Energy Data Collection in Tonga – Processes, challenges and opportunities

Development Account Tranche 10

Evidence-based policies for the sustainable use of energy resources in Asia and the Pacific

Consultancy Report – Tonga Phase 1

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Introduction/Background

Tonga belongs to the Small Island Developing States (SIDS). The UN General Assembly (UNGA) adopted a resolution on the outcome document of the Third International Conference on Small Island Developing States (SIDS), the 'SIDS Accelerated Modalities of Action (SAMOA) Pathway' (A/69/L.6). "The Samoa Pathway" using SAMOA as an example of SIDS, recognizes the adverse impacts of climate change and the rise of sea-levels on SIDS' efforts to achieve sustainable development.

Improvement of energy security through sustainable channels is one of such efforts in Tonga for achieving economic prosperity. According to "Tonga Country Energy Security Indicator Profile 2009" prepared by the SPC, the total electrification rate was 89% and rural energy access to modern forms of energy was still at 73%. The electricity tariff in 2009 amounted to USD 0.36/kWh in 2009 as the household energy burden averaged 14%. This data is based on the census of 2006. Taking the case of electrification rate, the improvement has reached 97% in the latest census of 2016.

Another important issue to be considered in the improvement of energy security is the role of renewables. According to Tonga Power Limited ("Combined Utilities Business Plan 2018-2022"), the current share of fuel cost in the electricity tariff is about 48% (41.51 seniti/kWh) of the total (85.86 seniti/kWh – about 0.38 USD/kWh). This part can be reduced by using domestic renewables such as solar power to replace imported diesel fuels. Thus, the contribution of renewable PV to energy security and energy access is significant. But how significant?

To understand the significance of the role of various aspects of energy on national economy and national security, data is of critical importance. Particularly quantitative data that enables 'evidence-based practices'. It also helps to think about substantive measures in mitigating associated risks. Without quantitative data on energy supply and demand, it is difficult to identify the sources of these risks and their impact on welfare. By the same token, if data is available, there are chances to mitigate and improve the status of energy security using appropriate policy responses and ensuring that the country meets the "Tonga Energy Road Map" and "Sustainable Development Goals".

1 Current energy data collection

1.1 Identification of data required from the needs

<u>National Needs</u>

The national needs of energy data in Tonga are particularly strong for concerns on 1) energy security, 2) future energy planning, and 3) trade balance from energy imports/exports.

To analyze these concerns, capturing the national energy flow and constructing the energy balance are critical first steps. The problem starts here implying huge improvements are needed for data collection. For example, the most fundamental numbers are total energy supply and consumption in energy equivalent units (ex. kcal, toe, joule etc.). Neither of these indicators can be found in any official publications, domestically or internationally, even in the "Tonga Energy Road Map 2010-2020".

The energy flow explains in terms of quantity 1) who (sector) consumes what type of end use energy, 2) what types of sources are used and lost (ex. wasted to convert from diesel oil to electric power) to transform to the end use energy (particularly electric power—diesel oil to electric power), and 3) what types of energy sources are produced, imported, or exported as primary energy sources. Using this information, we can see who wants what type of energy, the needs of energy importation and the outcomes and risks associated with energy security as well as the contributors of CO_2 emission from the point of consumers.

Roughly speaking, nearly 100% of energy or primary energy supply is imported as oil products. One third is used for power generation from diesel oil. Other data on the use of firewood and increased generation by renewables is scattered and not clear in terms of energy balance and flow.

There are three basic problems of note. Firstly, units are not unified in energy equivalent terms (toe or kcal), but in original physical units (kl, kWh, or ton). This lack of unification by energy units makes it difficult to capture the whole national energy flow. Secondly, data preparation is neither standardized nor systemized for capturing national issues such as energy security (ex. dataset in the format of energy balance table). Finally, the required data is also not accumulated and/or summarized within a centralized agency/place such as DOE or MEIDECC.

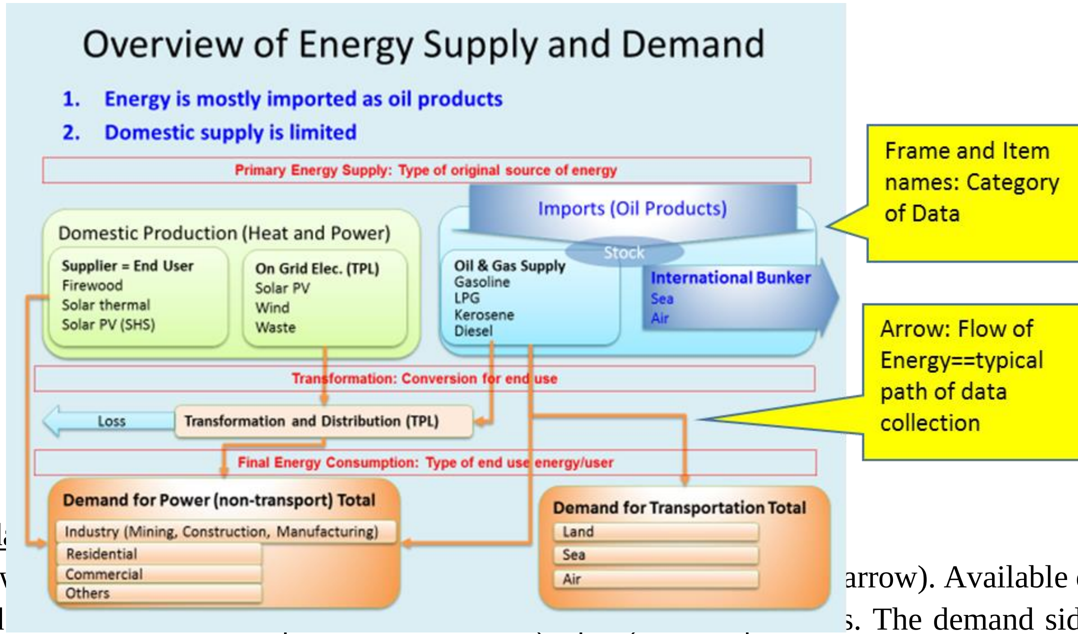
In this context, the required data for national needs is suggested to create the energy balance table – energy flows by energy products/type in DOE, MEIDECC. As a reference, the IEA Energy Balance Table – an internationally known framework – is used to identify the required data in Tonga.

Tonga's energy data collection and the availability of energy data and information fairs relatively well on the supply side of the power sector. The challenges lie with non-power data, particularly on the demand side – final consumption by sector for both power and non-power (particularly oil products) sectors. Final energy consumption data (by sector) can illustrate consumer preferences and thus, is very important to understand the future of energy utilization by types of energy. While TERM focuses on power, the analysis of non-power use is considered to be comparably difficult because of the lack of reliable data.

<u>Energy data and the collection path required</u>

The required data and the collection paths are shown below based on the flow of energy balance.

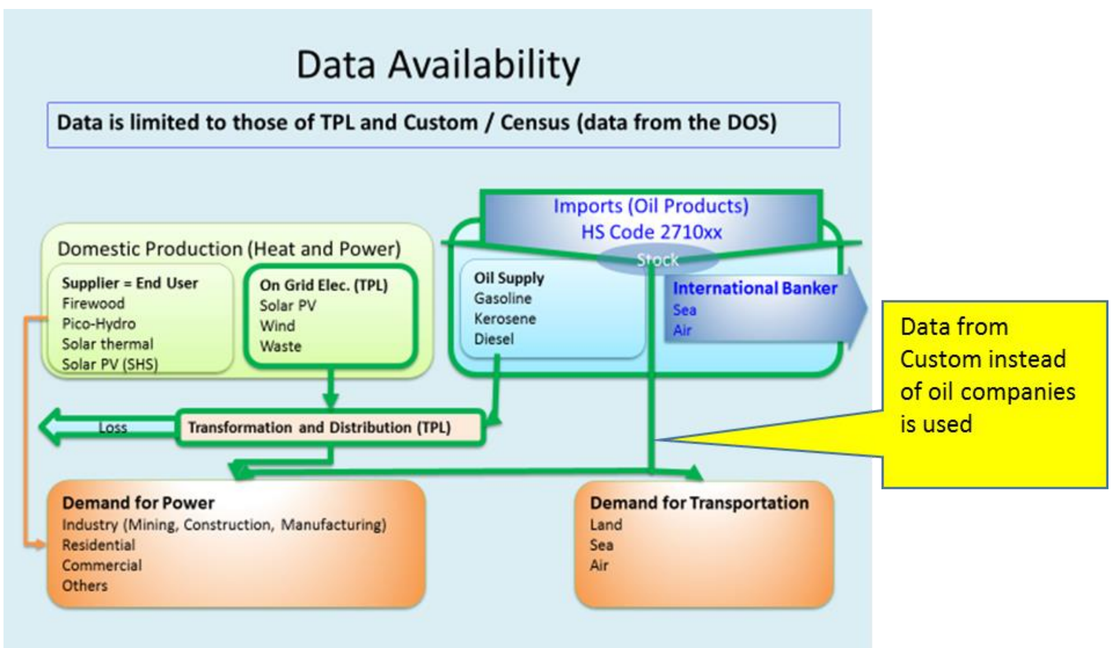
Figure 1 - Energy Supply and Demand



Current d…

The follo… arrow). Available data is limited … s. The demand side is based on the data of household income expenditure from the Department of Statistics.

