source: http://www.originenergy.com.au/1760/Where-we-are)

Most of the LPG used in the countries south of PNG is sourced from the east coast of Australia (Brisbane and Sydney) and the west coast of the north island of New Zealand (Taranaki). New Zealand also produces LPG as a by-product of its natural gas production, shipping from Taranaki for domestic consumption and for export to Pacific islands. PNG, Vietnam or North America could emerge as a significant supplier of LPG to the Pacific region in coming years.

Geogas brings bulk shipments of LPG into Fiji, Guam, Tonga, the Cook Islands, New Caledonia, the Solomon Islands and Vanuatu, and uses 18-tonne ISO containers to distribute LPG to smaller-demand locations such as Kiribati. Sub-distribution occurs in the form of cylinder crate deliveries and individual cylinders at the smallest end of the supply chain.

In the region more broadly, only Hawaii currently has a gas distribution network of any notable scale. It uses Syngas manufactured from refined products,[16] which could be more expensive than imported LNG. Total gas volumes sold and consumed vary significantly throughout the region, but remain small relative to total world demands.

16 LNG for Hawaii study.

3 Research Question 1: Why would expanding the use of LPG and introducing natural gas be beneficial for Pacific Island Countries and Territories?

3.1 Context

PICTs face unique challenges in regard to their small, remote island economies, limited natural resources, and long distances to major markets. Their heavy dependence on imported liquid fossil fuels for their energy needs makes them vulnerable to high-cost and volatile fuel prices.

In addition, these countries are among the most vulnerable in the world to the impacts of climate change and natural disasters. The rises in sea levels and increases in ocean temperatures are impacting on communities and livelihoods. Many island nations on low-lying land are prone to land erosion, cyclones and tsunamis.

Demand for electricity in the region is forecast to grow by 7% each year from 2005 to 2030, with electricity generation estimated to increase by 6.4% each year. Imported liquid fossil fuels are expected to continue to generate electricity over this period.[17] For economic, social and environmental reasons, these Pacific countries are looking at options to reduce their reliance on imported fossil fuels and develop alternative renewable-energy sources. New approaches may broaden access to electricity and other energy sources for rural and remote areas, and may provide cleaner, cheaper and more reliable energy for industry and households. Such change is vital for the region's long-term future.

Although the majority of the Pacific countries are reliant on imported fossil fuels, almost all are installing renewable energy sources in some form, and PNG and Timor-Leste can use domestic gas reserves. At the same time, recent market shifts have improved the situation under which use of LPG could be expanded and natural gas could be a potential energy source for a few of the PICTs.

3.2 Findings

3.2.1 LPG and Natural Gas for Cooking in the Commercial and Residential Sector

LPG has a long presence in the Pacific Islands, having been used as an energy source for at least 50 years.[18] Its application as an energy source in the commercial and residential sector has been the primary use of LPG in the region, displacing kerosene and biomass for cooking, and also for heating (hot water systems), whilst providing a more socially and environmentally sustainable energy resource for households. It may also be possible to stimulate demand for LPG in other ways such as introducing subsidised cylinder exchange/deposit schemes; introducing microfinance initiatives; or other initiatives designed to reduce overall costs for individual domestic customers (e.g. supplying schools, hospitals, hotels and other business customers, thereby growing capacity of suppliers, agents and depots and expanding the secondary market through reduced overall costs for individual domestic customers).

17 Pacific Energy Update 2014, Asian Development Bank.
18 Hale & Twomey (2013) 'Pacific Islands: LPG Supply and Pricing', available at http://www.palauenergyoffice.com/wp-content/uploads/2013/06/Pacific-Islands-LPG-Supply-and-Pricing.pdf

For social, environmental and other reasons (as mentioned above), LPG has also received much promotion by development agencies such as the Asian Development Bank (ADB) and the World Bank.[19] The United Nations Development Program has also partnered with the World LPG Association in promoting LPG as a resource in achieving sustainable energy goals in peri-urban and rural populations.[20] Related to this work, the World LPG Association recently released a study specifically citing the benefits of LPG to small island developing states (SIDS). It set out the socioeconomic benefits of LPG in addressing the premature deaths of an estimated four million people annually from respiratory illnesses, cancers and diseases caused by indoor air pollution. However, the study highlights cost as the principal barrier to greater utilisation of LPG in SIDS, whereby poorer households often struggle with the upfront and ongoing costs of switching to LPG as primary household fuel, even when the higher efficiency rates of LPG are taken into account.[21]

In addition, major changes in the technology, scale and economics of liquefied gas supply are opening up opportunities for remote areas and island states to transform or augment their energy-supply mix. Over the last five to ten years, there has been a dramatic reduction in the economies of scale required to ship LNG cost effectively, with the advent of small-scale floating LNG storage and regasification plants and a greater supply of smaller-scale LNG tankers – although these techniques have not been used to date in the Pacific region.

3.2.2 Gas for Industrial and Power Generation

Australia, Indonesia and PNG are all progressing as major exporters of LNG for the region. They are nearby and have the potential to export greater volumes of LPG, LNG and CNG. From a broader perspective in relation to small-scale gas supply, Indonesia, some Caribbean Islands, Hawaii and Guam are all actively looking at, or have already invested in, small-scale LNG supply arrangements as an energy resourced for their power sectors. Small-scale LNG has also been used in remote parts of Western China, Western Australia, Tasmania, Victoria and Turkey, and is used increasingly for heavy-vehicle road transport along the east coast of Australia.

In this study, the power sector is a key focus for potentially increasing gas utilisation. Although there are various energy options for electricity generation, gas has the following benefits compared to other fuels:

- it is one of the cleanest burning from an air-quality perspective and can be used in cogeneration applications in dense urban areas
- regional gas supply is growing and new supply sources are opening up with lower costs
- supply costs are decreasing and technology is improving in small-scale shipping and distribution
- gas utilisation can improve the range of fuel options available to a utility and therefore the security of electricity supply
- gas can be used in a wide variety of technologies including gas turbines, which generally have very high efficiencies, low maintenance and quiet operation, and
- gas can be used in processing applications within both industrial and commercial settings.

3.2.3 Gas for Transport

Within the Pacific, the development of alternative energy options has largely been focused on the power sector. The application of alternative fuels has been limited within the transport sector, beyond a small penetration of LPG (currently around 4%) in Fiji.

19 See for example: The World Bank (2011) The Role of Liquefied Petroleum Gas in Reducing Energy Poverty. Available at http://siteresources.worldbank.org/INTOGMC/Resources/LPGReportWeb-Masami.pdf

20 United Nations Department of Economic and Social Affairs. Cleaner fossil fuels initiatives. Available at http://www.un.org/esa/desa/climatechange/fossil.html

21 WLPGA (2015) LP Gas: Exceptional Energy for Small Island Developing States. World LP Gas Association. Available at http://www.wlpga.org/wp-content/uploads/2015/09/lp-gas-exceptional-energy-for-small-island-developing-states-2.pdf

In this regard, natural gas is a proven transport fuel that has the potential to be used in nearly any kind of land and marine vehicle (LNG for aircraft was not considered in this study). Worldwide uptake of LNG for transport has been significant in recent decades, with over 1,400 LNG refuelling stations now installed globally.[22] LNG trucks accounted for 7% of all truck sales in China in 2013,[23] and there are now more than 15 million natural-gas vehicles in operation across 84 countries. Iran is the global leader with over 2.86 million vehicles, followed by Pakistan with over 2.85 million.[24]

When used as a dedicated transport fuel in spark-ignition gas engines, LPG is also well proven and is used globally. However, because LPG has historically had a higher price compared to natural gas, diesel or gasoline, uptake has traditionally been in markets where subsidies exist either on fuel taxes, vehicle taxes, registration fees, or vehicle conversion costs.

The following are some of the numerous advantages of using LPG (rather than LNG or CNG) in light vehicles:

- LPG has lower storage pressures and requires less sophisticated storage tanks
- more readily available technology exists with an associated lower cost of conversion
- PICTs can leverage transportation usage off existing LPG logistics and storage infrastructure, and
- LPG use can be easily scaled if demand increases are guaranteed in order to justify investment.

3.3 Issues

A range of other new energy sources, apart from gas, may be used in the Pacific region. For example, electricity can be generated from a variety of competing resources, both renewable (e.g. solar, wind, hydro, geothermal, biofuels, biomass, wave and tidal) and non-renewable (e.g. diesel, HFO, LNG, LPG, CNG and coal). In addition, energy-efficiency and renewable-energy integration technologies, such as waste heat recovery turbines, exhaust-driven turbines, and battery storage, further crowd the landscape and compete for investment capital.

3.4 Conclusions

The Pacific region can benefit in a number of ways from the expanded use of LPG and the introduction of natural gas. These include:

- increasing the region's energy security by creating diversity in the market
- improving air quality by reducing liquid petroleum fuels and kerosene for cooking (and contributing to an improvement in GHG emissions)
- enabling a future transition to indigenously produced renewable biogas
- providing lower fuel costs and breaking the Pacific's reliance on volatile fuel prices (in some sectors and areas)
- promoting capacity building through the use of new equipment and technologies, and
- increasing rural and remote communities' access to energy.

22 IGU: FactsFigures_contentOct2014
23 IGU: World LNG Report 2014 Edition
24 NGV Global Statistics (2011) http://www.iangv.org/

4 Research Question 2: Is it technically viable to expand LPG and introduce natural gas into the Pacific Island Countries and Territories?

4.1 Context

LPG usage occurs in all PICTs and major storage systems exist at some import terminals. There is an established supply chain that could be incrementally expanded as needed. Supply is not constrained and the combined LPG demand of the PICTs is small relative to the rest of the region including Australia and New Zealand. LPG faces some technical challenges in its application in power generation, and commercial challenges around distribution and cost competitiveness against other fuels.

Overall, there is much greater capacity to produce LNG in the broader Asia–Pacific region than there would be potential demand from PICTs, with over 100 million metric tonnes (MT) per year of production capacity implemented or planned in Australia alone.[25] To put this production capacity into perspective, this study illustrates a potential demand in the Pacific of less than one million MT per year. Conversely, although significant LNG resource potential is available to PICTs, the inherent varying and mostly small size of PICTs' energy demands, their lack of LNG import facilities, and their distance from export terminals introduces a variety of challenges.

4.1.1 LNG Supply Within Region

As noted previously, PNG's and Timor-Leste's substantial domestic reserves of natural gas can be used locally. PNG's mining industry, and the PNG LNG liquefaction facility are already utilising natural gas for power generation. It is certainly technically viable to introduce natural gas to other sectors and for other uses. A recent agreement between Exxon Mobil PNG and PNG Power[26] will see 25 megawatts of gas-fired power supplied into the Port Moresby grid, whilst LNG could theoretically be transported to smaller scale power generators around the country. In Timor-Leste, the recent procurement of gas-compatible generators (currently running on HFO) indicates a commitment to domestic utilisation of gas reserves that could flow into other sectors within the country.

Other PICTs without their own reserves can access a wide variety of LNG supply terminals that are emerging in Australia, Asia and North America, with millions of MT per year available in supply capacity. Some are designed as liquefaction and export terminals suited to very large bulk shipments; some are multi-purpose liquefaction and storage facilities whose primary function is system security for a gas network; and others are solely an import terminal with a storage and regasification purpose. Within each of these terminals, the ability to load small bulk ships, road tankers, or ISO containers that would be suitable for shipments to PICTs also varies.

As shipping costs are significant in considering the overall delivered cost of LNG, the closer loading points of PNG and the north coast of Australia are of particular interest. These encompass the major LNG exporting terminals at Port Moresby (PNG) and Gladstone in Australia (see Figure 15), and the Australian truck and ISO container loading facilities of Melbourne (existing) and Tomago (planned). A summary of gas terminals within reasonable proximity to PICTs includes:

- PNG: PNG LNG (Port Moresby) – on stream

25 Peter Behrenbruch (2011). Liquefied Natural Gas–The Australian Race.
26 http://www.lngworldnews.com/exxonmobil-png-agrees-electricity-sale-to-png-power/

- Australia: Conoco Philips APLNG (Darwin) – on stream
- Australia: BG's QCLNG (Gladstone) – due to be operational in 2015
- Australia: Santos' GLNG (Gladstone) – due to be operational in 2015
- Australia: APA Group's LNG gas storage (Melbourne) – able to load ISO containers
- PNG: Interoil's development of new LNG projects from the Elk-Antelope field – due for a final investment decision in 2017, and
- Australia: AGL's proposed facility at Tomago, being built to meet AGL's peak gas market requirements over winter and to provide additional security of gas supply during supply disruption events – planned.

Figure 15. Gladstone LNG Plant

(Source: www.santosglng.com)

The Tomago facility will have the following key features that make it suitable to supply some of the smaller applications:

- capability of processing up to 66,500 tonnes of LNG per year
- an insulated, non-pressurised LNG storage tank capable of containing 30,000 tonnes or 63,000 cubic metres (m^3) of LNG, equivalent to 1.5 petajoules (PJ) of natural gas
- a truck-loading facility to allow the dispatch of up to 1,000 tankers of LNG per year, and
- an estimated capital cost of USD300 million.

Further away from the Pacific, LNG is also available in Singapore, Indonesia, Malaysia, Brunei and North America. The Singapore LNG facility's import terminal is being used to bunker and re-export LNG. Although it is ideal to source LNG locally near the point of demand, it could be viable to ship containments over longer distances if there is a price advantage on the LNG purchase. This could be the case with LNG supplied from North America.

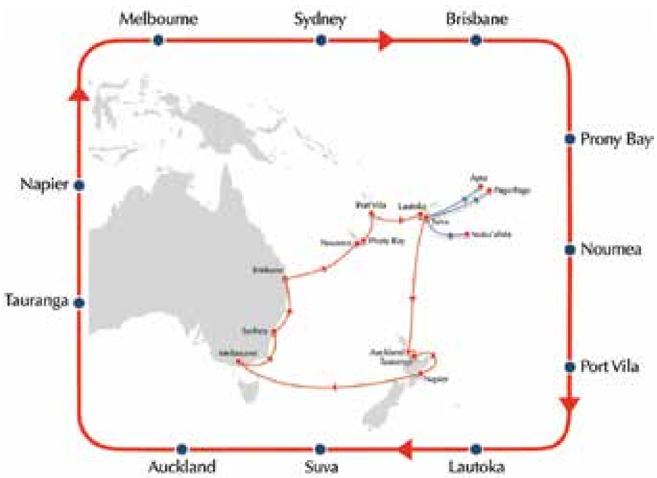
The Pacific is well served by container shipping (see Figure 16). This means that the use of LNG in ISO tanks is unhindered by lack of available shipping routes or capacity. Discussions with various shipping companies reaffirm this view. Furthermore, if volumes of LNG container-based shipping rise to where capacity ever became a constraint or a concern, dedicated ships can be chartered or contracted space can be purchased.

Figure 16. Shipping Routes Serving the Pacific

(Source: SPC)

Container ships visit PICTs with varying degrees of regularity. Figure 17 indicates one of the key supply routes for general cargo (on left), and one that can accommodate LNG containers. Other routes also serve the north Pacific from Asia and serve the east Pacific from the United States of America (USA). Regardless of existing shipping routes, logistics companies indicated during this study that once volumes are large enough, dedicated ships and routes may be negotiated and supplied.

Figure 17. Container Shipping Route for Swire Shipping's Pacific Island Service



Transit Times

Australia / Pacific Islands				Australia / Vanuatu / New Caledonia			
Northbound		Southbound		Northbound		Southbound	
Melbourne	*	Noumea	*	Melbourne	*	Santo	*
Sydney	2	Port Vila	1	Sydney	2	Prony	1
Brisbane	4	Lautoka	4	Brisbane	5	Melbourne	11
Prony	8	Suva	5	Santo	25	Sydney	15
Noumea	9	Apia	9			Brisbane	18
Port Vila	11	Pago Pago	10				
Lautoka	14	Nuku'alofa	12				
Suva	15	Melbourne	23				
Apia	19	Sydney	25				
Pago Pago	20	Brisbane	28				
Nuku'alofa	22						

T/S Suva to Tarawa, Majuro

4.1.2 CNG Supply Within Region

Shipping of CNG to PICTs may be considered in one of the following forms:

- derived from vapourised LNG shipped from an LNG terminal
- shipped in high-pressure cylinders collated in an ISO 40' container, with gas sourced from any major gas pipeline in countries such as Australia, Indonesia or PNG, or
- in a high-pressure bulk CNG ship (subject to the success of the Indonesian project), with gas sourced from any major gas pipeline in countries such as Australia, Indonesia or PNG.

Shipment of CNG in specialised containers is relatively common and could be achieved using existing shipping container routes. Around three ISO 40' containers of CNG at 250 bar would need to be shipped in order to deliver the equivalent gas contained in one ISO 40' container of LNG. This is because the energy density (kg/m^3) of CNG at 250 bar is around half that of LNG, and the packing density of CNG cylinders in a 40' container footprint reduces the effective carrying capacity.

Transporting CNG by bulk shipping is much less common. However, PLN (Indonesia) has announced that it will ship CNG from Gresik in East Java to Lombok in West Nusa Tenggara, a distance of approximately 580 kilometres. The planned project will fuel a 90 MWe power plant in Lombok.

In general, because the capital requirements for creating CNG are relatively small and scalable, the solution is worth investigating. Furthermore, if the Indonesian trial is successful, it may soon be possible to transport CNG in small-scale bulk ships.

4.2 Findings

4.2.1 Technical Viability of Expanding LPG Supply

Since LPG supply chains exist in many PICTs, the technical potential to expand LPG use is high. There is already substantial supply and distribution infrastructure, supply chains, regulations, experience in handling and use of LPG, and cultural acceptance of using it for different purposes. Incremental increases can probably be absorbed relatively easily within existing industry capacity, whereas large expansions might require investment in new unloading and/or port facilities.

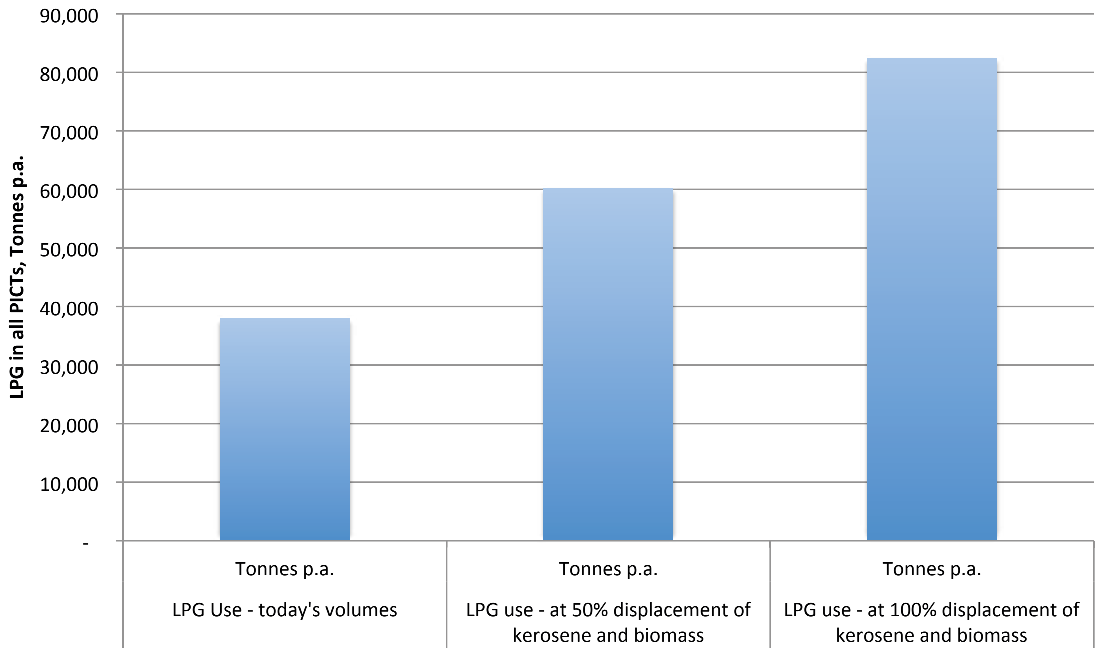
4.2.2 Technical Viability of Increased LPG Application for Households

In the residential sector, the fuel chosen for cooking by households varies according to affordability, availability and local norms. Dedicated LPG stoves are available and LPG has a higher stovetop efficiency than kerosene. It is also safer and cleaner than kerosene and traditional biomass. However, kerosene is used commonly in the PICTs because it can be purchased in smaller quantities and can be cheaper than LPG since it is delivered in bulk with aviation fuel and is often subsidised. In addition, the logistics of supply and return of gas bottles to a depot is problematic for remote communities. Biomass retains a strong foothold in rural areas as it is readily available, free if collected by householders themselves, and the fuel that has been used traditionally. However, there are significant opportunity costs for women (and children) who have the main responsibility for collecting biomass in terms of the time they lose that could be spent on income-producing or other activities.

It has been estimated that if LPG displaces all cooking kerosene and biomass in the Pacific region, the current quantities could double. In the larger markets, this sort of increase is not expected to reduce the price significantly. However, in some subregional markets, a move from an ISO container delivery to bulk delivery could have a significant impact on the delivered price.

Figure 18 shows the overall potential for increased use of LPG in household cooking across the region. However, any impact on local LPG prices will be country specific and likely to be greatest in places like the Solomon Islands where traditional biomass is used in large volumes.

Figure 18. LPG Growth Potential Due to Displacement of Kerosene and Biomass for Cooking



4.2.3 Technical Viability of Increased LPG Use in Commercial Applications

There are very few, if any, technical barriers to the greater use of LPG in the commercial sector.

This uptake could be in three main areas, as described below:

- LPG air conditioning in all countries
- hot water production in the more developed economies, and
- commercial cooking and piped networks.

LPG Air Conditioning

There are commercially available gas-driven air conditioning systems. These can be cost effective where the retail price of electricity is expensive but costs would need to be verified in any country where installation is being considered.

Hot Water Production

- There are few, if any, technical barriers to using LPG for hot water production. Electricity or diesel/oil is used for hot water generation in some PICTs. For example, New Caledonia is a developed economy that, somewhat surprisingly, uses comparatively little LPG (~8,000 tonnes per year). Subsidies have historically been given to hotels in the tourism industry for running electric hot water systems. LPG is likely to be cheaper if subsidies like this are removed, with both LPG and solar power available as potential alternatives.

Commercial Cooking and Piped Networks

The implementation of piped networks for commercial use would face planning, logistical, and possibly economic challenges, but few technical ones. It is possible to create LPG piped networks in economic zones to better stimulate uptake. Increasing LPG use in the commercial sector could benefit household LPG prices through better economies of scale in the supply chain. Opportunities for growth in LPG volumes for commercial and industrial use exist under the following condition: that there is an opportunity to develop small-scale gas pipe networks in economic zones to create an initial demand for LPG, or at least to benefit from bulk delivery cost structures.

4.2.4 Technical Viability of LPG for Power Generation

LPG has historically been a much more expensive fuel than diesel or gasoline. Therefore, it has not been feasible for use in large-scale power generation. However, in terms of technical viability, there are some trials underway (through BlueGas in Fiji) in which up to 30% LPG is being blended into large stationary diesel engines. This practice is not supported by all engine original equipment manufacturers (OEMs) because most would recommend the use of separate spark-ignition gas engines for LPG. Even so, some after-market equipment suppliers can modify diesel engines to suit. Results of these trials are currently being compiled and are not available to this study. If this approach is successful, it could provide an alternative fuel without major conversion costs, as well as some improved fuel security without the need to invest in major LNG storage infrastructure (since LPG is already being used in many countries).

Although LPG can also be used in gas turbines through liquid injection, it is not applicable in most PICTs. Gas turbines are generally found in larger power stations and where domestic natural gas supplies exist.

4.2.5 Technical Viability of LPG for Transport

Due to the established nature of the LPG transport industry worldwide, this study did not go into detail on the technical viability of increasing LPG use in the transport sectors of individual PICTs. Rather, it can be assumed that it is technically viable under the right regulatory conditions and with suitable industry capacity building. In reality, there may be some PICTs for which having an alternative fuel may not be pragmatic if the market is too small to support reliable and safe industrial practices over the long term, or if it is not cost effective to do so.

4.2.6 Technical Viability of LNG for Power Generation

LNG can be used for electricity generation through a variety of different technologies, including the conversion of existing diesel engines and boilers. This, of course, is in the situation where the logistics and costs of shipping make it cost effective. The following list details possible options for power generation using natural gas:

- convert existing engines to dual or tri-fuel, and accept a slight drop in efficiency (1–3%)
- install new gas-only spark-ignition engines
- install micro-turbines
- install gas turbines, and
- convert an existing boiler that currently uses HFO or diesel.

Discussions with some of the engine manufacturers which have the more significant numbers of installed engine capacity in the Pacific show different approaches to dual-fuel technology and gas conversions. Some have tested and will support dual-fuel engine conversions for some models, while others indicated they will not. All have gas-only technologies. The percentage of gas that may be used in a converted engine can vary significantly based on the engine model and manufacturer. Therefore, an individual engine-by-engine evaluation must be conducted to determine the costs of supplying gas to any particular power station and the diesel substitution potential.

To convert a diesel engine to dual fuel the following changes need to be allowed: installation of LNG storage, gas fuel train, and tanker unloading facilities; new engine head; new valves; new control system; and commissioning.

Conversion costs will vary but, for example, one company advised that the costs for conversion of a large 10 MW low-speed engine to dual-fuel capability would be around USD1.5 million per engine. Subject to delivered fuel prices and engine size, the payback on this investment could be very short (possibly less than two years). However, in reality, this may not be the case in the Pacific.

