Tonga Tariff Analysis

First order DRAFT outlining the approach and currently available data

9 July 2014

This document presents the starting point for the Tonga Tariff analysis. The report documents the data available for the IRENA analysis from different sources to date and it outlines the methodological approach. Moreover first analysis results and findings are documented. These findings may change as new data become available and assumptions are refined.

Key points:

- Tonga has embarked on an ambitious transformation of its electricity sector to renewables. One of the objectives is to reduce the electricity tariff.
- Tonga electricity tariff consists of half fuel cost and half non-fuel cost (Sept 2012). Renewable power incurs no fuel cost (with the exception of biomass projects). Capital cost of renewable projects are typically higher than for diesel generators. However capital cost for commercial project have fallen dramatically in recent years and LCOE of commercial PV projects in the Pacific are lower than diesel generation cost. Moreover the installed plant were grant funded, so no investment cost needs to be recovered.
- Tonga renewables power share stands at about 5% end 2013. This is the upper limit for the percentage savings. Marginal savings (fuel cost only) are about half: a percentage point ground mounted PV in the electricity mix yields 0.5% reduction in the tariff. If a buffer is built to allow for replacement investments of PV installations at the end of life, savings per kWh can fall further.
- Renewables projects are so far grant-funded projects. However the tariff calculation accounts for return on all assets and depreciation, including grant funded assets. That means a capital buffer is built that can be used for future replacement investments.
- Three critical issues arise regarding this practice: what is a reasonable return on assets, what will be the expense for replacement investments and what is a reasonable depreciation period. Current accounting practice is 24%, present project value (USD 10 000- 15 000/kW) and 10 years. IRENA proposes 12.6%, USD 5 000/kW (incl battery storage) and 20 years. This will not significantly affect the current tariff but it will increase tariff benefits of high RE shares while maintaining the financial sustainability of TPL.
- The Tongatapu Maama Mai PV plant (1.3 MWp) and Vava'u (500 kWp with advanced controls) solar PV project are on line, and Vaini Solar Farm (1 MWp with storage) is under construction (est. completion in March 2015). Non-utility PV renewable power generation projects are under consideration of the TERM. ADB is funding additional 1.25 MWp distributed PV in the outer islands.
- For all projects funded through grants and without depreciation (built-up of a capital buffer), the savings per kWh will be similar for other RE technologies that may be applied in the future (biomass, wind, wave, tidal, wave).

- For PV percentages above 15-20% of power generated system effects will gain importance and savings per percentage point PV power added will be reduced, as soon as storage will become necessary. However there is still room for 2-3 MW PV systems on Tongatapu before that situation is reached. For more specific assessment, a dynamic grid model is necessary (i.e. those developed by IRENA for assessing grid stability)
- A diesel generator operating at full load may achieve 40% efficiency, which is halved if the same machine operates at 30% load. Introduction of PV may reduce the load on diesel generators which reduces efficiency. However this will depend on the operating practice of the utility (including the level of automation and control of diesel generators) and the likelihood of several PV plant reducing their output drastically and at once if a cloud passes. This will depend on the distribution of the PV plants across the island.
- Two operating practices exist: either all diesel generators operate at partial load if PV comes on stream or one or more diesel generators are switched off by a controller and remaining diesel generators continue to operate at high load. The latter results in negligible efficiency effects, the former can reduce efficiency significantly. Therefore the latter configuration should be aimed for. The control strategy of TPL and level of automation was not known at the time of writing of this note and should be assessed in more detail. Improvement in power plant controls might be a cost-effective measure to consider.
- For distributed PV there are also grid and overhead savings. Currently line losses are 10-12%. Savings for customers and society are therefore higher than for ground mounted systems. However the impact on the tariff will be negligible or tariffs may even rise.
- Future tariff increases may occur if TPL has to take care of the cost of integration of high shares of PV and wind beyond 20% of power generated through electricity storage.

Tonga electricity tariffs

Tonga is burdened with high electricity tariffs and an unfavourable trade balance because of diesel imports for power generation. Therefore Tonga has embarked on an ambitious programme for introduction of renewable electricity, with the aim to improve this situation.

The original target was 50% renewable electricity by 2012. Actual RE share stood at 5% end 2013. The electricity tariff has been rising by 26% between April 2009 and April 2014 (Figure 1). The diesel fuel price has increased by 64% in the same period. There has been a positive but modest benefit of renewables on the tariff in the order of 2-4 percentage points reductions, but this beneficial effect is lost in the tariff rise due to higher fuel cost.

