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Presentation of Tonga Draft Baseline and Least-Cost Options

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Webinar Presentation
April 3, 2018

Agenda

- Context and relevant reports and policies
- Update on concurrent Tonga projects
- Baseline data, sources, and assumptions
  - Electricity end-use and Transportation
- Business-as-Usual scenarios for electricity and transportation
- Least-cost options for improving efficiency

Context

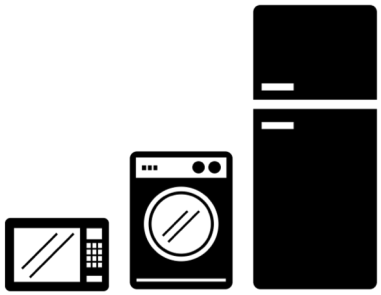
- The Electricity Act (2007)
- The Renewable Energy Bill (2008)
- Tonga Energy Road Map 2010-2020 (2009)
- The National Strategic Planning Framework (2009)
- Joint National Action Plan on Climate Change Adaption and Disaster Risk Management (2010)
- Ozone Layer Protection Act (2010) Amended (2014)
- Tonga Village Network Upgrade Project (2012)
- Promoting Energy Efficiency in the Pacific (2014)
- Tonga Strategic Development Framework II (2015-2025)
- Outer Island Renewable Energy Project (2017)
- Tonga Renewable Energy Plan (2017)

Update on Projects from Tonga:

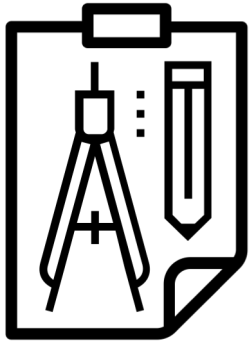
- To help us model electricity usage going forward, clarity surrounding steps already being taken in Tonga is needed:
  - How is recovery from Cyclone Gita—what's the status of the grid and what needs to be rebuilt?
  - What's the status of LED streetlight conversions, are almost all LED by this point?
  - What's the status of smart-meter conversions, how are these helping TPL reduce line-losses?
  - Introducing a MEPs or electrical appliance standards have been discussed before, is any action already being taken?
  - What's the status of new renewable projects under development?
  - Have energy efficient building codes or energy audits been discussed/undertaken?

Energy Efficiency in Electric End-Use

The data we're using leads us towards targeting areas like appliance standards and building design. We're concerned that a shortage of electricity end-use data could be causing us to look in the wrong directions. Is there larger concern over commercial and industrial customers not reflected in our data?