The following additional observations of gas-engine options for generation were made after discussions with various other engine manufacturers:

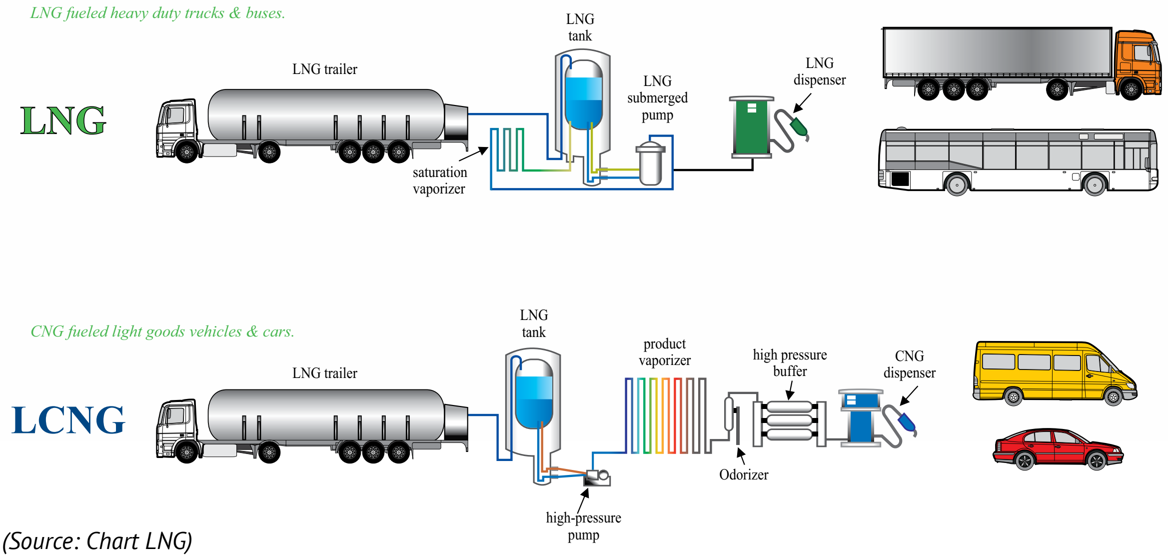
- larger, low-speed diesel engines are more tolerant of dual fuel than smaller, high-speed diesel engines
- engines converted to dual fuel exhibit a lower efficiency when running on either diesel or HFO (up to 3%) and lower efficiency when running on gas (up to 1%)
- it may make sense to install new gas engines rather than convert old ones to maximise efficiency when operating them on gas
- once commissioned on dual fuel, the percentage of diesel use can vary from 0% to 99%, depending on the brand of engine
- having dual or tri-fuel capability (LNG+HFO, or LNG+diesel) improves fuel security
- both OEM supplied and after-market conversion systems exist, but OEM-supplied systems are generally constrained to select models, and
- some engines in the Pacific are already configured as dual fuel and the effort to convert them to run on LNG could be relatively minor.

4.2.7 Technical Viability of LNG for Transport Sector

Assuming that the considerations of transporting and processing LNG in small countries have been addressed, then the focus in looking at the application of gas in the transport sector has primarily been on investigating the potential use in heavy vehicles (trucks and buses) of LNG or CNG derived from the so-called LCNG process (i.e. vapourising LNG at the desired CNG pressure – see Figure 19). This is technically feasible and there are already over 400 LCNG refuelling stations around the world[27].

[27] IGU: FactsFigures_contentOct2014

Figure 19. Natural Gas in Transport Applications: LNG and the LCNG Process

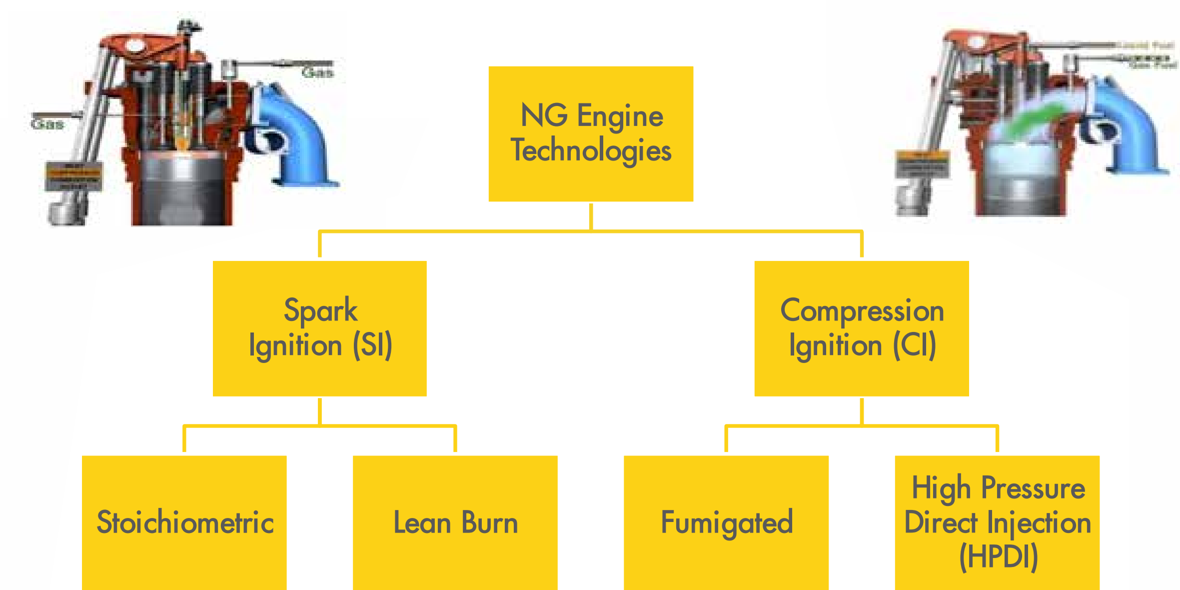


(Source: Chart LNG)

In larger engines or vehicle fleets, the cost of fuel switching or blending generally needs to be justified by intensive fuel use. There are substantial costs involved in undertaking engine conversion, having on-vehicle fuel tanks, developing land-based storage of LNG, providing skills training for the conversion work and ensuring good vehicle maintenance. Therefore, the more specialised and intensive utilisation environments of commercial and industrial vehicles are considered more likely to take up LNG/CNG. Heavy vehicles can also be set up as dual-fuel capable (i.e. diesel engines with gas injection) or gas-only (i.e. using spark-ignition engines).

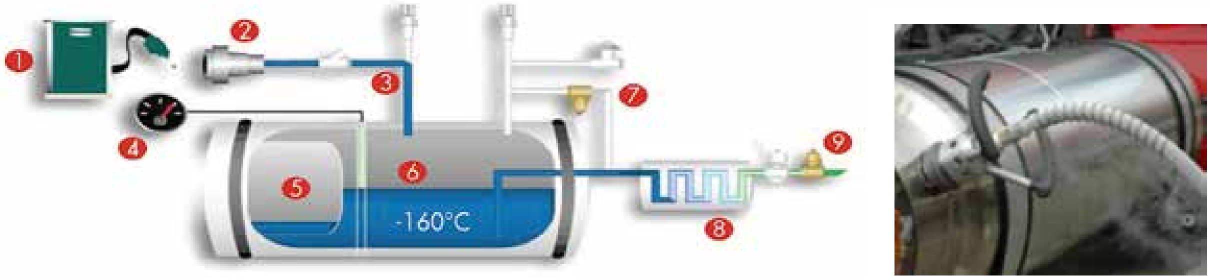
This study also conducted a brief review of the potential in smaller commercial and private vehicles. Unlike in heavy vehicles, gas stored on board light vehicles and buses is typically CNG, created through the so-called LCNG process, as described above. Some potential exists, though it is not likely to be a substantial demand. LNG and CNG conversions are currently available as OEM or after-market solutions in a variety of configurations (see Figures 20 and 21).

Figure 20. Gas Engine Technologies



(Source: Shell)

Figure 21. Typical Transport Configuration



1) Liquid dispenser unit – Fuel stored as cryogenic liquid at fuelling depot → **2) Top fill** – Spray of liquid allows faster filling → **3) Relief valve (PRD)** – allows escape of boil off gas to prevent pressure build up → **4) Fuel gauge** – can be mounted in cab or by fuel receptacle → **5) Vapour space** – small hole near top of tank absorbs excess pressure, extends tank hold time

→ **6) Tank** - Insulated by double walled stainless steel tank, vacuum space between layers to act as thermal barrier → **7) Economizer regulator** – determines and controls tank operating pressure to minimise boil off → **8) Vaporiser** – heated with engine coolant to evaporate fuel → **9) Fuel** – enters engine as a gas (pressure depends on engine type)

(Source: The Shell Company of Australia)

Industry consultations during this study indicated that one supplier in China recently reported double-digit growth in its supply of gas-only engines. This growth has been attributed to its capacity to avoid some of the early problems with dual-fuel engines. Figure 22 illustrates current uptake and typical applications of LNG and CNG.

Figure 22. LNG and CNG Use in Vehicles, 2012

Application	Power	Payload	Fuel / Year	Gas Technology	Fuel Choice	Current Uptake
Large Marine	>5,000 HP	>300T	Up to 30M L	■ Direct Injection ■ Dual Fuel		~100
Off-Highway ■ Rail/Marine ■ Mine Truck	1,000-5,000 HP	>200T	~1,000,000 L	■ Direct Injection ■ Dual Fuel	LNG	~0
Heavy Duty ■ On-highway trucks	400-600 HP	30-140T	~100,000 L	■ Direct Injection ■ Dual Fuel ■ Spark Ignited		~10,000
Medium Duty ■ Buses ■ Refuse	200-350 HP	5-30T	~40,000 L	■ Spark Ignited ■ Lean ■ Stoich + EGR		~ 300,000
Light Duty ■ Pass. Cars ■ LD Trucks	<300 HP	0.5-2T	~4,000 L	■ Spark Ignited	CNG	~ 14,000,000

Values are coarse estimates and information is based on Westport's best knowledge

(Source: Westport Power Inc.)

Various OEM and after-market suppliers are now offering dual-fuel conversions. Feedback from industry representatives indicates a preference for OEM solutions to ensure that the formal engineering assessment is completed to suit the rough roads and remote conditions of many PICTs, and that the most suitable engines are converted.

Some fleet operators contacted during this study indicated that operation costs for dual-fuel engines used in heavy vehicles are higher than for diesel, while other industry participants claim they are lower. Advice from one of the leading heavy vehicle gas-engine technology providers is that the LNG cost needs to be 30% less than the cost of diesel to justify the capital and operational cost of fleet conversion. The same is not true for passenger vehicles, which operate small spark-ignition engines (as opposed to traditional diesel engines).

4.2.7.1 Mining Fleet

The use of LNG in surface-based mining fleets is currently at the research and development stage. Trials and demonstrations on a Caterpillar 793 Haul Truck have been conducted in the USA by a third-party technology provider. It allows 30–50% use of LNG blended with diesel and uses high-pressure direct injection (HPDI) technology.

4.2.7.2 Maritime Transport

For the marine sector, natural gas is emerging as a promising fuel option for large international tanker and cargo vessels. This is due in part to the greater availability of LNG as a fuel, and to the increasing stringency of various ports around the world in regard to sulphur and particulate emissions.

There are now reference projects with ferries and off-shore supply vessels operating on LNG engines. Feedback from the industry at the consultation workshops indicates that a simple engine change-out or fuel-blending solution may not optimise a large vessel's efficiency. The fuel, engine and propulsion system should therefore be optimised together. For example, one company has developed a complete fuel-gas handling system that can be used in conjunction with a gas engine, with over 20 installed to date.

Common equipment required for a fuel substitution includes:

- new engine or dual-fuel conversion kit
- replacement fuel-storage tank (either fixed or replaceable)
- vaporisation system
- new fuel-control system, and/or
- new fuel-loading system or replaceable fuel-tank system.

4.2.8 Technical Viability of Gas for Industrial Use

Current fuel use in commercial and industrial applications is very small relative to that in power generation and transport. Even in New Caledonia, which has the largest industrial sector of countries in this study, much of the 'industrial' fuel demand is ultimately for on-site power generation purposes.

Typical uses in industry where LNG would be suitable are in direct combustion applications such as boilers, hot water and process heat. Such an example exists in Puerto Rico where a company is successfully substituting LNG for LPG in industrial use at a high energy-use bottling plant. However, it is important to note that this example is also characterised by having access to lower-cost LNG from the USA and short transport distances, which means that the use of 40-foot shipping containers is viable. Therefore, industrial use in the Pacific is not likely to be a key driver of fuel switching to LNG, but it may provide benefits as a secondary use following the establishment of an LNG industry.

4.3 Issues

4.3.1 Issues in Using Gas for Transport

4.3.1.1 Maritime Transport

The conversion of domestic marine fleets to gaseous fuels appears to be challenging. It is also likely to be difficult to establish sufficient demand and develop the skill base for installation and maintenance. The expected costs of conversion are also projected to be very high. In comparison to land vehicles, more specific technical requirements would need to be determined for each conversion, including associated fuel-storage capability on a vessel-by-vessel basis. Based on its lower energy density, LNG would require more space for the same energy storage and reduce vessel range. That being said, the tourism sector (with smaller fleets) has a higher turnover than other marine classes and could be an early 'up-taker' of alternative energy supplies in the region.

The opportunities to retrofit local ships face challenges on several fronts:

- insufficient demand
- high cost of conversion
- low engine/vehicle turnover
- use of low-cost HFO, and
- lack of in-country stocks of LNG.
- Similar to the power sector, the viability of converting a ship would need to be determined on an individual case-by-case basis, which was not possible under the scope of this study.[28]

4.3.2 Energy Efficiencies through Maintenance

During the site visits in this study, it was observed that many buses are not tuned or well maintained. A comparable or much lower investment in maintenance and tuning of the heavy and commercial vehicle fleet might yield similar or better fuel-cost savings than any investment in gas infrastructure and use. One such policy mechanism might be to require annual tune-ups with renewal of registration.

4.3.3 Issues in Using Gas for Power Generation

As the viable application of gaseous fuels in PICTs' power sectors is very much determined by site-specific characteristics, visits to several power stations were undertaken during the research phase of this study. These stations included:

- Kinoya, Fiji: a 50 MW plant with 37% industrial diesel oil (IDO) and 53% HFO use
- Tagabe, Vanuatu: an 8 MW plant powered mainly by coconut oil, and
- Tonga: a 12 MW plant with diesel used in the engines as well as 17% renewable electricity (mostly from solar power).

Based on the LNG pricing identified in this study, none of these three power stations would be viable to convert, considering cost savings only. The delivered cost of LNG to each power station is higher than the existing and projected fuel costs. Each station also has good reasons why other courses of action are being taken.

- Kinoya (Fiji) is moving away from diesel+HFO to HFO-only generation, based on historical prices showing that HFO costs less than landed diesel and possibly LNG

28 Data on specific engine details and associated fuel consumption were not readily available for the majority of countries.

- Tagabe (Vanuatu) uses mostly coconut oil and, at 8 MW, is too small to justify the LNG infrastructure for bulk delivery, while containerised LNG is at this stage not cost-effective. Unelco also stated that locally sourced coconut oil was cheaper than diesel, and pursuing this is consistent with its corporate objectives of greater penetration of renewable energy
- Tonga has ~7 MW peak demand and would therefore need to rely on LNG delivered in ISO containers, since it is too small to justify LNG delivery using bulk ships. This is not cost effective. Furthermore, it is aggressively pursuing increasing amounts of renewable energy and already has 2 MW of solar PV installed, which is producing around 6% of overall electricity needs.

4.4 Conclusions

4.4.1 LPG for Households

Using LPG is technically feasible and beneficial but expansion would require public policies to encourage its use.

4.4.2 LPG for Commercial and Industrial Use

Using LPG is technically feasible and expansion could be achieved in either the commercial sector (for air conditioning) or the industrial sectors (for boilers and process heat).

4.4.3 LPG in the Transport Sector

Using LPG is technically feasible in transport in the PICTs since it is an established industry worldwide. There are significant barriers to overcome, however, including policy, regulations, and industry capacity in those PICTs that do not currently use LPG in vehicles.

4.4.4 LPG for Power Generation

Blending LPG with diesel into existing engines is not generally supported by OEMs, but is offered by after-market suppliers. It can, however, be used in dedicated spark-ignition gas engines as a direct fuel in gas turbines. To date it is has not been cost effective to use as a base-load fuel anywhere within the PICTs studied.

4.4.5 LNG for Power Generation

Stationary power generation can offer a large single-point load source around which costly LNG can be introduced. Each power station, however, will face different challenges in regard to the technical feasibility of converting existing engines or securing LNG supply, the location of storage systems, and the technical skills required to operate it. The cost of converting some of the older engines to LNG is likely to exceed the total cost of procuring a new gas-fired engine, or is simply not technically possible. Furthermore, each PICT has multiple power stations that would face individual logistical challenges in securing, delivering, and storing LNG supply (see Appendix H for fuel consumption by power station and country).

4.4.6 LNG for Transport

This study finds that LNG for transport, as either LNG or LCNG, is technically feasible but it faces many technical and commercial challenges in PICTs. There is virtually no near-term market for conversion to LNG of the maritime fleet based in the Pacific, but there could be an increasing demand for offering LNG bunkering facilities to international fleets, or for new ships purchased that are LNG fuelled. If LNG refuelling capabilities develop over time, PICTs may be able to consider LNG fuel ships either as a new or second-hand purchase.

Due to the costs and technical challenges of converting and running transport fleets on alternative fuels, it may only make sense to carry out fuel conversions in countries in which high numbers of heavy vehicles exist, and an established technical skill base exists, so that a conversion 'industry' could be established. Fiji, with over 1,600 buses in operation, may offer one of the best opportunities to use LNG or CNG as an alternative fuel. A hypothetical scenario has been prepared to examine and identify the potential opportunities (see Appendix C).

5 Research Question 3: Is it economically feasible to expand LPG and introduce natural gas into the Pacific Island Countries and Territories?

5.1 Commodity Prices

5.1.1 LPG

Retail LPG prices vary significantly across the Pacific where the delivered specific cost per MMBTU is generally higher than either diesel or gasoline. This is due to the relatively low volumes, low levels of competition, more costly infrastructure for storage and transportation, and current wholesale pricing structure.

This study assumes that the current link to Saudi Aramco CP prices remains in place and that LPG is not a competitor to diesel and gasoline for either the power or transport sector if it is taxed equivalently. Table 6 illustrates the recent wholesale Saudi Aramco CP pricing history for LPG.

Table 6. Saudi Aramco CP Prices, USD/Tonne

	Jul-13	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14
Propane	795	820	850	820	875	1100	1010	970	855	770	810	835
Butane	790	820	875	850	915	1225	1020	970	870	845	825	835

(Source: Argus LPG World Monthly Newsletter, Issue 14, 15 July 2014)

5.1.2 LNG

The price of LNG, either delivered ex-ship (DES) or free on board (FOB)[29], is usually set by one of four mechanisms:

- oil-linked pricing
- gas-linked pricing
- subsidised pricing, and/or
- regulated pricing.

Supplies of LNG to PICTs are potentially available from Asia (where oil-linked pricing is most common) and North America (where gas-linked pricing is more common). Therefore, for the purpose of this study, subsidised and regulated pricing structures are not discussed further.

Oil indexation has traditionally been the preferred pricing mechanism in East Asia. The formula below gives an example of how LNG prices move in accordance with oil prices.

$$\text{Price (in USD/MMBTU, FOB or DES)} = (0.14 \times \text{Brent}) + 0.60 + S + A$$

where:

- the factor of 0.14 varies with the characteristics of the market and individual deals (in a supply-long market and presumably for larger deals, the discount to oil will widen)
- *'Brent'* is a trading classification of sweet, light crude oil that serves as a major benchmark price for purchases of oil worldwide

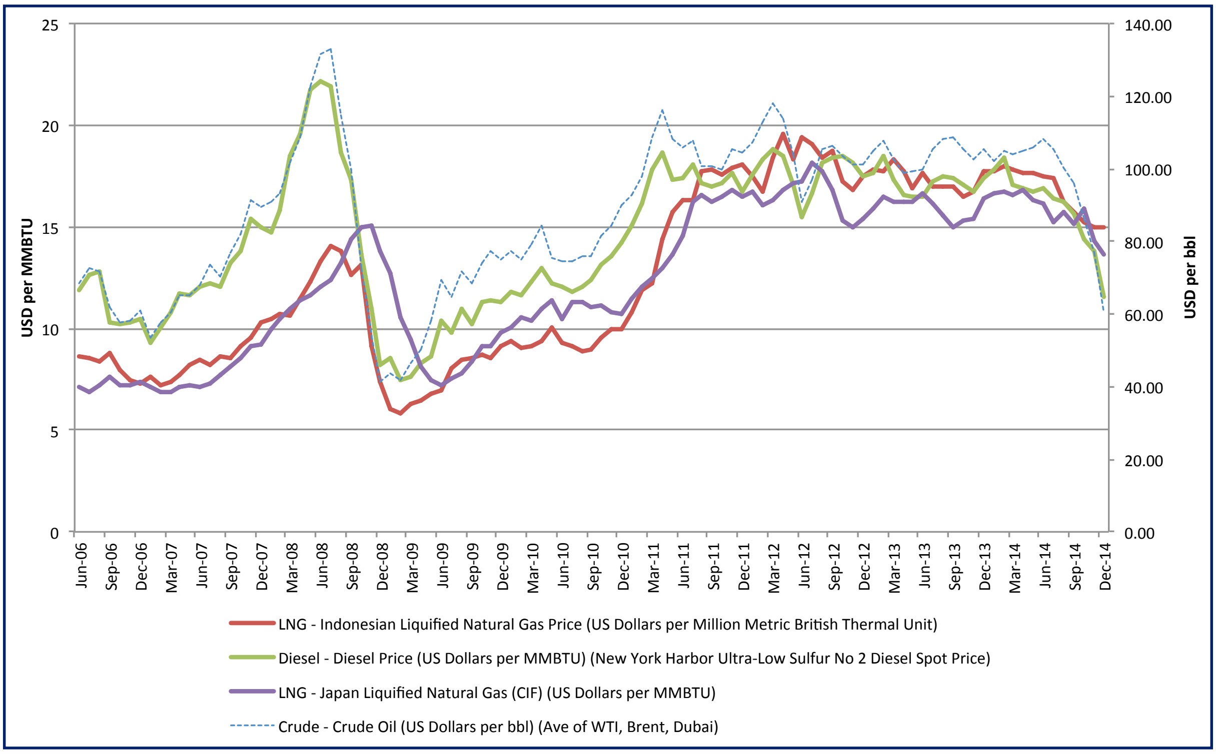
29 Refers to product loaded on ships i.e. the cost of the product plus all costs to put it on the ship.

- 'S' is an S-curve factor to provide extra margin to the Seller if Brent is below a certain threshold, and to reduce the overall price to the Buyer if Brent is high
- 'A' means all costs and expenses (expressed in USD per MMBTU) incurred by or on behalf of the Seller in relation to reloading cargo (LNG) at an international bunkering terminal and may include shipping if agreed
- 'DES' is delivered ex-ship to the buyer's terminal, and
- 'FOB' is free on board the delivery vessel.

For example, one such contract structure for gas-linked pricing is offered by Fortis BC, Canada and is detailed in Appendix G. Gas-linked pricing, however is forecast to maintain a relatively low percentage share of the near-term forward market, which also currently appears to be dominated by contracts with USA suppliers.[30] To access gas-linked LNG pricing, LNG must be shipped from the USA to the Pacific. This may prove to be economical provided there is enough price discount to Asian LNG markets. Some Asian buyers have already purchased LNG from North America.

Price can, and does, vary substantially among markets, applications and specific contracts with a range (ex-terminal) of USD7–15/MMBTU (see Figure 23). Quotes obtained during this study and other work show that LNG is currently priced at approximately USD15/MMBTU in Singapore, USD15–16/MMBTU delivered to Japan, and approximately USD7–10/MMBTU ex-terminal in Vancouver, depending on volumes and contract length. Small Australian-distributed applications see USD15+/MMBTU ex-terminal price (subject to contract quantities and conditions) with USD17–23/MMBTU delivered to Australian industrial sites for transport and stationary energy applications.

Figure 23. LNG Price Comparisons to Oil and Diesel

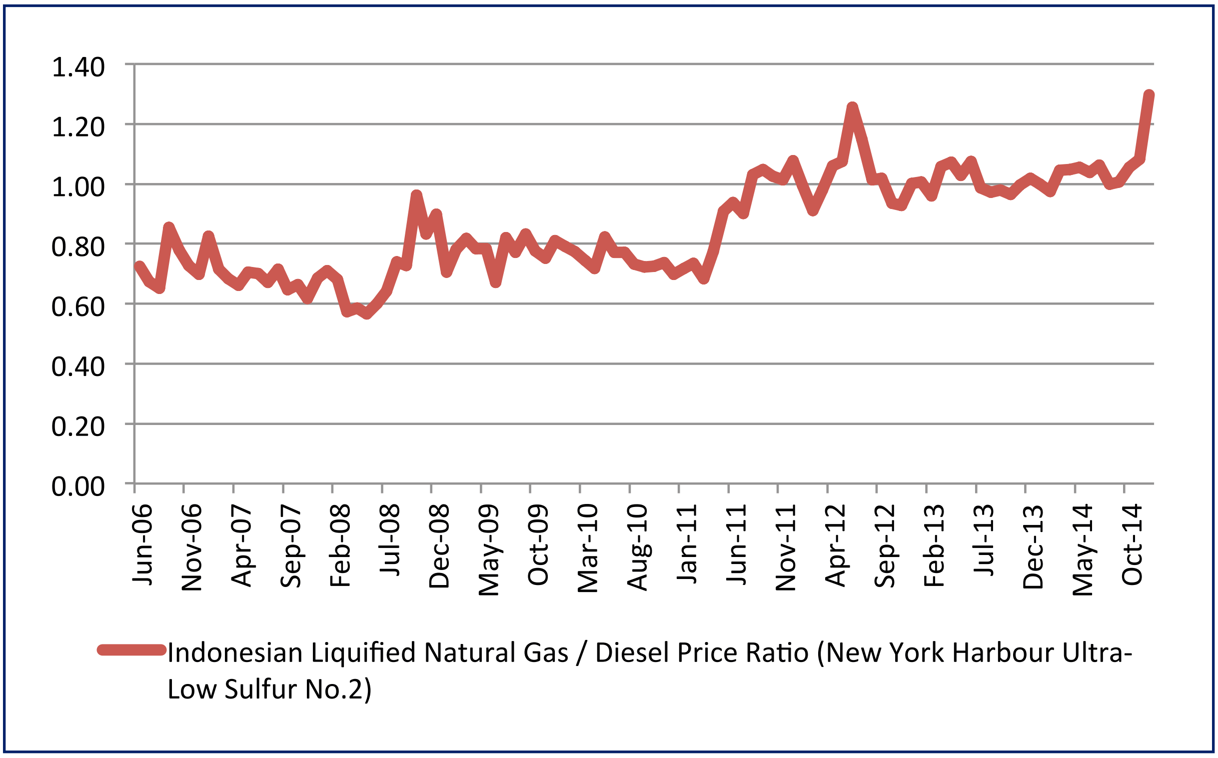


(Source: www.indexmundi.com – World Bank)

It is interesting to note that data on Indonesian LNG show that LNG has become less competitive against diesel over the last eight years (see Figure 24). Some private contracts may, however, still be discounted relative to delivered diesel prices.