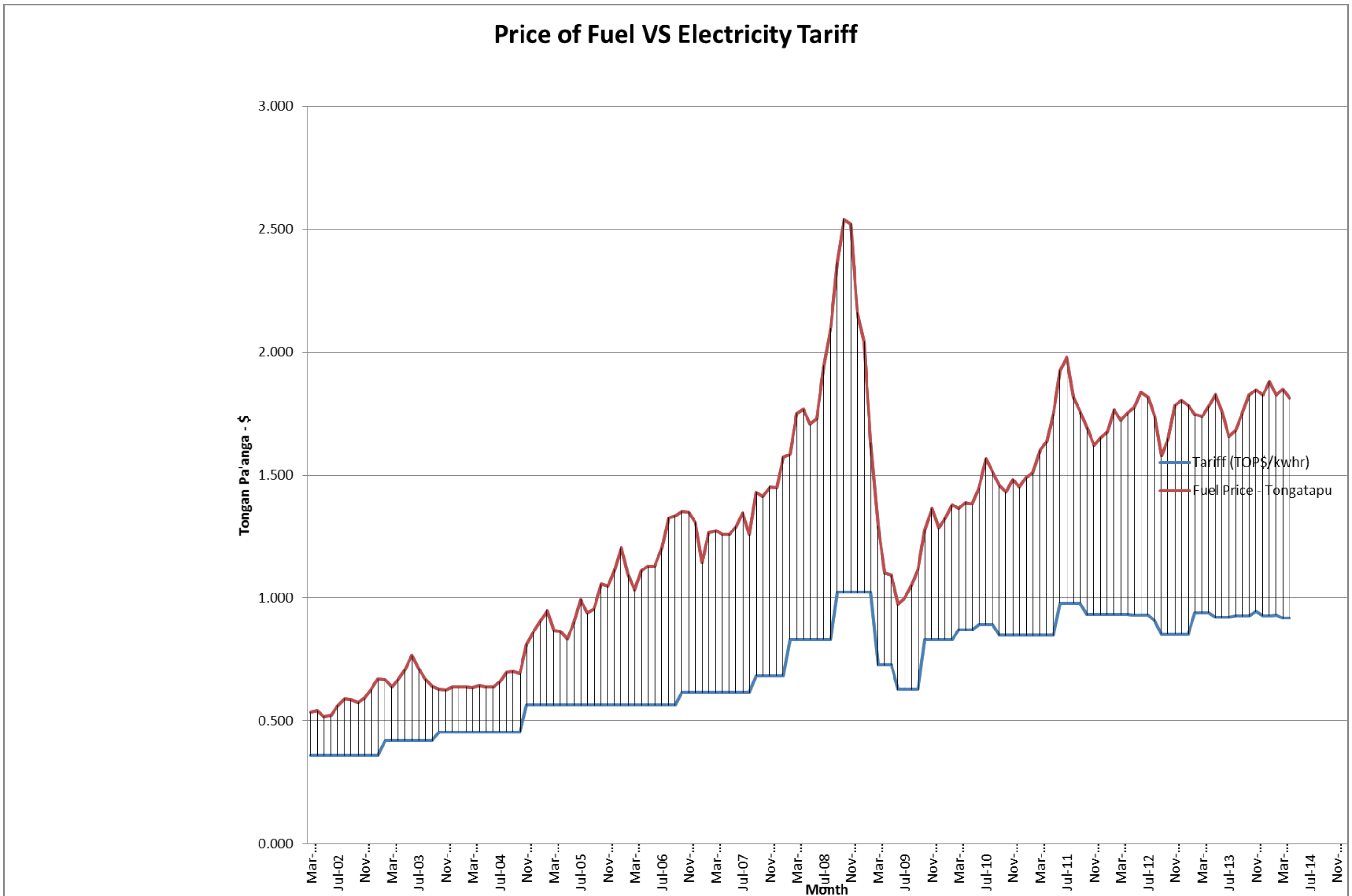

Figure 1: Tonga electricity tariffs and fuel cost 2002-2014

This study takes a closer look at the tariff benefits of renewables. It look at the benefits to date and it assesses the benefits of future RE projects. For this purpose, a methodology is proposed. This methodology can be applied for other island situations as well.

Tonga power and renewable energy

Electricity in the urban islands is provided by Tonga Power Ltd (TPL) – a government owned corporate entity that operates under a concession agreement monitored by the Tonga Electricity Commission, the electricity regulator. The rural areas in Tongatapu have TPL-operated diesel grids, while the outer islands have either solar power or community managed diesel mini-grids (IRENA, 2013).

All electricity in the islands of Tongatapu, 'Eua, Lifuka (Ha'apai) and Neiafu (Vava'u) is generated and distributed by the government-owned national utility, Tonga Power Limited (TPL). Small grid systems for the larger Ha'apai islands ('Uiha, 168 customers; Ha'ano, 106; Ha'afeva, 69; and Nomuka, 110) were constructed with Australian Agency for International Development (AusAID) funding in 2001–2003. The systems are powered by diesel generators and operated by an electricity cooperative on each island.

TPL has embarked upon a ten year TOP100 million (1 USD = 1.84 TOP) capital investment plan with the objective of being a fully renewable electricity business, as part of its commitment to TERM, and to provide safe and reliable electricity at the most economic costs to its customers.

A new regulator, the Electricity Commission, was introduced under the Electricity Act of 2007 to reflect the best international practice for public utility regulation and, since privatisation of the utility remains a long-term government goal, to facilitate a possible future sale of the government's interest in TPL. The reforms of the 2007 Utility Act balanced the interests of consumers regarding fair tariffs and receipt of high-quality power, against the need for private investors to minimise their risks regarding earning a fair return on their investment.

The Electricity Commission is legally required to regulate tariffs, consumer service standards and electrical safety. The regulatory framework employed is of the concession-contract type. Tariffs, tariff adjustment formulas, operational efficiency benchmarks, consumer service standards and penalties for non-achievement are all specified in a contract between the Electricity Commission, representing the government, and the electricity provider, TPL, which, although owned by the government, is an independent commercially operated business, with a board consisting of local and foreign members appointed by the government.

TPL has over 15 000 meters in service for consumers. Consumer service standards are regulated and cover the rights and responsibilities of both TPL and its customers. These include the rights and responsibilities to provide proper customer service, good quality power and for disconnection for non-payment of fees.