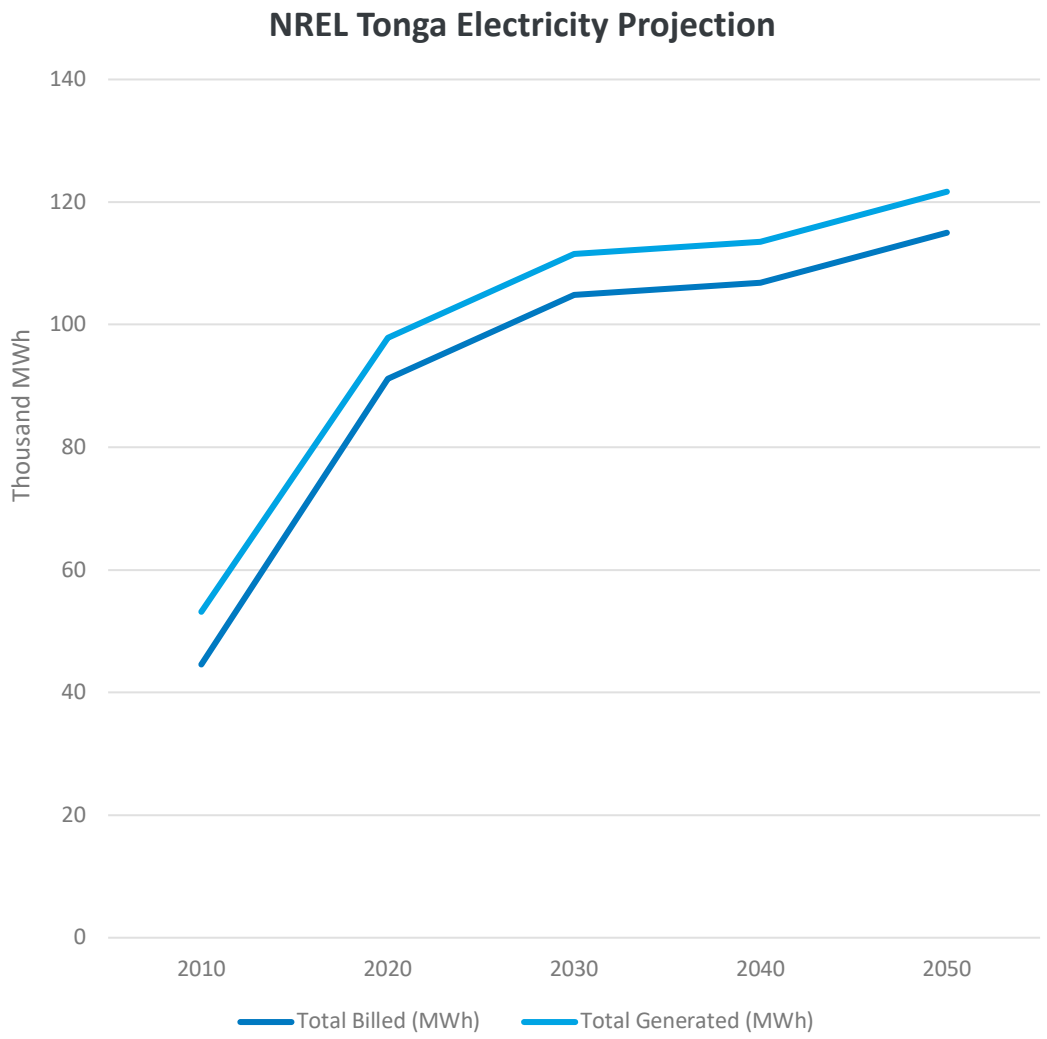
MEPs



Building Design and Standards

Commercial and Industrial Customer Data

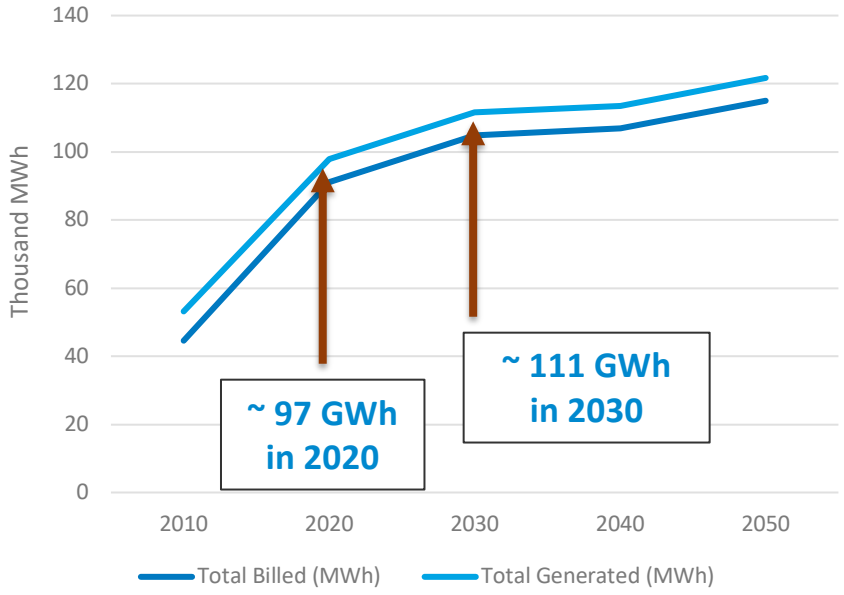
Electricity Business-as-Usual Projection



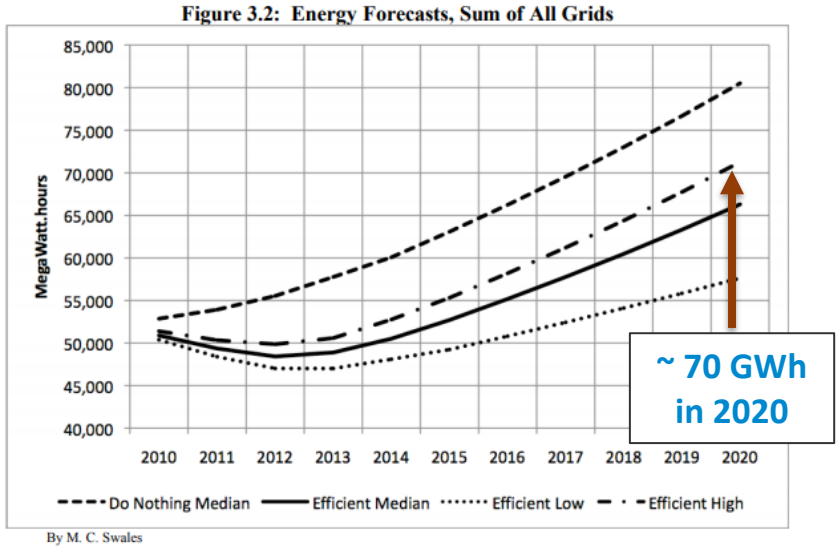
- Our model is currently showing a 104% growth in total generation between 2010 and 2020, largely fueled by a growth in number of around 6,500 between 2017 and 2020.
  - We need to revise this based on what TPL projects customer growth to be. Increased accounts in Tongatapu? Increased Outer Island Electrification?

Electricity BAU: What accounts for different projections?

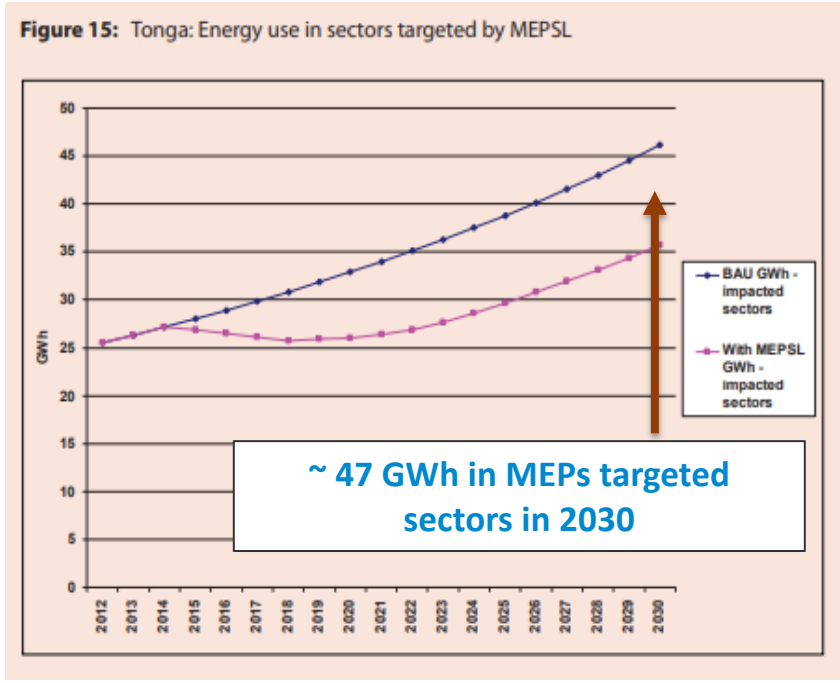
NREL Tonga Energy BAU (2018)



TERM Projection (2006)



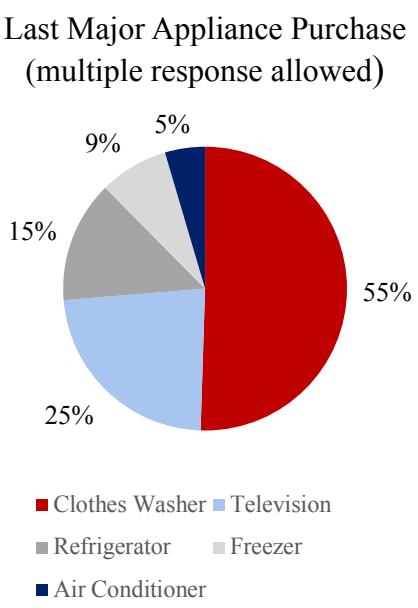
Australian Aid MEPs Projection (2016)

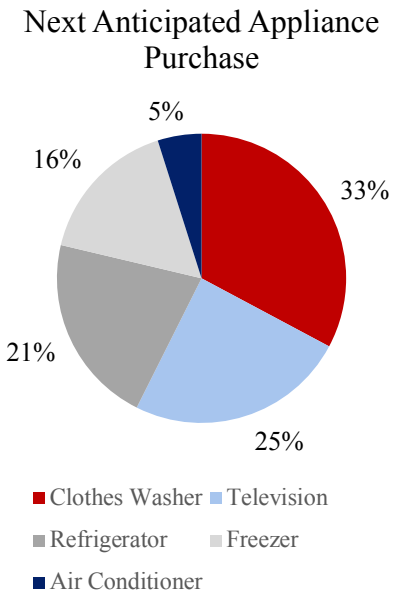


Although the trends in these BAUs are similar, our projection shows a potentially steeper increase in consumption to 2020, followed by a flattening.