30 IGU World LNG report, 2014 edition.

Figure 24. Indonesian LNG and New York Diesel Price Ratio (USD per MMBTU)



(Source: www.indexmundi.com – World Bank)

The most proximate detailed example of LNG procurement studies for the region is the work undertaken in Hawaii. The Hawaii LNG study undertook a detailed analysis of the projections for LNG FOB prices. It identified that the difference between the forecasts for oil-linked LNG prices in Australia, Canada, Alaska (at USD15.66–20.36/MMBTU to 2030) and the gas-linked projects on the US Gulf Coast and US West Coast (at USD8.63–11.02) varies from 50% to 85%.[31] As a result, the authors of the study concluded that shipping LNG from the US mainland to Hawaii was the preferred option compared to the oil-linked projects being targeted at Asia.

Another study exists for Guam, which also discussed future LNG prices extensively in order to conclude that what looks like a marginal benefit could easily disappear, for a very large capital expenditure.

For the purposes of this study, the costs were compared as a snapshot in time of LNG supply from Australia and North America. It was assumed that there were no constraints in supply of the quantities requested, and that:

- bulk shipped LNG is available from Gladstone at USD15/MMBTU, FOB
- bulk shipped LNG is available from Vancouver at USD8/MMBTU, FOB, and
- ISO container LNG is available from Dandenong (Melbourne) at USD15/MMBTU, FOB.

5.1.3 CNG

CNG can be easily created from pipeline natural gas in small quantities and, as such, can be located much more flexibly than LNG liquefaction plants. The gas-compression infrastructure is scalable, quick to establish (i.e. it takes less than one year) and relatively inexpensive. For this reason and the purposes of this study, it was assumed that CNG is available in Brisbane, a major port close to Fiji, Tonga and Kiribati, which are used as case studies in this report. A nominal price for natural gas (prior to compression) at the gas pipeline in Brisbane was USD5/MMBTU.

[31] Facts Global Energy (2012). Liquefied Natural Gas for Hawaii: Policy, Economic, and Technical Questions.

In terms of CNG use in transport, this study assumed that CNG could not be shipped to the Pacific in a cost-effective manner, but could be used in-country if it is derived from vaporising LNG at the working pressure with a relatively small amount of additional equipment. Therefore, the price of CNG for in-country use can be assumed to be the same as that of LNG.

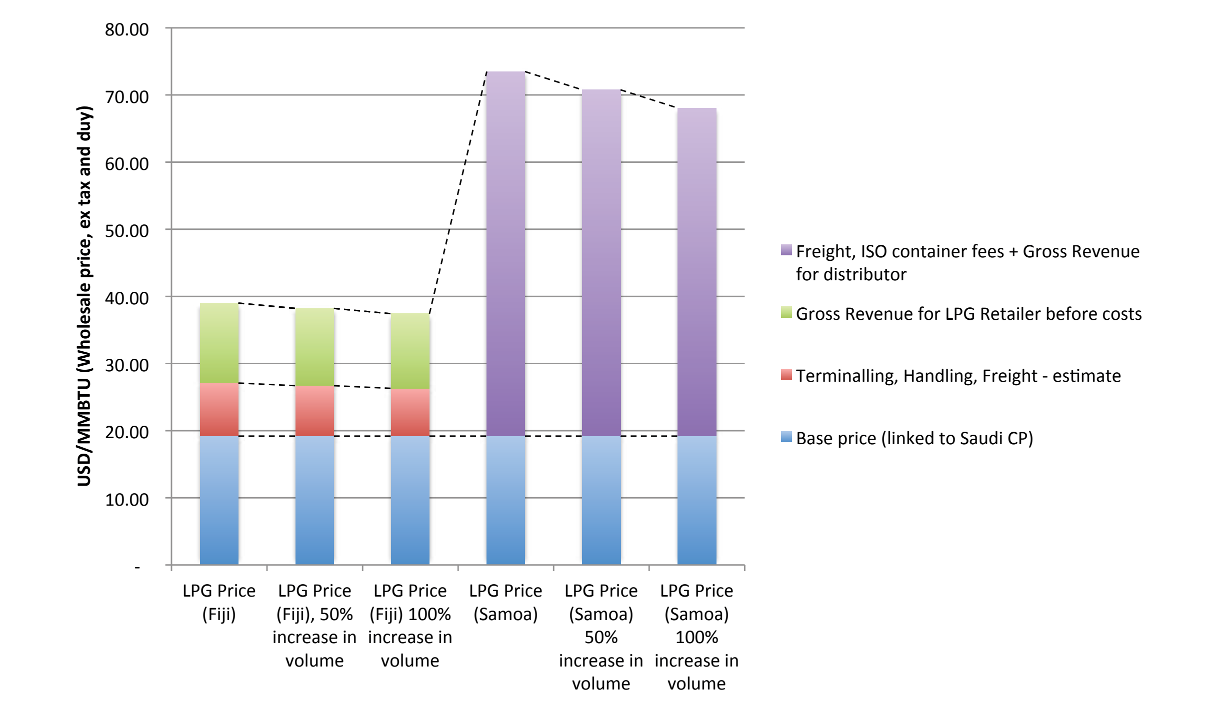
5.2 Findings

5.2.1 LPG Delivered Cost

Other studies have examined in detail the landed cost of LPG in various Pacific countries. The price 'build-up' includes some or all of Saudi Aramco CP, as well as costs associated with bulk storage, handling, freight, and retailers' margins. Figure 25 illustrates a coarse LPG price breakdown in a high- and low-cost PICT. The LPG base price of USD850/tonne shown is an approximation of the historic Saudi Aramco CP that all wholesale LPG suppliers currently pay.

To illustrate the potential economies of scale associated with increases in volume, an assumption has been made that the costs associated with bulk storage, handling, freight and retail margins would reduce by 10% for each doubling in volume.

Figure 25. LPG Price Assuming a 10% Reduction for Every 100% Increase in Volume

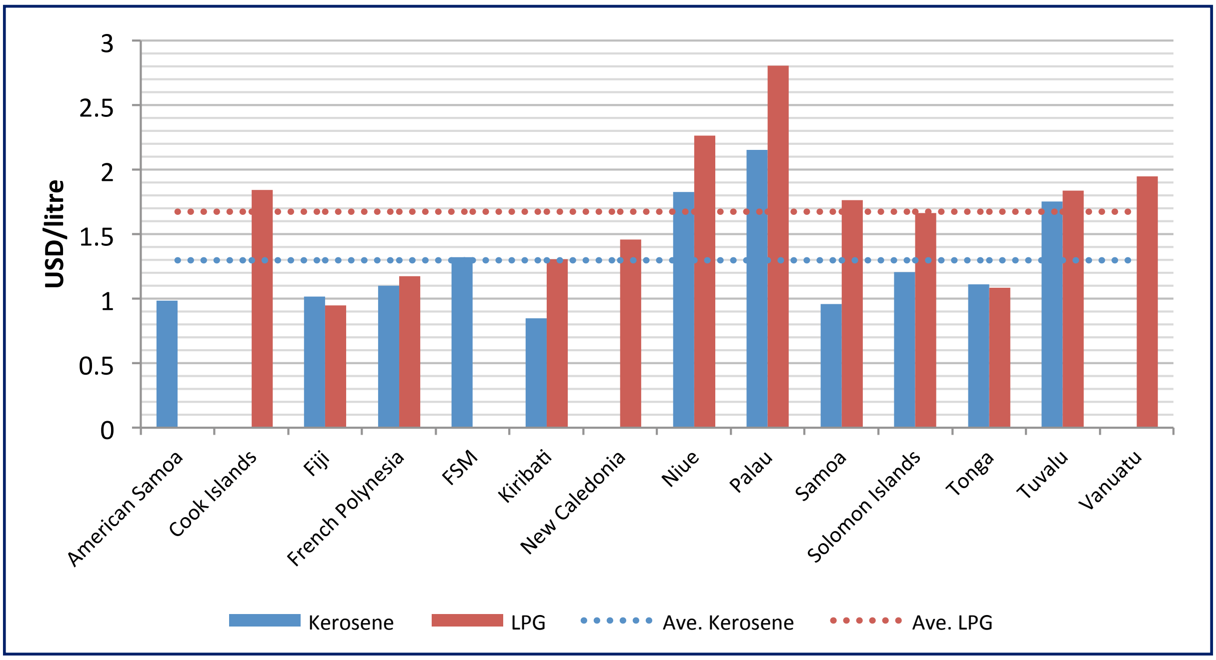


5.2.2 Cost of LPG versus Kerosene for Households

One of the key factors in considering whether LPG consumption should be promoted more heavily is whether disruption in global LPG markets is likely to result in price reductions. At present, LPG pricing is linked strongly to the Saudi Aramco CP, but industry sources suggest that this could change or at least increase in volatility. If so, and if flexible and cost-effective contracting arrangements become possible, then stimulating LPG demand could deliver beneficial results. Furthermore, LPG may also become available soon in reasonable quantities in PNG which could change the supply–demand balance in favour of local users in the Pacific region.

The World LPG Association acknowledges that the principal barrier to more widespread use of LPG in the Pacific islands is the cost issue, both in terms of the fuel itself and the equipment needed to utilise it.[32] As Figure 26 illustrates, this appears to be the case in almost all of the countries in the Pacific where comparative data is available, including French Polynesia, Kiribati, Niue, Palau, Samoa, Solomon Islands and Tuvalu. In addition, as gas cooking equipment is more sophisticated, it is often more expensive than cheaper kerosene or basic wood stoves even when higher stove energy efficiency is taken into account. There is also the logistical challenge of transporting and returning cylinders for refuelling in remote rural or in outer islands.

Figure 26. Cost Comparison Between Kerosene and LPG: Retail Price Excluding Tax and Duties, First Quarter 2014



(Source: SPC Pacific Fuel Price Monitor)

Data on the cost of energy delivered to the end-use application is also interesting. Several studies that have compared kerosene and LPG cook-stove efficiencies have found them to be roughly similar[33], so the key issues for end-users are likely to be availability and cost. In some countries, kerosene may be the lowest-cost option since it is often derived from larger aviation fuel imports (approximately 10%-20%). This raises the issue of whether subsidies need to be considered by governments if they decide to introduce LPG for health and environmental reasons. Alternative energy sources may also be considered, including locally and/or regionally produced biofuels and distributed small scale renewable energy sources (e.g. solar PV or wind).

5.2.3 LPG for Commercial and Industrial Sectors

Table 7 presents a brief comparison of electric versus LPG-driven air conditioning based on real gas and electricity prices in Tonga as well as data derived from the engineering characteristics of heat pumps and other engineering calculations. The data shows that, at this pricing, electricity is the cheaper alternative and, only if the relative cost of LPG is more favourable, would further investigation of this option be warranted. As mentioned earlier, LPG air conditioning is currently available in Fiji, Tonga and Vanuatu, which could indicate that different costs or improved economies of scale could be factors. However, cost comparisons need to be verified in any particular situation where change to LPG is being considered.

32 The World LP Gas Association (2014). LP Gas Exceptional Energy for Small Island Developing States.
33 Center for Energy Studies (2001). Efficiency Measurement of Biogas, Kerosene and LPG Stoves, plus others.

Table 7. Potential Scenario for Gas Air Conditioning

Item	Electric Heat Pumps	Gas (propane/butane) Heat Pumps
Coefficient of Heat Pump Performance (assumed)	4	4
Gas Use per MMBTU of Cooling Capacity	0	0.71 MMBTU
Electricity use per MMBTU of Cooling Capacity	0.25 MMBTU	0.03 MMBTU
Energy Price Assumptions (Tonga)	US 0.37c/kWh (99/MMBTU)	USD1.70/kg (36/MMBTU)
Gas Cost (USD/MMBTU cooling)	0	USD26
Electricity Cost (USD/MMBTU cooling)	USD25	USD3
Total Cost	**USD25/MMBTU cooling**	**USD29/MMBTU cooling**

(Source for Tonga power prices as at July 2015: http://www.tongapower.to/NewsRoom/ElectricityTariffIncreaseEffectivefrom1stJul.aspx*; Source for Tonga LPG prices as at June 2015:* http://www.tongapower.to/NewsRoom/ElectricityTariffIncreaseEffectivefrom1stJul.aspx)

5.2.4 LPG for Vehicles

An opportunity exists to grow the LPG market for vehicles in PICTs. At present this is limited to Fiji, but it could also be adopted elsewhere. This would require a public policy decision by governments and this section of the report provides a summary of a few suggestions that could be investigated.

The first is the use of LPG in government fleets, buses and private vehicles (as indicated earlier in the report). The second is the introduction or expansion of an LPG scooter market, especially given that many second-hand scooters are becoming available from regions such as China, where LPG/CNG small vehicles are encouraged through policy positions aimed at improving air quality. Moreover, scooters are a far more accessible entry-level transport option for PICTs. Their low up-front transport investment costs can improve market access for residents in the distribution of goods and services.

At one of the consultation workshops with the industry, a Fiji-based LPG distributor advised that it is undertaking successful trials of LPG blending on recreational boats and in its own diesel-truck fleet. Therefore, it is seeking to expand such efforts to grow this market. This development could be monitored for its potential in the PICT marine and land transport sectors.

5.2.5 LNG Transport Options

Some of the significant components of the LNG delivered cost, which are unaffected by oil or gas price fluctuations, are shipping, electricity costs for liquefaction, fixed costs and capital amortisation related to capital infrastructure. Shipping and transport are a particular cost issue for PICTs, due to the long distances from markets and varying port and transport infrastructure in each country.

For the purposes of evaluating transport costs in the built-up cost analysis, this study assumes that LNG is available for supply to PICTs under the following arrangements:

- Vancouver: small-scale bulk ships;
- Gladstone: small-scale bulk ships; and
- Melbourne: ISO containers.

Regional experience in LNG transport includes small-scale bulk shipping, road transport and 20' or 40' ISO containers. Existing facilities in Australia are receiving LNG over long distances by means of single- or twin-trailer haul trucks. Shipping companies in Singapore confirm that they have already received LNG loads from Conoco-Philips' Darwin LNG terminal in 10,000–12,000 cbm small-scale ships.

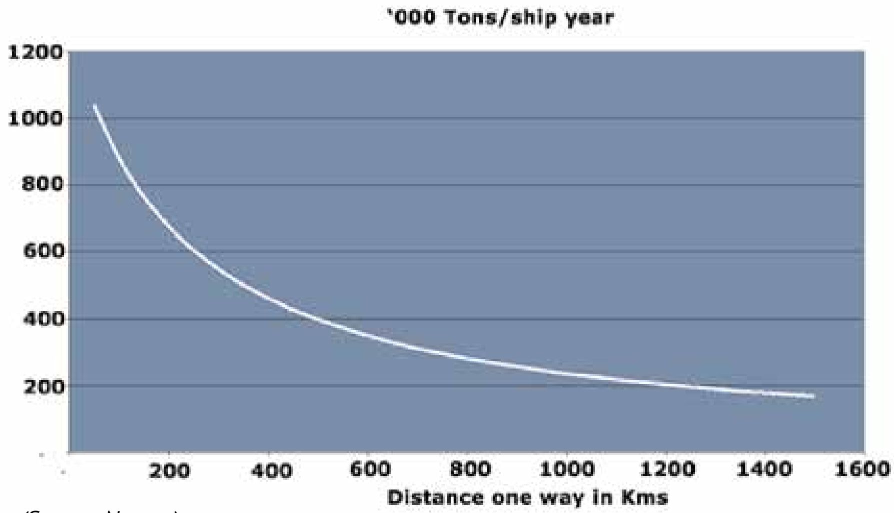
The main LNG transport solutions investigated in this study are:

- small-scale LNG shipping: from an LNG supply terminal (e.g. Gladstone or Vancouver) to a central storage terminal in a Pacific country, followed by truck transport to localised storage at the end-user's site; at site, the cargo would be discharged into on-site storage tanks and the empty truck returned to the port for refilling, and
- ISO container LNG shipping: 20' or 40' ISO containers delivered from the supply point in Melbourne to a site in the Pacific; at site the cargo would be discharged into on-site storage tanks and the empty container returned to the port for return shipping.

5.2.6 LNG Shipping Using Small-Scale Bulk Ships

A variety of ships are suitable for small-scale delivery of LNG to PICTs, where annual supply volumes are dependent on proximity (see Figure 27).

Figure 27. Shipping Capacity for Small-Scale LNG Multi-Gas Carrier

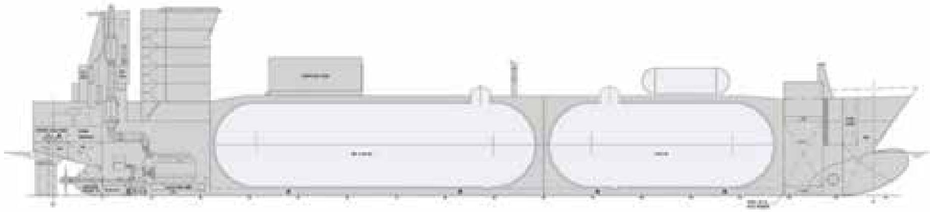


(Source: Norgas)

Ships suitable for small-scale bulk delivery to PICTs are available and operating in Asia (see Figures 28 and 29). One such ship has the following key specifications and was used to estimate shipping costs in this study:

- a semi-refrigerated ship capable of carrying LNG at -163°C
- a re-liquefaction facility to eliminate boil-off losses
- dual upper and lower cargo manifolds to allow loading at large terminals in Australia, PNG, Singapore or Vancouver
- capacity = 10,000–12,000 m^3
- discharge time = 10–12 hours, and
- speed = 16.5 knots.

Figure 28. Small-scale LNG Multi-gas Carriers, 10,000 cbm/4,500 tonne



(Source: Norgas)

Figure 29. LNG Carrier

(Source: www.skaugen.com)

Table 8 below presents an example of an estimation of the costs for small-scale bulk shipping to PICTs. The example assumes that Suva in Fiji would be a regional hub, although it is possible that the ship could easily transfer bulk to other major ports such as New Caledonia or Tahiti. These figures are consistent with the study for Hawaii Gas of USD3–5/MMBTU for transport and boil-off for LNG delivered to Hawaii from the US Gulf Coast or West Coast.

Table 8. LNG Shipping Times and Cost with Budget Charter Rates for Small-Scale Ship

From	To	Nautical Miles	Sailing and Port Days at 16.5 Knots	Charter Cost	Shipping Capacity (per annum)	Estimated Shipping Cost (USD/ MMBTU)
Vancouver	Suva	5,100	13 + 1	~USD2.18 m per month*	71,000	USD6.35
Singapore	Suva	4,600	12 + 1	~USD2.18 m per month*	78,100	USD5.77
Darwin	Suva	3,000	8 + 1	~USD2.18 m per month*	114,900	USD3.92
Melbourne	Suva	2,200	6 + 1	~USD2.18 m per month*	150,300	USD3.00
Gladstone	Suva	1,700	5 + 1	~USD2.18 m per month*	170,000	USD2.65

**Charter rate of USD1.2 million per month includes crew and ship charter, but excludes port fees and fuel, which are estimated at ~USD30,000 per day.*

5.2.7 LNG Shipping in ISO Containers

ISO containers used to ship LNG are commercially available (see example in Figure 30), and the question of whether LNG should be shipped in ISO containers or by bulk is a decision mostly of transport and container cost (not the commodity cost). These containers are vacuum-insulated and hold LNG without boil-off for up to 80 days. Various designs are available with different holding times, and the choice affects cost. The model evaluated in this study uses the following assumptions:

- a fleet of containers is owned by the buyer, seller, shipping line, or other third party
- cost of the containers and a nominal financing cost is spread over their full lifespan
- containers are delivered to the site, where their contents are discharged into local storage tanks and then returned to the point of origin, and
- containers take around two to three months for each rotation, depending on the PICT.

When LNG containers are shipped between two locations – whether full or emptied - they are classed as a Dangerous Goods Class 2[34] and require special handling at ports and on ships. Discussions with shipping companies and regional port operators indicate that this attracts a premium cost that can be negotiated downwards with volume.

Figure 30. ISO 20' Container for LNG

(Source: Cryeng, Australia)

For the study, budget quotes were obtained for the purchase of ISO containers. It was difficult to confirm a narrow average price band and economies of scale for 40' containers, but prices seemed consistent across suppliers for 20' containers. Quotes indicated that containers are available at:

- USD130,000 for a 20' LNG container, and
- USD150,000–200,000 for a 40' LNG container.

The 2012 Hawaii gas study quoted 40' containers at USD180,000–200,000 each. Some industry sources quoted USD150,000, while others believe that container costs could be lowered substantially by:

- international sourcing for a large order, and
- optimising the design and minimising LNG holding-time requirements based on specific transport routes.

In considering this diversity of industry advice, for the purposes of this study it was assumed that ISO containers used for transport of LNG have the characteristics shown in Table 9.

34 Given that, even when emptied, they may contain some residual gas.

Table 9. ISO LNG Container Solutions

Item	20' Container	40' Container
Max. Working Pressure	10 bar	6–17 bar
Volume	20kL	44.5–46kL
Tare Weight (ASME[35] code)	6.6–10 T	10.7–18.5 T
Mass of LNG (Tonnes)	~9 T	~18 T
Energy Content for LNG	~468 MMBTU	- 937 MMBTU
Hold Time without Releasing Boil-off	52–75 days	53–85 days
Cost used in this Study	USD130,000	USD150,000
Regasification Rate	1.65 tonnes per hour	1.65 tonnes per hour
Cost per Tonne	USD14,444/Tonne	USD8,333/Tonne
Life of Container in the Pacific	10 years	10 years
Ownership	Third party or shipping line	Third party or shipping line
Time Spent on Round Trip to PICTs	Varies from 2–3 months	Varies from 2–3 months
Loading Port	Melbourne's APA facility in Dandenong	Melbourne's APA facility in Dandenong

In order to understand the cost of shipping, budget quotes were obtained for shipping a 40' LNG container from Melbourne to Fiji, Tonga and Kiribati, as examples of a major end-user and sub-regional delivery points. The quotes include both en-route and return voyages (inclusive of port fees, forklifts, transport to and from ports, shipping line charges, and surcharges for handling and transport of dangerous goods), as well as an amortised container cost (i.e. reflecting the gradual 'writing-off' of the initial cost over the life of the asset). These are added up and divided by the total amount of LNG delivered to work out the specific shipping cost. Table 10 illustrates the cost per MMBTU for ISO container delivery from Melbourne to Fiji, Tonga and Kiribati.

Table 10. Costs of Shipping ISO Containers of LNG to Selected PICTs

Item	Fiji	Tonga	Kiribati
Container Type	40'	40'	20'
Tonnes of LNG per Container	18	18	9
Energy per Container	938	938	469
Container Turnaround Time	2 months	3 months	3 months
Life of Containers	10 years	10 years	10 years
No. of Container Loads p.a. for 50% of Power Consumption and Some Transport	2,316	322	268
Total No. of Containers	386	80	67
Total Delivered Cost per Container (Return to Melbourne)	USD9,901	USD12,188	USD7,561
Cost per MMBTU for Shipping	USD10.55	USD12.99	USD16.12
Cost per MMBTU for Amortised Container Cost	USD3.68	USD5.51	USD9.26

35 American Society of Mechanical Engineers

5.2.8 LNG Import Terminal, Floating Storage and Regasification Unit, and On-shore Storage Costs

LNG storage will be required in any logistics solution. For bulk shipping, large volume storage will be required at the port as a land-based tank, floating storage unit (FSU, without regasification) or floating storage and regasification unit (FSRU). For both container and bulk solutions, the LNG would be trucked to a site (e.g. a power station, bus/truck depot) from the port and stored there in tanks with 20–90 days' holding time.

The costs of these facilities have been estimated and amortised over a project life, with results shown in Table 11. A cost of USD5,870/tonne was used for site storage, and USD5,000/tonne for bulk import terminal storage and handling facilities. It was also decided to use 60 days as the required storage for the bulk terminals, but only 30 days' storage for the site tanks. This is because any power station or transport operator which converted to LNG would probably retain dual-fuel capability and additional fuel supplies of, for example, diesel. Therefore, long-term storage at site was not likely to be required.

Whilst a risk assessment has not formed part of this study, it would need to be completed for each storage facility, and this would influence the final construction cost. Consideration would need to be given to urban planning, public safety, local construction capability, cyclones/weather events, and geological events such as earthquakes. In this respect, those promoting floating storages claim they are less susceptible to major events since they can be floated out to deeper waters where the impact of these is generally less.

Table 11. LNG Storage Solutions

Item	Vertical Steel Tanks–General	On-Site Storage (Cryeng 300 m³ vessel)	On-Site Storage (Cryeng 1,000 m³ vessel)	Bulk Receiving Terminal Storage–Finland	Bulk Receiving Terminal Storage–Hawaii Study	FSRU Storage
Max. Working Pressure	17–18 bar					
Net Capacity	3–102 kL	300kL	1,000 kL			120,000 kL
Daily Evaporation Rate at 15°C and 100 kPA	0.9–0.37 %/day					
Overall Width	2–3 m					
Overall Depth	2.1–3.3 m					
Overall Height	4–23 m					
Mass of LNG (Tonnes)	1.5–48	~140	~460	50,000	55,000	~55,000
Energy Content for LNG	55 GJ/tonne					
Regasification Rate		7 tonnes/hr	7 tonnes/hr			
Hold Time Without Releasing Boil-off		Unknown	Unknown			
Cost for Tanks Only		USD0.75 m ex works	USD1.5m ex works			
Cost for Full Installation (USD)		USD1.5 m (est. at twice the tank cost)	USD3 m (est. at twice the tank cost)	USD122m	USD275 m (including wharf, piping, re-gas costs)	USD80–140 m (excluding wharf, piping, re-gas costs)
Cost per Tonne of Storage Capacity (USD)		USD5,870/ tonne	USD5,870/ tonne	USD2,44/ tonne	USD5,000/ tonne	USD1,450–2,550/ tonne
Facility Life		20+ years	20+ years	20+ years	20+ years	20+ years

Figure 31. 300m3 Cryogenic LNG Tank in Tasmania

(Source: Cryeng)

The development cost for port storage is significant because it needs to be large enough to accept the entire load from a bulk supply ship. Due to the highly site-specific costs and significant engineering exercise associated with costing this storage, it has not been possible to quantify these amounts with any level of high accuracy for this study. Nonetheless, some reference pricing is available from other studies and market information.