With the exception of three small island cooperative operated grids, all grid-supplied electricity in Tonga is generated and distributed by TPL.

Around 15 000 customers are being served on the four larger islands with over 90% of them on Tongatapu. During the past five years there has been little change in generation with sales remaining in the 40 to 44 gigawatt-hours (GWh) range. Actual generation stood at 52.447 GWh, delivery from the powerhouse 51.212 GWh and sales at 45.168 GWh in 2012. Average efficiency for power delivered from the powerhouse stood at 40% - 4.2 kWh/l diesel (IRENA, 2013).

Table 1: Power generation capacities (July 2014) and actual generation 2013 (PWC, 2013)

	Rated/actual capacity July 2014 [MW]	Generation 2013 [GWh]
Tongatapu		46.72
Diesel	2 x 2.88 – 5.76	
Diesel	6 x 1.4 – 8.4	
Solar	1x 1.4 – 1.4	
Vava'u		4.54
Diesel	2x 0.60 – 1.2	
	1 x 0.30 – 0.3	
	2 x 0.186 – 3.72	
Solar	1x 0.5 – 0.5	
Ha'apai		1.34
Diesel	2 x 0.18 - 0.36	
'Eua		
Diesel	2 x 0.18 – 0.36	1.06

The load curve for Tongatapu is relatively flat with around 4 MW at night, 6 MW during weekdays and Saturdays dropping to 5 MW during Sundays, and a 7 MW peak around 9 PM every day.

Average diesel generation efficiency is 40% (4.05 kWh/l diesel), one of the highest in the Pacific (PPA, 2011). In May 2014 diesel cost FOB Singapore was USD 107/bbl plus transport yielding around USD 120/bbl (MCtl, 2014). That means fuel cost amount to USD 0.19/kWh (excluding taxes).

The existing 1.3 MW of solar will already reach 20% grid penetration at noon on weekends, which is a level that calls for an assessment of grid stability. Since the 1.3 MW of solar is at a single location the speed and size of variations in output will be at a maximum.

The second 1 MW of solar PV, which is expected to be installed in 2015, will be several kilometres from the 1.3 MW plant and will include a form of short-term energy storage to reduce the effects of power fluctuations. The cost of storage adds substantially to the total cost of PV.

The Electricity Act of 2007 states that the concessionaire has the legal right under the concession contract to pass on fuel costs to consumers and charge an additional inflation-indexed non-fuel tariff.

The non-fuel tariff covers agreed-upon operational costs, business overheads, interest payments, depreciation and an allowed return on investment to provide retained earnings for future capital expenditures and/or shareholder dividend payments. The tariff structure is flat and all customers pay the same rate, which is TOP 0.945 as of April 2013. However, since outer island generation is substantially more costly than that of Tongatapu, outer island customers are effectively subsidised by those on Tongatapu (IRENA, 2013).

A 1.3 MWp array at the Tongatapu powerhouse was completed in 2012 with funding from NZAID, the European Investment Bank (EIB) and Meridian Energy Ltd of New Zealand (Ma'ama Mai plant). The plant is owned and operated by TPL. A second 1 MW solar power plant is being planned for installation to commence in 2015 with funding from JICA. The JICA-funded PV installations will include some energy storage to help stabilise the power from the solar plant, thereby avoiding grid stability issues.

A grid-connected solar installations has been commissioned in Vava'u with a capacity of 500 kWp, funded by the Abu Dhabi Fund for Development. Since the noontime Vava'u peak load on the weekend is less than 500 kW, the installations included some battery storage and control technology to mitigate the effects of the variability of the solar energy in order to avoid grid stability problems.

Various private organisations have funded other smaller scale grid connected PV systems with a total capacity of around 500 MWh per year (1% of electricity demand).

TPL characteristics:

- 4 island grids with 8 MW peak demand, 55 GWh yearly generation. The company generates $45m revenue.
- T$2.5 net profit after tax; T$0.78m tax paid; T$1m dividend paid in FY12
- T$60m assets
- 20,000 customers; T$90 median monthly customer power bill

Electricity supply is a monopoly in Tonga and therefore prices should be regulated to ensure that they reflect costs (long-term best interests of customers). The Electricity Act 2007 provides the legal framework. The Electricity Concession Contract (ECC) makes TPL a concessionaire and defines the rules for setting prices. ECC provides "price control" – it fixes the maximum price that TPL can charge per unit:

- If demand is lower than expected, revenue is lower than expected - TPL bears this risk
- TPL has strong incentives to minimise controllable costs (e.g. generation O&M, distribution O&M, administration) so as to maximise net revenue
- TPL has strong incentives to maximise efficiency of its generators and its network – it gets to "keep" efficiency gains above a pre-defined benchmark

The tariff structure is shown in Figure 1. Fuel cost account for around half, other cost for the other half. This includes nearly a quarter return on assets.

