Asia-Pacific
Economic Cooperation

Peer Review on Low Carbon Energy Policies in Papua New Guinea

Final Report

APEC Energy Working Group

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APEC Peer Review on Low Carbon Energy Policies (PRLCE) Phase 4

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TABLE OF CONTENTS

PREFACE

The APEC Peer Review on Low Carbon Energy Policies (PRLCE) was endorsed by the APEC Energy Ministers in the 2010 Energy Ministers Meeting. The review is an extension of APEC Peer Review on Energy Efficiency and follows its guidelines. The PRLCE seeks to achieve the following objectives:

- Share information on low carbon energy performance as well as on policies and measures for improving and promoting low carbon energy in respective economies;
- Provide opportunities for learning from the experiences of other economies and for broadening the network among low carbon policy experts;
- Explore how low carbon goals on an overall and/or sectoral basis and action plans could be effectively formulated in each economy under review, taking into account the range of possible strategies that could be used, according to the circumstance of each economy;
- Monitor progress on attaining low carbon energy goals on an overall and/or sectoral basis and implementing action plans, if such goal and action plans have been already formulated at the time of the review;
- Provide recommendations for voluntary implementation on how implementation of action plans could be improved with a view to achieving low carbon energy goals.

Papua New Guinea volunteered to undertake the sixth peer review on low carbon energy supply policy, after Thailand; the Philippines; Indonesia; Malaysia and Viet Nam. A Peer Review Team of 11 experts (*see Appendix A*) visited Port Moresby, Papua New Guinea from 1–4 August 2017 to conduct the peer review. This report presents the peer review results in Papua New Guinea. Papua New Guinea and the Peer Review Team share the primary accountability of this review.

During the visit, the Peer Review Team had open and constructive discussions on Papua New Guinea's low carbon energy policies and programs with representatives and experts from different lines of government ministries, academic institutions and energy companies *(see Appendix B*). The Peer Review Team wishes to thank all the presenters and participants who spent time with the team for discussions, especially the representatives from the Energy Wing, Department of Petroleum and Energy who co-organised the event.

EXECUTIVE SUMMARY

Blessed with a good geographical location and a wealth of natural resources, Papua New Guinea (PNG) has immense potential to tap on the full range of renewable energy (RE) options to promote low carbon energy development in the economy. However, current installed RE capacity is far below its potential. Even hydropower, the most dominant RE resource in PNG today, has less than 2% of its potential capacity installed in the economy (Department of Petroleum and Energy, 2017)[1].

With 53% of its population living below the national poverty line (PNG Department of Treasury, n.d.) and a 13% electrification rate, the PNG government has made it imperative to develop its RE resources to improve living standards and drive higher economic growth. In the "Papua New Guinea Development Strategic Plan 2010-2030", the government set an ambitious target of achieving 100% of power generation from RE sources by 2050, and increasing electrification rates to 70% by 2030.

The Peer Review Team noted that the targets set by PNG appear overly challenging, given the current low starting point and PNG's economic conditions. Furthermore, the feasibility of these targets are unable to be properly determined given the lack of thorough resource assessment. While a number of energy policies has since been developed to work towards the targets, stronger government commitment is necessary to drive these draft policies to implementation. This includes a commitment to do the following:

a. Have **sufficient political will** at all levels of the government to prioritise energy issues and push through policies;
b. Obtain **sufficient data** for proper assessment of the requirements of the economy (and its people) versus available resources;
c. Dedicate **sufficient human and monetary resources** to strengthen build up the necessary capabilities in the RE and energy sector;
d. Foster **better communications with all stakeholders** (private and public) to ensure alignment of objectives;
e. Other than the focus on quantity such as increasing RE and electrification rates, PNG should also look into the quality of energy services, by maintaining the **reliability of electrical supply** to boost confidence from the public as well as private investors.

[1] Based on the PNG Background Information, current installed hydropower capacity in PNG is 230 MW whereas a full resource mapping of hydropower reveal that PNG has a potential of 15 000 MW capacity.

To help PNG advance towards its RE targets and improve the effectiveness of its policies and implementation programs, the Peer Review Team made 44 recommendations to the PNG government for voluntary implementation. They are centred around 12 focal areas – overarching findings; institutional context; renewable energy goals, targets and strategy; regulations and infrastructure; bioenergy: hydropower and ocean energy; solar PV, geothermal energy, wind energy; power supply system, smart grid and private participation; and greenhouse gas management.

The recommendations detail possible steps that the PNG government could adopt in enhancing its commitment to meet the RE targets, such as:

a. **Seek inputs from various stakeholders** through surveys and consultations first, to get a good grasp of their thinking and requirements. After incorporating their feedback, the government will be able to make better-informed decisions when structuring policy strategies and action plans. For example, the willingness and ability to pay for electricity by the urban and rural areas would serve as good inputs to the ongoing electricity tariff review.
b. **Phase out its priorities** and narrow down its focus at each point of time. This will help increase policy success rate by preventing overstretched resources and attention. For example, while PNG has put in place various sub-sector programs for all forms of RE, there have not been much data or policy guidelines regarding ocean energy, geothermal energy, bioenergy and wind energy. It might be better to focus on the development of certain RE at different times.
c. **Adopt best practices from APEC economies and international standards.** PNG can consult other economy stakeholders to learn about the challenges and success factors in implementing RE technologies. It will also be good to rely on international standards (e.g. standards established by the International Electrotechnical Commission) when establishing regulations on technological performance to ensure workability and consistency.
d. **Support pilot projects starting within the government or at academic institutions** to boost confidence and awareness on new RE technologies.
e. **Raise public awareness on the importance of sustainable energy developments and benefits of RE to the community.** The implementation of various RE efforts requires land space and upfront costs. The public and landowners should be adequately apprised of the benefits and costs of the projects, so that they can work with the government under a common understanding.