One example is at the Tornio port unloading facility in Northern Finland. One equipment supply company was awarded a contract that includes unloading, a 50,000-tonne storage tank, regasification equipment, and a 10-year maintenance contract for approximately Euro(€)100 million (representing around €2,000/tonne stored).[36] In the Hawaii gas study, estimated bulk import terminal costs were:

- USD145 million for a 55,000-tonne bulk storage tank
- USD50 million for other onshore infrastructure including piping, controls, buildings and gasification (not necessary in the Pacific)
- USD80 million for a marine berth
- Total: USD275 million, or USD5,000/tonne stored.

The end-result is that large variations in this cost are not very significant in the overall delivered cost analysis, but port storage does represent a large upfront investment and potential capital barrier. Table 12 illustrates the costs of storage for the three case studies selected here.

36 http://www.lngglobal.com/lng-for-fuel/waertsilae-receives-full-notice-to-proceed-for-its-first-lng-terminal.html

Table 12. Storage Capital and Maintenance Costs[37]

Item	Fiji – Bulk Delivery	Tonga – ISO container Delivery	Kiribati – ISO container Delivery
No. of Days of Storage	60	30	30
Bulk Import Terminal and Storage Cost (USD)	USD34 m	Not applicable	Not applicable
Site Storage Cost (USD)	Not included	USD4.6 m	USD1.9 m
Maintenance Cost for Storage at 6% of Capital (per annum)[37]	USD0.95	USD0.93	USD0.93
Amortised Cost of Storage (USD/MMBTU)	USD1.49	USD1.45	USD1.45

5.2.8.1 Floating Storage Units (FSU) and Floating Storage and Regasification Units (FSRU)

Discussion with suppliers indicates the existence of some 20 FSRUs in total around the world, mostly much larger than the targeted 25,000 m^3 required for the largest need in the Pacific.

Although some are built new, others are converted from second-hand LNG ships that still have vessel and tank integrity suitable for lasting 20+ years. The cost for a 120,000 m^3 vessel would be around USD80–140 million, with the bulk of this cost being for the conversion. As these vessels have multiple tanks (up to six), it is theoretically possible to operate at smaller capacities but the fixed operating costs would be amortised over a smaller volume.

Due to the relatively small, early-stage, and 'bespoke' nature of this segment of the industry[38], broad cost data were not available.

5.2.9 LNG Truck Transport

Truck transport is most likely required in the supply chain for bulk ships and ISO container deliveries to PICTs. For a bulk shipping solution, either road tankers (see Figure 32) or gas pipelines are required to ship the LNG from the receiving storage tanks to the end-use site. For an ISO container solution, container trucks would be required at both the supply and receiving ends to move the container to and from the port. These road tankers cost around AUD1.5 million each and two would likely be required in-country in the bulk receiving solution.

Figure 32. LNG Road Tanker

(Source: BOC)

37 Hawaii LNG Study
38 Includes commercial-in-confidence arrangements, something that is not available on the open-market, or something previously contracted.

5.2.10 LNG Delivered Cost

Figures 33 and 34 illustrate the delivered LNG price using a 'bottom-up' cost model, compared to other fuels as determined in this study. The data in these Figures has been developed using a range of different data sources. Delivered LNG pricing using a small-scale bulk ship was developed using the following sources:

- LNG pricing (from two suppliers)
- Norgas Ship volume (from Norgas public data)
- Norgas Ship capacity (from Norgas public data)
- ship charter cost + fuel at 25 t/day of fuel oil (from Norgas data)
- sailing time - return trip (calculated based on nautical miles travelled)
- port loading fees at supply port (estimate based on discussions with LNG suppliers)
- port unloading fees - destination port (estimate)
- storage at receiving terminal (personal communications and reference reports based around total capex estimates, scaled for each country)
- storage tanks, pipelines, wharf, excluding regasification (personal communications and reference reports based around total capex estimates)
- storage - maintenance costs @6% of capital
- road tanker pricing for delivery to power station sites (BOC pricing provided in industry workshop)
- operating expense (opex) for road tanker (estimate).

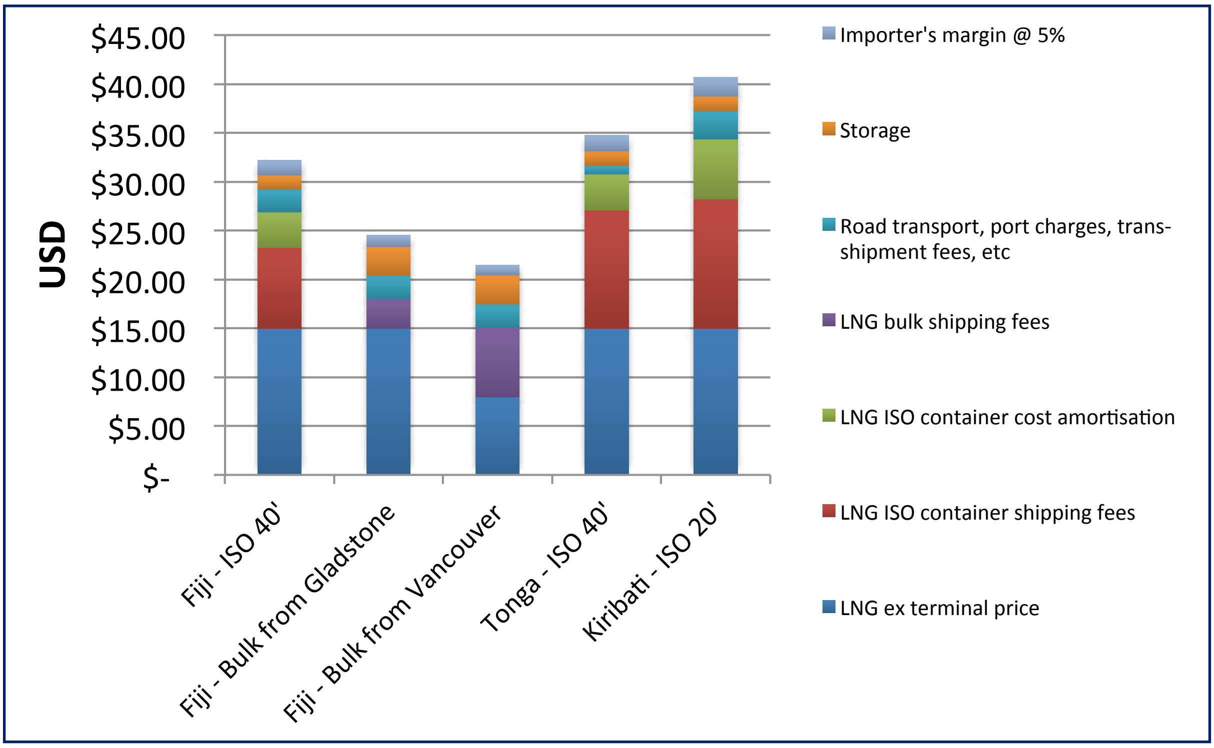
The fixed costs are amortised over the total fuel volume assumed to be delivered for each PICT over the life of the plant. Transport costs (including the empty return voyage) are amortised over the volume of fuel in each delivery.

The delivered cost of LNG in ISO containers was a bottom-up cost model using:

- 20' and 40' ISO container prices based on budget pricing from Cryeng Industries, personal communications with Singapore LNG (SLNG), and discussions with Agmark Logistics and FuelGarden LNG
- transport of LNG containers from APA Group's LNG facility in Dandenong, Victoria to/from the Port of Melbourne by TOLL Logistics
- LNG pricing, including truck loading, from APA Group
- shipping and transport charges to Fiji and Tonga by Williams & Gosling Limited including sea freight, dangerous good surcharge, origin and return port charges, port services, forklift use, biosecurity, wharfage, agency fees, port congestion charges, cartage to site
- shipping and transport times based on Swire Group's published routes for shipping container fleets in the Pacific
- amortisation of the ISO container cost was based on the return voyage times for containers using the above shipping route times, allowance for time in Australia for refilling, and allowing some time in the destination country for unloading of the whole container at the destination port, delivery to site, emptying the LNG into land-based storage, and return of the empty ISO container to port.
- site costs for small-scale LNG storage and gasification were based on:
    - budget quotes for site facilities from Cryeng
    - information obtained at the workshop in November 2014 that was part of this study, and
    - industry reports

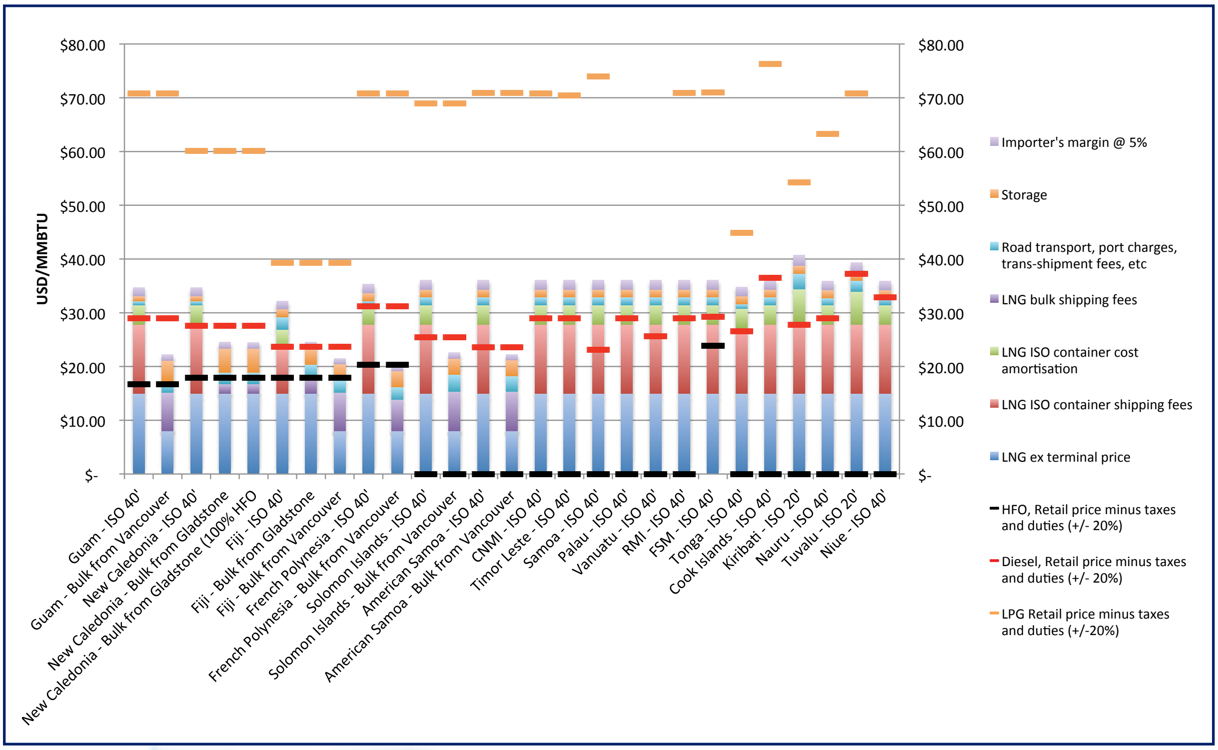
- road tanker pricing for delivery to power station sites (BOC pricing provided in industry workshop), and
- opex for road tanker (estimate).
- An importers margin of 5% was assumed. Import duty and VAT was excluded from the analysis.

Figure 33. LNG Built-Up Cost Analysis for Selected PICTs and Technologies



Note: The data in this Figure is for delivery to site using various transport methods.

Figure 34. Built-Up Delivered Cost Analysis for all PICTs



Note: Includes LNG, HFO, diesel and LPG but excludes bulk LPG prices

5.2.11 CNG Delivered Costs

The main CNG transport solutions investigated in this study involved the delivery of ISO 40' containers of CNG from a supply point in Brisbane to Tonga. At site, the cargo would be discharged into on-site storage tanks and then the empty containers would be transferred back to the port for return shipping. The 40' containers for high-pressure CNG cost approximately USD300,000 each. The following Figures show several examples.

Figure 35. CNG 20' Containers

(Source: Hexagon Raufoss)

Figure 36. CNG 40' Containerised Solution

(Source: Hexagon Raufoss)

Compression infrastructure suitable for providing gas to a 10 MW power station was selected to include compressors, a container filling station, and associated engineering drawings. The total capital cost is estimated at approximately USD2 million without gas connection costs, civil works, electrical and mechanical works, planning and environmental approvals, etc. For the purposes of this study, the total installed costs of the 'mother station' are estimated at USD5 million.

In contrast to LNG, around USD77 million in 40' containers would need to be purchased in order to supply a 10 MW load. CNG has around half the density of LNG and cannot fill as much space in a 40' container footprint as LNG. In this regard, shipping costs become very important. Like LNG, 40' containers with CNG tanks need to be shipped and returned to the point of origin for refilling. The estimated annualised costs required to deliver CNG are presented in Table 13.

Table 13. Costs of Shipping ISO Containers of CNG to Tonga

Item	Tonga
Container Type	40'
Tonnes of CNG per Container	7.1
Energy per Container	370 MMBTU
Container Turnaround Time	2 months
Life of Containers	10 years
No. of Container Loads p.a. for 50% of Power Consumption and Some Transport	812
Total No. of Containers	203
Total Delivered Cost per Container, return to Melbourne (USD)	USD12,188
Cost per MMBTU for Shipping (USD)	USD30.52
Cost per MMBTU for Amortised Container Cost (USD)	USD104.77

Due to the very high-cost penalty of shipping lower volumes of gas (in both the shipping cost and container amortisation), international CNG supply was not investigated in greater detail than this. Shipment of CNG appears most viable over very short distances where high utilisation of the transport vessel can be achieved.

5.3 Issues

Due to the uncertain nature of commodity markets (e.g. oil supply, demand and pricing are influenced by the Organization of the Petroleum Producing Countries [OPEC],[39] market conditions, natural disasters or geopolitical events), it is impossible to know with any certainty what the future competitive position of oil and LNG will be. However, it could well be the case that delivered LNG might at times be cheaper than delivered diesel, and vice versa. Hawaii has moved forward on the basis of a high probability that LNG shipped from the US mainland will be competitive with its existing Syngas and/or diesel costs for the foreseeable future. This sort of probability analysis is beyond the scope of this study.

For the Pacific, it will be important to understand the extent to which both oil and gas-linked pricing structures are affected by fluctuations in oil or gas prices. Both spot and contract markets exist for LNG, with the spot market growing to 33% of global trade in 2013,[40] which was a new peak for the industry.

Some of the significant changes that would need to occur for LPG to become competitive on a specific energy cost basis are listed below:

- the need for greater demand in the Pacific to reap the benefits of economies of scale

39 OPEC is an intergovernmental organisation established in 1960 by Iran, Iraq, Kuwait, Saudi Arabia and Venezuela and later joined by other countries. OPEC's objective is to coordinate and unify petroleum policies among its member countries in order to secure fair and stable prices for petroleum producers, efficient, economical and regular supply of petroleum to the customer base, and a fair return on capital to those investing in the industry. (Source: OPEC website: http://www.opec.org/opec_web/en/about_us/24.htm, as at 17 September 2015).

40 IGU World LNG report, 2014 edition.

- the basis of LPG pricing would need to shift from the Saudi Aramco CP and provide more flexible contract pricing for wholesale suppliers, and
- bulk delivery and receiving facilities may need to be expanded.

5.4 Conclusions

5.4.1 Economic Viability of Expanding LPG

For LPG the main point to be drawn from this analysis is that the current high underlying base price of LPG limits the reduction in the specific price that might occur from increased supply volumes. This means that LPG remains a high cost fuel relative to diesel and HFO for power generation or industrial use.

Incremental expansion of LPG is, however, relatively easy compared to the introduction of LNG due to the existence of import facilities and supply chains in most PICTs. Incremental increase in use will likely continue in niche applications such as gas air conditioning, and household or commercial cooking where it can be the cheapest alternative, and the incumbent LPG industry and some NGOs are actively promoting it as a cleaner alternative to kerosene.

Therefore, whilst it may be economically feasible to incrementally increase market share, large-scale displacement of diesel and HFO using LPG seems unlikely.

5.4.2 Economic Viability of Gas for Power Generation

Prices for renewable energy technologies generally decrease over time, while the prices of extractive industries such as oil and gas tend to increase. Future pricing of LNG is a hybrid between cost reductions through technological development in liquefaction and distribution, with possible cost increases in the primary gas commodity. What is certain is that fuel prices will continually vary in relation to each other and it is impossible to forecast this with any accuracy.

It would appear that for many stationary power applications, renewables and energy efficiency are increasingly good long-term investments. The exception to this are large point-source electricity generators/users, such as mining and smelting operations, in which power systems may be subject to limited investment timeframes, tightening emissions and air-quality requirements, and high power densities. For these sites, LNG could present a viable alternative (or addition) to diesel, HFO or renewables.

For many small Pacific countries where LNG and/or LPG are generally expensive compared to diesel, pursuing an aggressive strategy of using renewables, energy storage, and energy efficiency (both supply side and demand side) is possibly the most viable approach to reduce overall fuel costs.

To cost-effectively supply LNG to the Pacific countries, two pre-conditions are required. First, individual or collective points of demand must exist; these must be large enough to justify bulk LNG shipping and local unloading, storage and regasification facilities. This appears possible for power-generation demand in Fiji, French Polynesia, Guam and New Caledonia. The approach of delivering LNG using ISO containers and returning them to the point of origin is a higher-cost option, with capital and operating costs being amortised over the volume of gas supplied. Second, the market conditions and supply arrangements should be such that the delivered cost of LNG must be less than the predicted diesel or HFO price (depending on which fuel is being replaced) on a USD/MMBTU basis over the life of the contract, which would typically be 15+ years.

Power generation could be the necessary 'anchor demand' for an LNG supply chain. When compared to transport applications, the advantage of using LNG in power generation is that the costs of converting an engine fleet to dual fuel or natural gas can be spread over a larger energy base because power generators often have a much higher utilisation relative to installed capacity. Furthermore, stationary power generation can offer a large single-point load source around which costly LNG infrastructure could be built and broader uptake by smaller uses could occur. An example of this is in Melbourne where APA's LNG storage facility is primarily used for gas network security, but is also being used now to supply industrial LNG loads by means of road tankers.

However, as renewable energy technology develops and implementation experience grows, many PICTs realise the potential for use of renewables in stationary power (electricity) systems. Therefore, it is very difficult to make broad assumptions about the opportunity for each PICT to introduce LNG into its power sector because each power station will face different challenges in the technical and economic feasibility of converting existing engines or securing LNG supply. The cost of converting some of the older engines to LNG is likely to exceed the total cost of procuring a new gas-fired engine, or is not technically possible. Furthermore, each PICT has multiple power stations that would face individual logistical challenges in securing and delivering LNG supply (see Appendix H for fuel consumption by power station and country).

There is also an issue related to whether LNG can be cost effective for different sizes of power plants. For small power stations operating on diesel, the avoided cost of diesel is relatively high and, at first glance, it seems to be a good target for substitution. However, at this scale, LNG infrastructure is relatively expensive and renewables offer many additional advantages. For larger power systems, the economies of scale for delivering LNG improve significantly but, at that point, utilities and IPPs show a preference for cheaper fuels such as HFO and even coal, and it is difficult for LNG to compete. This means that non-cost drivers, such as regulations on air quality or GHG emissions, in medium to large systems could make the business case successful.

Ultimately, this study finds that, although LNG for power generation in PICTs is technically feasible, it faces many commercial challenges. Even so, introducing LNG in the short to medium term could be viable under certain circumstances. An individual or collection of medium to large power stations (i.e. more than 40 MW in aggregate) such as those in Fiji, French Polynesia, Guam and New Caledonia, could justify dedicated small-scale bulk shipping and storage facilities and attract competitive LNG pricing if:

- high emissions standards require substitution of HFO and/or diesel
- prospective power stations do not have any realistic prospects over the coming 10 to 15 years to use cost-effective renewable energy such as solar PV systems or coconut oil on a large scale
- the large capital cost of LNG infrastructure is not a barrier and the end-user has a sufficient credit rating to underwrite the contract for LNG off-take over a long term
- the contract for LNG supply can be confirmed for longer than 10 years
- new engines or boilers are planned, provided that their conversion to dual fuel is relatively low cost compared to the expected savings in fuel costs
- the delivered cost of LNG can be confirmed as competitive with alternatives (e.g. diesel, HFO, coal) with a high likelihood over the contract timeframe
- there is potential for secondary use in industry and/or transport
- there are skilled labourers to maintain and operate the equipment and maintain high safety standards
- using LNG is considered on its merits to improve fuel security through energy diversity
- fuel diversity and the use of LNG are consistent with regional government or utility policies, and

- power generation efficiencies are not severely penalised by using LNG instead of the incumbent fuel.

Larger power-generation capacities could initially be targeted in order to justify the economies of scale necessary for bulk LNG shipping. Therefore, the potential sites for consideration have been identified as French Polynesia, Guam, New Caledonia and possibly also Fiji (see Research Question 4 for additional details).

5.4.3 Economic Viability of Gas for Transport

This study finds that LNG for transport, as either LNG or LCNG, is technically feasible but it faces many commercial challenges in PICTs. An individual land transport 'hub-and-spoke' application is unlikely to be large enough on its own to justify the large-scale shipping of bulk LNG, which would be required to minimise the delivered cost. Nevertheless, it might be possible for such an application to leverage off a major LNG hub created for other purposes, as noted above.

This study finds that there is virtually no near-term market for conversion to LNG of the maritime fleet based in the Pacific, but there could be an increasing demand for offering LNG bunkering facilities to international fleets, or for new ships purchased that are LNG fuelled. If LNG refuelling capabilities develop over time, PICTs may be able to consider LNG fuel ships either as a new or second-hand purchase.

Due to the costs of converting and running transport fleets on alternative fuels, it may only make sense to carry out fuel conversions in countries in which high numbers of heavy vehicles exist, so that a conversion 'industry' could be established. Fiji, with over 1,600 buses in operation, may offer one of the best opportunities to use LCNG or LNG as an alternative fuel. A hypothetical scenario has been prepared to examine and identify the potential opportunities (see Appendix C).

In conclusion, increasing LNG and LCNG for transport in the medium to long term could be viable under all or some of the following circumstances:

- centralised LNG infrastructure is installed in the country on the back of an 'anchor demand' such as a large power station, and LNG for transport can subsequently leverage off this
- if new vehicles are purchased directly with dual-fuel or gas-only engines, the marginal cost needs to be relatively small compared to the expected savings in fuel costs
- trucks operating on LNG would need to travel a minimum distance of 200,000 kilometres (kms) per year with LNG 30% cheaper than diesel to justify the additional costs of running on LNG, or less distance if the conversion is subsidised
- the delivered cost of LNG or LCNG needs to be cheaper than alternatives (diesel, gasoline, LPG) with a high likelihood of remaining so over the vehicle life
- there are skilled labourers to maintain and operate the equipment
- there are high safety standards associated with operation and maintenance of vehicles running on LNG, LCNG or CNG, and
- the fuel diversity and use of LNG are consistent with regional government or utility policies.

The expansion of LPG for transport is relatively straightforward using existing infrastructure, but its use would need to be subsidised because it is often more costly than gasoline or diesel in PICTs. Further work would need to be conducted to estimate the wider economic impact of subsidising the use of LPG in vehicles to stimulate demand.

In conclusion, increasing LPG for transport in the short to medium term could be viable if subsidies or incentives put in place to drive LPG uptake are offset by wider economic benefits that outweigh the costs (this would need to be the subject of an economic study).

6 Research Question 4: Which Pacific Island Countries and Territories have the highest potential to benefit from expansion of LPG or the introduction of natural gas?

6.1 Context

As noted earlier, PICTs have varying sizes of population, economies, energy needs, and levels of infrastructure development. The use of LPG could be expanded. PICTs with smaller demands may seek to leverage off any use of LNG in the larger economies. If LNG is established in a country on the back of an 'anchor demand', it could be further used in transport, commercial, industrial or pipeline applications.

6.2 Findings

6.2.1 LPG for Light Vehicles in all PICTs

As mentioned, Fiji is the only PICT with significant numbers of LPG vehicles. It also enjoys the lowest LPG price in the Pacific. It could be inferred that the low LPG price is a result of the fact that more than 50% of LPG is used in vehicles, and that this drives economies of scale and encourages competition.

There appears to be an opportunity to replicate this situation in other countries in the Pacific; for example, by artificially stimulating LPG demand through vehicle concessions. Barriers to the uptake of this would include:

- ensuring trained support for installing and maintaining LPG vehicle technologies, and
- adjusting transport safety and other acts or regulations for vehicles.

Moving this forward would first require a detailed economic analysis to assess the potential impact on these economies. Governments would then need to decide whether to encourage the necessary LPG vehicle uptake.

6.2.2 LPG for Air Conditioning in all PICTs

LPG distributors in the Pacific are already operating and promoting gas-powered air conditioning. Although there are a few technical barriers to the further use of this technology, there are also some commercial barriers that may need to be resolved. These include the following:

- LPG-based air conditioning is viable at a certain price spread between LPG and retail electricity prices, but this spread varies across and within PICTs (therefore, success in one installation is not necessarily transferable to another)
- sales and marketing of air conditioning systems are limited to a few retailers, and the awareness of LPG among local air conditioning contractors (and the market in general) is low
- some people may perceive the requirement to continually refill or replace gas bottles as an inconvenience, and
- few contractors outside of the gas companies with the skills and knowledge to maintain the equipment once it is installed.

Nevertheless, none of the barriers appears to be major and can be resolved locally. Adoption will take time and at a rate in proportion to the sales and marketing effort of incumbent appliance retailers. There is some justification for involvement by governments or third parties to help overcome the abovementioned barriers to uptake. This might include:

- conducting an information campaign targeted at buyers, specifiers (e.g. building-design consultants) and contractors who are not fully informed of gas-fired heat pumps as a choice, and/or
- fostering increased competition in the retailing of these appliances.