Figure 2 - Data Availability



<u>Needs beyond the energy market</u>: Future planning (ex. TERM) and regional (PRDR)/international (APEP) requirements

Decision-making in the energy sector takes into consideration data beyond the energy market. One type is socio-economic, particularly to be used as potential driver of the economy of Tonga and changes in energy consumption. This data includes demographics of population, labour, value added by sector –industry, services (particularly tourism is the largest source of foreign currency), agriculture, and fishery. Data of national accounts, income per household, number of cars for transportation among others are also important data as indicators of economic activities that rely on energy consumption. This data becomes important to estimate future energy demand and to develop supply plans such as the TERM.

International databases dedicated to energy such as the Asia Pacific Energy Portal (APEP) managed by ESCAP and the Pacific Regional Data Repository (PRDR) managed by SPC also emphasize socio-economic data. The former is a quantitative database based on standardized categorization. The latter is a database of individual report, survey, and project information the unit of each record in the database is not numeric data, but electronic file in the format of pdf and excel sheet.

The additional data required from APEP includes data on energy trade, price of electricity, fuels, subsidies, and foreign/domestic investments as a reflection of international needs. Given Tonga's energy context, the most important trade data required is within the oil sector. Also, there are no price subsidies, but the retail prices of oil products and power are regulated in Tonga (Price and Wage Control Act of 1988 for oil products and Electricity Act 2007 for concession agreement of electricity tariff). On the other hand, indicators of energy access and related data on investment can be important in terms of international contribution to the promotion of renewable energy in Tonga. There are other required data categories, such as energy efficiency, environment (CO2 and other emissions), and energy self-sufficiency, which can be estimated using other data such as the consumption of fossil fuels for estimating CO2 emissions. The requirement of data on the energy reserve can be neglected in case of Tonga. The last category of "socioeconomic context" is very important as explained later to be utilized as primary driver of the future energy demand, that should be considered for future energy planning.

The data of PRDR is categorized into five. They are 1) Economic and demographic data, 2) Petroleum and transport data, 3) Utility data, 4) Resource monitoring data, and 5) Renewable energy project data. The first three categories are compatible with the required numeric data for Tonga's national needs and APEP. However, utility and resource monitoring data are new, but are not yet subjected to data collection, rather a record keeping of non-periodical projects and surveys. The needs of these categories in PRDR could be solved, for example, by preparing a data record of electronic links to these documents in the electronic database of Tonga national energy in DOE, MEIDECC.

Differences in classifications and interpretations

The names, classification and categorization of energy related products are not necessarily harmonized with internationally defined standards such as the International Recommendations for

Energy Statistics (IRES). Such differences are typically found in products supplied in different blends and products produced domestically such as unleaded and premium gasoline for automotive gasoline. Thus, the categories and names used in the Department of Statistics, which follows international standards, can be different from the one used in the domestic market. In case of Tonga, categories and names of oil products such as kerosene, gasoline, diesel oil can be different from those of international standards.

It should be noted that even within accepted international standards, there are different ways to categorize the data (for example biogas is categorized into subcategories such as landfill and sewage in IRES, while it does not have subcategories at the IEA). IRES of the United Nations is leading the coordination of such differences. From Tonga's perspective, the disaggregation of biogases is not necessary at this stage.

1.2 Identification of key stakeholders

<u>Key Stakeholders</u>

The most important key stakeholder of energy data on the supply side is DOE of MEIDECC. The other important stakeholders of the supply side are TPL, petroleum companies (PE SWP/Total), and retailers of petroleum products as the source of original data of power and petroleum products.

Socio-economic data is related to energy demand/consumption such as activity of transportation and energy consuming industries. Thus, the stakeholders of these socio-economic activities should be listed as key stakeholders as in the table below:

Table 1 - Role of Key Stakeholders

Stakeholders	Current and potential role
Government ministries 1.Ministry of Meteorology, Energy, information, Disaster Management, Environment, Climate change and Communication (MEIDECC): Department of Meteorology Department of Energy (DOE) Department of Information Department Environment Department of Climate change Department of Communication 2.Ministry of Land and Natural Resources (MLNR) 3.Ministry of Public Enterprises (MPE)	Current role -Department of Energy, MEIDECC has the role of preparation of TERM -But required role of collection of energy data collection is not legally empowered -The availability of data is limited to the supply side of electricity collected from Tonga Power Limited -Rough energy data as a part of socio-economics is collected, compiled, and stored by the Department of Statistics, MFNP Potential role -DOE, MEIDECC is expected to be the center of energy data

4.Mnistry of Infrastructure (MI) 5.Ministry of Labor Commerce and Industries (MLCI) 6.Ministry of Agriculture Fishery Food and Forest (MAFFF) 7 Ministry of Tourism (MT) 8 Ministry of Finance and National Planning (MFNP)9. Ministry of Revenue and Customs 9 Ministry of Health 10. Department of Statistics (DOS)	-Demand side data sources can be the same as those of socio-economic data. Collection of such data as the consumption of kerosene in household, commercial, industries needs cooperation with the Department of Statistics, and other Ministries like Ministry of Agriculture, Fishery, Food and Forest -Similarly, transportation data as domestic navigation, road transportation needs cooperation with the Ministry of Infrastructure (data of transportation)
Public enterprises and government agencies 1.Tonga Power Limited (TPL) 2.Tonga Electric Commission (TEC) 3.Tonga Water Board (TWB) 4.Port Authorities Tonga (PAT) 5.Tonga Water Authority (WA) 6. Tonga Gas Limited	Current role -Tonga Power Limited is the primary source of electric power supply and sales Potential role -Port Authority of Tonga can be one source of domestic navigation
Community, church, schools (SSC) 1.Tonga College 2.Tuppu College 3.Beulah College 4.Liahona College 5.Tailulu College	Currently no role, but colleges could be a partner for potential needs of a survey for demand side data—use of petroleum of residential, commercial, and industries
Civil society (CS) 1.Residential Households 2.Business community 3.Public in general	Currently no role, but important source of demand side data for the residential sector
Private enterprises (PE) 1.Petroleum Companies 2.Shopping malls 3.Hotels 4.Vehicle sales dealers 5.Tourist Companies	Currently petroleum companies of Pacific Energy and Total are the primary sources of petroleum, but supply side only. Potential role of petroleum companies is important as a source of both supply and demand (sales data) of petroleum products. Similarly, private

6.Manufacturing factories 7.Industry Associations	organizations are the important sources of demand side data

From the point of data collection, most of the data is stored at the source. The table below shows candidates in consideration of national needs of data.

Who has? Who collects? Who stores? For Whom? And for What purpose?

Table 2 - Data sources, collection and purpose

Type of data	Data source (Who has = Who stores)	Who collects and stores?	For whom for what purpose (national needs)?
Primary energy supply	Electricity - TPL - Residential (PV) Oil Products - Pacific Energy - TOTAL - Ministry of Revenue and Customs for import custom data Others - Solar thermal - Firewood/Charcoal	DOE, MEIDECC With collaboration with DOS, MFNP for Residential PV, Solar thermal and others (biomass)	For national government to make national planning - To see the total needs of energy in Tonga)
Transformation	- TPL (Electricity)	TPL DOE, MEIDECC	For national government to make national planning - To see the efficiency and loss in power generation - To see the magnitude of loss of fossil fuels in total energy demand and supply
Final energy consumption	- Industry (Manufacturing, Mining, Construction) - Residential - Commercial - Agriculture/Forestry	DOE, MEIDECC Collaboration with - DOS, MI for data of Residential, commercial,	For national government to make national planning - To see the driver of energy demand - To see the needs of energy by type and by user

	- Transportation	and transportation - MRC for data of imported oil products - M. of Infrastructure for data of Construction - MAFFF for data of agriculture, fishery, and forestry	

1.3 Legal and regulatory framework

Currently, there is no legal framework for data collection focused on the energy sector in Tonga. Data is scattered on both the supply and demand side, with supply-side data collection mainly limited to the electricity sector and the demand side data limited to socio-economic data surveys conducted by the Department of Statistics.

Collection and analyses of energy data and information are clearly needed to support national interests. In terms of the institution where these tasks should be based, the Department of Energy in MEIDECC is the most important agency as it was established in 2014 to institutionalize the implementation of TERM.