Energy Efficiency and Appliances

- As GDP per capita increases, consumers will purchase new electrical appliances. Air Conditioning is a particular concern. In a recent study, few Tongans stated that they had short term desire to purchase AC. Does this seem realistic?
- Other studies (World Bank, 2012) have indicated that larger buildings with Air Conditioning are using significant electricity. A Church of Latter Day-Saints Temple is noted to consume 3-3.5% of electricity in Tongatapu. Is this data current? Are there other notable heavy users of electricity, and have any energy efficiency audits been performed? Does anyone know why the LDS facility uses so much energy?



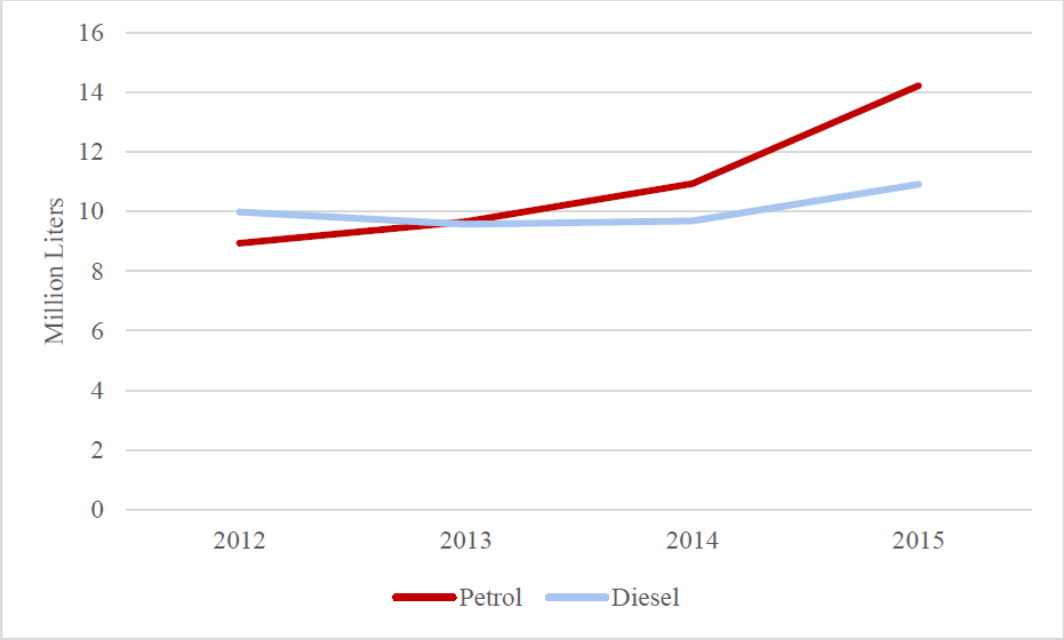


Transportation Baseline

- Focusing on Land Transportation
  - 100% domestic (unlike air and sea)
  - Many cost-effective options for how to improve efficiency
- Key Land Transportation Data
  - Fuel Usage
  - Number of Vehicles
  - Vehicle Kilometers Travelled
  - Other more targeted data (bicycles, motorcycles, cell phones, ferries)

Land Transportation Fuel Usage

Figure 9 Land Transportation Fuel Usage in Tonga



Source: MCCTIL Fuel Volume 2012-2015 Report

- Assumed that all diesel and petrol being used in the service stations, government, and commercial sectors is land transportation fuel.
  - Implicit assumption that amount of fuel purchased at service stations that is used in boats and off-road equipment cancels out the fuel purchased by govt or commercial used in boats and off-road
- Realistic when checked against VKT data
- Good baseline, but not enough history to base projections off of