6.2.3 Potential Sites for Gas Power Generation: New Caledonia, Guam, French Polynesia and Fiji

The research in this study suggests that larger power-generation capacities must be initially targeted to achieve the economies of scale necessary for bulk LNG shipping. In addition, there should be as many non-cost drivers (such as EPA air-quality targets or limits) as possible to help justify and support the conversion. Therefore, the potential sites are French Polynesia, Guam, New Caledonia, and possibly Fiji.

6.2.3.1 French Polynesia

French Polynesia uses a considerable amount of HFO in power generation, and is also geographically located relatively close to the USA. For these reasons, it is in a good position to utilise bulk LNG supplied from Vancouver or the US Gulf Coast or West Coast.

This study shows that the price difference between HFO and LNG delivered to French Polynesia from Vancouver is marginal. The country also uses the same diesel supply as Vanuatu and New Caledonia, which is of high standard and cost, operates under French law, and thus has relatively high air-emissions standards. Therefore, there may be some non-cost drivers that could shift the balance in favour of LNG in this location.

Further study of the costs and benefits of LNG at specific power stations in French Polynesia should be considered in further studies which are beyond the scope of this project.

6.2.3.2 Guam

A number of factors have led the Guam Power Authority to consider LNG as an alternative fuel. These factors include an ageing power-generation plant, tightening emissions controls, and large power demand. The Authority plans to phase in LNG and build combined-cycle power plants over the next seven or eight years, utilising ultra-low-sulphur diesel fuel oil as an interim and alternative fuel source in the near term. This involves replacing old oil-fired steam boilers and turbines that are likely to have a lower efficiency compared to new combined-cycle power plant.

The range of costs for the generation facilities and the LNG regasification plant are estimated at USD 500–800 million, depending on the number of generators to be installed. These investments are expected to deliver nearly a billion dollars in net present value savings over a 30-year period, despite the significant capital infrastructure cost associated with the plan's implementation.

6.2.3.3 New Caledonia

New Caledonia has around 500 MW of installed generation capacity. An opportunity to replace the ageing power generation plant at the nickel smelter (comprising 160 MW of boilers and steam turbines) led the country to consider LNG several years ago. The site is in the main population centre of Noumea where emission standards are tightening, and there are good economies of scale for small-scale bulk LNG.

Discussions with authorities in New Caledonia indicated that, when they considered LNG supply as an alternative fuel to replace HFO at the smelter, they deemed it too expensive compared to using pulverised coal, which is the current technology being used. However, the project is currently stalled and there is still a slim possibility that LNG will be reconsidered. If this is the case, it would establish a good supply hub in the South Pacific and act as an anchor-demand point for other uses to be investigated.

New Caledonia has other advantages in relation to LNG supply. The first is its close proximity to Gladstone, so shipping costs for LNG would be relatively low in comparison to other PICTs. In addition, if LNG were to be used in transport, the avoided diesel cost would be one of the higher prices in the region since the country uses a relatively expensive, high-grade quality diesel.

The interesting aspect of this example is that, as the size of power generation increases in any particular location, so do the available options for fuels. For example, coal has become available in New Caledonia since the power plant size increased to very large capacities. Therefore, it is difficult, if not impossible, for LNG to compete.

6.2.3.4 Fiji

Although existing utility power stations do not exhibit ideal characteristics for LNG substitution, Fiji is a large regional fuel user for transport and power and, if a large 'anchor demand' can be found, it might foster increased use of LNG over time in the transport and industrial sectors. Two such anchor-demand points could be:

- the existing gold mine with 20 MW of baseload power generation using diesel, and/or
- the planned copper mine, where the 100 MW of power generation is currently proposed to be generated using HFO.

During this study, both mining companies expressed interest in the LNG solution, and both emphasised that cost drivers would be very strong in selecting the fuel of choice. Prospective LNG fuel suppliers would benefit from investigating these specific opportunities in greater detail.

6.2.4 Potential for Gas-Piped Networks: PNG, Timor-Leste and Fiji

PNG and Timor-Leste have domestic natural gas resources, some of which are close to urban centres (e.g. Port Moresby). In such cases, these countries may decide to extend pipelines to major power generation or thermal loads where diesel or LPG is currently being used. The decision to further extend the gas pipelines to commercial and industrial centres would need to take into account the likely end-use patterns, the energy-demand profiles, and the competing environment of more cost-effective electricity that should be produced from gas-fired electricity generation.

During industry consultations in this study, it was proposed that a small gas pipeline network in an economic zone could provide a potential 'anchor demand' to justify larger-scale gas supply to a Pacific country that lacks natural gas resources. The heating, cooling or power demands for industrial and commercial sectors in this zone could be met with gas. Furthermore, it was proposed that LPG could be used as a transitional fuel to supply the initial needs. As demand grows, the transition to LNG might become economical.

Of the countries studied in this research, there is one piped LPG network in Fiji's Denarau Island tourism precinct. Of interest is a Syngas-piped network in Kapolei, West Oahu, Hawaii, which is a major contributing factor to Hawaii's choice to pursue LNG. Currently, the costs for producing Syngas in Hawaii are high: up to USD 40/MMBTU.[41] This means that imports of LNG using either ISO containers or small-scale bulk shipping to substitute for Syngas would be cost effective.

41 Liquefied Natural Gas for Hawaii: Policy, Economic, and Technical Questions.

As a consequence, Hawaii Gas:

- has applied to US federal agencies to diversify its fuel used at the Syngas plant by up to 30% LNG, and
- is seeking a third-party supplier to supply in bulk, ship, store in an FSRU, and re-gasify LNG (as of December 2014).

In Hawaii's case, there is a clear cost driver for LNG imports to substitute Syngas with cost savings of 30% to 65%.

6.2.5 Potential Gas Use in Land Transport Sector: Hypothetical Scenario

It is difficult to make general assumptions about the opportunity for uptake of gas in the transport sectors of the various PICTs, so case-by-case-basis assessments are therefore required. However, the following are observations relevant to the conditions under which a successful LNG and/or CNG transport opportunity could be proposed:

- CNG is better suited to shorter routes due to its lower energy density (this should not be a problem in many PICTs that are geographically small)
- LNG and CNG suit central 'hub-and-spoke' systems in which the vehicle returns to a central location for refuelling
- delivered cost of LNG/CNG should be significantly cheaper (more than 30%) than that of diesel
- where trucks travel a minimum of around 200,000 kms per year (in order to justify the engine conversion costs)[42], or less if the systems are subsidised
- where air quality and noise are relevant local considerations
- because no CNG systems currently exist in PICTs, the initial projects should rely on large fleet operators to be the first movers to create LNG demand, and
- it is more cost effective to convert trucks and taxis than buses, personal cars or other light vehicles.

In summary, hub-and-spoke transport operations involving heavy vehicles (particularly buses) represent a strong prospect for CNG utilisation in PICTs. A hypothetical scenario was completed for a bus and truck fleet in Fiji (see Table 14). It represents a potential end-use with some scale because Fiji has one of the largest numbers of registered vehicles in the Pacific (around 1,600 in total).

The cost of vehicle conversion is estimated at USD80,000, with the following range observed:

- USD30,000 for conversion of a large vehicle to CNG (Exxon Mobil, 2014);
- USD70,000–90,000 for conversion of a large vehicle to LNG (Exxon Mobil, 2014); and
- USD45,000–100,000 for large vehicle conversion (suggested by participants at an industry workshop held in February 2015 as part of this study).

In contrast, the marginal cost of purchasing an LNG-fuelled prime mover or bus direct from an OEM is estimated at USD45,000 for a prime mover of USD 250,000 purchase value.

This assumes a scenario in which the delivered cost of LNG is cheaper than that of diesel. That might occur under a circumstance where an 'anchor demand' has helped to establish a LNG supply route from Vancouver to Fiji via small scale bulk ships as indicated in Figure 34, and this LNG is then made available for transport uses. It assumes that gas is used in heavy vehicles as LNG. Table 14 shows potential total annual savings of USD227,000 for buses and USD323,000 for trucks.

42 Industry workshop conducted as part of this study.

Table 14. Transport LNG Hypothetical Scenario, Fiji: Buses and Trucks

Item	Unit	Bus	Truck
Vehicles in Fleet	No.	50	20
Fuel Use	L/day	70	150
Fuel Use	L p.a.	24,500	52,500
Fuel Cost - Diesel	USD/L	USD1.12	USD1.12
Fuel Cost – Diesel	USD/MMBTU	USD27.62	USD27.62
Fuel Cost – LNG (best case)	USD/MMBTU	USD 22.19	USD22.19
LNG % (assumes new fleet)	%	100%	100%
Marginal Capital Cost	USD	USD80,000	USD80,000
Engine Efficiency Before Conversion		40%	40%
Engine Efficiency After Conversion		40%	40%
Energy Use Before Conversion	MMBTU	896	1,921
Energy Use After Conversion	MMBTU	896	1,921
Diesel Cost	USD p.a.	USD27,440	USD58,800
LNG Cost	USD p.a.	USD19,891	USD42,624
Additional Maintenance Cost	USD p.a.	USD3,000	USD3,000
Savings (per Vehicle)	USD p.a.	USD4,549	USD16,176
Total Savings	USD p.a.	USD227,446	USD323,525
Cost of Conversion	USD	USD80,000	USD80,000
Simple Payback	years	17.6	4.9

Note: Based on dual-fuel conversion

Another scenario was developed to investigate the opportunity for use of CNG (converted from LNG) in a private vehicle or taxi in Fiji (Table 15) in view of the potential for LNG substitution in the country.

For small passenger vehicles, others have estimated the cost of vehicle conversion to be:

- USD8,000 for conversion of a small vehicle to CNG (Exxon Mobil, 2014), and
- USD1,900 for conversion of a small vehicle to CNG (PTT, Thailand).

Given Thailand has converted over 300,000 vehicles and is very experienced in the requirements of the process, this study has chosen to use a conversion figure closer to that of Thailand.

Table 15. Transport LNG Hypothetical Scenario, Fiji: Passenger Vehicles

Item	Unit	Private	Taxi
Vehicles in Fleet	No.	1	50
Fuel Use	L/day	5	50
Fuel Use	L p.a.	1,750	17,500
Fuel Cost – Diesel	USD/L	USD1.12	USD1.12
Fuel Cost – Diesel	USD/MMBTU	USD27.62	USD27.62
Fuel Cost – LNG	USD/MMBTU	USD22.19	USD22.19
CNG % (assumes new fleet and conversion from LNG)	%	100%	100%
Conversion Capital Cost	USD	USD2,000	USD2,000
Engine Efficiency Before Conversion		40%	40%
Engine Efficiency After Conversion		40%	40%
Energy Use Before Conversion	MMBTU	64	640
Energy Use After Conversion	MMBTU	64	640
Diesel Cost	USD p.a.	USD1,960	USD19,600
CNG Cost (converted from LNG)	USD p.a.	USD1,421	USD14,208
Additional Maintenance Cost	USD p.a.	USD500	USD500
Savings per Vehicle	USD p.a.	USD39	USD5,392
Total Savings	USD p.a.	USD39	USD269,605
Cost of Conversion	USD	USD2,000	USD2,000
Simple Payback	Years	51	0.4

This scenario shows there is some potential for use of CNG as a transport fuel in taxis under the following conditions:

- if LNG can be delivered to the country for less than the cost of diesel – this can only happen if it is delivered in bulk ships based around a large 'anchor demand' (i.e. not simply a taxi fleet)
- if cost of conversion is kept low – certainly less than USD 2,000 per vehicle
- if the distance travelled or fuel used for the vehicle is significant at more than 10,000 L per year, and

more frequent fuel refilling may be required for CNG powered vehicles compared with conventional fuels.

6.2.6 Further Opportunities for Increased Gas Use in the Pacific: New Caledonia and Fiji

In addition to the preceding discussion, five of the most promising opportunities for increased gas use in the Pacific are:

- LPG for light vehicles in many PICTs where broader benefits from uptake can be demonstrated
- LPG for air conditioning in PICTs where LPG already exists and electricity is expensive
- LNG for New Caledonia's nickel smelter, and
- LNG for Fiji's current and future mining sector (~120 MW of power generation).

Table 16 summarises the commercial and regulatory considerations for these opportunities. The following sections discuss some potential pathways to realising these and other opportunities.

Table 16. Commercial and Regulatory Consideration for Gas Opportunities in PICTs

Issue	LPG for Light Vehicles in all PICTs	LPG for Air Conditioning in all PICTs	LNG for New Caledonia Nickel Smelter	LNG for Fiji's Current and Future Mining Sector
Commercial Readiness of the Technology	Technology at this scale is fully commercial.	Technology at this scale is fully commercial.	Technology at this scale is fully commercial.	Technology at this scale is fully commercial.
Competing Fuels	Gasoline, diesel	Electricity	Coal	Diesel and/or HFO
Long-term, Large-Supply Off-take Required	No	No	Yes	Yes
Existing Fuel Importing Infrastructure	Yes, but LPG blends for household and transport use are different.	Yes	No	No
New Infrastructure and Land Requirements	May need increased LPG import storage capacity.	May need increased LPG import storage capacity.	Limited port space at the nickel smelter. Would probably need FSRU.	Several options exist, including FSRU, new ports for the mines, gas pipelines, trucking routes.
Fuel-Importing Arrangements	LPG importing exists in many PICTs.	LPG importing exists in many PICTs.	LNG would be a new fuel for the country.	LNG would be a new fuel for the country.
Sovereign Risk	Varies	Varies	Low	Medium
Skills and Training Requirements	Service and support staff and infrastructure would be required for all countries except Fiji.	Some training for service and support staff in regard to gas air conditioning.	Required–would not be problematic.	Required–would not be problematic if confined to mining sector.
Regulatory Changes Required	Yes–significant if LPG is a new transport fuel.	Probably minor if LPG is already being imported and distributed.	Yes–possibly significant	Yes–possibly significant.
Scale of Investment Required for Governments, Private Sector or Development Partners	Possible increased LPG storage requirements at port, investments in new vehicles, and/or vehicle conversions.	Possible increased LPG storage requirements at port.	USD200–300 million in FSRU plus associated changes to boilers at nickel smelter.	USD50 –200 million in port infrastructure plus associated piping or trucking to get gas to sites.
Non-Cost Drivers	Possible flow of benefits in reducing household LPG pricing.	None	Strong air-quality driver due to location of the nickel smelter in Noumea.	None
Barriers	Current pricing of LPG is higher relative to diesel and gasoline in small-volume LPG markets.	Market understanding of gas air conditioning. Different energy-price structures in each PICT mean that assumptions on viability need to be tested at each site.	Société Le Nickel (SLN) has already started down the pathway of utilising coal but is currently experiencing difficulties. A small window of opportunity to change direction may exist.	The Vatukoula gold mine is already operating at around 20 MW load but this is about half the required capacity to justify full-time charter of a 12,000 cbm LNG ship. The 100 MW Namosi JV is in planning stage only.

6.2.6.1 LNG for New Caledonia's Nickel Smelter

The opportunity to use LNG in powering up to 200 MW for the SLN smelter in New Caledonia is significant. The smelter has committed to changing fuels from HFO but had previously committed to using pulverised coal technology as the replacement. However, there appears to be a small window of opportunity to change direction because the project costs for this option have increased since they were first conceived.

Although it is not known whether a fully developed LNG project will be competitive with coal, it does appear competitive with HFO at this scale.

In order to realise this opportunity, several points need to be considered. The government-owned SLN would need to agree to the possibility that LNG could be used to supply the smelter and then place the coal-repowering project on hold while a fully costed proposal is developed. Assuming that this occurs, the project does not appear to face any significant technical obstacles, and the Government of New Caledonia would have the capacity to fund the infrastructure requirements and/or attract private-sector investments. If this LNG project takes place, LNG would consequently become available in closer proximity to many PICTs than to any other current supply point.

6.2.6.2 LNG for Fiji's Mining Sector

- Fiji's has one major operating mine, which has a relatively flat 20 MW electricity demand. This is approximately half the capacity required to fully occupy a 12,000 cbm LNG supply ship that delivers LNG from Vancouver. Mining personnel consulted during the study confirmed that they are very interested in fuel-cost reduction opportunities, including the possibility of using LNG. Even so, the use of LNG to displace diesel at the mine may not be economical. This means that other parties would need to be involved for it to be feasible. This could potentially include:
- Fiji Electricity Authority's (FEA's) use of LNG for some of its diesel-power generation
- a future copper mining project (with a projected 100 MW electricity demand) as a potential user when the project is completed
- governments or development agencies partly funding or financing storage infrastructure in the country, and/or
- joint commitment by other diesel power stations in the region to purchase LNG; the ship delivering LNG could make multiple drops on the same fuel run, as MRTs and LCTs do for other fossil fuels.

However, there are many challenges to achieving a project such as this. For example, arrangements in which multiple private-sector and/or government parties need to collectively negotiate are likely to be relatively complex, time consuming and costly, and likely require one party to initiate and manage the process. In addition, because mining operations can move from viable to unviable if the commodity price drops too far, an investment in LNG infrastructure and fuel switching at mining power stations is inherently riskier than power stations that supply public power.

6.3 Issues

For both the power and transport sectors, it is difficult to make general assumptions about the opportunity for uptake of gas in various Pacific countries. Therefore, case-by-case assessments are required for each power station and transport sector in each country and territory.

6.4 Conclusions

There appears to be a case for encouraging increased use of LPG in most PICTs in niche applications where it can provide cost, air quality, and/or health benefits. This includes using LPG for vehicles in cities where pollution is an issue, household cooking where there are air quality and health benefits, and commercial air conditioning where the cost of LPG relative to electricity makes this a viable alternative.

In the short term, LNG is most beneficial to only a few countries. Guam may be the first country in this study to import LNG into its fuel supply chain. It may create opportunity for other PICTs to benefit from the establishment of supply chains and from experience in the region.

For PNG and Timor-Leste, the development of piped networks could be fed either by domestic LNG or piped natural gas, depending on the location of the end-use demand. For PICTs with no natural gas resources, an initial investment in a piped gas network within an economic zone may create a larger gas demand that could initially be supplied by LPG. Transition to LNG could take place over time as demand grows and LNG becomes more widely available in the region.

If market conditions for cost-effective supply of LNG to one or more PICTs are achieved, the following actions could be considered:

- an individual power station, IPP, government, gas importer, or consortium could enter in to a long-term contract for LNG supply, and/or
- PICT governments could consider facilitating LNG use in transport or industry once LNG infrastructure is established in a country building on the 'anchor demand' in power generation.

7 Research Question 5: What factors need to change in order to realise the benefits?

7.1 Context

There is scope to increase LPG use cost-effectively in a broad range of PICTs. This could have a flow-on effect in improving economies of scale in supply chains. In some cases, the capacity of existing port and storage infrastructure is sufficient, while in others it would require investment and expansion.

In contrast, any shift towards introducing natural gas (LNG) requires considerable new capital investment in ports, fuel off-take and storage facilities, in-country distribution networks, and equipment conversion. It will also require the development of new skills and regulations for gas management and handling. In addition, there would probably be a need for extensive gas marketing to ensure adequate demand.

7.2 Findings

Most PICTs do not have regulatory frameworks for use of LPG as a transport fuel, and may require regulatory changes and/or concessions to allow for small LPG piped networks to be created for household and commercial use. On the other hand, the distribution and use of bottled LPG is common and so 'take-up' in small-scale appliances and commercial air conditioning should be possible.

This study suggests that the introduction of LNG into a PICT that lacks its own natural gas requires a sufficient collective demand to justify a large investment in new fixed infrastructure, optimal market conditions, and suitable technologies for gas use. The recent move towards LNG imports in Hawaii is a good example of a place where such conditions exist.

However, because most PICTs in this study do not individually experience the same conditions as those of Hawaii, they would each need to install multi-fuel technologies suitable for using LNG in the future, and then collectively aggregate fuel demand to incentivise supply to the region. The most relevant PICTs with sufficiently large fuel demand, either individually or in aggregate, are Fiji, French Polynesia, Guam and New Caledonia. PNG and Timor-Leste could investigate local use of their domestic reserves of LNG or piped natural gas. PICTs with smaller demands could conceivably seek to leverage off any use of LNG in these larger economies.

LNG can be shipped cost-effectively over considerable distances in bulk ships as small as 10,000 m^3. To use LNG in PICTs that lack domestic gas resources, the unloading facilities and storage systems that would need to be built require large-scale capital investment. These storage systems could be fixed land-based facilities, floating storage units with land-based regasification, or floating storage and regasification units.

This study shows that, *under current market conditions and with infrastructure costs amortised over a 25 years project cycle,* LNG would be more competitive as an alternative fuel option in some PICTs.

7.3 Issues

7.3.1 Issues for Converting to Gas for Power Generation

PICTs and their utilities would need to consider the following issues when deciding to convert their power generation to LNG:

- LNG is at its most cost effective at a scale larger than the power consumption of most individual PICTs (i.e. above 40 MW baseload)
- LNG needs large upfront investment in infrastructure and is not easily scaled to demand
- LNG is highly volatile, is transported at cryogenic temperatures, and needs very costly storage and handling systems relative to diesel, gasoline, coal, LPG or HFO
- well-trained and skilled operators are needed, and
- engines running on gas are not as flexible as current diesel engines in their capacity to take step changes in load.

7.4 Conclusions

Infrastructure and/or energy ministries within PICT governments could consider developing (and/or developing concessions for) small piped LPG networks to supply LPG for cooking and air conditioning. This approach would help to improve economies of scale and create centres of demand for future LNG substitution.

If LPG use is encouraged to grow, it may be possible to expand its use cost-effectively with little additional investment. Planning regulations and activities for any LPG storage and distribution infrastructure should take into account this projected growth.

Although a number of commercial, technical, policy and environmental factors need to change for a fuel transition to occur, power-generating utilities and IPPs can invest in multi-fuel capability (gas, diesel, HFO, LPG) when buying new generators to give them maximum flexibility in future fuel choices with relatively small incremental costs (likely to be less than 5% of the power generator's capital cost).

Relevant end-users with an aggregate power-generation capacity of more than 40 MW could test the market by means of an Expression of Interest (EOI) for a multi-site procurement to supply bulk LNG, as well as an FSU or FSRU. A collective approach by power producers within and among one or more countries would form an 'anchor demand' in the region, and would indicate those parties interested in supplying LNG/LPG under a long-term contract. A cost-effective FSU or FSRU would substantially reduce the overall cost of delivered LNG if it becomes available.

Policy frameworks would need to be developed in order to allow and regulate for LNG importation and use in those countries where there is realistic potential for LNG substitution.

8 Research Question 6: Given the development of renewable energy, what is the likely scenario for LPG and natural gas in the longer term?

8.1 Context

Globally, individual countries are at differing stages of transition from the use of fossil fuels to renewable energy. A country's choice of fuels and its energy market are related to factors such as its surrounding natural resources, its economy, government incentives for renewables and prices for carbon emissions, its location and infrastructure, as well as social and cultural values.

With vast supplies of natural gas in many regions, gas development and use has increased and is likely to continue expanding. Its importance is further highlighted when a carbon dioxide emissions price is applied to fossil fuels without subsidies. There has been growing recognition that natural gas can play a significant role as a bridge to a low-carbon future.

8.2 Findings

8.2.1 Stationary Power – Other Renewable Energies

Utilities and IPPs have an increasing number of options in electricity-generating technologies and associated fuels. The availability of such options is a benefit to the sector, but it also makes decisions about future investments challenging. For many stationary power applications, renewables and energy efficiency appear to be increasingly sound long-term investments.

The use of coconut oil in stationary power, which is now proven in Vanuatu, offers a genuine alternative to diesel for some small-island power-generation systems. Although this application is not widespread, the technical barriers to expanding coconut-oil power generation to other medium- and high-speed diesel engines appear to be relatively minor. This fuel is unique: it can be substituted for diesel and/or HFO in extremely high quantities (up to 100% in base-load operation), can be produced locally, has regional employment benefits, is renewable, and is cheaper than diesel in the Vanuatu application at the time of writing this report.[43]

For many small Pacific countries in which LNG and/or LPG are generally expensive compared to diesel, an aggressive strategy of using renewables, energy storage, and energy efficiency (both supply side and demand side) may be the most viable approach to reduce overall fuel costs.

8.2.2 Transport Sector – Hybrids

In terms of alternative fuels for the transport sector, there are other additional transport technologies that could reduce overall fuel expenditure for PICTs and ultimately be more cost effective than LNG, LCNG or CNG. These include hybrids, which are now very common and reduce fuel use by up to 30%. Hybrids can be used in private vehicles, taxis, buses and light commercial trucks. As with any alternative energy technology, an individual purchaser would need to weigh the additional capital cost of the hybrid against future fuel savings.

Fiji has provided exemptions to import duty on hybrid vehicles, and this has led to the desired market response with an increase in hybrid vehicle use.

43 Personal communication: UNELCO, December 2014.

8.3 Issues

At the present time, solar and wind energy, hydropower and coconut oil are providing cost-effective reductions in diesel and HFO use across the Pacific, particularly in electricity generation. The beneficial feature of solar PV systems is that they can be deployed in virtually any size, are silent, are emission-free during operation, and can be located close to urban areas. Governments and utilities, third-party financiers, IPPs and donor agencies could structure graduated capital programs that make solar PV installation programs attractive. However, it is important to note that this is curtailed by the lack of technologies for managing grid stability and energy storage with high penetrations of PVs.

One of the concepts tested in this study is whether diversifying fuel sources with gas would improve energy security in the region. This study's findings suggest that using LNG and/or LPG would be an expensive way to provide a strategic fuel reserve, although some additional energy security is achieved through fuel diversity. If a strategic fuel reserve for PICTs is sought, other options to be considered might include:

- holding strategic reserves of diesel somewhere in the region (diesel tanks are much cheaper than LNG or LPG tanks)
- continuing to pursue a renewable-energy strategy that will extend the effective holding days of the existing fuel storages at import terminals and power generation sites, and
- introducing fuel flexibility to power generation systems that could enable the use of LPG in emergency situations. LPG does not currently appear to offer any cost advantages for base load operation, but could provide emergency backup to some systems.

8.4 Conclusions

Renewable energy is expanding in PICTs. It currently totals around 25% of the annual electricity generated by public utilities. The most significant impact of renewables has been for those utilities where access to reliable hydropower is available (e.g. Fiji, New Caledonia and PNG). Some PICTs have made significant wind-power investments. For example, in 2011 Tahiti (French Polynesia) used hydropower to generate over 25% of its electricity needs.