The most notable characteristic in terms of energy data and information availability is the lack of integration of the transport sector into the framework of energy data and information, particularly on the demand side.

<u>Role of Ministries/Governmental Agencies and their regulatory responses</u>

Among government ministries and agencies, the Department of Statistics is the only agency which has the legal responsibility and budgetary capacity to execute data collection and storage. As mentioned before, the primary focus is on socio-economic data. Data on energy consumption is very limited, however, data on energy access and demand side indicators such as household expenditure on utility bills such as electricity and fuel can be obtained through census surveys. Census of manufacturing can be used as a rough indicator of energy consumption in industry sector.

Experiences in other countries

The system of data collection/preparation differs by country. Philippines for example, is one of the first countries to prepare such a regulatory framework, dedicated to petroleum data. In 1992, the responsibility of the submission of data was assigned to the 'Department of Energy' under the 'Department of Energy (DOE) act of 1992'. Petroleum companies submit data to DOE, based on a format that include sales volume and sales value, disaggregated by fuel and by sector (large industry only). Demand side data, however, needs to be surveyed separately with the help of the Philippines Statistics Authority. For the power sector, because it is fully liberalized in the Philippines, DOE added circular law (No. DC2015-04-0002) in their power to collect data.

In the case of Malaysia, data reporting is mandated through the 'Electricity Supply Act 2015' for electricity data and the 'Gas Supply Act 2015' for gas supply data. Other data is based on voluntary submission and questionnaire via online, email, fax and postage. For final energy demand, they also use surveys for manufacturing, residential and commercial sectors.

In Indonesia, PUSDATIN (Pusat Data dan Informasi—Center of Data and information) of Ministry of Energy and Mineral Resources has the responsibility of collection, compilation and storage. Although, legal empowerment is currently in preparation, their data collection is based on voluntary submissions. Besides, the data source is limited to the stakeholders on the supply side, namely petroleum companies and governmental agencies.

Similarly, in the case of Papua New Guinea, there is no law or regulation that mandates data collection. Although a data preparation mechanism is under development, currently there are no organizations that prepare the data. Voluntary submissions are also limited.

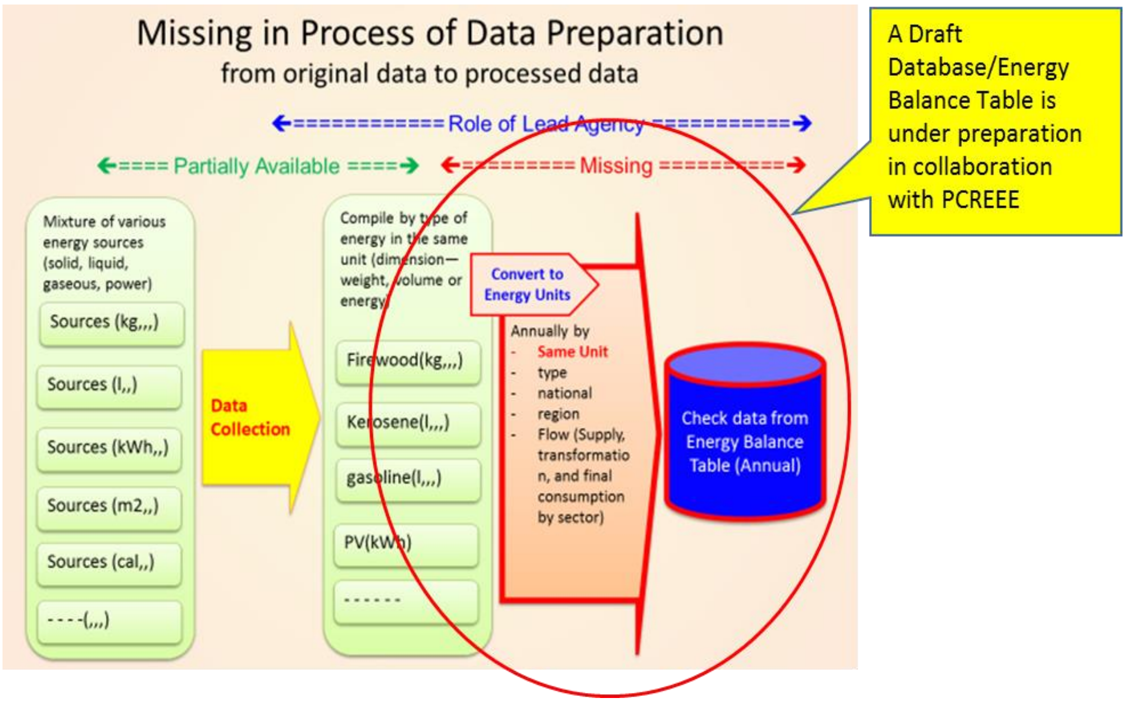
As such, the difficult part with data is the disaggregation by type of sector/consumer for example for power, industry, transportation, residential, commercial, agriculture and fishery. Generally speaking, rough disaggregation of data is the responsibility of petroleum companies. But further disaggregation of demand side data is the task of the government. To estimate consumption or to disaggregate data, the data of utilization (output from power generation, number of cars, output/value added of the industry) is used.

1.4 From Data collection to creation of database

There are basically three processes of data collection 1) data collection from original source, 2) data compilation/aggregation based on the same category and the same physical unit, and 3) creation of database/energy balance table.

Currently, data collection and processing is partially in progress as mentioned in the previous sections. The third part (creation of energy database/balance table) is tried for occasional needs for research, but not in a sustainable way. Under a trial, a draft version of the energy balance table is now prepared with the help of Secretariat of the Pacific Community (PCREEE, Pacific Center for Renewable Energy and Energy Efficiency) and the Georesources and Energy Programme (GEM).

Figure 3 - Overview: Process of Data Preparation and the Current Status (Missing Process)



<u>Process of data collection</u>

Data must be collected in its raw form and compiled into a useful format. Data collection methods vary based on who needs to collect the data and from whom, in addition to cost constraints and the availability of alternative sources. The collection methods can be categorized as follows:

1) CASE 1: Number of data sources are few and easy to access. Typical cases include supply of petroleum products and power generation/distribution. In these cases, data can be collected directly from the sources through voluntary or mandatory submission.

2) CASE 2: Data is widespread among a large number of sources and is difficult to reach. Typical cases include data on final energy consumption. The household consumption of kerosene, charcoal, firewood, PV are one such example. In this case, periodical sample survey (interview by direct visit, mail, telephone interview, fax or else) or the use of census survey is necessary.

3) CASE 3: Data is difficult to obtain and/or its availability is not clear. However, alternative data sources that are available and easily accessible can be used to estimate the original required data. For example, if imported capacity of PV module for residential use can be obtained from the import/export data (trade data at custom/port), the installed capacity of rooftop PV capacity and the outputs for residential sector can be estimated. Similarly, in Tonga, data of importation of oil products can substitute the sales data of oil companies. This substitution can be effective if the category of domestic supply and demand can be linked directly to the category of import data.

Who is responsible for data collection?

The responsibility of data collection and its categorization is not yet clear in Tonga – although certainly of national interest. Considering that DOE, MEIDECC is responsible for energy policy, DOE should be the center of the energy data and its collection. Data related to electricity is prepared and stored in TPL. Although some aggregated data is available, disaggregated data by sector and by type of generation would be necessary. Data related to petroleum and Tonga's socio-economic landscape needs a well-defined coordinated effort that could take the form of voluntary submissions or be mandated through regulation. Other data needs to be estimated using alternative data as indicated in the examples above.

How often (monthly, annual, or else)?

The answer depends on the purpose of data utilization. At the very least, an annual data collection cycle is needed to support long-term evidence-based energy planning of 10 years or more for example in the case of TERM. Quarterly and/or monthly data would be helpful if the seasonal variation in energy supply and demand is large. Given that seasonal variation in Tonga is minimal, preparation of annual data would be the first step.

Who checks?

Input mistakes are common if the numbers are prepared manually. Also, changes in units and categorization can cause inconsistencies in the data. These mistakes should be checked by an actor independent of the ones involved in preparation of the data such as SPC and GEM.

Cost of data collection

If the data collection process is systemized, MEIDECC's responsibilities will mainly include organization, unit conversion, and storage in electronic file. If the disaggregation of demand side data is required, additional estimation techniques need to be employed. In consideration of the types of data required in case of Tonga, the required cost depends on the methods. Below is the summary table that show the differences by collection methods and the applicable sources.