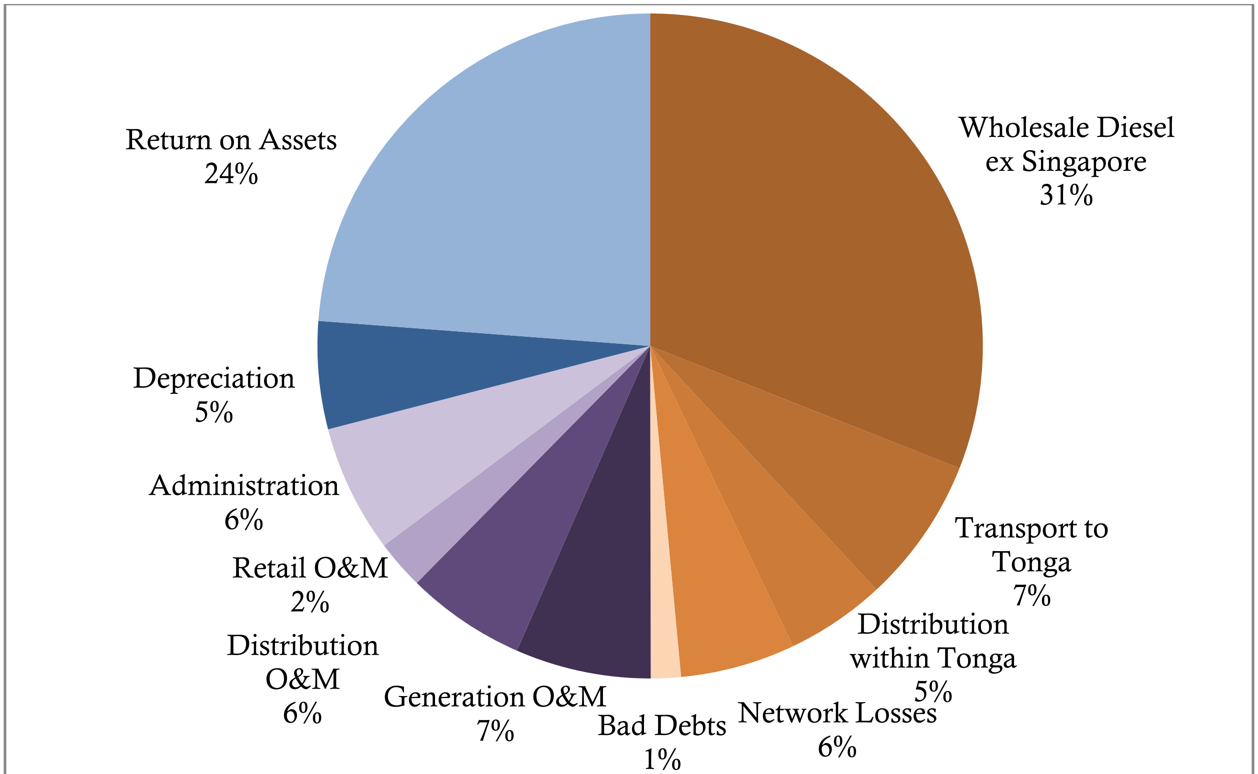

Figure 1: Tonga tariff structure Sept 2012 (Wedgewood and White, 2013)

Table: TPL audited financial results July 2012-June 2013 (PWC, 2014)

	TOP000	Share [%]
Fuel	22 133	
Other cost of sales	6 625	
Selling and distribution	62	
Administrative and other *Including:* *Depreciation*	9267 *4835*	
Operating profit	3 768	
Finance cost	829	
Profit before tax	2939	
Total expense/revenue	41 783	

There are two tariff components:

Non-Fuel Component - Standard “building block” model, Five year “regulatory period”: Set in 2008, regularly adjusted for actual inflation. Next “reset” in 2015

Reasonably standard price reset process

Fuel Component Adjustment to reflect actual cost of delivered diesel every three months

Fuel cost represent around half of the tariff (Figure 1). Generation efficiency and fuel prices vary by island (Table)

Table: Generation efficiency and fuel cost by island

	Fuel efficiency October 2013 [kWh/l]	Fuel price	Fuel cost component [
Tongatapu	4.25		
Vava’u	3.9		
Ha’apai	3.5		
‘Eua	3.59		
Average	4.24		

It should be noted that introduction of PV can also benefit efficiency. Opening of the Popua solar generation facility has improved the average fuel efficiency from 4.0 to 4.2 kWh/l (PWC, 2014).

ECC has flexibility to cope with non-diesel fuel sources but the responsibility for planning and acquiring generation (between Government and TPL) is unclear

- Wedgewood and White (2013) recommended a review of TPL’s allowed rate of return on assets and suggested that a range of 8% to 12% (post-tax nominal) is a reasonable return, given inherent risk and current market conditions. It is currently 18.5% <not consistent with data fig 1>.
- The ECC states at Point 18 that “At each reset the allowed rate of return may be changed if there is reasonable evidence”. This report suggests evidence to reduce the currently adopted rate of return for donated RE generation assets.
- Consider separate treatment of debt and equity at the 2015 price reset for the next regulatory period, including a pass through of debt costs. As a minimum, we recommend that the allowed return on equity and debt be separately debated and reported against at the 2015 reset.