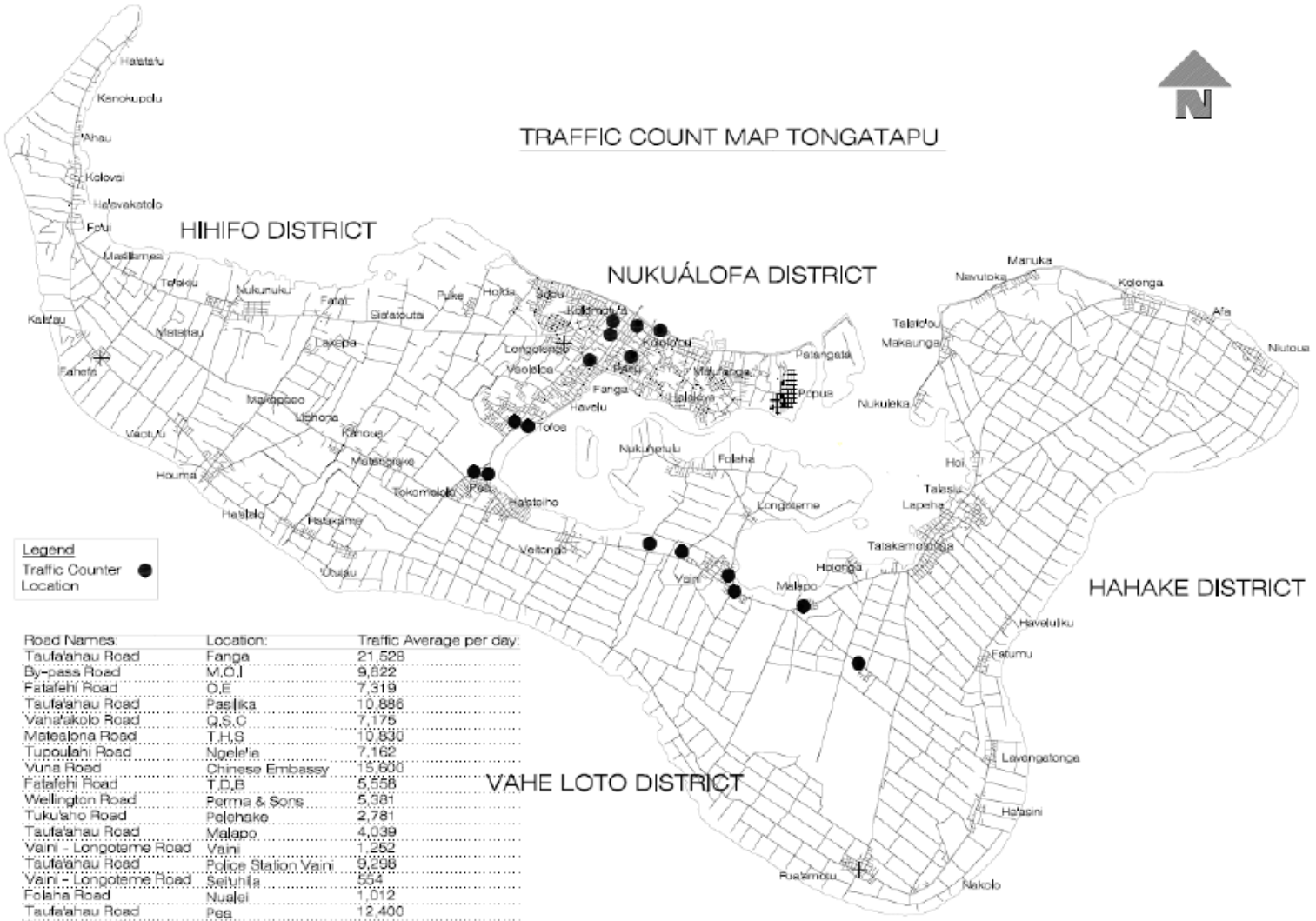
Vehicle Stock

- Converted annual new vehicle registrations (Ministry of Infrastructure) into stock by assuming that vehicles are used for 7.3 years (2016 Census showed 59% households had vehicles and 8% had purchased within year)
- Replaced "government" category with govt fleet tally
- This count was 3.5% less than imports-based number and 16% more than 2016 Census—probably due to commercial vehicles

Table 6 Tally of Vehicles in Tonga by Type

Vehicle Type	# of Vehicles
Cars	6,031
Light trucks, vans, SUVs	7,103
Heavy duty vehicles	2,099
Taxis and rentals	953
Motorcycles	306
Buses	225
Total	**16,717**

Vehicle Kilometers Travelled



Road Names:	Location:	Traffic Average per day:
Taufa'ahau Road	Fanga	21,528
By-pass Road	M,O,I	9,822
Fatafehi Road	O,E	7,319
Taufa'ahau Road	Pasifika	10,886
Vaha'akolo Road	Q,S,C	7,175
Mateialona Road	T,H,S	10,630
Tupoulahi Road	Ngele'ia	7,162
Vuna Road	Chinese Embassy	15,600
Fatafehi Road	T,D,B	5,556
Wellington Road	Perma & Sons	5,381
Tukuaho Road	Pelehake	2,781
Taufa'ahau Road	Malapo	4,039
Vaini - Longoteme Road	Vaini	1,252
Taufa'ahau Road	Police Station Vaini	9,298
Vaini - Longoteme Road	Seiuniia	554
Folaha Road	Nualei	1,012
Taufa'ahau Road	Pea	12,400
Fononga'ahina Road	Pea	4,451
Vaha'akolo Road	Tofoa (sioata)	7,988
Taufa'ahau Road	Tofoa (ion vest)	13,201

Source: Ministry of Infrastructure

Vehicle Kilometers Travelled, *continued*

Table 5 Traffic Counts, Traffic Destinations and Daily VKT on Tongatapu

Road	Counter Location	VEH's/day	Destination A	Km's to A	Vehicles to A	Daily VKT	Destination B	Km's to B	VEH's to B	Daily VKT
Taufa'ahau Road	Fanga	21,528	Tofoa	1.2	15,837	**19,111**	Havelu & Vaoloa	0.5	5,691	**3,022**
Bypass Road	MOI	9,822	Western suburbs	2.5	4,911	**12,169**	Hihifo district	10.0	4,911	**48,991**
Fatafehi Road	OE	7,319	Intra-Nuku traffic	2.5	7,319	**18,135**	-	-	-	-
Taufa'ahau Road	Pasilika	10,866	Intra-Nuku traffic	2.5	10,866	**26,924**	-	-	-	-
Vaha'akolo Road	Queen State College	7,175	Sopu	2.5	7,175	**17,779**	-	-	-	-
Matealona road	THS	10,830	Western suburbs	1.2	5,415	**6,535**	Hihifo District	10.0	5,415	**54,019**
Tupoulahi	Ngele'ia	7,162	Intra-Nuku traffic	2.5	7,162	**17,746**	-	-	-	-
Vuna	Chinese Embassy	15,600	Ma'ufanga and peninsula	2.5	15,600	**38,655**	-	-	-	-
Fatafehi Road	TDB	5,558	Intra-Nuku traffic	2.5	5,558	**13,772**	-	-	-	-
Wellington	Perma&Sons	5,381	Intra-Nuku traffic	2.5	5,381	**13,333**	-	-	-	-
Tuku'aho	Pelehake	2,781	Fua'amotu, Lavengatonga, and coast towns in between	5.3	2,781	**14,766**	-	-	-	-
Taufa'ahau Road	Malapo	4,039	Tatakamotonga	4.8	2,020	**9,748**	NE coast towns	13.0	2,020	**26,320**
Vaini-Longoteme Rd	Vaini	1,252	Accounted for in Pea line	-	-	-	-	-	-	-
Taufa'ahau Road	Vaini Police Stn	9,298	Accounted for in Pea line	-	-	-	-	-	-	-
Vaini-Longoteme Rd	Sei'uhila	554	Accounted for in Pea line	-	-	-	-	-	-	-
Folaha Road	Nualei	1,012	Accounted for in Pea line	-	-	-	-	-	-	-
Taufa'ahau Road	Pea	12,400	Viani	7.2	10,550	**76,387**	Folaha*	10.5	1,566	**16,378**
Fonongahina	Pea	4,451	West on Taufa'ahau	6.4	4,451	**28,647**	-	-	-	-
Vaha'akolo	Tofoa	7,988	Pea	1.6	4,451	**7,162**	-	2.5	3,537	**8,821**
Taufa'ahau	Tofoa	13,201	Pea	1.6	12,400	**19,952**	-	2.5	801	**1,998**
Intra-Hihifo trips	No Counters**	-	-	4.8	5,000	**24,135**	-	-	-	-
Intra-Hahake trips	No Counters**	-	-	4.0	5,000	**20,113**	-	-	-	-
Total Daily VKT on Tongatapu		**545,531**								