Table 3 – Costs of Data Collection

Type of data	Data source	Collection methods (options and applicable sources)	Cost
Primary energy supply	Electricity - TPL - Residential (PV) Oil/Gas Products - DOE, MEIDECC - Pacific Energy - TOTAL - Tonga Gas	Volunteer/Mandatory - TPL - Pacific Energy - TOTAL - Tonga Gas - DOE, MEIDECC - Customs Surveys	Low (requires volunteer/legal arrangement) High (requires collaboration with

	- Customs Solar thermal and Firewood/Charcoal - National census, - Tonga Household Income and Expenditure Survey (HIES), - Post Disaster survey	- Residential PV - National census, - Tonga Household Income and Expenditure Survey (HIES), - Post Disaster survey - Others Estimates - Residential PV - Others	DOS and other stakeholders) Low (requires alternative sources, low reliability)
Transformation	TPL (Electricity)	Volunteer/Mandatory	Low (requires volunteer/legal arrangement)
Final energy consumption	Industry (Manufacturing, mining, construction) Residential Commercial Agriculture/Forestry Transportation	Volunteer/Mandatory (Large industry only) - TPL - Pacific Energy - TOTAL - Tonga Gas Surveys - All or selected sources Estimates - All or selected sources	Low (requires volunteer/legal arrangement) High (requires collaboration with DOS and other stakeholders) Low (requires alternative sources, low reliability)

1.5 Data Base and Information Sharing (Storage of energy data and utilization of energy data)

Database (storage of energy data)

Here storage refers to electronically accessible files and/or documents, which contain data. Database (or database management system) means a computer software to manipulate the electronically stored data. Currently, there is no storage of energy data in Tonga, which contains both supply and demand side data except a draft database prepared last year by PCREEE and DOE for trial – although many missing parts of the table need to be filled. Institutional roles and empowerment are to be clarified and improved to complete and maintain such database. Thus, to design an energy database including storage in Tonga, in addition to technology and cost, institutional design becomes critically important. The following items should be considered to prepare the energy database.

a. Institutional: The role of DOE has to be clarified, particularly the definition and the boundary of data and information that DOE has to prepare, store and maintain.
b. Technology: Database linked to internet and intranet in electronic file and applications using cloud computing technologies are becoming increasingly common and cost efficient. Traditional paper-based data/information could also be used in parallel as protection against system failure.
c. Database: The database must support functions such as the storage of data, function of data receipt, access, submission, and compilation of aggregation and disaggregation. Among these functions, security is particularly important for storage from the point of risk control and efficiency. It is worth noting here that some data should be protected from access.
    i. One typical system is to collect original data from various sources and store it in one place. Then the original data can be compiled to construct useful formats such as an energy balance table.
    ii. If DOE and its data sources can share data and information through an on-line system, then DOE need not store the original data of outside sources—the data can be electronically linked.
d. Cost of maintenance: The cost of maintenance can be minimized through an on-line data system and can be further reduced by systemizing the compilation of data including aggregation, disaggregation, and creation of energy balance table.

<u>Information Sharing (Utilization of Energy Data)</u>
Tonga's dependence on imported petroleum products makes data such as diesel power generation, number of cars and industrial activities that use petroleum products particularly important. The point is that these data belong to socio-economic data, not energy data. Without them it is difficult to estimate the demand side if there is no direct way to collect data from the consumers. Given the importance of socio-economic data in estimation of demand side energy data, co-operation and information sharing with the collectors and custodians of this data is necessary. In Tonga's case, the relevant entities include Department of Statistic, Department of Transportation, Central Bank, and Department of Tourism. Here are the findings of the current system.

i. Institutional mechanism: There is systematic communication between TPL and the Department of Energy because of the need to oversee the progress of the TERM. Also, systematic communication is available with petroleum companies because of the Petroleum Act. However, the communication on the data with TPL is limited within the current regulatory framework.
ii. Efficiency (for example, shared through direct contact or web cloud or else?): Currently the data sharing is limited to electricity. But the data is not systematized to

be used for TERM and other analysis. If the data could be available through internet, particularly in the format of a spreadsheet, then data sharing would be much more efficient.

iii. Frequency of information sharing: Information sharing is neither regular, nor periodical

1.6 Summary: Flowchart of findings: Options of data collection

Figure 4 - Options of Data Collection (Supply Side)

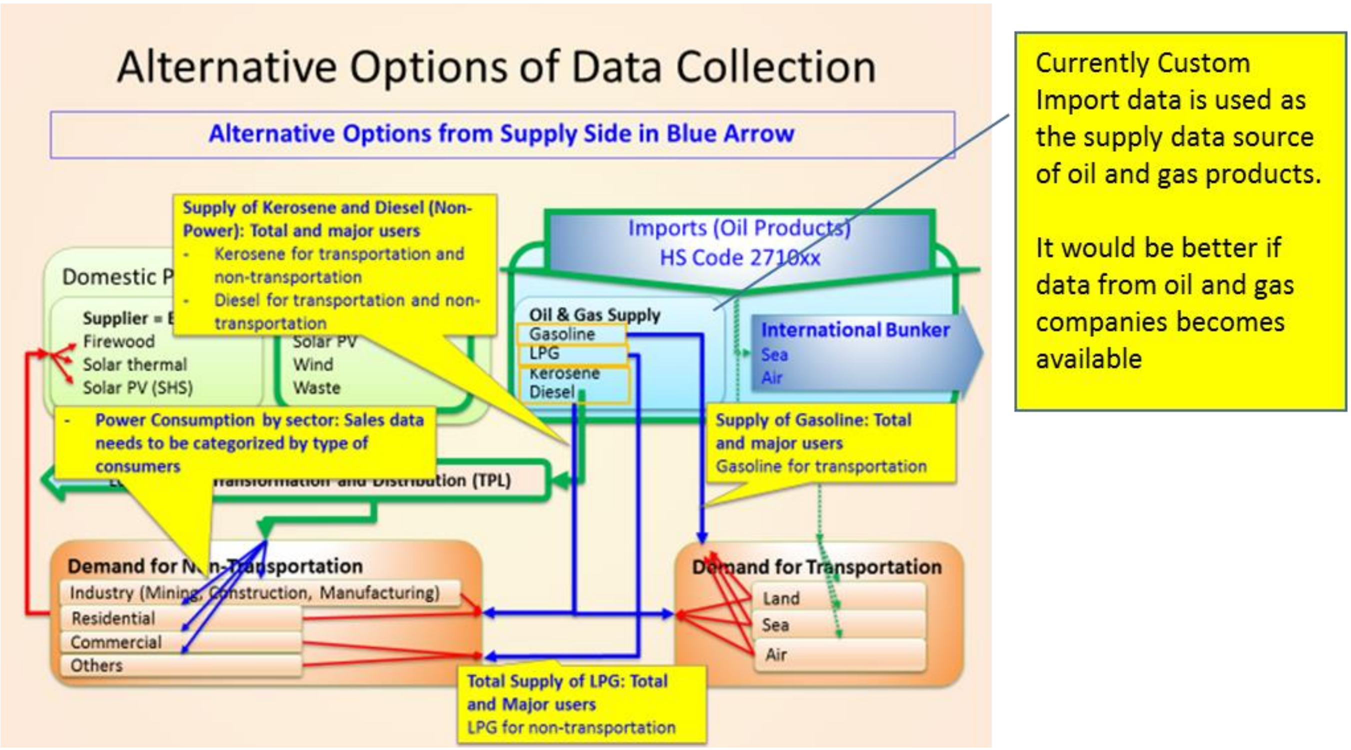


Figure 5 - Options of Data Collection (Demand Side)