Table 1: Existing and planned renewable energy projects

Masdar in Vava’u missing. Needs update

Project	Nominal Capacity (MW)	Plant Factor (%)	Energy Output (MWh p.a.)	Fuel Tariff Saving (s/kWh)	Incremental O&M (incl Fuel) (s/kWh)	Net Tariff Saving (s/kWh)	Cumulative Renewables Penetration (%)
Maama Mai	1.30	17%	1,900	1.5	0.3	1.2	4%
ADB Solar - Vava'u	0.40	18%	613	0.6		0.6	5%
ADB Solar - Ha'apai	0.20	17%	300	0.3		0.3	5%
ADB Solar - Eua	0.20	17%	289	0.3		0.3	6%
Biomass - Tongatapu	1.25	91%	10,000	7.8	5.7	2.1	24%
Biomass - Eua	0.25	47%	1,032	0.9	0.7	0.2	26%
Wind - Tongatapu	4.40	27%	10,453	8.1	0.8	7.3	46%
Heat Recovery - Tongatapu	0.24	64%	1,340	1.0	0.0	1.0	48%
						13.0	

Table 2: Characteristics of existing solar PV projects in Tonga

	Maama Mai	Vavau	Vaini
Size	1.3 MW/2050 MWh	0.5 MW /873 MWh	1 MW
Developer	Meridian energy	Masdar/Ingenero	MPK / Fuji Electric
Development partner	New Zealand	UAE	Japan
Components	5760 Photovoltaic panels	1680 Trina Honey panels Screw foundations 21 SMA Sunny Tripower 20000TL inverters, 15 SMA Sunny Backup 5000 inverters SMA Fuel Save Controller. 120 gel lead-acid batteries 1000Ah Sonnenschein (1/2 hour storage max)	300 000 panels Concrete foundations 2 buildings Micro-grid controller system connecting Maama Mai, Popua, Vaini
Cost	NZD 7.9 M	USD 5 M	USD 14 M
Savings	540 kl diesel/yr		
Start of operations	July 2012	November 2013	Early 2015
Comments		13% total ele generation/70% peak	

Sources:

http://www.tongadailynews.to/?p=3315

http://www.ingenero.com.au/wp-content/uploads/2013/09/Ingenero-Fact-Sheet-Tonga-Hybrid-Solar-Farm.pdf

TPL, 2013

Tariff impacts of renewable power

Tariff and cost structure

Tariffs are built up from components:

- Generation cost (assets replacement, return on assets, interest on loans, operation and maintenance cost)
- Transmission and distribution cost
- Overhead (administration and management cost, miscellaneous)
- Taxes

In principle the tariff should be set in a way that allows the utility to recover its expenses and build a capital base that can be used for future investments.

In principle the main impacts will relate to generation cost. However there may also be impacts on transmission and distribution cost.

Cost for whom?

Cost comparisons can be done in two ways: based on full cost accounting or based on expenditures. The most appropriate approach depends on the fact if the project is commercial funded by the utility or paid for by a donor.

Many projects are realized in cooperation with development partners. A significant share or all investment expenses are covered by the development partner. However the operational cost are generally covered by the utility. The LCOE of a diesel generator contain perhaps 20 percent capital cost and eighty percent operational cost, mainly diesel fuel. A solar PV ssytem, in contrast, has an LCOE that contains ca. 95 percent upfront cost and 5 percent operational cost. So if in both cases the equipment is donated but the operational cost are covered by the utility, even for an identical LCOE the solar project results in much lower generation cost for the utility than the diesel power generation project. In fact the LCOE of a solar PV project is lower than diesel generated electricity, under today's market conditions, as long as electricity storage can be avoided or kept small (i.e. not for storing many hours of PV production). The savings due to the free equity can be stored into an asset replacement fund, unless donor-funded replacement is expected. This reduces the savings but increases the sustainability of the project.

System-wide effects

A renewables project can also have system wide effects. For example if diesel generators must operate at partial load, their efficiency is reduced. As a consequence the LCOE of electricity production from that diesel generator rises because of the renewable project. These cost must be allocated to the renewables project.

A controller may be needed to regulate the diesel generator output and allow higher shares of PV (i.e. ADFD-Masdar system in Vava'u).

Similarly if the grid needs reinforcements to enable an RE project or if decentralized renewables generation reduces the need for grid reinforcements or reduce grid losses, this must be accounted for. The same is true for electricity storage investments: they can be part of the donated PV project, like in the case of Vaini solar farm, or have to be installed by TPL to maintain grid stability, in which case they have to be allocated to renewable energy and accounted for in the tariff.

Decentralised PV systems help to reduce grid investments and T&D losses. Line losses stood at 9% on Tongatapu, and 9-12% on the other islands end 2013, on top of 2% parasitic losses (PWC, 2014).

Grid effects may depend on the renewable energy share. While low shares can be integrated without adjustments, higher shares may require storage or replacement of ageing inflexible diesel generators. Initially batteries with small capacity can play an important role in maintaining power quality (eg Vava'u case) but more storage capacity will be needed if batteries are charged during the day to provide electricity in the evening and at night. However that situation is still some time away for Tongatapu where soon 2.3 MW PV capacity will be operational in a power system with 5 MW minimum daytime load.

The fact that a park of nine diesel generators is deployed on Tongatapu (Annex 1) means that variable load can be dealt with by switching individual generators on and off while the operating machines function close to full load. This maintains a high efficiency of operation. Efficiency shortfalls because of variable renewables are not significant in such a situation.