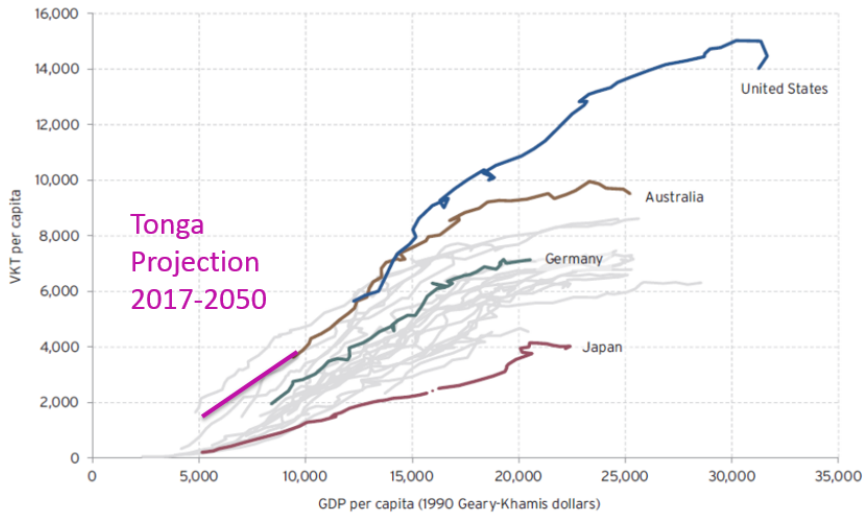
*284 of these cars are assumed to continue 3.2 km past Faloha on to Vietongo and Coast
** There were no counters in the Hihifo or Hahake districts. See text for how the vehicle numbers were estimated.

Parameter	Value	Assumption/ notes
Daily VKT Tongatapu	545,531	
Annual VKT of Tongatapu	170,751,231	Counted traffic occurs 6 days/week
Annual VKT of Tonga	200,977,431	16% of Km's occur on other islands (same as fuel use)
Population of Tonga	100,651	2016 Census
Per-capita VKT (including commercial)	1,997	
Land transport fuel Use in Tonga (L)	25 million	
Average fuel efficiency (L/100km)	12.5	Realistic with mix of vehicle type
Percent of traffic that is commercial	23.6%	Average in New Zealand
Per-capita VKT (Personal)	1,526	Realistic when compared to other countries

Note: Deliverable 1.3 contains an error. It uses the per-capita VKT of Tongatapu (2,289) instead of the per-capita VKT of Tonga (1,997). This change has cascading effects.

Transportation Business-as-Usual Projection

Figure 12 VKT of Motorized Passenger Travel and per-capita GDP for 22 Developed Countries



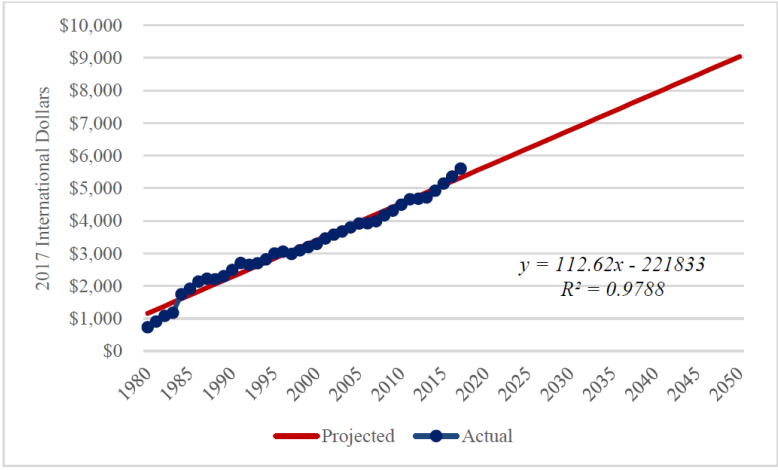
Source: Rand, 2014 (Note: these numbers omit freight and focus on passenger travel. Geary-Khamis dollars are the same as the international dollars described earlier in this report)

Tonga Statistic	2017	2050
GDP in $Int	$5,600	$9,000
Per-capita Personal VKT (in chart)	1,526	3,900
Per capita total VKT (including 24% commercial)	1,997	5,103

2.9% compounded annual growth rate

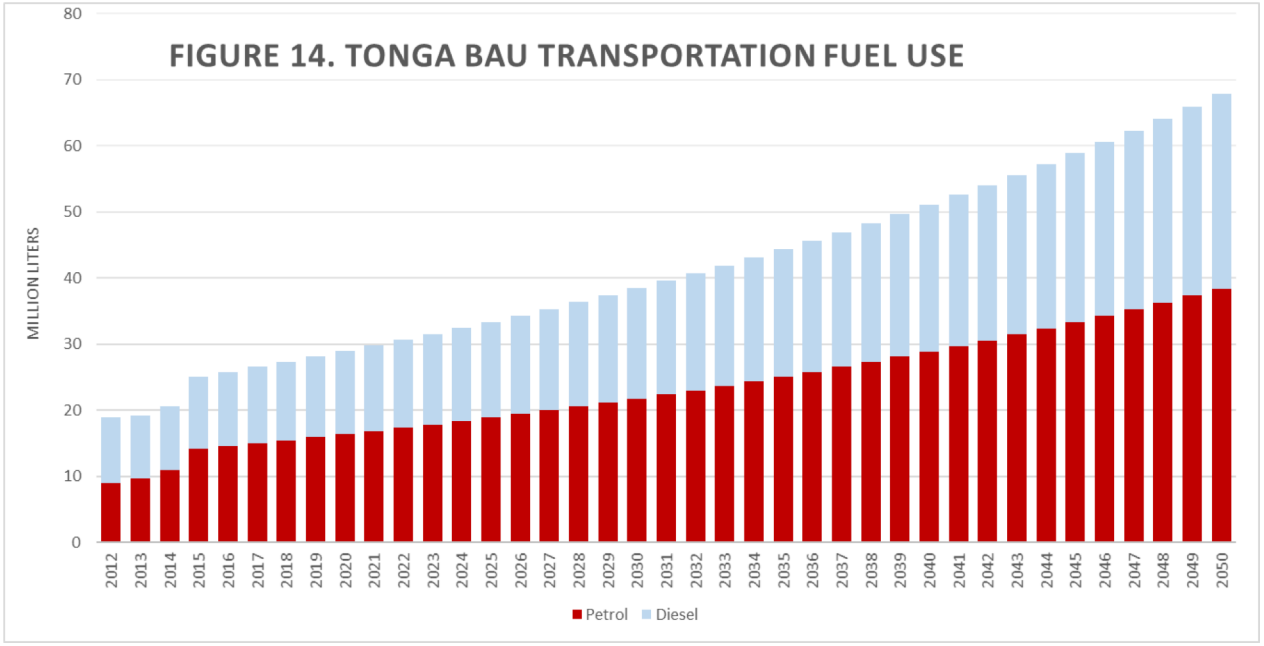
VKT tied most closely to per-capita GDP, but also to spatial dispersion, car infrastructure, fuel prices, and alternatives to driving