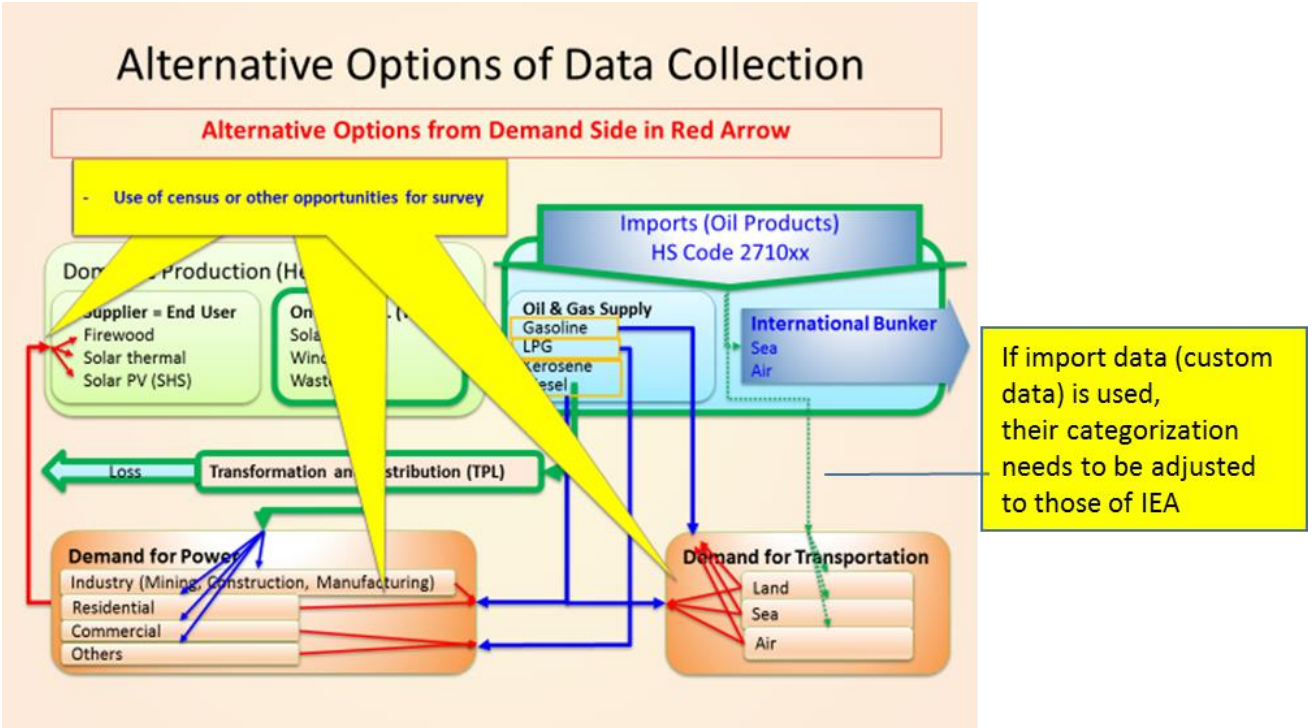
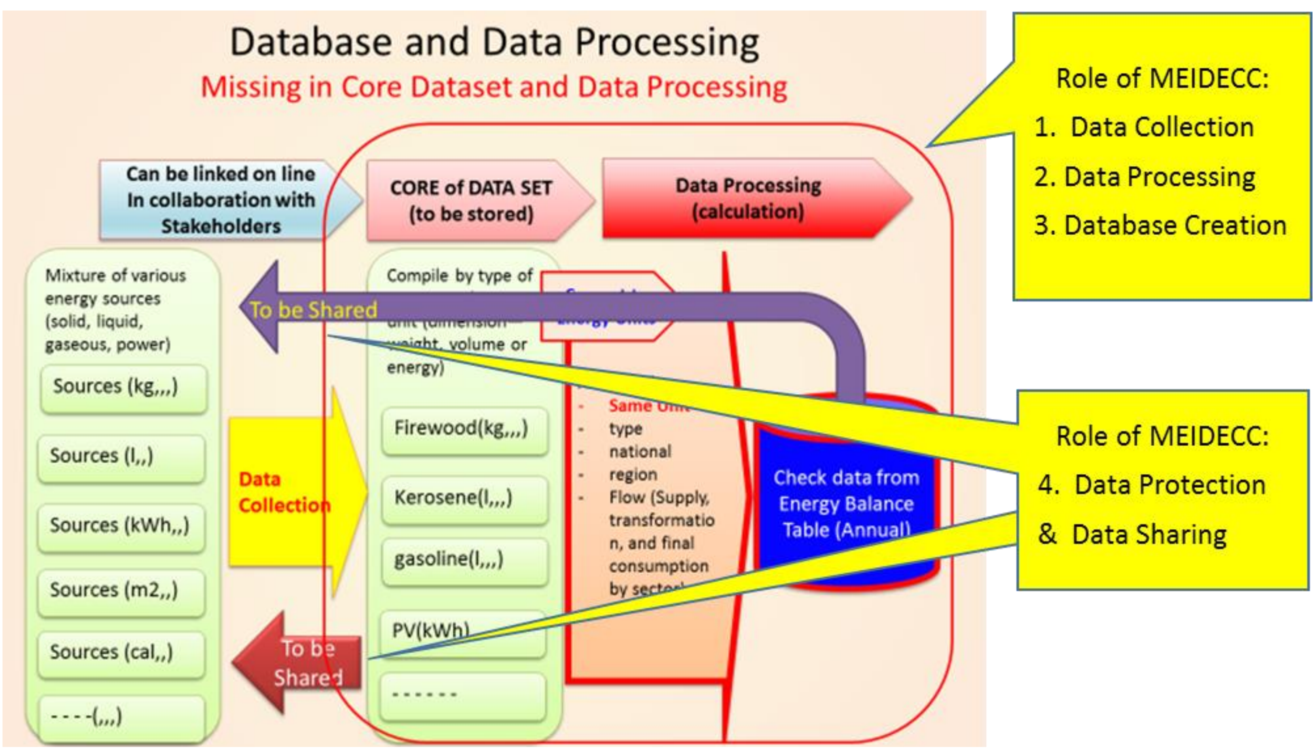


Figure 6 - Flowchart of Data Collection and the Role of DOE, MEIDECC



1.7 Conclusion: Gaps and challenges in current system

Required data and the available data

Tonga depends largely on oil products including for power generation. The data related to TPL, namely the use of diesel oil for power generation and the outputs of the power (GWh) is available. Most of the other data is very limited in terms of availability.

Stakeholders and the regulatory framework

Key stakeholders include Department of Energy, Department of Statistics, TPL, and oil companies. Among all, the role of DOE is the most important for data collection at the national level, storage, and utilization. Currently, however, a regulatory framework to empower DOE for data collection is missing. Agreements for voluntary data submission or other alternative ways have to be used if mandatory submission of the data is difficult.

Data collection

Currently, there is no clear system of data collection focused on energy. There are many ways of data collection including voluntary submission and mandatory submission for supply side, sample survey, use of census and use of alternative data for estimation. Institutional roles need to be clarified to select the most effective method of data collection that is implementable within resource and institutional constraints.

Database and data sharing

Currently there is no database (except a draft version by SPC), which covers the whole flow of energy, from its supply to consumption. The design and construction of database in parallel to data collection is very important to take advantage of the existing data as well as to share information with other stakeholders.

Challenges and recommendations

There is a large gap between the current and the ideal status of data preparation (IEA's requirement as an example). Achieving this ideal status will require a practical step-by-step approach, as listed in the example below:

- Set priority of data based on needs;
- Explore various options for data collection subject to feasibility constraints:
    - Seek agreements for voluntary (or mandatory) submission of data from oil companies and TPL (supply side);
    - Seek cooperation from DOS to use census survey for residential and commercial data;
    - Explore the use of sample survey to find the use of oil products for each sector;
    - Explore the options of alternative data for estimation of data such as rooftop PV and the use of firewood.
- Construct a database and energy balance table using currently available system for example excel spreadsheet (recommended), which can be easily upgraded to a sophisticated software

later. The expansion and refinement of the draft database currently in preparation by SPC are highly recommended;

- Assignment of expert staff for the database. It is strongly recommended to support the current expert of MEIDEC/PCREEE to strengthen data collection and the creation of database.

2 Review of Tonga Energy Road Map

2.1 Review of the progress

Tonga Energy Road Map (TERM) 2010-2020 is a 10-year action plan that aims to address concerns on energy security and other national interests. The roadmap outlines actions for the Government of Tonga, development partners and entities such as Tonga Power Limited. This includes achievements of targets of renewable energy (RE), efficiency (EE), and institutional reform. The evaluation of RE and EE targets is not possible without quantitative data. To this respect, TERM is currently under review with a focus on quantitative achievements.

Generally speaking, significant progress has been made in Phase 0, but the achievement by 2020 seems very difficult – the actual implementation is behind the schedule.

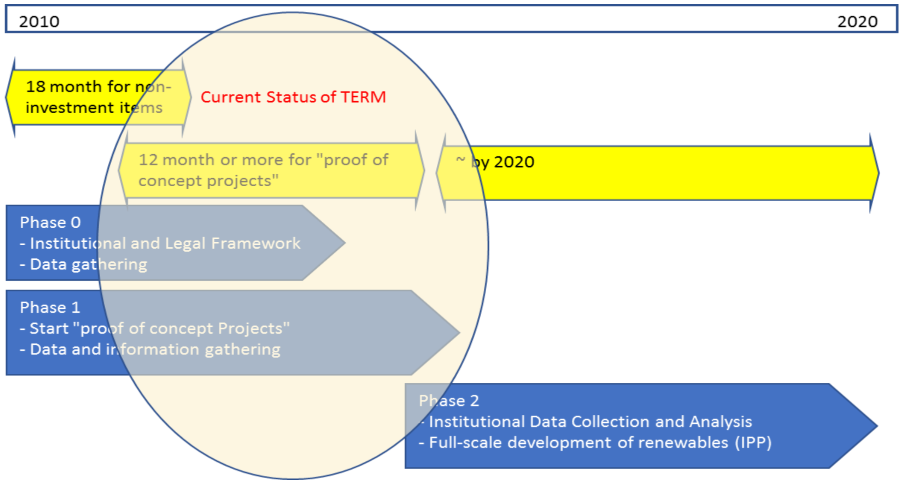
Phase 0: Big steps include the establishment of DOE and preparation of Petroleum Act 2.