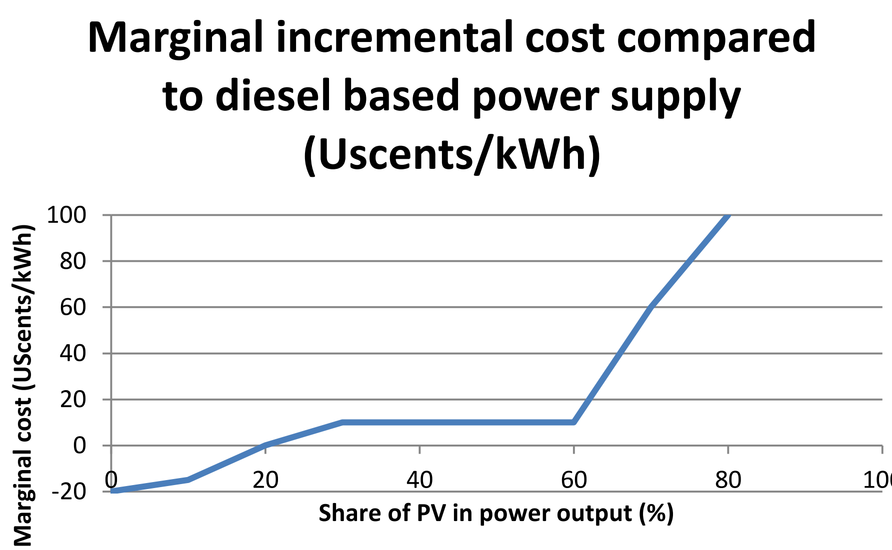

Figure: Schematic graph of rising solar PV cost for rising shares. The figures are only indicative and not representative of Tonga's situation

Staffing effects

A renewable energy project requires operation and maintenance. The staff for the diesel generator may initially stay at the same level.

Revenue minus O&M, interest and tax costs equals the operating cash surplus

Operating cash surplus less capital expenditure, debt repayment and dividends paid equals net cash flows

Over longer periods, net cash flows should be zero or slightly positive

Methodological approach

A First order estimate: savings equal the amount of RE electricity produced times the electricity tariff.

This approach will overestimate the savings, as grid and overhead expenses will generally not be reduced

B Second order estimate: savings equal fuel savings

This approach will underestimate savings as diesel generator capital cost can be avoided. Estimation of fuel savings requires either measurements or generator fuel efficiency curves. In some cases they may be lower than average fuel use per kWh as diesel generators operate less efficient at partial load.

C Third order estimate: savings equal fuel savings plus any systems effects

Most accurate estimate, however results are dynamic (i.e. changing load and new projects will change systems effects) and data-intensive (need to have an automatic data collection process to allow for smooth tariff review). Individual projects must be assessed and decision on an asset replacement fund will be key.

Impact of low levels of solar PV penetration on the Tongan electricity tariff: High-level results

Donor-funded solar PV projects can have an extremely beneficial impact on the Tongan electricity system. The incorporation of an increasing proportion of solar PV will reduce diesel consumption, CO_2 emissions and local pollutants (SO_x, NO_x, particulates, etc.), and reduce overall generation costs. This will allow for tariff reductions, or at least keep tariff increases below what they otherwise would have been without PV penetration.

A simple analysis of the saving per unit of electricity generated highlights how significant the per-unit savings are from donor-funded projects (Figure 2). Assuming that the donor-funded capital will be replaced by additional donor funds at the end of the PV plants economic life (25 years) results in very high savings per unit of electricity produced by the utility, as fixed O&M costs for the PV plant are very low.

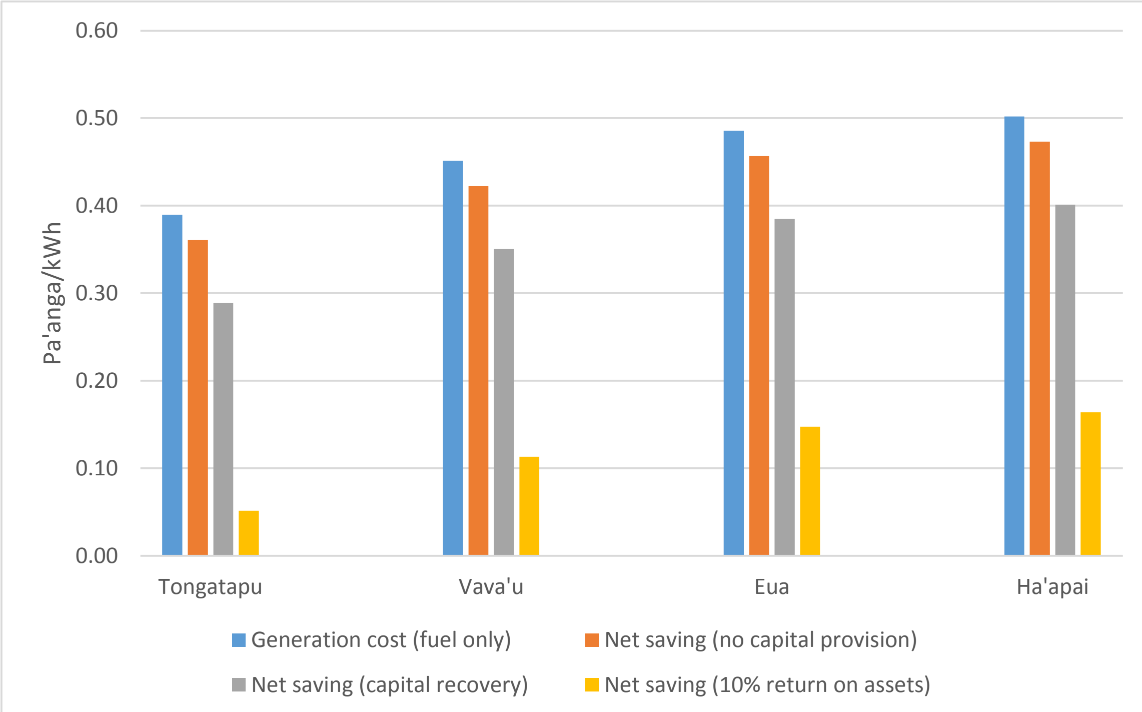

Figure 2: Analysis of generation costs and the impact of the addition of a unit of solar PV at the margin on generation costs, May 2014