The introduction of LPG and LNG does not represent a barrier to the pursuit of sustainable and renewable energy systems for power generation where these are viable. Rather, they represent options for countries to diversify their sources of energy and possibly capitalise on potential price disruptions and technical developments in global energy commodity markets.

9 Research Question 7: How can the findings of this study be applied or developed?

9.1 Context

The development of gas markets in the Pacific could require substantial multi-million-dollar investments in infrastructure, and involves technical and commercial risks that need to be minimised to encourage the private sector to invest. Although not every risk can be mitigated, international development agencies offer a range of products and services to assist private-sector and government investments in infrastructure.

Some of the specific products offered include loans, credits and grants, interest rate and currency swaps, partial risk guarantees, partial credit guarantees, technical assistance, political risk insurance (expropriation, transfer restriction, breach of contract, war and civil disturbances), and sub-sovereign guarantees without government counter-guarantees.

9.2 Findings

9.2.1 Policy Considerations

The political, social and commercial environment in each PICT is unique and this study is not in the position to make recommendations for individual governments. Instead, it offers a number of areas that governments may consider in determining policies for their countries. These are summarised below.

Using gas to improve fuel diversity

If PICTs want to diversify their fuel options, LPG and LNG could be helpful.

Providing education on gas

Political support and increased take-up by the community could be encouraged by the presentation of the report's findings at industry conferences/seminars where Pacific government representatives are in attendance. Alternatively, industry can attend conferences in the region (e.g. the PPA's annual meeting).

Using commercial Expression of Interest (EOI) processes for specific or pilot projects

Industry consultation workshops highlighted the importance of pilot projects in reducing the real or perceived risks associated with the introduction of new technologies and concepts. Based on the findings in this study, there are potential candidates for a pilot project that could be considered relevant in the Pacific. PICT governments or the private sector could test the market's interest in specific applications by using a formal EOI process. It would be very important to include details of risk mitigation products offered by the World Bank (as noted above) or others to encourage broad supplier interest.

Considering air quality and greenhouse gas emissions.

Participants in the industry workshops in this study stressed that it would be very challenging to supply LNG at a price lower than the delivered price of HFO in power generation, and that any policy position (e.g. control of particulates and other emissions) that limits HFO use would make a country a more attractive investment opportunity. For example, Hawaii's interest and moves towards LNG were justified by (a) strong EPA guidelines on emissions; (b) the existence of a gas network that uses high-priced Syngas (~USD 40/MMBTU; and (iii) the availability of cost-effective LNG from the West Coast of North America. However, this has now been superseded by the policy drive towards renewables.

Improving the distribution network for LPG

Participants in workshops in this study confirmed that the logistics of bulk LPG supply to PICTs was generally good, but the distribution of LPG within a country suffered from poor economies of scale and could be expensive for various reasons. Improving the distribution network for LPG would help improve the supply chain and delivered cost of LPG to consumers.

Incentivising and regulating LPG markets

Whether or not residential/commercial LPG markets and transport LPG markets are developed separately or in parallel, they need to be incentivised and regulated carefully. This is primarily because potentially unsafe practices can develop with 'leakage' from automotive markets into residential use, and perverse economic outcomes could occur in either the residential/commercial or transport sector.

Providing tax incentives

The competitiveness of LNG and/or LPG use could be improved by ensuring that duties and taxes are not applied to the importation of gas, gas vehicles, gas appliances, etc. Therefore, governments would need to be involved and to understand the longer-term benefits for the economy.

Removing subsidies on other fuels

Indonesia's innovative strategies for LPG offer lessons that could be transferred to the Pacific. PICTs governments could consider:

- removing subsidies on kerosene
- improving swap incentives for LPG cylinders (e.g. provide microfinancing to develop a cylinder swap system), and
- introducing improved cylinder designs: fibreglass makes them lighter (easier to transport), and the liquid level is visible through a sight glass (providing confidence to users about how much they have used).

Leveraging existing work by others on policy options

The Global LPG Partnership has assessed the success of various policy scenarios for LPG use in numerous countries. Appendix J illustrates examples from Brazil, Morocco, India and Indonesia. This and other LPG industry associations would be a valuable resource for any PICT considering stimulation of its LPG sector.

9.3 Conclusions

The price of fuels is critical to investment decisions on fuel conversion but the market is highly volatile. End-users should understand the *long-term* price trends for various fuels, as well as future fuel supply-and-demand scenarios, and make investment decisions on this basis, rather than on present-day cost and demand. It is recommended that PICTs develop a watching brief on the world's bulk LNG and LPG markets to identify potential oversupply conditions and price anomalies. SPC could potentially perform this service as part of its fuel-price monitoring services.

10 Overall Conclusions

10.1 Expanding Use of LPG

10.1.1 Feasibility and Cost Factors

As it is already in use in many PICTs, expanding LPG is viable and will deliver significant health and environmental benefits. There are some constraints – including current higher cost relative to other fuels, cultural attachments to biomass and kerosene for cooking, and technical limitations for use in power generation. Even so, it benefits from being relatively easy to ship, transport in-country and store. In addition, infrastructure, distribution and retailing systems are well established in many countries.

10.1.2 Application in the Transport Sector

Considering the size of the transport sector in the PICTs, increased use of LPG as fuel is an important area for further development. Fiji has demonstrated that adoption of LPG for land transport can result in developing economies of scale and increased competition to deliver lower prices for household LPG. Similar opportunities exist in other PICTs. Governments could consider subsidies or incentives to drive LPG uptake and could take a lead in introducing it to government vehicles. Based on commercial technology already available in Australia, experimental work is currently being conducted in Fiji (by BlueGas with University of the South Pacific involved in verifying the results) on use of LPG in heavy vehicles and blending of LPG with other fuels in electricity generation.

10.1.3 Stimulating Demand for LPG

There are also other ways to stimulate demand for LPG – both in domestic and commercial settings, including:

- providing grants or microfinance initiatives for early market uptake of LPG
- organising information campaigns on LPG use for both domestic and commercial applications
- introducing subsidised cylinder exchange/deposit schemes
- adopting LPG in schools, hospitals, hotels and via other business customers
- developing a niche use for LPG in commercial air conditioning systems, and
- supporting or providing training of installers, contractors and building managers to operate LPG appliances.

This would not only directly stimulate use of LPG, but it would also grow the capacity of suppliers, agents and depots and expand the secondary market through reduced overall costs for individual domestic customers.

10.2 Potential for Introduction of LNG

10.2.1 Feasibility and Cost Factors

The research in this report shows that sufficient volumes of LNG are available on both sides of the Pacific to introduce and service a natural gas market for PICTs. Locations for these volumes include the east coast of Australia (Melbourne, Gladstone), PNG (Port Moresby or other locations) and North America (Vancouver). LNG can be delivered using bulk ships as small as 12,000 m^3 or in 20' or 40' ISO containers.

LNG prices vary between regional markets and over time. Oil-linked pricing is dominant in Asia, and gas-linked pricing is dominant in North America. LNG pricing relative to oil has worsened in recent years, but the market dynamics are complex and may change, with a potential supply overhang in the next few years. At the time of writing, LNG prices (ex-LNG terminal) were around USD15/MMBTU (linked to oil) in Asia, and around USD7–9/MMBTU (linked to gas) in Vancouver. The Vancouver pricing is significantly cheaper than delivered prices for diesel and somewhat cheaper than HFO. It is representative of the potential disruption that might occur in world LNG markets if sufficient capacity is introduced through the use of gas-linked pricing.

LNG distribution requires significant new capital investment in ports, storage facilities, in-country distribution networks, and equipment conversion. This results in much higher storage and transport costs per unit of energy delivered than diesel, gasoline and LPG. For these reasons, it is not a fuel that should be stored 'just in case' it is needed. Instead, the research in this report has shown that LNG is best used in a 'baseload' application in order to justify the infrastructure investment and adequately recover costs. The high storage and distribution costs contribute to a delivered cost that varies across PICTs in terms of its competitiveness with incumbent fuels.

These high investment and distribution costs present a barrier to investment and require that the base FOB price of LNG be at a significant discount to diesel, HFO or gasoline. Market price fluctuations in all fuels present another challenge for comparing the merits of fuel investments[44]. In addition, its introduction would require the development of new skills and regulations, as well as extensive marketing to ensure adequate demand.

To be delivered cost-effectively, this study finds that LNG would have to be shipped to the region in bulk. Small-scale bulk ships are currently available for this purpose. If they are fully utilised throughout the year, shipping costs would represent around 10% of the delivered cost of LNG. The additional costs to ship LNG from the cheaper Vancouver source to the Pacific would probably be justified by the lower LNG prices available there (LNG in Vancouver is USD6–8/MMBTU cheaper than Australian sources).

10.2.2 LNG for Stationary Power Applications

If LNG is introduced to a new market in the Pacific, it is initially best suited to a limited number of stationary power applications that are geographically concentrated in a few areas around sites and/or major ports. Not including the known opportunity in Guam, the other main opportunities appear to be:

- New Caledonia's nickel smelter (~160–200 MW of power generation)
- Fiji's current and future mining sector (~120 MW of power generation), and
- French Polynesia due to its relative proximity to Vancouver's LNG markets and its relatively high HFO price.

An alternative suggested in industry workshops is to focus on an economic zone where LNG could be used by means of a new gas pipeline network to displace existing fuels. These projects would need to justify the upfront investments in infrastructure, whereupon secondary markets could be developed over time, such as LCNG, CNG and LNG for transport and industrial/commercial use, which generally use much smaller volumes per individual application.

It may be viable to send ISO containers of LNG from a regional hub to subregional islands once centralised storage was established, but it is highly unlikely that the long-distance shipping of ISO containers of LNG will be viable. It is worthwhile to note that Hawaii recently imported a trial run of LNG in ISO containers, but in January 2015 it called for tenders for bulk delivery.

44 Fuel-price forecasting was not under the scope of this study.

10.2.3 LNG for Transport Sector

Compared to LPG, the application of LNG for transport appears less probable at this stage. There are not likely to be any large-scale transport operators that could singly justify the required investment. It would be better for transport operators to wait until a regional LNG hub is developed (if this occurs) and then investigate its potential as a secondary use in transport.

Therefore, in the longer-term, increasing LNG and LCNG for transport could be viable in all or some of the following circumstances:

- centralised LNG infrastructure is installed in the country on the back of an 'anchor demand', such as a large power station or economic zone development, and LNG for transport could subsequently be developed
- if new vehicles are purchased directly as dual-fuel or gas-only, the marginal cost needs to be relatively small compared to the expected savings in fuel costs
- trucks operating on LNG would need to travel a minimum distance of 200,000 kms per year with LNG 30% cheaper than diesel to justify the additional costs of running on LNG
- the delivered cost of LNG or LCNG needs to be cheaper than alternatives (diesel, gasoline, LPG) with a high likelihood over vehicle life
- there are skilled labourers to maintain and operate the equipment
- there are high safety standards that can be enforced for operation and maintenance of vehicles running on LNG or CNG, and/or
- fuel diversity and LNG use are consistent with regional government or utility policies.

10.3 LPG and LNG for Power Generation

The use of LPG in power generation has an advantage over LNG in the sense that the supply chains and infrastructure already exist. However, LPG has historically been a more expensive option than diesel. The key additional circumstances under which use of LPG for power generation would be viable are:

- if it can be shown that diesel+LPG blends operate with reliability
- if the new generators installed are designed to run on 100% LPG, and/or
- if long-term delivered LPG pricing to the engine inlet can be secured at a discount to diesel, HFO or LNG.

As indicated above, although LNG for power generation in PICTs is technically feasible, it faces many commercial challenges. Even so, the use of LNG in the short to medium term for power generation could be viable if all or some of the following circumstances occur:

- an individual, or a collection of, medium to large power station(s) (>40 MW in aggregate), such as those in Guam, New Caledonia, Fiji, and French Polynesia, can be found to justify dedicated small-scale bulk shipping and storage facilities and attract competitive LNG pricing
- higher national emissions standards require the substitution of HFO and diesel
- prospective power stations have no realistic prospects over the coming 10–15 years to use cost-effective renewable energy such as solar photovoltaics or coconut oil on a large scale
- the large capital cost of LNG infrastructure is not a barrier and the end-user has a sufficient credit rating (or credit risk guarantees) to underwrite the contract for LNG off-take over a long term

- the contract for LNG supply can be entered for more than 10 years
- new engines or boilers are planned and their conversion to dual fuel is relatively 'low cost' compared to the expected savings in fuel costs
- the delivered cost of LNG can be confirmed as competitive with alternatives (e.g. diesel, HFO, coal) with a high likelihood over the contract timeframe
- there is potential for secondary use in industry and/or transport
- there are skilled labourers to maintain and operate the equipment and maintain high safety standards
- using LNG is considered as a means of improving fuel security through energy diversity
- fuel diversity and LNG use are consistent with regional government or utility policies, and/or
- power-generation efficiencies are not severely penalised by using LNG instead of the incumbent fuel.

In the near term, utilities and IPPs could benefit from ensuring that future generation investments incorporate multi-fuel capability to give them as much flexibility as possible in future fuel choices.

11 Recommendations and Next Steps

Although many additional commercial, technical, policy and environmental factors need to align for a fuel transition to occur, the following recommendations can be made. These require a relatively low investment of time and resources.

11.1 Expansion of LPG

The study outlines four recommendations in regard to LPG that would help a PICT to increase LPG supply and position it for further growth.

1. **The transition to LPG from biomass and kerosene for cooking be accelerated, given that it has positive documented health and environmental benefits.** This could include assessing the need in some PICTS to reduce the import duty and tax for LPG relative to household kerosene (given it is subsidised in some PICTs), supporting subsidised cylinder exchange/ deposit schemes, microfinance initiatives or other initiatives designed to reduce health risks (particularly for women), environmental impacts and overall costs for individual domestic customers and some commercial enterprise as well.
2. **PICT governments consider approaches for developing small piped LPG networks in urban areas to supply LPG for cooking and other purposes.** This approach would help to improve economies of scale and create centres of demand for future LNG substitution.
3. **PICT governments consider developing LPG options for the transport sector.** In addition to providing a cleaner burning fuel, the increased demand may improve economics for LPG across the region. Applicability may vary between PICTs, but governments could consider instigating a two-phase development of five years each. In the first phase, new transport sector vehicles can be encouraged through a mix of financing and tax incentives with government fleets being an early example. The second phase could begin about two years later and target existing vehicles. Older vehicles could be replaced or converted first, with progressive targeting of vehicles. For example, the first year can address ages over 10 years, the second year can focus on 8-10 years, and so on. Current oil prices would be a factor in government decisions and the 'take-up' rate and timing of these developments.
4. **PICT governments consider introducing appropriate incentives for private sector and other stakeholders to increase their LPG import and storage capacities to facilitate increased LPG usage.** Assuming that LPG use is encouraged to grow, it may be possible to cost-effectively expand LPG use with little additional investment. The planning regulations and activities for any LPG storage and distribution infrastructure should take into account this projected growth.

11.2 Potential Introduction of Natural Gas

5. **Relevant end-users with an aggregate power-generation capacity of more than 40 MW assess the economic viability of importing bulk LNG, including using FSUs or a FSRU.** A collective approach between power producers within and between countries could result in an 'anchor demand' in the region, and would indicate the parties interested in supplying LNG/LPG under a long-term contract. A cost-effective FSU or FSRU would substantially reduce the overall cost of delivered LNG if it becomes available.

6 **Governments develop policy frameworks on LNG import and use in those countries where there is realistic potential for LNG substitution.**

If the market conditions for cost-effective supply of LNG to one or more PICTs are achieved, the following actions could be considered:

- an individual power station, IPP, government, gas importer or consortium could enter into a long-term contract for LNG supply, and/or
- PICT governments could consider facilitating LNG use in transport or industry once LNG infrastructure is established in a country on the back of the 'anchor demand' in power generation.

11.3 For Both LPG and Natural Gas

7 **Power-generating utilities and IPPs consider investing in multi-fuel and gaseous fuel injection capability (LNG/natural gas, diesel, HFO, LPG) when buying new generators in relevant countries.** This offers maximum flexibility in future fuel choices with a relatively small incremental cost (likely to be <5% of the power generator's capital cost).

11.4 Fuel Pricing

8 SPC and PPA develop an ongoing 'watching brief' on the world's bulk LPG and LNG markets to identify potential oversupply conditions and price anomalies and keep Governments and private sector groups informed of emerging opportunities.

11.5 Next Steps

This report will be distributed to development partners, governments and industry. The recommendations and activities mentioned above provide some suggestions towards making decisions about the technical and economic viability of increased gas use in PICTs. They do not represent a barrier to the continued pursuit of sustainable and renewable energy systems for power generation where viable. Rather, they may prepare countries to capitalise on potential price disruptions and technical developments in world fuel markets.

For social, environmental and economic reasons, PICTs need to reduce their reliance on imported liquid fossil fuels and develop alternative renewable energy sources. Gas and other new approaches may broaden access to energy for rural and remote areas, and provide cleaner, cheaper and more reliable energy for power generation, industry and households. Such change is vital for the region's long-term future.

Appendix A: List of People Consulted/Involved in Study

In addition to people mentioned specifically in the Acknowledgements section at the beginning of the report, the following organisations and individuals are thanked for their participation and support:

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Appendix B: Some Regional Resources

Agreement/Framework/Policy	Description	Website Address
Framework for Action on Energy Security in the Pacific (FAESP): 2010–2020	Regional blueprint for the provision of technical assistance to the energy sectors of PICTs.	http://www.spc.int/edd/en/document-download/viewdownload/11-reports/360-energy-framework-final
Implementation Plan for Energy Security in the Pacific (IPESP) (2011–2015)	A five-year plan for pursuing the vision, goal and outcomes of FAESP	http://www.spc.int/edd/en/document-download/viewdownload/11-reports/2173-implementation-plan-for-energy-security-in-the-pacific-2011-2015
Pacific Regional Data Repository	This database is designed to support Pacific governments working in the energy sector (and their development partners) by facilitating access to up-to-date, reliable energy data and project information	http://prdrse4all.spc.int

Appendic C: Fuel Substitution Potential in Fiji and Tonga: Hypothetical Scenarios

Two scenarios have been developed for this report to identify and communicate in greater detail the potential for substituting gaseous fuels in the energy markets of PICTs. For this purpose, Fiji and Tonga have been selected. Optimistic and pessimistic scenarios are priced and developed for purposes of considering fuel substitution in their power and transport sectors. Both scenarios assume that LNG or CNG has already been made available in the country and that CNG is available at the same delivered price as LNG, since the additional infrastructure for CNG is minimal in comparison to the bulk infrastructure and the shipping and commodity costs associated with delivery of LNG to a country.

Fuel Substitution Potential in Fiji

Country Fuel-Use Overview

When considering the potential for substituting Fiji's fuels for gaseous products, we excluded (a) aviation kerosene because it has no real substitution potential with gas, and (b) re-exported fuels because they do not represent a country's genuine fuel use.

Table C.1. Fuel Use Breakdown in Fiji

Fuel	Volume p.a.	Energy Equivalent (MMBTU)	Wholesale Unit Price (USD/Unit)	Wholesale Value (USD)
Heavy Fuel Oil - Power Generation	41 ML	1,544,128	0.91/L	USD37m
Diesel – Power Generation	35 ML	1,307,143	0.96/L	USD34m
Diesel – Land Transport	68 ML	2,479,351	0.96/L	USD65m
Diesel – Maritime Transport	74 ML	2,699,640	0.96/L	USD71m
Diesel – Industry and Construction	76 ML	2,778,254	0.96/L	USD73m
Unleaded Petrol (gasoil)	69 ML	2,369,050	0.92/L	USD63m
LPG – Household	7,200 T	341,072	1.72/kg	USD12m
LPG – Other	12,800 T	606,349	1.72/kg	USD23m
Kerosene for Cooking and Other Use	2.5 ML	88,005	0.95/L	USD2.3m
Biomass Use for Cooking	8,000 TOE	317,466	-	-
TOTAL		**14,530,458**		**USD380m**

Note: Excludes aviation, kerosene and re-exported fuels

Focus of Scenario

Although many uses of LNG, CNG and LPG are possible, the focus of the scenario is on the potential uses that (a) have existing successful applications, (b) are most repeatable within and outside Fiji, and (c) can be delivered in a reasonable timeframe (<5 years) in the Fiji context, specifically:

1. **LNG in publicly and privately-run large power plants, where:**
   - engines are able to be converted to either dual fuel or gas-only using proven OEM-supplied and warranted technologies, or
   - new equipment, such as gas engines, micro gas turbines, or large gas turbines, can be installed.
2. **LNG or CNG in bus and truck transport fleets, where:**
   - a hub-and-spoke transport system from a depot allows centralised fuel storage for use in the vehicles
   - gas or dual-fuel engines can be retrofitted to the existing fleet, and
   - fleet turnover allows new vehicles to be brought in that are gas- or dual-fuel-powered because retrofitting is costly.
3. **LNG in large marine vessels, where:**
   - engines can be converted to either dual fuel or gas-only using proven OEM-supplied and warranted technologies
   - vessel types are of a category with high turnover, and there is typically high-quality maintenance on engines, for example, passenger ferries used in the tourism industry.
4. **LNG/CNG use for private vehicles to displace ULP, where:**
   - vehicles can be converted
   - regional centres may act as a focal point and reduced vehicle range is not problematic.

Note: LPG use in cooking to displace kerosene and biomass has been excluded from this study because (a) there appears to be no market failure due to the existence of competitive commercial operations in LPG sales, marketing and distribution across the Pacific; and (b) there is a plethora of studies on why using LPG is better for householders, in which both formal and anecdotal evidence suggests that, although there is high proportion of rural populations with low GDP per capita, a wide variety of cooking fuels will continue to be used, including biomass and kerosene, for cost, cultural, and practical reasons.

LNG in Publicly and Privately-Run Power Plants

Diesel used in Fiji's electricity sector is currently dominated by (a) Fiji Electricity Authority-operated power plants, and (b) one large gold mine that operates its own power plant and network. Table C.2 shows the currently installed power stations and associated fuel consumption.

Table C.2. Power Stations and Associated Annual Fuel Consumption in Fiji

PICT	Power Station	Island	Annual Fuel Consumption (ML)		Energy Equivalent (MBTU)	
			ADO/IDO	IFO/HFO	ADO/IDO	IFO/HFO
Fiji*	**Total**	**Fiji**	**35.71**	**41.07**	**1,306,610**	**1,634788**
	Kinoya	*Viti Levu*	*14.56*	*26.76*	*532,622*	*1,065,239*
	Korovou	*Viti Levu*	*0.01*		*522*	
	Vuda	*Viti Levu*	*2.10*	*14.31*	*76,841*	*569,549*
	Nadi	*Viti Levu*	*0.81*		*29,561*	
	Sigatoka	*Viti Levu*	*3.23*		*118,244*	
	Deuba	*Viti Levu*	*1.02*		*37,441*	
	Rakiraki	*Viti Levu*	*1.17*		*4,2970*	
	Qelelola	*Viti Levu*	*0.04*		*1,524*	
	Labasa	*Vanua Levu*	*7.25*		*265,266*	
	Savusavu	*Vanua Levu*	*2.68*		*98,218*	
	Levuka	*Ovalau*	*2.83*		*103,399*	
Fiji: Private		*Gold Mine*	*23.8*		*873,717*	

The focus of this scenario is Kinoya since it is the largest diesel/HFO power station owned by the Fiji Electricity Authority, and therefore has suitable fuel demands in order to demonstrate some of the issues associated with fuel substitution. Table C. 3 shows the specific generator-engine types installed at Kinoya. Figure C.1. shows an image of the Caterpillar CM32s.

Table C.3. Engine Types Operating at Kinoya Power Station

Engine	Year	Qty	Capacity (MW)	MWh p.a. (2014)	Load Factor	Fuel type	Notes on ability to be converted
Caterpillar CM32	2005	4	7.45	61,796	24%	Diesel	Can possibly be converted to run on 70% LNG
Wartsila W38	2001	2	10.3	117,355	65%	HFO	None around the world has yet been converted to dual fuel
TOTAL Current		6	50	179,151			
Wartsila W20B32	2015 (being installed now)	4	8.75			HFO	HFO specification, but can run on diesel or be converted to run on 99% LNG and Diesel at a cost of approx. USD1.0–1.5m per engine

Figure C.1 Kinoya: Caterpillar Engines

(Source: Pernixgroup.com)

Kinoya Power-Station Assessment

As mentioned in this report and acknowledging the broader market and regional supply challenges of bringing gas supply to PICTs, the actual practical feasibility can still be determined in the end by site-specific constraints. Table C.4 outlines the key parameters and specific potential in terms of fuel substitution at the Kinoya Power Station.

Table C.4: Hypothetical Scenario for Kinoya Power Station LNG Fuel Conversion

Item	Description	
Diesel Power Station	Kinoya, Fiji	
Diesel Power Generation Installed Capacity (MW)	50 MWe across 6 engines	
Annual Electricity Generated from Diesel and HFO (MWh)	179,000 MWh p.a. Scheduled when hydropower output is low	
Load Factor	HFO engines = Diesel engines =	65% 24%
Specific Fuel Costs	HFO = Diesel = LNG in ISO containers = LNG bulk shipped =	USD 17.74/MMBTU USD 23.54/MMBTU USD 32.22/MMBTU USD 21.48/MMBTU
Engine Efficiency	On HFO or diesel = On LNG (dual fuel) =	40% (assumed) 38% (assumed)
LNG Substitution	99% of HFO 70% of diesel	
Fuel Use	Prior to LNG = Using HFO ,diesel, LNG =	1,594,381 MMBTU 1,678,296 MMBTU
Cost of Fuel Used in Generation	Prior to LNG = Using LNG in ISO = Melbourne) Using LNG in bulk =	USD31.4m USD48.2m (from USD32.2m (from Vancouver)
LNG ISO Container Solution Details	386 ISO containers in a 3-month rotation between Melbourne and site 27 deliveries of 40' ISO containers per week	
% Fuel Contributed by LNG	89%	
Investment Required in Port and Site Storage or FSRU Estimated at USD 5,000/Tonne Stored	USD34m	

Beyond the site-specific technical challenges at the Kinoya Power Station, the following commercial and regulatory points should also be taken into consideration:

- the site is currently operated under a third-party operation and maintenance agreement with Pernix Group (though this is not seen as a barrier)
- FEA has just purchased four new Wartsila engines that run on HFO, which is a relatively cheap fuel for now, making fuel conversion less cost effective
- there are no current particulate or air-quality regulations with which the Kinoya Power Station needs to comply and which would penalise the further use of HFO
- the site is currently being developed to accept the new four Wartsila HFO engines
- the site has room to install suitable fuel storage for LNG
- fuel-delivery trucks are received around three to five times per day
- the site currently has around eight days of fuel storage and the country would rely on further fuel storage at the port for system security
- inspection shows that access to the site is good
- because the new Wartsila HFO power generators are designed to operate instead of diesel generators, the load factor on the Caterpillar engines is expected to drop significantly
- overall generation from Fiji's diesel-power stations is dependent on rainfall and hydropower output - from 2010 to 2014, the combined output from Kinoya and Vuda ranged from 83,000 to 253,000 MWh/p.a. and is expected to remain variable
- the power station's dispatch profile is such that it runs at constant load when dispatched, which may be around 80% to 100% - this is well suited to gas-engine operations that do not accept step-loads as well as diesel engines.