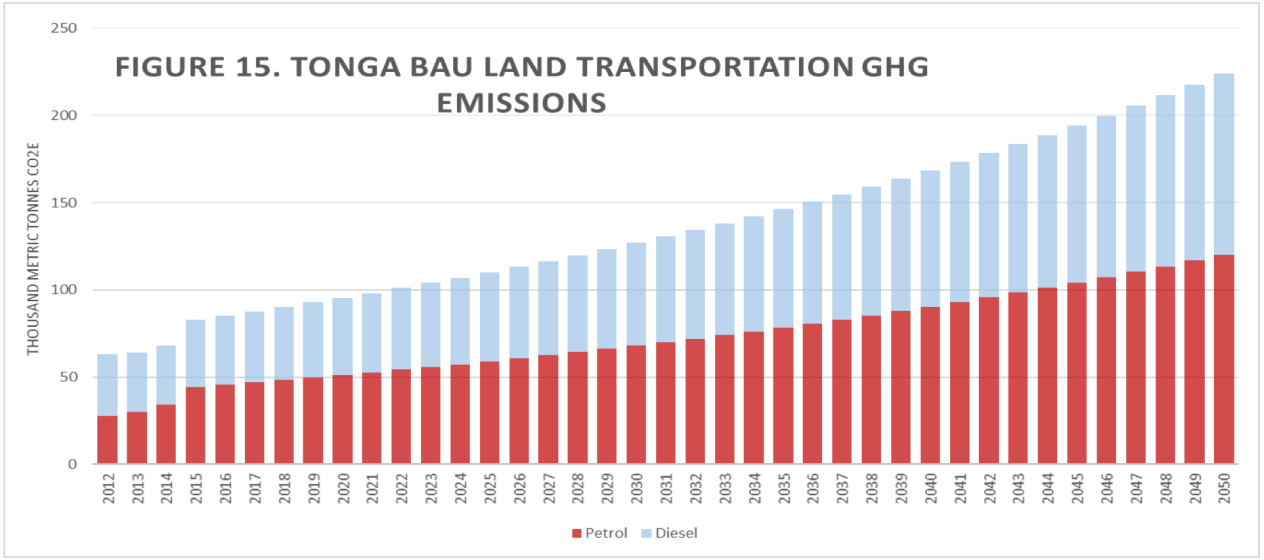
Figure 13 Tonga per-capita GDP with Purchasing-Power Parity



Data Source: Knoema Tonga GDP per-capita[28]

Transportation Business-as-Usual Projection





- 2.9% compounded annual growth rate
- Population constant
- Fuel economy constant

Least-Cost Building/Appliance EE Policy Options

Policy Options / Projects	Impact	Upfront Cost	Time to Implement	Ancillary Benefits	Support Available	
Implement **building standards** for resilience and energy efficiency (e.g. passive ventilation and daylighting with appropriate external shading)	High	Low	Med	High	High	*Low Hanging Fruit*
Set **packaging and recycling standards** to limit the amount of waste imported to Tonga	High	Low	Med	High	Med	
Implement a **public awareness campaign** on energy efficiency and conservation	High	Low	Med	Med	Med	
Establish a demand-side management **revolving loan or rebate program** to aid in financing more efficient equipment (residential, commercial and industrial)	High	Med	Med	High	Med	
Prioritize **on-site RE** with islanding controls and energy storage within critical infrastructure	High	High	Med	High	High	*Energy Transformation Projects*
Implement **distributed energy generation** projects that incorporate RE and fossil fuels to enhance resilience and reduce emissions associated with diesel generation, particularly when electrifying new areas or islands	High	High	Med	High	Med	
Work with TPL to create an **integrated resource plan** to incorporate RE, EE, and more efficient reciprocating engines that can be dual fuel	High	High	High	High	High	
Work with TPL to **underground lines** along the coast that are susceptible to cyclone damage	High	High	High	High	High	
Work with TPL to ensure **grid hardening** is adequately carried out (e.g., pole depth and composition can impact survival rate of T&D lines during cyclones)	High	High	High	High	High	
Explore **waste-to-energy** options to reduce the landfill capacity challenges	High	High	High	High	Med	
Perform **energy audits** of buildings to create baselines and implement energy conservation measures	Med	Low	Med	High	Med	*Incremental Improvements*
MEPs for equipment and appliances	Med	Low	Med	Med	High	
Data collection exercise/database to manage energy data by sector	Med	Med	Low	High	Med	
Influencing the transportation sector: anti-idling legislation, vehicle registration fees, and electric vehicles PV charging stations	Med	Med	Med	Med	Med	
Continue to **reduce T&D losses**	Med	Med	Med	Med	Med	
Create or implement a **certification process for sustainable/green hotels** for the tourist industry	Med	Med	Med	Med	Med	
Continue the **street lighting upgrade** program and **using roundabouts** rather than traffic lights	Med	Med	High	Med	High	
Create a **cool roof program** to reflect heat from rooftops and save energy on air conditioning loads where buildings are air tight and have AC units installed	Med	Med	High	Med	High	

Top Five EE Policy Options and Projects

New Construction Standards and Audits

As GDP per capita increases, an increasing amount of power is used to supply load that could be better satisfied by mindful construction practices.

Public Awareness Campaign

Focus on both the environmental, and personal economic benefits to rate-payers who reduce their consumption. The introduction of an MEP program goes hand in hand with this.

Revolving Loan or Rebate Program

Leverage the Tonga Development Bank to provide ultra-low interest loans to projects that demonstrate they can generate energy savings.

Integrated Resource Planning

Lay out a long-term, realistic framework outlining how goals will be met in a scope not captured by annual reports.

Data collection exercise

Standardize annual reports, and increase reporting of data to include figures such as sectoral consumption and load profiles by source of generation.