However, a perhaps more appropriate measure of savings is what occurs when revenue is collected for a fund to replace the solar PV plant at the end of its economic life. On Tongatapu, where fuel efficiency is highest due to larger and newer gensets, this results in savings of around 70% for each unit of electricity substituted. However, on the smaller islands, where fuel efficiency of the gensets is lower, the savings are between 74% and 76%. For illustrative purposes, the savings if the utility is allowed to make a post-tax 10% rate of return on a competitive value[1] of the donated solar PV assets are also presented. As is to be expected, they are greatly reduced, but still significant. However, it is not clear what the justification for making a commercial return on donated assets would be and this case isn't presented in the following analysis.

The calculations are based primarily on material extracted from the previous review of electricity tariffs in Tonga (White, 2012) and Tonga Power Ltd's Regulatory Annual Report 2012/2013 (TPL, 2013).

Assumptions

The key underlying assumption relates to the current generating cost for diesel-fired electricity on each of the islands. Diesel pricing for Singapore is presented in Figure 3. As can be seen, volatility significantly reduced since mid-2013, but prior to this, large swings in diesel pricing were experienced in the Singapore benchmark price.

[1] This is assumed to USD 3 500/kW, rather than the higher values that occurred in the donor-funded procurement process.

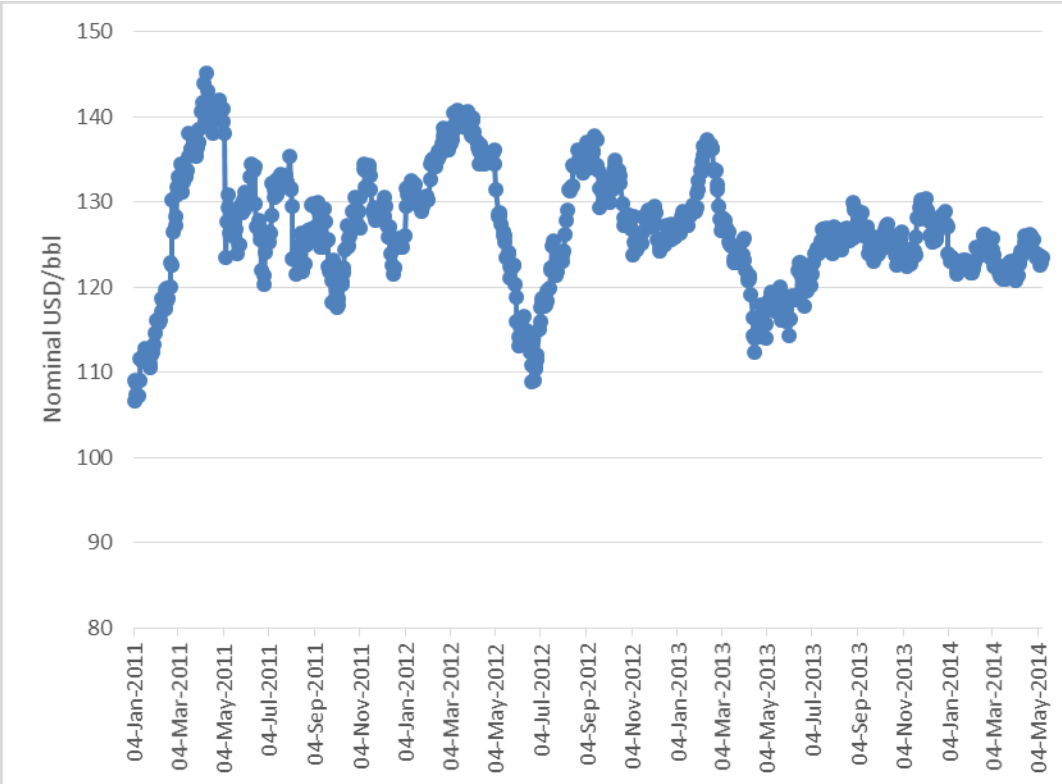

Figure 3: Singapore Diesel Prices, 2011 to 2014

A critical assumption around which greater clarity is needed, is the average cost of freight to deliver to Tongatapu. Assuming current month pricing, the implied delivery costs to Tongatapu from the consultants data for April, August and September and the Singapore pricing in Figure 3 varied from TOP 0.14/litre to TOP 0.37/litre (White, 2012 and Figure 3). However, the implied approved average rate from the November 2012 regulated tariff was between TOP 0.25 and 0.32/litre.[2] This analysis assumes that the upper value is appropriate as this most closely approximates the value identified in the discussion of the first year of the Maama Mai Solar PV projects first year of operation which identified and average landed diesel cost in Tongatapu of TOP 1.82/litre. Delivery costs to the outer island were taken from Table 8 of White, 2012 and add TOP 0.035 to 0.1/litre to the Tongatapu landed costs.