Phase 1: Focused on information and experiences. Many projects of training and trial implementation are in progress. Data collection based on the national needs is also critical, as shown in this report.

Phase 2: Focused on data analysis and institutionalization of data collection system. Full scale development of IPP of renewables.

Currently, the progress of each phase is in parallel and the achievements are late Phase 1 or early Phase 2 (see below chart).

Figure 7 – Phases of TERM 2010-2020



The TERM identifies a clear and quantifiable target of achieving 50% electricity generation from RE by 2020. Tonga Power Limited shows indicators of 1) accumulated fuel displacement (amount of estimated use of diesel oil for the total power generation replaced by renewables in %), and 2) Accumulated tariff reduction (%) due to RE, and 3) RE penetration (%) in its annual report. The accumulated fuel displacement is 6% against a target of 20% in 2017. The penetration of renewables is 11%, short of the 25% target in the same year.

The accumulated tariff reduction is better than the target. However, the tariff is regulated and can be changed depending on the price of diesel oil. If diesel oil prices rise, the accumulated tariff reduction can be large.

The TERM specifies an efficiency target of 4.0 kWh/l. This is equivalent to a thermal efficiency of 37.3% (assuming 9200kcal/liter of diesel oil). This efficiency is determined by the specification of the generator and the pattern of operation. An efficiency of 37% is usually satisfactory for small-scale generators (for large scale generators 5 kWh/l or more should be the target). However, as the use of PV increases, the operational pattern of diesel generators may need to be adjusted at the cost of efficiency to optimize the use of renewables and fossil fuels.

In summary, although the progress is slow, achievements are emerging gradually.

Table 4 - Progress of RE implementation

Strategic measures	**2011 Actual**	**2012 Actual**	**2013 Actual**	**2014 Actual**	**2015 Actual**	**2016 Actual /Target**	**2017 Actual /Target**	**2018 Target**	**2019 Target**	**2020 Target**
Accumulated fuel displacement (%)						8 /12	6 /20	30	40	50
Accumulated tariff reduction (%) due to RE						6 /4	10 /5	8	10	12
RE penetration (%)					8.9	10 /15	11 /25	40	50	60
Fuel efficiency (kWh/l)	4.13	3.95	3.99	4.06	4.11 /4.15	4.15 /4.0	4.1 /4.0	4.0	4.0	4.0
Generation (GWh)	53,159.6	523,91.5	53,312.9	54,560.7	55,404.6	60,037.2				
Sales(GWh)			46,388.3	49,165.2	47,817.8	53,341.9				
Fuel consumption (kl)	12,871.6	13,263.7	13,361.6	13,438.6	13,480.4	14,466.8				
Cost of fuel (000$)		22,535.4	22,132.9	23,583.0	19,768.4	15,347.5	19,197.1			
No. customers	20,773	20,758	20,498	20,580	20,633	21,385				
Sales (000$)		44,512.5	40,513.2	41,955.5	44,302.8	44,864.7				
Average tariff (Senitil/kWh)			87.3	85.3	92.6	84.1				

Source: Annual Report of TPL

2.2 *Emerging problems and opportunities*

The challenges that TERM faces can be categorized into 1) internal/domestic and 2) external/foreign. While the former can be solved through domestic efforts, those efforts fall short in formulating solutions against external/foreign challenges. Internal or domestic would include institutional challenges, regulation, tariffs, energy access, and public-private partnerships. These matters fall into the hands of private and public entities including the government of Tonga. The prices of oil products are an external factor and most importantly, the required technologies and finance for renewables are also heavily dependent on foreign countries.

As far as the target of renewables is low, and the scale is small, donor countries can afford to contribute, but it will be relatively difficult once a full-scale renewable energy implementation becomes the target. Although the challenges at the current stage are rather domestic as in Phase 0 and 1, the future for the Phase 2 and beyond can be even more difficult as the source of finance is expected to be external. To make the renewable energy investment in Tonga sustainable, financing needs to be internalized and private sector involvement will be critical for the full-scale development of renewable energy projects on an Independent Power Producer (IPP) basis.

The good news is that the costs of PV and related technologies such as battery storage are decreasing rapidly, while the prices of oil products are not expected to decrease in the future. TERM was prepared in 2010 and the assumptions made then for the development of RE may no longer hold and require updating. The most notable change is the reduction in PV module costs. The possibility of Solar House Systems (SHS) or PV based micro-grid for community level can be a realistic option if compared to the use of diesel generators. Private ownership of PV for personal use and connection to grid for the surplus can contribute to the daytime activity of each household. This can contribute particularly to the welfare and working style of women, who stay in house during daytime. Data on the activity of households, particularly women (gender specific data) could help the emerging importance of private ownership or own use of PV in TERM.

2.3 *Needs of information to capture the emerging national needs*

Currently, Tonga meets most of its energy needs through importation of oil products. Oil products have different characteristics by type. Particularly to be noted is that the usable amount of energy is different by type of fuel. The table below shows the measure of oil products in “litre” and in “kcal”. The share of power in the total energy supply increased from 45.3% (12776489/28176274) to 47.6% (117543699/246794898) in 2012.

Table 5- Petroleum fuels use by type (Litres), 2010–2012

Fuel type and usage	**2010**	**2011**	**2012**
Aviation gasoline (Avgas) used for in-country flights	115,000	226,782	115,000
Jet fuel used for in-country flights	1,611,266	1,224,587	1,069,944

Diesel fuel used for electricity generation	13,086,288	13,105,889	12,776,489
Diesel fuel used for land and sea transport	14,001,342	13,170,987	14,214,841
Total	28,813,896	27,728,245	28,176,274

Source: IRENA Pacific Lighthouses

Table 6 - Petroleum fuels use by type ('000 kcal), 2010–2012

Fuel type and usage	**2010**	**2011**	**2012**
Aviation gasoline (Avgas) used for in-country flights (8400kcal/l)	966,000	1,904,969	966,000
Jet fuel used for in-country flights (8300kcal/l)	13,373,508	10,164,072	8,880,535
Diesel fuel used for electricity generation (9200kcal/l)	120,393,850	120,574,179	117,543,699
Diesel fuel used for land and sea transport (8400kcal/l)	117,611,273	110,636,291	119,404,664
Total	252,344,630	243,279,511	246,794,898

Energy from oil products can be measured in terms of physical dimensions such as weight and volume. On the contrary, energy from renewables such as PV cannot be measured except as output in the form of power in kWh (or equivalent caloric value). Thus, an energy balance table should be constructed based on comparable energy units (e.g. kcal) for all sources of energy.

3 Important regional/international databases: Relevance and potential

The review of the required data structure and available data for Tonga for databases of both PRDR and APEP was prepared in chapter 1. This section focusses on the value of relevance in regional (PRDR) and international (APEP) context. They have distinguished characteristics as international database for Asia-Pacific countries for the case of APEP and as a regional data base of the community of SIDS in the case of PRDR. They are particularly useful for comparison among the members of the community. For example, comparison of supply and demand data to see the differences in energy efficiency, penetration of REs, energy prices etc. can suggest the way to reach to improve and plan the energy supply and demand. Essentially, these databases are an accumulation of data to learn from other countries.

3.1 Example of the use of PRDR as ONE STOP SEARCH

PRDR is a useful source for learning and comparing information across SIDs. However, given that the data structure is not unified, and the level of data collection differs by country, it is difficult to design a database that hosts standardized quantitative data. Rather, PRDR is very well designed for ease of submission and access using an electronic file as one unit to represent a focused group of information.

Table 7 – Data sample from PRDR database

Sample by island/country	**1) Consumption** **MWh/capita- 2012**	**2) Income** **GDP/capita (USD 2011 const.)**	**3) Price** **Tariff (USD cost for 200 kWh/month--2011)**
Am Samoa	2.79	10442.73	86.81
Chuuck	0.46	2961.79	112.4
Samoa	0.58	3634.57	86.52
Fiji	0.96	3719.89	32.47
Kosrae, FSM	0.12	2961.79	77.6
Niue	1.86	5800	99.86
Nauru	2.19	5469.16	20.65
Palau	4.41	9439.07	68.2
Kiribati	0.21	1471.55	82.87
Solomon	0.16	1428.86	176.16
Cook Is	1.93	12900	117.71
Tuvalu	0.62	3219.36	93.75
Tonga	0.51	3631.54	99.47
Vanuatu	0.26	2932.87	175.24

Source: MWh/Capita from http://prdrse4all.spc.int/data/content/pacific-utilities-2012-electricity-tariff-table-ppa-benchmarking, Tariff from http://prdrse4all.spc.int/data/content/regional-power-utilities-basic-information-2011, GDP (2011) from WDI and CIA Fact Book (Niue -2003 and Cook Island – median of 2005 and 2016 data)

For example, the above table is a set of cross-country data to estimate the elasticity of income and price on the power demand. The data for power demand and tariff was retrieved from the PRDR database. GDP and population statistics are from the World Development Indicators and the CIA Fact book. The example's cross-sectional variables are 1) Consumption, 2) Income, and 3) Price using the data of these countries. The purpose is to formulate regression models to explain consumption as variable using income and price as explanatory variables. In this case, linear regression models "Y=β0 + β1 x [X1] + β2 x [X2]" and log transformed "LN(Y)=β0 + β1 x LN[X1] + β2 x LN[X2]" are used by using Consumption for Y, Income for X1, and Price for X2.