Heat-Map of Least-Cost Transportation Options

Policy Options / Projects*	Impact	Upfront Cost	Time to Implement	Ancillary Benefits	Support Available
Use a platform such as NextBus to **track and coordinate busses**	High	Low	Low	High	High
Send a mechanic to EV maintenance training in Japan or New Zealand	High	Low	Low	Med	High
Enact a **3-foot minimum distance rule** for drivers passing cyclists or pedestrians	High	Low	Low	Med	High
Provide pedestrians (particularly school children) and cyclists with **safety lights and reflectors**	Med	Low	Low	High	High
Install **rumble strips** and painted lines demarcating lane boundaries parallel to sidewalks to increase pedestrian safety	High	Low	Low	Med	Med
Set **Vehicle Registration fee and/or import tariff according to fuel consumption**	High	Low	Low	Med	Low
Introduce **fuel economy standards** for vehicle imports	High	Low	Med	Med	Med
Begin a **water taxi in the laguna** (and some associated dredging)	High	Med	Med	High	Med
Build a **strategic parking lot and bus stop** at intersection of Taufa'ahau Rd. and Loto Rd.	High	High	Med	High	High
Fuel economy and fuel cost **labeling requirements**	Med	Low	Low	Med	Med
Implement **motorcycle/scooter safety program** and vest requirements	Med	Low	Low	Med	Med
Incentivize tuk tuks to queue at major bus stops in the countryside to **complete the last-mile travelled**	Med	Med	Low	High	Med
Construct **left hand turn lanes** at key intersections to improve traffic flow	Med	Med	Med	High	High
Introduce **rebates on EVs**, including low-speed electric vehicles such as **GEMs and EV scooters**	Med	Low	Low	High	Low
Rebates on the installation of public EV chargers with timers, then smart meters to smooth the load of 50% renewable	High	High	High	High	High
Construct **bus pull-offs** to improve traffic flow	Low	Med	Med	High	High
Construct a **toll bridge** across the top of the laguna, with parking lots at either end	High	High	High	High	Med
Coordinate taxis (with a common dispatch and/or coordination apps such as FlyWheel) to increase the convenience of not owning a vehicle	Med	Med	Med	Med	Med
Blend diesel fuel with **coconut biodiesel** at 5% blend	Med	Med	High	Med	High

*Projects were prioritized by allocating 1 point for green, zero points for yellow, and -1 points for red. Ties were broken by prioritizing attributes further left on the table before those on the right.

Top Five Transportation Policy Options and Projects

Use a platform such as NextBus to coordinate busses

Trackable buses greatly reduce time wasted due to arrival-time unpredictability, especially on routes such as those in Tonga, where buses don't circulate frequently.

Send a mechanic to EV maintenance training in Japan or New Zealand

This facilitates the adoption of both hybrids and EVs. While ensuring that Tonga has the technical capacity to repair and maintain new vehicle technologies.

Enact a 3-foot minimum distance rule

A minimum passing distance law sends a signal that pedestrians and bikers have the right to be on the road, and that it is the responsibility of drivers to avoid hitting them.

Provide pedestrians and cyclists with safety lights and reflectors

VKT will increase so long as pedestrians feel safer in cars than on foot. Travelling on foot at night is a particular concern as seventy-five percent of US accidents resulting in a pedestrian casualty occurred in the dark.

Install rumble strips and painted lines

Rumble strips are a relatively inexpensive and effective way to keep drivers off the shoulder of the road, providing pedestrians with a reassurance of safety.

Thank You

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Supplemental Slides

High-Priority Transportation Policy Options and Projects

1. **Use a platform such as** NextBus to **coordinate busses**: o Trackable buses greatly reduce time wasted due to arrival-time unpredictability, especially on routes such as those in Tonga, where buses don't circulate frequently. Reduced stress and lost time associated with riding the bus, encouraging more ridership. Census data indicates that a significant (and growing) portion of Tonga's population owns a cell phone, which can be leveraged to provide transportation data to customers on demand.
   - Resource: How NextBus Works
   - Resource: Urban Bus Services in Developing Countries and Countries in Transition

2. **Send a mechanic to EV maintenance training** in Japan or New Zealand: o This facilitates the adoption of both hybrids and EVs. Toyota operates a training program in Japan specifically for foreign nationals, and MITO is developing a similar technical program in New Zealand. Scholarships could be available through Toyota, MITO, or JICA to make this a low-cost option to ensure that Tonga has the technical capacity to repair and maintain new vehicle technologies.
   - Resource: *Toyota Tajimi Service Center*
   - Resource: *MITO Automotive Electrical Engineering Program*

3. Enact a **3-foot minimum distance rule** for drivers passing cyclists or pedestrians: o A minimum passing distance law sends a signal that pedestrians and bikers have the right to be on the road, and that it is the responsibility of drivers to avoid hitting them. Of course, the law is only effective if police actively enforce it. One study found that in a state with such a law, while violations were plentiful, enforcement was rare.3
   - Resource: *League of American Bicyclists--Model Safe Passing Law*