Overall diesel-fired electricity generation efficiency is taken from section f of TPL, 2013 and averaged around 3.65 KWh/litre for Eua and Ha'apai, 3.95 KWh/litre on Vavau and 4.25 kWh/litre on Tongatapu. No allowance has been made for any decline in average overall operating efficiency over the year for an incremental unit of solar PV. Information on the likely impact of different levels of solar PV penetration on each islands diesel-fired generating efficiency would be needed to accurately analyse savings at different penetration levels and to identify if storage to smooth these effects would be economic.

[2] The uncertainty stems from whether the value in the 2012 regulated tariff was meant to be applied to forecasted electricity sales or actual electricity sales. The lower value for freight is based on forecast electricity sales, the higher on the actual electricity sales.

Solar PV operations and maintenance costs are assumed to be around USD 25/kW/year, which is the industry benchmark for O&M costs. This translates into TOP 0.03/kWh for an 18% capacity factor (e.g. the capacity factor of Maama Mai in its first year of operation).

The creation of a fund for the replacement of the solar PV project after 25 years of economic life is assumed to target a value based on USD 2/Wp for solar PV. This is a very conservative assumption, as analysis by IRENA of utility-scale solar PV project costs in 2030 targets a value of USD 1/Wp in large developed and developing countries. Assuming that funds set aside can achieve a 3% real rate of return, the capital recovery fund would require TOP 0.07/kWh over the 25 year economic life of the project. This also includes provision for one replacement of the inverter after 15 years.[3]

With an overall reduction in Tariff of around 71% with a capital recovery fund on Tongatapu for each marginal unit of solar PV, the overall reduction in tariff possible is in the order of 3% for solar PV generation that accounts for 5% of the annual total and rising to 6% for 10% solar PV penetration in annual generation.

[3] Inverter costs in 15 years are highly uncertain and a conservative value of USD 0.15/Wp has been assumed, the value that some market forecasts assume for 2017 in major solar PV markets (Photon, 2014).

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Annex 1: Existing and planned power generation capacity

Table: Existing and planned power plants in Tonga <needs validation>

STATE	CITY	COMPANY	FUELTYPE	MW	STATUS	YEAR	TURBMFR	TURBTYPE
'Eua	'Eua	TPL	DIESEL	0.056	OPR	1983	DORMAN	20893
'Eua	'Eua	TPL	DIESEL	0.056	OPR	1983	DORMAN	20893
'Eua	'Eua	TPL	DIESEL	0.08	OPR		GARDNER	
Vava'u	Neiafu	TPL	DIESEL	0.3	OPR		VOLVO	
Vava'u	Neiafu	TPL	DIESEL	0.3	OPR		VOLVO	
Vava'u	Neiafu	TPL	DIESEL	0.3	OPR	1998	VOLVO	
Vava'u	Neiafu	TPL	DIESEL	0.3	OPR	1998	VOLVO	
Tongatapu	Nuku'alofa	TPL	DIESEL	1.198	OPR	1972	MIRRLEES	KS S6
Tongatapu	Nuku'alofa	TPL	DIESEL	1.198	OPR	1972	MIRRLEES	KS S6
Tongatapu	Nuku'alofa	TPL	DIESEL	1.729	OPR	1978	MIRRLEES	K5 MAJOR
Tongatapu	Nuku'alofa	TPL	DIESEL	1.729	OPR	1981	MIRRLEES	K5 MAJOR
Tongatapu	Nuku'alofa	TPL	DIESEL	1.4	OPR	1998	CAT	3516B
Tongatapu	Nuku'alofa	TPL	DIESEL	1.4	OPR	1998	CAT	3516B
Tongatapu	Nuku'alofa	TPL	DIESEL	1.4	OPR	1998	CAT	3516B
Tongatapu	Nuku'alofa	TPL	DIESEL	1.4	OPR	1998	CAT	3516B
Tongatapu	Nuku'alofa	TPL	DIESEL	1.4	OPR	1998	CAT	3516B
Ha'apai		TPL	DIESEL	0.056	OPR	1983	DORMAN	20893
Ha'apai		TPL	DIESEL	0.056	OPR	1983	DORMAN	20893
Ha'apai		TPL	DIESEL	0.08	OPR		GARDNER	
Tongatapu	Popua	TPL	PV	1.3	OPR	2012	SOLARWLD	
Vava'u	Neiafu	TPL	PV	0.5	**PLN**			
Tongatapu		ARGOENV.	WAVE	1	**PLN**		WAVEGEN	OWC
Vava'u	Neiafu	TPL	DIESEL	0.07	**UNK**			
Vava'u	Neiafu	TPL	DIESEL	0.07	**UNK**			
Vava'u	Neiafu	TPL	DIESEL	0.07	**UNK**			
Vava'u	Neiafu	TPL	DIESEL	0.07	**UNK**			
Vava'u	Neiafu	TPL	DIESEL	0.187	**UNK**		LISTER	EVS
Vava'u	Neiafu	TPL	DIESEL	0.187	**UNK**		LISTER	EVS
Vava'u	Neiafu	TPL	DIESEL	0.187	**UNK**		LISTER	EVS
Vava'u	Neiafu	TPL	DIESEL	0.187	**UNK**		LISTER	EVS
Tongatapu	Nuku'alofa	TPL	DIESEL	0.187	**UNK**			
Tongatapu	Nuku'alofa	TPL	DIESEL	0.187	**UNK**			
Tongatapu	Nuku'alofa	TPL	DIESEL	0.695	**UNK**			