The results of the regression analysis are shown below:

Linear model: RSquare 0.67, [Consumption] = 0.57(tStat .91) +.00027(tStat 4.47) x [Income]-.0075(tStat -1.53) x [Price]

Table 8 – Regression results 1

Variable	Constant	Income (GDP per Capita)	Price (Tariff)
Coefficient	0.57	0.00027	-0.0075
t-value	0.91	4.47	-1.53

Double Log model: RSquare 0.82, LN[Consumption]=-10.03(tStat -4.19)+1.41(tStat 6.32) x LN[Income]-.46(tStat -1.79) x LN[Price]

Table 9– Regression results 2

Variable	Constant	Income (GDP per Capita)	Price (Tariff)
Coefficient	-10.03	1.41	-0.46
t-value	-4.19	6.32	-1.79

Both models show significant impacts of income and price on power demand, particularly in the double log model. Both income and price elasticity are represented by the coefficients. In the double-log model, income elasticity is 1.45 and price elasticity is -0.45. The strong positive impact of income on power demand and the negative response to tariff are clearly indicated within these results for the pacific region in the years 2011 and 2012.

The limitation is that the data is not updated, and the dataset is not from the government, but from the Pacific Power Association. Timely and reliable data from the government could contribute to the reliability of this kind of analysis.

3.2 Example of the use of APEP

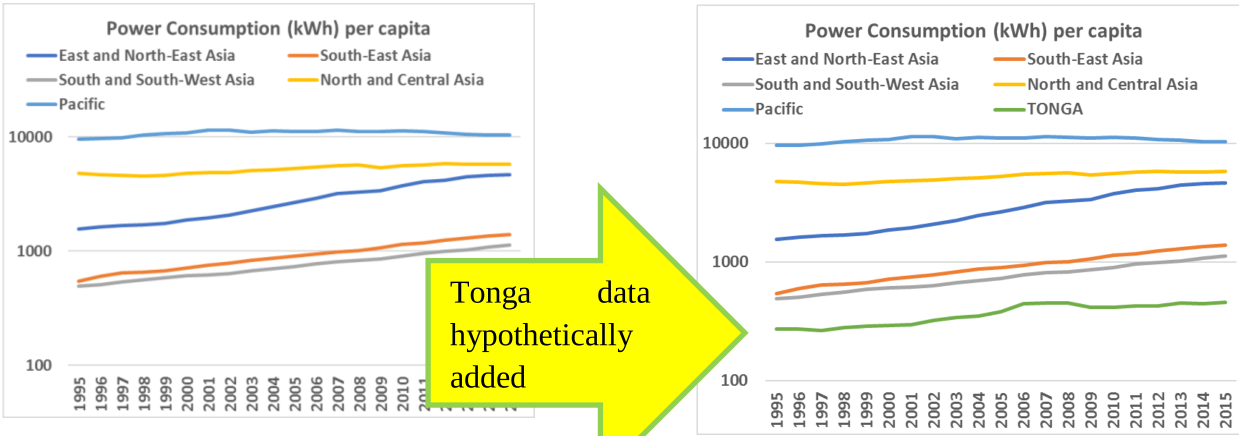
ESCAP's APEP is the most comprehensive energy and energy policy database available for the Asia and the Pacific region, offering an interface for research, analysis and decision-making. The portal consists of 200+ integrated datasets, 3000+ policy documents and 6100+ mapped power plants. Comparisons across ESCAP member states and other world regions can be conducted as shown in the following figures. The indicator used is 'power consumption per capita (kWh)'.

Due to a lack of data, a comparison with Tonga is unavailable. However, a hypothetical comparison has been constructed in this report (as shown in the following figure to visualize a possible comparison. There are other important indicators missing for Tonga, such as 'primary energy supply' and 'final energy consumption'. However, these can be easily derived after the creation of an energy balance table.

Data related to energy is in the menu "Energy and Natural Resources". The first two items; are considered highly important.

Figure 8 - Power consumption per capita in Asia-Pacific sub-region (left)

Figure 9- Power consumption per capita including Tonga (right)



Source: ESCAP

Source: ESCAP and Tonga from TPL

4 Data requirements for demand and supply forecasts

4.1 Trial estimates of relationship between demand and the drivers

The starting point for any energy related future planning is knowing the future demand. This requires identifying the drivers of demand and formulating their numeric relationship. Since energy consumption is a result of socio-economic activity, econometric analysis is one of the most popular techniques for doing this.

This section offers a ‘trial analysis’ and selects two types of energy products 1) electric power and 2) motor gasoline, to represent the transport sector. These energy products are regarded as commodities and are thereby influenced by two drivers: 1) income as a driver of use and 2) price. Both these drivers are prepared to quantify their impacts on demand.

Variables:

Electric power consumption: annual total consumption of Tonga (kWh)

Motor gasoline: annual total consumption of motor gasoline (liter)

Income: GDP in constant USD (inflation adjusted)

Price of electric power: annual average electric power tariff (average of all 12 month). The tariff was adjusted by the price deflator. Typically, the price deflator is CPI (consumer price index), but in consideration that the dominant energy prices to be compared is the prices of oil products, crude oil price, not CPI, was used as the index for deflation.

Price of motor gasoline: Crude oil price in constant USD. Although, actual market) sales prices are preferable, the availability is limited. Thus, crude oil price data (inflation adjusted constant USD) from the BP statistics was used as the fuel prices and crude oil prices are closely linked.

Regression results: formulation of the relationships—1) linear and 2) double log

There are various formulations in the regression model. The selection of the formulation starts typically from the simplest form. To represent simple formulations, two types of 1) linear and 2) double log (or growth model) are prepared. The first model is the simplest in the form of Y=β0 + β1 X1+ β2 X2…….+ βn Xn. The second model is the simplest in the form of Y=β0 x X1^β1x X2^β2…….x Xn^βn. The latter can be transformed to LN(Y)= LN(β0) + β1 LN(X1) + β2 LN(X2)…….+ βn LN(Xn). The selection of model will be followed through the interpretation of the various statistical properties, which will be explained in the next phase of the project. In this trial case, two major indicators, 'R-square' and 't-statistic' is also analyzed. The former represents the fitness of the whole equation and the latter represent the fitness of each coefficient.

CASE of electric power demand 1: Explanatory variable - GDP only – t-values are followed in "()" after the coefficient.

1) 1995-2015: R.767; [Power Consumption (kWh)] =-44178200(-4.26) +.23815(7.91) * GDP
2) 1995-2015: R.798; LN[Power Consumption (kWh)] =-26.975(-5.26)+2.259(8.66) * LN(GDP)

CASE of electric power demand 2: Explanatory variable - GDP and price

1) 1995-2015: R.743; [Power Consumption (kWh)] =-35710300(-2.31) +.23052(5.97) GDP-594045000(-1.32) [Tariff/Crude oil price]
2) 1995-2015: R.779; LN[Power Consumption (kWh)] =-25.96(-4.03)+2.1629(6.44) LN(GDP)-.19(-1.55) LN(Tariff/Crude oil price)

CASE of motor gasoline 1: Explanatory variable - GDP only

1) 2004-2016: R.301; [MOGAS Consumption (liter)]=-13005700(-1.07)+.071866(2.18) GDP
2) 2004-2016: R.245; LN[MOGAS Consumption (liter)]=-16.106(-.94)+1.6481(1.89) LN(GDP)

CASE of motor gasoline 2: Explanatory variable - GDP and price

1) 2004-2016:R.503;[MOGAS Consumption (liter)]=-7560150(-.681)+.067128(2.29) GDP-43372(-2.02) [Crude oil price]
2) 2004-2016: R.450; LN[MOGAS Consumption (liter)]=-10.503(-.67)+1.417(1.79) LN(GDP)-.2375(-1.93) LN(Crude oil price)

The above analysis indicates a positive relationship between demand and income (GDP) and negative relationship between the demand and prices. For both power and transport, income elasticity is more than 1 and the price elasticity is around -0.2. This analysis foretells that as income levels rise in Tonga, the rise in energy consumption is disproportionately larger.