In reviewing these parameters, the following conclusions can be drawn from the Kinoya Power Station scenario:

1. The expected loss in efficiency from the conversion of these HFO or diesel engines to dual fuel will cause an increase in overall energy use. This would not be the case if new gas engines with higher design efficiency were installed.
2. The specific cost of LNG shipped in bulk from Vancouver should be more than 20% cheaper than diesel and would likely provide a good return on investment in diesel-engine conversions.
3. When substituting for LNG, the business case is marginal at current prices.
4. An ISO container solution for LNG is not a viable option at the Kinoya Power Station.

Fiji-Wide Substitution Potential

When considering a broader application of gaseous fuels in Fiji, the highest potential end-use applications suited to substitution for gas are:

1. Taxi fleets: conversion to CNG, subject to:
   - confirmation of a conversion cost per vehicle of less than USD2,000
   - a delivered cost into the vehicle of LCNG of less than about USD20/MMBTU
   - a reasonable network of LCNG refuelling stations.
2. Truck fleets with hub-and-spoke refuelling operations, subject to:
   - confirmation of a conversion or marginal cost per new vehicle of less than USD30,000
   - a delivered cost into the vehicle of LCNG of less than about USD20/MMBTU.

Table C.5. Fiji Country Expenditure With and Without LNG and LCNG: Optimistic and Pessimistic Scenarios

Fuel	Units	Current Fuel Use	LNG Substitution %		MMBTU with LNG in Mix		$/MMBTU	Country Expenditure (approx.)		
			Optimistic	Pessimistic	Optimistic	Pessimistic		Base Case (USD)	Optimistic (USD)	Pessimistic (USD)
HFO: Power	MMBTU	1,634,788	100%	0%		1,634,788	17.91	$29,279,053		$29,279,053
Diesel: Power	MMBTU	1,296,940	100%	25%		972,705	23.66	$30,685,593		$23,014,195
Diesel: Land	MMBTU	2,501,241	50%	10%	1,250,620	2,251,117	23.66	$59,179,359	$29,589,679	$53,261,423
Diesel: Marine	MMBTU	2,686,518	10%	0%	2,417,866	2,686,518	23.66	$63,563,015	$57,206,713	$63,563,015
Diesel: Industry	MMBTU	2,779,157	50%	10%	1,389,578	2,501,241	23.66	$65,754,843	$32,877,421	$59,179,359
Gasoline: Land	MMBTU	2,222,931	50%	10%	1,111,466	2,000,638	25.35	$56,351,305	$28,175,652	$50,716,174
Gasoline: Marine	MMBTU	22,454	0%	0%	22,454	22,454	25.35	$569,205	$569,205	$569,205
LNG	MMBTU	0			6,952,044	1,074,568	21.73	$-	$151,067,911	$23,350,358
TOTAL		**13,144,028**			**13,144,028**	**13,144,028**		**$305,382,372**	**$299,486,582**	**$302,932,781**

3 Power generators operating on diesel, subject to:
   - reasonable conversion costs per engine
   - load factors on the engines greater than about 30%
   - a delivered cost into the vehicle of LCNG less than about USD20/MMBTU
   - a future load profile that is reasonably certain for a minimum of 5+ years.

4 Power generators operating on HFO, subject to issues similar to diesel, but also a price for delivered HFO greater than the LNG price.

In such a case, the substitution potential for Fiji, as shown in Table C.5, is estimated to have the following merits in both an optimistic and pessimistic scenario, with:

- a potential fuel-cost reduction of USD7 million p.a. in a pessimistic scenario, and
- a potential fuel-cost reduction of USD33 million p.a. in an optimistic scenario.

Supply Chain Optimisation

This study has found that the two main methods of reducing the cost of delivered LNG are: (i) sourcing supply from the cheapest supply-point possible, and (ii) shipping supply in bulk. In this regard, bulk shipping of LNG at a scale suited to Fiji's potential consumption with several discrete power projects is proven and currently happening in Asia. Shipping of LNG in ISO containers is also technically possible and could be cheaper than diesel in some of the smaller PICTs, subject to (i) purchasing a cost-effective ISO container to reduce the amortised container cost over the life of the container, and (ii) considering a dedicated shipping line for the fuel so the customer does not pay an excessive premium for shipping of dangerous goods.

There is no barrier to the shipping of ISO containers and the Pacific is serviced well enough by container ships. LNG storage costs are not overly significant in the delivered cost of LNG to implementation are likely to be 12+ months (doesn't make sense, please add missing text), mainly to allow for conversion of end-use applications from the existing diesel and/or HFO fuel use, but also to allow for storage systems to be built and installed.

Commercial and Regulatory Considerations

Beyond the economics of markets and associated technical feasibilities, multiple regulatory and commercial issues must also be considered in creating a new fuel supply chain in the Pacific. Specifically for LNG and LCNG, consideration should be given to:

LNG storage and handling:

- container storage at port: there is a need for land/space to store containers in specific areas classified for dangerous goods (for example, the port in Fiji is already constrained)
- ISO 40' container handling: not all ports have the necessary materials handling equipment
- LNG holding time: because there is a limit of 50 to 90 days of pressurised storage time, depending on the container design, each container may need to be tracked and any potential discharge managed.

Technical skills and knowledge:

- LNG equipment, storage and vaporisation systems are sophisticated and require good technical knowledge, training and maintenance practices. It could make sense for the existing LPG suppliers to take the lead in this regard. Anecdotal evidence suggests that PICTs have difficulty in retaining personnel trained in high-quality maintenance of sophisticated equipment, including existing LPG and power systems.

New regulation to be written:

- It is highly likely that the importation and use of LNG would require new regulations or laws.

Barriers to entry may exist for suppliers, end-users and financiers to enter the LNG market, such as:

- there is a large capital cost for import terminals if a bulk solution is selected
- CNG take-up in vehicles may be hindered by the lack of a pre-existing refuelling network
- incumbent fuel suppliers are embedded in the market and can engage in aggressive market tactics to prevent new entrants.

Asset life:

- This study assumed that ISO containers would last 10 years and land-based storage would last 20 years. Changes to this assumption may alter the findings.

Length of contract:

- As with any major deal, the length of contract is significant for finance costs and pricing, and can be a 'showstopper' in any negotiation. For deals with utilities, the asset lives are generally long and would support a longer contract. This may not be the case for the transport sector.

Organic growth in consumption:

- In the transport sector, any bulk LNG imports would only be supported by very large numbers of vehicle conversions. Because slow growth in demand would make bulk importation difficult to justify, this would mean that ISO container deliveries may be too costly to justify any fleet changeover and a stalemate may occur.

In view of these issues, from a commercial perspective both ISO container and bulk solutions may make sense in particular circumstances, depending on the financial strength of the parties involved:

LNG use through ISO containers could be viable at some locations where diesel has a high delivered cost and low volume. It has some important benefits over bulk shipping:

- scalability through greater numbers of fuel containers to feed growth
- no need for a large import terminal; it uses existing transport infrastructure, which reduces the need for government or private-sector debt, and means a short time to implementation
- lower cash-flow requirements for local importers, particularly if containers are financed by larger international shipping companies.

Bulk LNG terminals may be attractive to larger investors as part of a long-term deal with a utility or IPP based on the conversion of a single engine or power station, if the projected LNG use is large enough.

Potential Opportunities

Suggestions on how to overcome potential barriers to LNG take-up include focusing on the creation of an 'anchor demand' for LNG in the region:

1. **A government-backed utility of sufficient scale could take the lead** by converting one major user (such as a large power station operating on diesel) to LNG. This would create the necessary economies of scale for bulk LNG delivery to that country. Smaller PICT utilities, smaller power stations, transport operators, and others in the private sector can then leverage this demand.

2 **A private-sector power generator with the support of governments (or multilateral development agencies) could take the lead** and create the 'anchor demand' in the region. Support from the government(s) should target potential barriers, such as financial guarantees, financial support for the private sector to access technical skills and knowledge, investment in shared storage facilities, assistance in obtaining the appropriate regulatory approvals, and development of safety and training systems.

3 **Group purchasing of LNG** within the power or transport sector or among utilities could build sufficient volume to ship in bulk.

An anchor-demand power system with sufficient size to prompt a bulk LNG shipping solution on its own is one with demand greater than about 50,000 tonnes (2,750,000 MMBTU) of LNG per year, and includes Guam, New Caledonia, Fiji, and French Polynesia.

Tonga as a Subregional Destination from Fiji

Tonga's total energy demand is 14% of Fiji's. It has a deep-water port and could take bulk LNG from a tanker with an investment in port unloading facilities. Tonga already receives bulk LPG by tanker. Table C.6 illustrates an estimated comparison of the delivered fuel prices.

Table C.6. Estimated Comparison of Delivered Fuel Prices in Tonga

	Diesel	LNG: 40' Container	LNG: Bulk
Estimated fuel price delivered (USD/ MMBTU)	26.56	34.78	23.00, which is an estimated, optimistic, theoretical price based on bulk to Fiji plus additional distance travelled to Tonga (similar to the way in which LPG is delivered)

Table C.7 illustrates the potential savings in fuel expenditure in Tonga under optimistic and pessimistic scenarios. Under the optimistic scenario, with high LNG penetration into diesel and ULP use, and low LNG pricing due to bulk delivery through Fiji, Tonga could reduce its total fuel expenditure by some USD 1 million per year, or 2%.

Table C.7. Tonga Country Expenditure With and Without LNG and LCNG: Optimistic and Pessimistic Scenarios

Fuel	Units	Current Fuel Use	LNG/LCNG Substitution		MMBTU with LNG in Mix		USD/ MMBTU		USD/ MMBTU		Country Expenditure (approx.)
			Optimistic	Pessimistic	Optimistic	Pesimistic	Optimistic	Pessimistic	Base Case (USD)	Optimistic (USD)	Pessimistic (USD)
HFO - Power	MMBTU	-	0%	0%	-	-	17.91	17.91	$-	$-	$-
Diesel - Power	MMBTU	468,357	100%	25%	-	351,268	23.66	23.66	$11,081,333	$-	$8,311,001
Diesel - Land	MMBTU	478,539	50%	10%	239,269	430,685	23.66	23.66	$11,322,232	$5,661,105	$10,190,007
Diesel - Marine	MMBTU	71,272	10%	0%	64,145	71,272	23.66	23.66	$1,686,290	$1,517,671	$1,686,296
Diesel - Industry	MMBTU	-	50%	10%	-	-	23.66	23.66	$-	$-	$-
Gasoline – Land and Marine	MMBTU	411,303	25%	5%	308,477	390,738	25.35	25.35	$10,426,531	$7,819,892	$9,905,208
LNG	MMBTU	0			817,580	185,508	23.00	34.78	$-	$18,804,340	$6,451,968
TOTAL		**1,429,471**			**1,429,471**	**1,429,471**			**$34,516,386**	**$33,803,007**	**$36,544,480**

Appendix D: PICT Energy Market Breakdown

The fuel market for the PICTs covered in this study has been composed from data available (ranging in reported years from 2006–2013)* during the research phase of the report, including a breakdown by sector where data was either directly available or derivable from government reports or industry consultations (Table D.1). Data sources are referenced within Table D.2.

Table D.1: PICT Energy Market

Fuel	Unit	A. Samoa	CNMI**	Cook Islands	Fiji	French Polynesia	FSM	Guam	Kiribati	Nauru
HFO	**MMBTU**	**0**	**0**	**0**	**1634788**	**2952122**	**90164**	**17793347**	**0**	**0**
	ML	0.00	0.00	0.00	41.07	74.16	2.27	446.98	0.00	0.00
	Year	-	-	-	2013	2011	2011	2011	-	-
Power	%									
Industry	%									
Transport	%									
Diesel	**MMBTU**	**3670493**	**3185261**	**763238**	**9263855**	**6358654**	**954395**	**2327756**	**451252**	**323490**
	ML	100.33	87.06	20.86	253.21	173.80	26.09	63.63	12.33	8.84
	Year	2013	2013	2010–12	2009–13	2012–13	2010–13	2011–13	2013	2010–12
Power	%	40%	n/a	37%	14%	21%	55%	11%	47%	70%
Land	%	8%	n/a	n/a	27%	52%	n/a	83%	44%	n/a
Marine	%	46%	n/a	n/a	29%	21%	n/a	n/a	9%	n/a
Industry	%	5%	n/a		30%	6%				
Gasoline	**MMBTU**	**754072**	**n/a**	**190761**	**2245385**	**2019190**	**381522**	**5597792**	**227689**	**47577**
	ML	23.26	n/a	5.89	69.27	62.29	11.77	172.69	7.02	1.47
	Year	2010		2010	2009	2013	2010	2011	2013	2010
Land	%				99%	98%	30%		71%	
Marine	%				1%	2%	60%		29%	
LPG	**MMBTU**	**75794**	**20895**	**37897**	**947421**	**521081**	**3804**	**393907**	**13627**	**474**
	Tonne	1600	441	800	20000	11000	80	8315	288	10
	Year	2010	2013	2013	2013	2008	2013	2010	2013	2009
Commercial		70%			64%					5%
Residential		30%			36%					95%
Kerosene	**MMBTU**	**3382**		**71**	**88005**	**72869**	**43145**	**0**	**14915**	**0**
	ML	0.1	-	0	2.54	2.1	1.24	-	0.43	0
	Year	2010	-	2011	2008	2013	2013	-	2013	2012
Biomass	**MMBTU**				**323010**		**484515**		**504469**	
	Year	-	-	-	2013	-	2000	-	2009	2012
Coal	**MMBTU**									
	Year									
TOTAL	**MMBTU**	**4503741**	**3206156**	**991967**	**14502464**	**11923916**	**1957545**	**26112801**	**1211952**	**371541**

*No standard year available for data capture. Latest available year of reported data has been used between 2006 and 2013 (see Appendix H for detailed references).

**CNMI: Diesel volumes unavailable for sectors other than power, and all gasoline volumes unavailable at time of writing; RMI: Volumes for gasoline unavailable at time of writing
n/a = not available at time of writing.

New Caledonia	Niue	Palau	PNG	RMI**	Samoa	Solomon Islands	Timor-Leste	Tonga	Tuvalu	Vanuatu	TOTAL
10004324	0	0	2158091	0	0	0	3050317	0	0	0	37683154
251.32	0.00	0.00	47.11	0.00	0.00	0.00	76.63	0.00	0.00	0.00	**939.53**
2013	-	-	2012	-	-	-	2013	-	-	-	-
			49%								
			37%								
			13%								
8092507	42402	1026116	39068270	1441672	1586637	3574362	4097529	1018168	108738	1298770	88653565
221.20	1.16	28.05	1067.87	39.41	43.37	97.70	112.00	27.83	2.97	35.50	2,423.22
2010–13	2011–12	2010	2012–2013	2010–12	2011	2009–12	2013	2013	2011–12	2011–13	-
1%	62%	89%	6%	47%	47%	23%		46%	61%	32%	-
n/a	n/a	9%	28%	n/a	26%	n/a		47%	2%		-
n/a	n/a	2%	13%	n/a	11%	n/a		7%	37%		-
37%			53%		16%	20%					-
2670652	24019	592288	4562520	n/a	913204	610435	777954	411303	26626	303402	22356391
82.39	0.74	18.27	140.75	n/a	28.29	18.83	24.00	12.69	0.82	9.36	**517.13**
2010	2012	2012	2012	n/a	2011	2010	2013	2011	2012	2011	-
	90%	50%			99%				75%	54%	-
	10%	50%			1%				25%	46%	-
378968	1481	9261	854398	6774	56665	80531	23686	63980	12284	77860	3580788
8000	31	196	18036	143	1196	1700	500	1351	259	1644	75590
2010	2013	2013	2012	2009	2011	2013	2006	2010	2012	2011	-
	14%		86%		50%	60%		5-10%	26%	60%	
	86%		14%		50%	40%		90–95%	74%	40%	
0	21	0	1736180	0	23664	21803	104068	11724	6893	40418	2167157
-	0	-	50.05	-	0.68	0.63	3	0.34	0.2	1.17	**62.47**
-	2013	-	2012	-	2011	2010	2006	2011	2012	2008	**-**
			52045025		605644	3028221	1344530	40376	2481	1756368	60134641
-	2013	2004	2012	2013	2012	2005	2006	2008	2012	2008	-
2168987											2168987
2013											
23315438	67923	1627666	100548838	1448446	3185814	7315352	9398085	1545552	157021	3476818	216869037

Table D.2. PICT Energy Market Data Sources

American Samoa

Power Sector: American Samoa Power Authority. (2014). Email advice on annual volumes, dated 23 September 2014.

All other volumes: Territorial Energy Office. (2012). *American Samoa Greenhouse Gas Inventory*. Territorial Energy Office, April 2012. Available at www.asrec.net/wp-content/uploads/2013/09/GHG-INVENTORY.pdf

Commonwealth of the Northern Mariana Islands (CNMI)

LPG: Geogas trading (2014) Estimation of annual LPG demand. Email dated 30 October 2014.

All other data: EIA (2014) 'Northern Mariana Islands: Territory Profile and Energy Estimates'. *U.S. Energy Information Administration*. Accessed: September 2014. Available at: http://www.eia.gov/state/?sid=CQ

Cook Islands

Diesel and Gasoline: United Nations. (2010). United Nations Energy Statistics Database: 1990 to 2012. Available at: http://unstats.un.org/unsd/energy/edbase.htm

Kerosene and LPG: Government of the Cook Islands. (2011). 'Miscellaneous Statistics'. Ministry of Finance and Economic Management. Accessed: September 2014. Available at: http://www.mfem.gov.ck/miscellaneous-statistics

All other volumes: SPC. (2009). Cook Islands Country Energy Security Profile. Secretariat for the Pacific Community (SPC). Available at: http://www.spc.int/edd/en/section-01/energy-overview

Fiji

Biomass: ADB. (2013). *ADB Energy Outlook for Asia and the Pacific*. Asian Development Bank. Available at: http://www.adb.org/publications/energy-outlook-asia-and-pacific-2013

Diesel and Gasoline: IRENA. (2013). *Pacific Lighthouses: Renewable Energy Roadmapping for Islands: Fiji*. International Renewable Energy Agency. Available at: http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=353

Kerosene: ADB. (2013). *Energy Statistics in Asia and the Pacific (1990-2009)*. Asian Development Bank. Available at: http://www.adb.org/publications/energy-statistics-asia-and-pacific-1990-2009

LPG: Probert, H. (2014). Fiji Gas estimations of LPG market size and distribution in Fiji. Fiji Gas. Meeting in September 2014.

Power sector (diesel and HFO): Fiji Electricity Authority. (2013). *Fiji Electricity Authority: Annual Report 2013*. Fiji Electricity Authority. Available at: http://www.fea.com.fj/about-us/company-information/company-reports/

French Polynesia

LPG: United Nations. (2010). United Nations Energy Statistics Database: 1990 to 2012. Available at: http://unstats.un.org/unsd/energy/edbase.htm

Power sector: PPA. (2012). *Pacific Power Utilities Benchmarking Report 2012*. Pacific Power Association (PPA). Available at: http://www.ppa.org.fj/

All other volumes: PRIF. Pacific Infrastructure Performance Indicators (draft). Available from PRIF Coordination Office.

Federated States of Micronesia (FSM)

Diesel: IRENA. (2013). *Pacific Lighthouses: Renewable Energy Roadmapping for Islands: FSM*. International Renewable Energy Agency (IRENA). Available at: http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=353

Gasoline: United Nations. (2010). United Nations Energy Statistics Database: 1990 to 2012. Available at: http://unstats.un.org/unsd/energy/edbase.htm

Household kerosene and LPG volumes: Government of the Federated States of Micronesia. (2013). FSM Household Income Expenditure Survey (Preliminary Results 2013). Office of Statistics, Budget & Economic Management, Overseas Development Assistance & Compact Management (SBOC)

LPG : South Pacific Petroleum Corporation (SPPCorp). (2014). Volume estimations based on actual volumes through the first 9 months of 2013. Email dated 22 September 2014.

Guam

Gasoline and Diesel: Guam Energy Office. (2013). *Transportation Petroleum-Use Reduction Plan*. Available at: http://www.guamenergy.com/outreach-education/guam-energy-task-force/

LPG: Guam Energy Office. (2011). Guam Initial Technical Assessment Report, April 2011. Available at: http://www.guamenergy.com/outreach-education/guam-energy-task-force/

Power sector (diesel and HFO): PPA. (2012). *Pacific Power Utilities Benchmarking Report 2012*. Pacific Power Association (PPA). Available at: http://www.ppa.org.fj/

Kiribati

Biomass: SPC. (2009). Kiribati Country Energy Security Profile. Secretariat for the Pacific Community (SPC). Available at: http://www.spc.int/edd/en/section-01/energy-overview

All other volumes: Kiribati Energy Office. (2013). Data obtained in person from office by SPC representative on mission throughout September 2013.

Nauru

Biomass, Kerosene, LPG, Gasoline and Diesel: IRENA. (2013). *Pacific Lighthouses: Renewable Energy Roadmapping for Islands: Nauru*. International Renewable Energy Agency (IRENA). Available at: http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=353

Power sector (diesel): PPA. (2012). *Pacific Power Utilities Benchmarking Report 2012*. Pacific Power Association (PPA). Available at: http://www.ppa.org.fj/

New Caledonia

Diesel: ENERCAL (2012) Rapport d'activités – statistiques 2013-2013. Available at: http://dev.enercal.nc/

Gasoline and LPG: United Nations. (2010). United Nations Energy Statistics Database: 1990 to 2012. Available at: http://unstats.un.org/unsd/energy/edbase.htm

Niue

Gasoline: IRENA. (2013). *Pacific Lighthouses: Renewable Energy Roadmapping for Islands: Niue*. International Renewable Energy Agency (IRENA). Available at: http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=353

Power sector: PPA. (2012). *Pacific Power Utilities Benchmarking Report 2012*. Pacific Power Association (PPA). Available at: http://www.ppa.org.fj/

All other volumes: PRIF. Pacific Infrastructure Performance Indicators (draft). Available from PRIF Coordination Office. Other Attributed Source: Niue Department of Energy (2011).

Palau

Biomass: SPREP. (2004). Pacific Islands Renewable Energy Project. (PIREP). Palau National Report. Secretariat of the Pacific Regional Environment Program (SPREP). Available at https://www.sprep.org/Pacific-Islands-Greenhouse-Gas-Abatement-through-Renewable-Energy-Project/pirep-documents

LPG: South Pacific Petroleum Corporation (SPPCorp). (2014). Volume estimations based on actual volumes through the first 9 months of 2013. Email dated 22 September 2014.

All other volumes: IRENA (2013) *Pacific Lighthouses: Renewable Energy Roadmapping for Islands: Palau*. International Renewable Energy Agency (IRENA). Available at: http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=353

Papua New Guinea

Biomass and Kerosene: SPC. (2012). *Facilitating Private Sector Participation in the Promotion of Energy Security in Papua New Guinea, Solomon Islands and Vanuatu – PNG Country Review*, October 2012. Secretariat for the Pacific Community (SPC). Available at: http://www.spc.int/

Power sector: PPA. (2012). *Pacific Power Utilities Benchmarking Report 2012*. Pacific Power Association (PPA). Available at: http://www.ppa.org.fj/

All other volumes: APEC. (2012). APEC Energy Statistics 2010. Asia Pacific Economic Community (APEC). Available at: http://publications.apec.org/publication-detail.php?pub_id=1354

Republic of the Marshall Islands

Biomass: IRENA. (2013). *Pacific Lighthouses: Renewable Energy Roadmapping for Islands: RMI*. International Renewable Energy Agency (IRENA). Available at: http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=353

SPC. (2009). RMI Country Energy Security Profile. Secretariat for the Pacific Community (SPC). Available at: http://www.spc.int/edd/en/section-01/energy-overview

Power sector (diesel): PPA. (2012). *Pacific Power Utilities Benchmarking Report 2012*. Pacific Power Association (PPA). Available at: http://www.ppa.org.fj/

All other diesel: United Nations. (2010). United Nations Energy Statistics Database: 1990 to 2012. Available at: http://unstats.un.org/unsd/energy/edbase.htm

All other volumes: SPC (2009) RMI Country Energy Security Profile. Secretariat for the Pacific Community (SPC). Available at: http://www.spc.int/edd/en/section-01/energy-overview

Samoa

Power sector: PPA. (2012). *Pacific Power Utilities Benchmarking Report 2012*. Pacific Power Association (PPA). Available at: http://www.ppa.org.fj/

All other volumes: Government of Samoa. (2011). *Samoa Energy Review 2011*. Ministry of Finance Energy Policy Coordination and Management Division. Available at: www.mof.gov.ws

Solomon Islands

Biomass: SPC. (2012). *Facilitating Private Sector Participation in the Promotion of Energy Security in Papua New Guinea, Solomon Islands and Vanuatu – Solomon Islands Country Review*, October 2012. Secretariat for the Pacific Community (SPC). Available at: http://www.spc.int/

Diesel: SPC. (2009). Solomon Islands Country Energy Security Profile. Secretariat for the Pacific Community (SPC). Available at: http://www.spc.int/edd/en/section-01/energy-overview

Gasoline: United Nations. (2010). United Nations Energy Statistics Database: 1990 to 2012. Available at: http://unstats.un.org/unsd/energy/edbase.htm

Kerosene: Solomon Islands Government. (2010). Import Statistics FY 2010. Obtained through Secretariat for the Pacific Community (SPC).

LPG: Geogas Trading. (2014). Estimation of annual LPG demand. Email dated 30 October 2014.