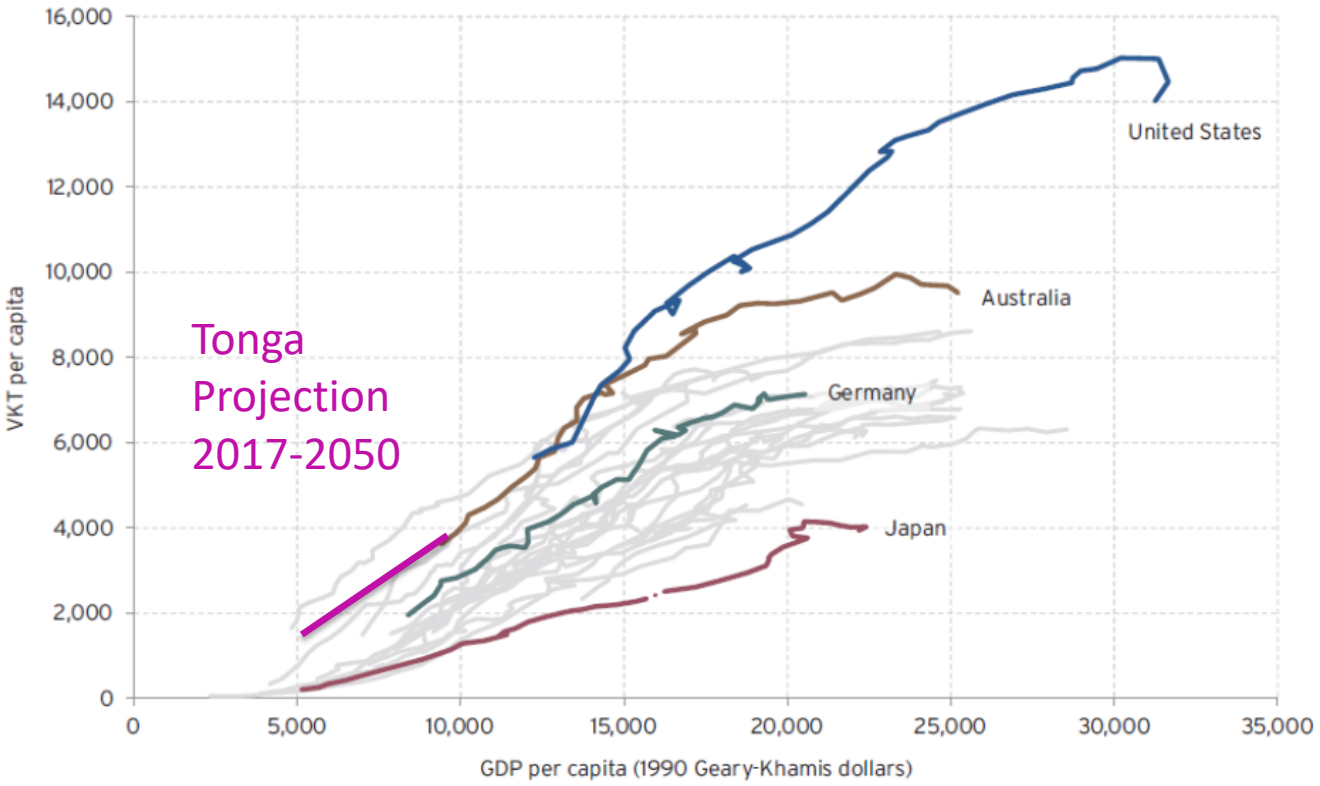
High-Priority Transportation Policy Options and Projects- *continued*

4. Provide pedestrians (particularly school children) and cyclists with **safety lights and reflectors**:
   - VKT will increase so long as pedestrians feel safer in cars than on foot. Travelling on foot at night is a particular concern as seventy-five percent of US accidents resulting in a pedestrian casualty occurred in the dark. Various pilot programs to distribute lights or reflectors to school children have proven effective at mitigating accidents. Studies identify that reflector vests are the most effective option for increasing the visibility of cyclists to drivers.
   - Resource: *A Road Safety manual For Decision-Makers and Practitioners (Pages 78-81)*
5. Install **rumble strips** and painted lines demarcating lane boundaries to increase pedestrian and biker safety:
   - As most countries develop, they initiate a negative feedback loop. Cars are prioritized, VKT increases, pedestrian and biker safety decreases, which incentives travel by car instead of walking or biking. Tonga therefore needs to safeguard pedestrian and biker space before this feedback loop commences. Rumble strips are a relatively inexpensive and effective way to keep drivers off the shoulder of the road, providing pedestrians with a reassurance of safety. In areas where the road is too narrow, "sharrows" reserve space for bikers and increase driver awareness.
   - Resource: *Decision Support Guide for the Installation of Rumble Strips on Non-Freeways*
   - Resource: *A Road Safety manual For Decision-Makers and Practitioners (Page 28)*
6. **Set Vehicle Registration fee and/or import tariff according to fuel consumption:**
   - People are most responsive to up-front costs when purchasing vehicles. Therefore, registration fees and import tariffs can be set to make efficient vehicles much less expensive than inefficient ones. Countries have implemented such registration fees that are based on CO2 emissions, fuel consumption, fuel economy, engine displacement, or vehicle size. Some have even implemented a "feebate" system that actually pays people that register the most efficient vehicles.
   - Resource: Vehicle Registration Fees Implemented by Countries

High-Priority Transportation Policy Options and Projects- *continued*

7. Introduce **fuel economy standards for vehicle imports:**
   - A fuel tax is the most direct way to reduce fuel usage. However, fuel taxes are generally unpopular and difficult to implement. Many countries around the world have implemented fuel economy standards (or the closely-related fuel consumption or GHG emissions standards). Used vehicle age requirements for import , when adequately enforced, are another policy to ensure that vehicles brought to Tonga are efficient and in proper working order.
   - Tool: *New Zealand Fuel Economy Rating Database*
   - Resource: *Fuel Economy State of the World 2016*
8. **Water taxi in the laguna** (and some associated dredging):
   - Transporting passengers via water taxis can be more efficient than road transportation on an energy per passenger-mile basis, depending largely on the size and occupancy of the vehicles6. Furthermore, the distance from Nuku'alofa to various towns lining the laguna is much shorter travelling across the laguna instead of around the laguna on Taufa'ahau Road. Ancillary benefits include time and traffic reductions. However, the laguna would likely require dredging in some locations.
   - Resource: Sarasota Water Taxi Feasibility Study
   - Resource: Forget Flying Cars: We Need Floating Ones
9. **Build a strategic parking lot and bus stop at intersection of Taufa'ahau Rd. and Loto Rd.**
   - Strategic parking lots are often located at bottlenecks where traffic gets worse or at confluences of roads. They provide good locations where people can park their vehicles and catch a bus or carpool into congested areas with limited parking. This intersection in Pea meets these requirements, with nearly 17,000 vehicles passing through it per day on their way to and from Nuku'alofa. Parking lots in this location could alleviate the need for additional parking in Nuku'alofa as vehicle ownership increases, and could enable the city to remain dense and pedestrian-friendly.
   - Resource: Washington DC Park & Ride System facilitates carpooling and mass transit
10. Introduce **Fuel economy and fuel cost labeling requirements**:
    - Economics provides a powerful reason for people to purchase more efficient vehicles. However, this is not clear unless people know the fuel economy of vehicles that they are considering purchasing. Stickers on vehicles at dealerships that clearly state the expected annual fuel cost of the vehicle further illustrate this point. Using fuel economy on the Japanese test cycle would be a good start or combining test cycles from multiple countries the way New Zealand does. However, to maximize accuracy Tonga could develop their own test drive cycle.
    - Example: *Fuel Economy Labeling, Focus on non-EU Countries*
    - Review: *Evaluation of Vehicle Fuel Efficiency Labeling and Consumer Information Programs*

Figure 12 VKT of Motorized Passenger Travel and per-capita GDP for 22 Developed Countries



Source: Rand, 2014 (Note: these numbers omit freight and focus on passenger travel. Geary-Khamis dollars are the same as the international dollars described earlier in this report)