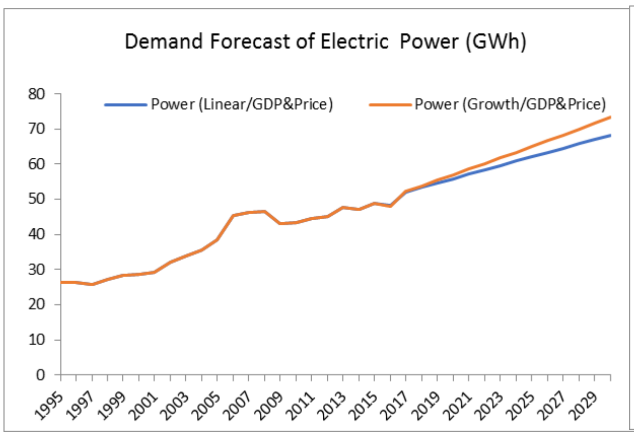
4.2 Trial forecast

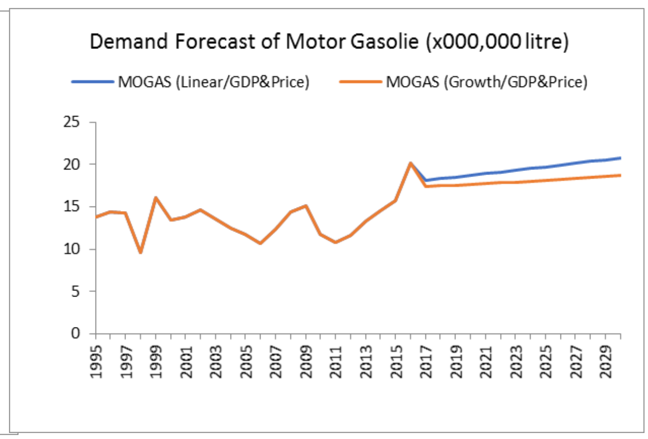
Based on the above result, a business-as-usual (GDP and prices are projected in linearly) case is developed below for the linear and growth (double log) models. The past variations in MOGAS is comparatively large compared to the demand of the power. As a result, the reliability of the MOGAS model is relatively weak and the result should be carefully analyzed.

More detailed analysis will be conducted in the next phase.

Figure 10 – Electricity Demand Forecast (Left)

Figure 11– Motor Gasoline Forecast (Right)





4.3 Computer Software for database and data analysis

There are many software packages, which can potentially assist the national needs of energy planning in Tonga. One way to categorize them is as supply oriented and demand oriented. In practice, many packages are oriented to the supply side. Examples include WASP (Focused on Power), MARKAL, EFOM (or TIMES: Integrated MARKAL/EFOM), ENPEP-BALANCE. Most of them are based on a method of optimization, which try to find out an optimum supply option under given demand. These models use so-called mathematical programing (linear and non-linear optimization), requiring intensive data of various kind of technologies. Looking at current status of the energy market in Tonga, these supply-oriented packages seem too complex and rather difficult to handle in terms of theoretical and practical requirement of data.

As for demand side models, they deal with economic activities and treat energy as a commodity. Most methods utilize economic and/or econometric analysis and there are few software packages that do this with a dedicated focus on energy. Moreover, the energy-economy interactions can vary significantly by country. Hence, it is difficult to create a generalized package, which can be applied to all countries.

One exception is LEAP (Long-range Energy Alternatives Planning), which is a database-oriented accounting model and the use of methods such as optimization and econometrics are rather complementary. Essentially, it is a tool to analyze an energy balance table; therefore, from Tonga's perspective, LEAP may be a suitable first option.

However, considering the size and the limited characteristics of the energy market in Tonga and its organizational capacity, an Excel spreadsheet will be the most useful and realistic option in terms of its versatility and flexibility. Data in excel spreadsheets can later feed into the above software as Tongan energy markets develop further, and advanced models are needed to handle the resultant complexity. Hence, if models are prepared in excel worksheets, they can then be integrated or upgraded to the above packages at a later time with relative ease.

5 Conclusions

5.1 Findings

Information is available but scattered around various Ministries and Agencies. With regards to energy information:

1) The aggregate information on imported petroleum products is collected by the Inland Revenue Department the Port Authorities, and the Ministry of Labor, Commerce, Industries and Innovations (MLCII).
2) Sometimes there are discrepancies in the aggregate information kept by various entities.
3) The information gathered by the MLCII, from the private sector entities, focuses more on financial and economic information and less on energy. Changes to the regulation or legislation must be made to include more relevant energy information from the companies involved in petroleum imports and wholesale, including retail companies perhaps.
4) With regards to the power sector, energy information is gathered and shared by the Tonga Power Limited (TPL). TPL has its own home page to show its sales data and information. However, the data is not yet disaggregated by sector and the data is in a format of a report. Thus, the most pressing needs are perhaps in the validation area and the information dimension and format.
5) Linkages, coordination and flow of information [frequency and how] are not very clear. Legislation and policy development (see below) can help speed up and clarify the responsibilities, type, frequency and restrictions on certain data.

6) The private sector provided the least information perhaps due to commercial sensitivity and due to the effort and expenses involved. A clearer and expanded information requirement must be included as part of their reporting responsibilities and linked to their various business licenses, to be managed and collected by the MLCII and the Inland Revenue. This information can be validated by cross-checking with the information provided by the petroleum wholesale companies.
7) A centralized energy information hub has not been established or put into practice. There are two prongs proposed: 1] National Hub – for all information and 2] and Sector Hub – for the various sectoral Ministries.
8) An information validation process or methodology does not exist.
9) Information sharing, alignment and availability, particularly with global or regional data sources is not well organized.
10) Information dimensions and format are not consistent, internally or externally.

5.2 Energy Balance Table

1) Based on the national, regional and international needs of energy, existing data and missing data are explored from the point of view to create database based on energy balance table of Tonga. The energy balance table can be harmonized with international standards using IEA guidelines.
2) The energy balance table is a vital information tool which can contribute to and enable 'evidence-based policy development' and 'monitoring of the various projects in Tonga'.
3) In fact, even with the currently available data, a rough energy balance table can be constructed as demonstrated by a draft database prepared by PCREEE (which is even located in Tonga).
4) It is strongly recommended to support the creation of energy balance table by establishing official data collection paths and expanding collaboration between MEIDECC and other stakeholders, particularly oil/gas companies, department of statistics and inland revenue (custom data).
5) Since several stakeholders are involved in the collection of energy data, it is important to establish a central government agency such as the National Planning Office, that can be assigned the leadership role in coordinating the exchange of required data and information.

5.3 Proposed Changes

1) The Ministry of Statistics continues to be the National hub for information.
2) However, each major Ministry [including the Energy Department of MEIDECC] should produce and collect data directly from the relevant source and validate core information relevant to its work. In addition, they should also include the following characteristics and core functions:
    i. Frequency, format and dimensions

ii. This Ministry [including the Energy Department] must validate the information gathered.
iii. Other relevant Ministries producing information appropriate to the work of the core Ministry [including the Energy Department] should coordinate the information produced and its frequency, dimension and format so that it can reduce duplication and collection expenses.
iv. MEIDECC and particularly the Energy Department must have the capability to produce an energy information table which must be aligned and compatible with similar tables used globally.

3) The data and information collected and produced in 2) above should be centralized and consolidated into an online platform e.g. a data portal. The same information should be made available on the statistics department website or alternatively a web link could be established.
4) General economic information can still be collected, validated and stored by the Statistic Department but should be done in close collaboration with various Ministries. For the Energy Department information regarding household spending on energy – [power, vehicles, others], type of home appliances etc. questionnaire(s) should be developed in collaboration with the Energy Department. Its frequency should also be agreed upon with the Statistic Department
5) The need for coordination and alignment is a very vital one and can be addressed through a clearly defined process and procedures in place.

5.4 Policy Development

1) A Memorandum of Understanding can be developed and agreed upon and signed between the Department of Energy and the relevant Ministries to formalize this relationship. These Ministries and Agencies must include at least the following entities:
    i. MEIDECC
    ii. Ministry of Revenue and Customs
    iii. Ministry of Infrastructure
    iv. Ministry of Labour, Commerce, Industry and Innovation
    v. Ministry of Finance and especially the Department of Statistics
    vi. Tonga Power Limited
    vii. Tonga Airport Limited
    viii. Port Authority Tonga
    ix. Tonga Power Commission
2) The Memorandum must specify the energy information required by the Department of Energy in terms of information type, format, dimensions and frequency.
3) The Department of Energy must develop its own capability to validate this information. International organizations such as ESCAP can play a valuable role in developing such data-relevant capabilities through its technical co-operation and capacity building functions.
4) The Department of Energy must have a website where this information can be made available and accessible.

5) The energy balance table must be the tool utilized to record and align this information.
6) The energy balance table must be formatted in alignment with the formats used globally and must be updated regularly – at least on a semi-annual basis.

5.5 Public relation/dissemination

It is recommended to publish a periodical analysis using such a national database for example an 'energy security index'; as an example of using national data to share the activities and achievements of the data collection and database creation.