Power sector: Power sector: PPA. (2012). *Pacific Power Utilities Benchmarking Report 2012*. Pacific Power Association (PPA). Available at: http://www.ppa.org.fj/

Timor-Leste

Biomass, Kerosene and LPG: World Bank. (2010). *Timor-Leste: Key Issues in Rural Energy Policy*. The World Bank 2010. Available at: http://documents.worldbank.org/curated/en/2010/01/13570479/timor-leste-key-issues-rural-energy-policy

Diesel and Gasoline: ANP. (2013). Autoridade Nacional do Petróleo Timor-Leste - Annual Report 2013. Available at: http://www.anp-tl.org/

Power sector: Guterres, V. F. (2013). 'Access to Energy in Timor-Leste'. Presented at the Asia-Pacific Energy Forum. Bangkok, December 17-19, 2013.

Tonga

Biomass: ADB (2013) Energy Statistics in Asia and the Pacific. (1990-2009). Asian Development Bank. Available at: http://www.adb.org/publications/energy-statistics-asia-and-pacific-1990-2009

Power Sector: PPA. (2012). Pacific Power Utilities Benchmarking Report 2012. Pacific Power Association (PPA). Available at: http://www.ppa.org.fj/

All other volumes: PRIF. Pacific Infrastructure Performance Indicators (draft). Available from PRIF Coordination Office.

Other Attributed Source: Ministry of Revenue and Customs (2010).

Tuvalu

Power sector: PPA. (2012). Pacific Power Utilities Benchmarking Report 2012. Pacific Power Association (PPA). Available at: http://www.ppa.org.fj/

All other volumes: PRIF. Pacific Infrastructure Performance Indicators (draft). Available from PRIF Coordination Office.

Other Attributed Source: Tuvalu Annual Statistical Report (2012)

Vanuatu

Biomass, Kerosene and LPG: PRIF. Pacific Infrastructure Performance Indicators (draft). Available from PRIF Coordination Office. Other Attributed Source: Department of Customs & Inland Revenue (2011); and ADB (2013) Energy Statistics in Asia and the Pacific (1990-2009). Asian Development Bank. Available at: http://www.adb.org/publications/energy-statistics-asia-and-pacific-1990-2009

Diesel and Gasoline: SPC. (2012). *Facilitating Private Sector Participation in the Promotion of Energy Security in Papua New Guinea, Solomon Islands and Vanuatu – Vanuatu Country Review*, October 2012. Secretariat for the Pacific Community (SPC). Available at: http://www.spc.int/

Power sector: PPA. (2012). Pacific Power Utilities Benchmarking Report 2012. Pacific Power Association (PPA). Available at: http://www.ppa.org.fj/

Appendix E: Registered Vehicles and Maritime Vessels

Available data were collated for the land and marine sectors in terms of registered vehicles and vessels. Tables E.1 and E.2, respectively, provide details on this information.

Table E.1. Registered Vehicles in PICTs

	Cars and 4-Wheelers	Motorized 2- and 3-Wheelers	Trucks	Buses	Minibus	Other	TOTAL
American Samoa	8048	73	499	182			8802
CNMI*							
Cook Islands	4470	4849		32		95	9439
Fiji	107309	5165	46687	1600	861	8819	161622
French Polynesia*							
FSM	7356	96	747	138		0	8337
Guam	96631	2987	7086	720			107424
Kiribati	975	480		163		0	1618
Nauru*							
New Caledonia*							
Niue	806	30	6	6		0	848
Palau	4091		1335				5426
RMI	1715	37	55	85		0	1892
Samoa	13491	153	1028	293		0	14965
Solomon Islands		468	1898				5297
Timor-Leste	1684	7370	586	20		0	9660
Tonga	4411	62	1285	48		0	5806
Tuvalu	63	598	36	9	45		751
Vanuatu	3974	118	227		834	0	5153
TOTAL	**255024**	**22486**	**61475**	**4130**	**906**	**8914**	**347040**

*Information requested from relevant authorities but not available at time of report writing.

All vehicle class and numbers data taken from:

WHO (2013) *Global status report on road safety 2013: supporting a decade of action*. World Health Organization (WHO). Available at http://www.who.int/violence_injury_prevention/road_safety_status/2013/en/

Except for the following PICTS:

- American Samoa: Territorial Energy Office (2012) *American Samoa Greenhouse Gas Inventory*. Territorial Energy Office, April 2012. Available at www.asrec.net/wp-content/uploads/2013/09/GHG-INVENTORY.pdf
- Fiji: Fiji Bureau of Statistics (2012) 'Distribution of Vehicles Registered in Fiji [As at 31 December]'. *Fiji Bureau of Statistics*. Available at http://www.statsfiji.gov.fj/index.php/other-statistics/52-other-statistics/transport/126-distribution-of-vehicles-registered-in-fijias-at-31-december
- Solomon Islands: Solomon Islands Government (2010) *Solomon Islands Population and Housing Census 2009*. Solomon Islands National Statistics Office. Available at http://www.spc.int/prism/solomons/

Table E.2. Registered Maritime Vessels in PICTs, Segregated by Class*

PICT	Cable layer	Car carrier	Cargo/ PAX	Chemical tanker	Cruise Ship	Cruising & diving	Dry bulk	Fishing	General cargo	Gas tanker	High speed	Military	Oil tanker	PAX	Pleasure craft	Reefer	Rescue	Research	Tug	Workboat	Total
American Samoa							2	12	6			1			246				3		**270**
CNMI																					
Cook Islands			1					9	4						12		1	3	4		**34**
Fiji			69		7	21		194	10		4	1	2	502	179		2	1	43	2	**1037**
French Polynesia			3						12					10							**25**
FSM		1	12					183	20		1		2		9		2	1	2		**233**
Guam													1								**1**
Kiribati			3					9	5			1			2				2		**22**
Nauru																					
New Caledonia															31						**31**
Niue								13													**13**
Palau			1					1							1						**3**
RMI	1	1		2	1		21	32	35		1		12		10						**116**
Samoa			10			1		118	2			1			7		1		4		**144**
Solomon Islands			45		12			34	46		38				3		6		28		**212**
Timor-Leste																					
Tonga			9				2	2	3	2			2		3						**23**
Tuvalu			6				1	5	4												**16**
Vanuatu							3	47	6	1	1				10	1			1		**70**
Total	1	2	159	2	20	22	29	659	153	3	45	4	19	512	513	1	12	5	87	2	2250

All vessel class and numbers data taken from: UNCTAD (2013) Review of Maritime Transport 2013. Available at: www.unctad.org/en/PublicationsLibrary/rmt2013_en.pdf

Except for the following PICTS:

- French Polynesia: French Polynesia maritime affairs (2013) Obtained from the Ministry of Maritime Affairs. Email dated 1 October 2014
- Palau: Department of Transport (2013) Email dated 26 September 2014.

Appendix F: Small LNG Ship Specifications

Table F.1. Specifications on Norgas Small-Scale LNG Multi-Gas Carrier

Particulars	
LOA	137.1 m
LBP	127.2 m
Beam	19.8 m
Depth	11.5 m
Design Draft	6.7 m
Speed	16.5 knots
Consumption	27 tpd IFO 380
Range	12,800 nm
Cargo Tanks	1 x 4,000 m3 1 x 6,000 m3
Design Pressure	IMO/USCG5.2/3.8 barg
Min. Temperature	-1630C
Max. Density	970 kg/m3
Discharge Rate	1,000 m3/h
Reliquefaction Plant	SINTEF 20 tpd
Gas Combustion Unit	Saacke 20 tpd
Nitrogen Plant	PSA Type

Capacity	
Cargo Volume	10,000 m3
Deadweight	10,600 tons
Main Engine	MaK7M43C
Output	7,200 kW @ 500 rpm
Drive	Geared CPP
Shaft Generator	1,900 kWe
Auxiliaries	3 x 910 kWe

(Source: Norgas)

Appendix G: Fortis BC LNG Rate Schedule

The Fortis BC pricing in Vancouver is a published tariff in a rate schedule and is shown below.

Table G.1. Fortis BC Energy Inc. Rate Schedule 46: LNG Sales, Dispensing and Transportation Service (Summary)

Item	Units	2014 ($)	2014 ($)	2014 ($)
Contract Demand **Where on 1 January of a given year each of the aggregate prorated daily contract demand for all customers and the available LNG capacity**	GJ/day	0–35,000	35,000–100,000	100,000 +
Equivalent range in tonnes/p.a.	T/a	0–636	636–1,818	1,818+
LNG Facility Charge **An LNG Facility Charge, which is the unit cost per gigajoule (GJ) to deliver natural gas from the interconnection point to the LNG facilities, and to produce, store, and dispense all LNG at the LNG facilities, excluding the electricity surcharge**	CAD/GJ	3.54	2.73	1.88
Electricity Surcharge **An electricity surcharge, which is the unit cost per GJ for electricity consumed by the LNG facilities to produce, store and dispense all LNG at the LNG facilities**	CAD/GJ	0.88	0.87	0.86
Process Fuel Gas **Compensates for the gas used in the liquefaction process**	%	1%	1%	1%
2014 LNG Spot Charge	CAD/GJ	$4.67	$4.26	$3.40
Sumas Monthly Index Price **Henry Hub prices–not exactly the same as Sumas location, but Oct 2014 market report indicates market prices are actually lower at Sumas**	CAD/GJ	$5.07	$5.0	$5.07
Market Factor **Unknown, but indicators are <0.10/GJ**	CAD/GJ	$0.10	$0.10	$0.10
Delivery Charge **(LNG facility charge + electricity surcharge) or (spot charge), depending on how the LNG is contracted**	CAD/GJ	$4.42	$3.60	$2.74
Commodity Charge **(Qty dispensed + process fuel gas) x (Sumas monthly index price + market factor)**	CAD/GJ	$5.22	$5.22	$5.22
Premium for <5,000 GJ/day	CAD/GJ	$0.15	$0.15	$0.15
Premium for <10 year Contract	CAD/GJ	$0.26	$0.26	$0.26
Total: Small Customer, Short Contract **(Delivery charge + commodity charge + premiums)**	CAD/GJ	$10.05	$9.23	$8.37
Total: Large Customer, Long Contract **(Delivery charge + commodity charge)**	CAD/GJ	$9.64	$8.82	$7.96
Total: Small Customer, Short Contract	USD/MMBTU	$8.57	$7.87	$7.14
Total: Large Customer, Long Contract	USD/MMBTU	$8.22	$7.52	$6.79

Note: Amounts in both Canadian dollars (CAD) and US dollars (USD)

Appendix H: Estimated Annual Fuel Consumption by Power Station/Utility

PICT	Power Station	Island	Annual Fuel Consumption (ML)		Energy Equivalent (MBTU)	
			ADO/IDO	IFO/HFO	ADO/IDO	IFO/HFO
American Samoa	**Total**	**Tutuila**	**40.56**		**1483811**	
	Satala	*Tutuila*	*19.95*		*729795*	
	Tafuna	*Tutuila*	*20.61*		*754017*	
CNMI	**Total**	**CNMI**	**87.06**		**3185261**	
	Saipan	*Saipan*	*50.46*		*1845915*	
	Other		*36.61*		*1339346*	
Cook Islands	**Total**	**Cook Islands**	**8.55**		**312951**	
	Roratonga	*Roratonga*	*7.70*		*281656*	
	Outer Islands total		*0.86*		*31295*	
Fiji*	**Total**	**Fiji**	**35.71**	**41.07**	**1306610**	**1634788**
	Kinoya	*Viti Levu*	*14.56*	*26.76*	*532622*	*1065239*
	Korovou	*Viti Levu*	*0.01*		*522*	
	Vuda	*Viti Levu*	*2.10*	*14.31*	*76841*	*569549*
	Nadi	*Viti Levu*	*0.81*		*29561*	
	Sigatoka	*Viti Levu*	*3.23*		*118244*	
	Deuba	*Viti Levu*	*1.02*		*37441*	
	Rakiraki	*Viti Levu*	*1.17*		*42970*	
	Qelelola	*Viti Levu*	*0.04*		*1524*	
	Labasa	*Vanua Levu*	*7.25*		*265266*	
	Savusavu	*Vanua Levu*	*2.68*		*98218*	
	Levuka	*Ovalau*	*2.83*		*103399*	
French Polynesia	**Total**	**French Polynesia**	**23.53**	**73.40**	**860683**	**2922047**
	Tahiti	*Tahiti*		*73.40*		*2922047*
	Outer Islands	*Marquises*	*1.81*		*66165*	
		Tuamotu	*1.70*		*62272*	
		Australis	*1.36*		*49818*	
		Moree	*8.09*		*295794*	
		Bora Bora	*8.94*		*326931*	
		Rangiroa	*1.02*		*37363*	
		Tubuai	*0.60*		*21795*	
		Makatu	*0.01*		*545*	

PICT	Power Station	Island	Annual Fuel Consumption (ML)		Energy Equivalent (MBTU)	
FSM	**Total**	**FSM**	**13.36**	**2.3**	**488613**	**90164.21**
	Chuuk	*Chuuk*		*2.3*		
	Kosrae	*Kosrae*	*0.41*		*15038*	
	Pohnpei	*Pohnpei*	*8.75*		*320033*	
	Yap	*Yap*	*4.20*		*153543*	
Guam	**Total**	**Guam**	**7.29**	**446.98**	**266554**	**17793347**
	Cabras	*Guam*		*264.70*		*10536915*
	Tanguisson	*Guam*		*51.58*		*2053327*
	MEC			*130.71*		*5203105*
	Other		*7.29*		*266554*	
Kiribati	**Total**	**Tarawa Atoll**	**5.74**		**210133**	
	Bikenibeu	*Tarawa Atoll*	*4.11*		*150437*	
	Betio	*Tarawa Atoll*	*1.63*		*59697*	
Nauru	**Total**	**Nauru**	**6.20**		**226992**	
New Caledonia*	**Total**	**Grande Terre**	**4.16**	**266.59**	**152288**	**10612385**
	Doniambo	*Grande Terre*		*219.01*		*8718400*
	Népoui	*Grande Terre*		*47.58*		*1893985*
	Diesel plants	*Grande Terre*	*4.16*		*152288*	
Niue	**Total**	**Niue**	**0.71**		**26132**	
Palau	**Total**	**Palau**	**25.00**		**914759**	
	Aimeliik	*Aimeliik*	*13.78*		*504156*	
	Malakal	*Malakal*	*10.03*		*367067*	
	Outer Islands total		*1.19*		*43536*	
RMI	**Total**	**RMI**	**18.70**		**684295**	
	Ebeye	*Ebeye*	*3.46*		*126666*	
	Majuro	*Majuro Atoll*	*15.24*		*557629*	
Samoa	**Total**	**Samoa**	**16.99**		**621407**	
	Fiaga, Tanugamanono, Vaitele	*Upolu*	*13.83*		*505910*	
		Savaii	*3.16*		*115497*	
Solomon Islands	**Total**	**Solomon Islands**	**22.14**		**810156**	
	Total	*Out-stations*	*2.21*		*81016*	
	Lungga	*Guadal-canal (Honiara)*	*19.78*		*723770*	
	Other	*Guadal-canal (Honiara)*	*0.15*		*5370*	

PICT	Power Station	Island	Annual Fuel Consumption (ML)		Energy Equivalent (MBTU)	
Timor Leste*	**Total**	**Timor Leste**		**76.63**		**3050317**
	Hera					
	Betano					
Tonga	**Total**	**Tonga**	**12.78**		**467429**	
	Popua	*Tongatapu*	*11.08*		*405509*	
		Vava'u	*2.27*		*82945*	
		Ha'apai	*0.65*		*23699*	
		'Eua	*0.74*		*27122*	
Tuvalu	**Total**	**Tuvalu**	**1.81**		**66371**	
Vanuatu	**Total**	**Vanuatu**	**11.24**		**411188**	
	Efate	*Efate*	*9.67*		*353621*	
	Outer Islands total		*1.57*		*57566*	
		TOTAL	**341.55**	**828.05**	**12495634**	**32962567**
			ADO/IDO	IFO/HFO	ADO/IDO	IFO/HFO
			(ML)	(ML)	(MBTU)	(MBTU)

All volumes estimates derived from data in Pacific Power Benchmarking Report (2012) and the KEMA Energy Efficiency Studies, unless otherwise noted.

**American Samoa Power Authority (2013); Fiji Electricity Authority (2013); ENERCAL (2013); Electricidade De Timor-Leste (2013)*

Appendix I: Engine Types in Power Utilities

These data have been sourced from the KEMA Energy Efficiency Studies[45], with associated gaps filled by means of direct correspondence with the power utilities.

Country	Site	Make	Model	Number	Power (kW)
American Samoa	Tafuna	Deutz	BV 12M 640	4	4750
	Satala	Caterpillar	3516C	13	1500
CNMI (CUC)	Plant 1	Mitsubishi	18V 40/54A	4	7270
	Plant 1	Mitsubishi	18V 52/55B	4	13040
	Plant 2	GM	L20-645-E9	5	2500
	Plant 2	GM	20-645-E4	1	2500
	Plant 4	GM	20-645-E4	2	2500
	Plant 4	GM	20-645-E3	1	2600
	Plant 4	Cummins	Newage Stamford KTA50G3	4	5740
	Plant 4	Cameron	DSR-48	1	1500
	Plant 4	Nordberg Mfg	FS-1312-HSC	2	2200
Cook Islands	Rarotonga Island	Cummins	KTA50-G3	1	850
	Rarotonga Island	Deutz MWM	12V26N	2	2000
	Rarotonga Island	MAN	Lister Blackstone ETSL	2	600
	Rarotonga Island	MAN	Mirrlees Blackstone MB 275-8	1	1600
	Rarotonga Island	MAN	Mirrlees Blackstone ESL 16	1	1200
	Rarotonga Island	MAN	MAN B&W L9-27/38	1	2700
Fiji	Kinoya-HFO	Wartsila	W38	2	10300
	Kinoya-IDO	Caterpillar	CM32	4	7450
	Vuda	MAN	Mirrlees KV16	2	5740
	Vuda	Wartsila	18V32LN	2	6000
	Vuda	MAN	Lister Blackstone EVS8	1	375
	Sigatoka	Caterpillar	3516	4	1000
	Deuba	Caterpillar	3516	3	1000
	Nadi	Caterpillar	3516	2	1000
	Rakiraki	Caterpillar	3516	2	1000
	Korovou	Cummins	VTA28G	1	550
	Qeleloa	Caterpillar	3516	3	1000

45 PPA and KEMA (2010) Energy Efficiency Reports for the North and South Utilities. Available at: http://www.ppa.org.fj/publication-report/

Country	Site	Make	Model	Number	Power (kW)
FSM	CPUC	Caterpillar	3516	3	1000
	CPUC	Caterpillar	D399 PC	1	1600
	KUA	Caterpillar	3512B	1	1000
	KUA	Caterpillar	3600'	2	1500
	KUA	Caterpillar	D398	2	740
	PUC	Caterpillar	3516	3	1000
	PUC	Dihatsu	12DS32	4	2000
	YSPC	Alco	251F	1	2000
	YSPC	Deutz MWM	BV8M640	2	3200
	YSPC	Cameron	White Superior 40V–SX-12	2	750
Guam	Cabras Unit #1	TBA	Guam–66000	1	66000
	Cabras Unit #2	TBA	Guam–66001	1	66000
	Tanguisson Unit #1	TBA	Guam–26500	1	26500
	Tanguisson Unit #2	TBA	Guam–26,500	1	26500
	Cabras Unit #3	TBA	Guam–39300	1	39300
	Cabras Unit #4	TBA	Guam–39301	1	39300
	MEC Unit #8	TBA	Guam–44000	1	44000
	MEC Unit #9	TBA	Guam–44000	1	44000
	Dededo CT #1	TBA	Guam–23000	1	23000
	Dededo CT #2	TBA	Guam–22000	1	22000
	Macheche CT	TBA	Guam–22000	1	22000
	Marbo CT	TBA	Guam–16000	1	16000
	TEMES CT	TBA	Guam–40000	1	40000
	Yigo CT	TBA	Guam–22000	1	22000
	Dededo Diesel Plant1	TBA	Guam–10000	1	10000
	Manenggon Diesel #1	TBA	Guam–5300	1	5300
	Manenggon Diesel #2	TBA	Guam–5300	1	5300
	Talofofo Diesel #1	TBA	Guam–4410	1	4410
	Talofofo Diesel #2	TBA	Guam–4410	1	4410
	Tenjo Unit #1	TBA	Guam–4410	1	4410
	Tenjo Unit #2	TBA	Guam–4410	1	4410
	Tenjo Unit #3	TBA	Guam–4410	1	4410
	Tenjo Unit #4	TBA	Guam–4410	1	4410
	Tenjo Unit #5	TBA	Guam–4410	1	4410
	Tenjo Unit #6	TBA	Guam–4410	1	4410

Country	Site	Make	Model	Number	Power (kW)
Kiribati	Bikenibeu	TBA	Dihatsu–750	2	750
	Bikenibeu	TBA	Dihatsu–1750	3	1750
	Betio	TBA	Dihatsu–1250	1	1250
Nauru	TBA	Ruston	Ruston 2500	4	2500
	TBA	Paxman	Paxman–2000	2	2000
	TBA	Caterpillar	3516B–1400	2	1400
	TBA	Cummins	Cummins–1500	4	1500
New Caledonia	Noumea	Cummins	KTA-50	10	850
	Noumea	Cummins	QSK 60	1	600
	Lifou	Cummins	KTA-50	1	850
	Lifou	Cummins	QSK 23	1	530
	Lifou	Cummins	QST 30	1	950
	Lifou	Crepelle	4R26L	2	600
	Lifou	Wartsila	9L20	1	1400
	Lifou	Cummins	QSK 60	1	600
Niue		Caterpillar	700F	4	508
Palau	Aimeliik	MAN	Pielstick 10PC2MK2	4	3270
	Malakal	Alco	Unknown	1	400
	Malakal	Mitsubishi	TAKL	2	3400
	Malakal	Caterpillar	3516B	2	2000
	Malakal	Nigata	16V28HLX	2	6250
	Malakal	Wartsila	SR4BGD	3	2000
RMI	Ebeye	Caterpillar	Unknown	2	400
	Ebeye	Cummins	KTA 50 TQ1286E	4	1200
	Ebeye	Cameron	DSR-6	2	1500
	MEC	Caterpillar	3616'	1	1500
	MEC	Deutz MWM	BV16M640	2	6400
	MEC	MAN	Pielstick 10PC2VMK	4	3270
Samoa	TBA	Mirless	Mirless–3500	1	3500
	TBA	Mirless	Mirless–4000	1	4000
	TBA	Mirless	Mirless–3000	2	3000
	TBA	Mirless	Cummins–640	2	640

Country	Site	Make	Model	Number	Power (kW)
Solomon Islands	Honiara	Perkins	Perkins–1500	3	1500
	Lungga	Mirless	Mirless–1500	1	1530
	Lungga	Mirless	Mirless–3000	1	3000
	Lungga	Wartsila	Wartsila–4240	2	4240
	Lungga	Mitsubishi	Mitsubishi–4200	1	4200
	Lungga	Nigata	Nigata–4200	1	4200
Tahiti		Wartsila		3	
Timor Leste		TBA			
Tonga	Popua	Caterpillar	3516B	6	2000
	Popua	Caterpillar	CM32	1	7450
	Popua	Caterpillar	PM3516B	1	1400
Tuvalu	Funafuti	Dihatsu	Dihatsu–570	3	570
	Funafuti	TBA	Tuvalu–400	2	400
Vanuatu	1	Cummins	QSK 60	5	600
	1	Wartsila	6R32	2	800
	2	Cummins	KTA-50	4	850
	2	MAN	9R32L	2	1400

Appendix J: Global LPG Partnership – Policy Comparisons

Comparative Table of Developing Countries with High LPG Penetration of Households

	Brazil	Morocco	Indonesia	India
LPG % penetration of households	95%	95%	85%	50%
Cylinder model	LPG Marketer owns branded cylinder Consumer exchanges empty for full cylinder at authorized exchange point, supplied by Registered Distributor 50% home delivery	LPG Marketer owns branded cylinder Consumer exchanges empty for full cylinder at authorized exchange point, supplied by Registered Distributor Low level of home delivery	LPG Marketer owns branded cylinder Consumer exchanges empty for full cylinder at authorized exchange point, supplied by Pertamina (and its agents)	LPG Marketer owns branded cylinder At consumer's option, consumer exchanges empty for full cylinder at authorized exchange point or at home (for an additional fee), supplied by Marketer or its Registered Distributor Monitoring of LPG connections on web sites
LPG industry structure	Limited number of public and private sector companies	Limited number of private sector companies Shared import and storage assets	State energy monopoly controls all major LPG assets and primary distribution (through agents). It is the sole marketer of domestic cylinders	Three state oil companies sell both subsidized and non-subsidized LPG Limited number of private companies sell non- subsidized LPG
Autogas (LPG for transport)	Not permitted (CNG permitted including in flex fuel, but only in authorized automotive service stations)	Not permitted (CNG also not permitted)	Tightly controlled by state energy monopoly and available only in its automotive service stations	Permitted only in authorized service stations at unsubsidized (deregulated) price Some illegal auto conversions occur using household cylinders
Price mechanism / LPG subsidy	Deregulated since January 2002 after 40 years of subsidies at about 30% of Import Parity Price (IPP) Ex-refinery price is set by government at slightly below import parity (-5 to -10%) Social safety-net subsidy for the poor of about 25% of IPP, with LPG vouchers ("bolsa familia")	Price of LPG for household use (butane in 3, 6 and 12kg cylinders) is set by government and revised monthly LPG price for household users is about 50% of Import Parity Price (IPP) Subsidy does not apply to industrial users	Price is set by the government and revised monthly Subsidy applies to refills of 3kg cylinders only	Price for household use set by government and revised monthly Price for industrial use is deregulated and unsubsidized Price for households is about 60% of Import Parity Price (IPP), without reimbursement of the deficit incurred by importers Product subsidy being replaced by a direct social safety net payment to the poor as of Q1-Q2 2015
LPG composition (whether propane and butane are kept segregated, or are allowed to be mixed)	LPG for household and industrial use is a propane-butane mix	Mixing not permitted for household use (90%+ butane) Mixing is permitted for industrial use; butane price is set by government (without subsidy) and propane price is unregulated	LPG for household and industrial use is a propane-butane mix	LPG for household and industrial use is a 50/50 propane-butane mix

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