SUMMARY OF RECOMMENDATIONS

Overarching Findings

Recommendation 1: Conduct survey.

Recommendation 2: One step at a time.

Recommendation 3: Tariff review – Government should, with inputs from PPL, work towards setting a tariff level that reflect actual costs to support sustainable development of energy projects.

Recommendation 4: Capacity building.

Recommendation 5: Training – Assess the requirements of its workforce and review the need for training across the board, including knowledge transfer from foreign investors to the locals.

Recommendation 6: Education and public communications.

Recommendation 7: Awareness raising – The Department of Petroleum and Energy (DPE) to collaborate with relevant agencies to develop and circulate information, education campaign (IEC) on the energy policies/projects.

Institutional Context

Recommendation 8: Ensure sufficient human resources to drive energy policies.

Recommendation 9: The PNG Government should allocate enough budget for RE and other energy policies including personnel expenditure.

Recommendation 10: Many government officials are designated as “acting” officers. This situation should be made known to higher officials (maybe at the ministerial level) and rectified in order to give clear mandate to the relevant officials.

Recommendation 11: Communications across government agencies should be improved to ensure that each agency is aware of what another agency is doing. In the long run, there should be further streamlining across government agencies. It is important to provide individual agencies with a clear division of responsibilities so that resources can be deployed effectively.

Recommendation 12: DPE should foster closer contact with all RE stakeholders. It might be better to create a standing committee on RE policy for closer links and communication between relevant government agencies.

Recommendation 13: More consultation with private companies during the development of market policies, and more public engagement prior to rolling out public infrastructure plan.

Renewable Energy Goals, Targets and Strategy

Recommendation 14: PNG should focus attention and resources on a near-term action plan to develop the lowest cost renewable resource available near load centres.

Recommendation 15: PNG should engage with rural communities to develop a remote, off-grid power system as part of delivering other public services, such as health, mobile banking, agricultural marketing, or remote education.

Recommendation 16: PNG should prioritise new renewable and energy-efficient technologies as part of its energy development strategy.

Regulation and Infrastructure

Recommendation 17: PNG should rely on internationally-recognised standards when establishing new regulations covering the performance of technology.

Recommendation 18: PNG should consider establishing performance standards for electricity providers, such as benchmarks for reliability and line losses, to complement economic regulation.

Recommendation 19: PNG should analyse latent demand for electricity so that capital-intensive energy infrastructure investments can be optimised to meet customer needs in non-electrified areas.

Recommendation 20: PNG should consider whether electrification policies should be implemented by a dedicated entity or programme, such as a programme within DPE, to enable PPL to focus on meeting reliability needs in load centres and with new industrial customers.

Bioenergy - Biofuels, Biomass

Recommendation 21: Take best practices from other APEC economies regarding biofuel implementation.

Hydropower and Ocean Energy

Recommendation 22: Enact a law that provides policy direction and incentives on developing hydropower and ocean resources.

Solar PV

Recommendation 23: Establish solar energy demonstration projects at school campuses.

Recommendation 24: Design stand-alone solar lighting system pilot projects for rural villages and develop a sustainable financial model.

Geothermal Energy

Recommendation 25: Enact a law that provides policy direction and incentives on developing geothermal energy resources.

Wind Energy

Recommendation 26: Early planning of wind turbines installation

Recommendation 27: Offering of incentives to private investors.

Recommendation 28: Construction of off-grid wind turbines.

Recommendation 29: Enhancement of scale of target installation.

Recommendation 30: Encourage communication with various stakeholders.

Recommendation 31: Government support for research and training.

Power Supply System, Smart Grid, Private Participation

Recommendation 32: The investment focus should move from individual 'least-cost generation projects' to a 'least-cost generation portfolio' approach.

Recommendation 33: Better understand the drivers of electricity demand.

Recommendation 34: Start developing capability to assess the impacts of solar photovoltaic generation.

Recommendation 35: Better understand the affordability versus cost, and consumers' willingness to pay (particularly for rural electrification).

Recommendation 36: Consider moving to more cost-reflective pricing structures in the medium term (temporally, and spatially).

Greenhouse Gas Management

Recommendation 37: Expedite the implementation of National Climate Change Policy, and formulation of NEP.

Recommendation 38: Greening road transport.

Recommendation 39: Turning waste into energy.

Recommendation 40: Provide more incentives for energy efficiency (EE) and RE initiatives

Recommendation 41: Raise the awareness of EE and RE.

Recommendation 42: Encourage more sectors and NGOs to participate in market driven CDM projects to mitigate GHG emissions.

Recommendation 43: Adoption of GHG management tools.

Recommendation 44: Develop and implement building energy codes for new buildings.

APEC PEER REVIEW

ON LOW-CARBON ENERGY POLICIES (PRLCE)

Part I: Background Information

1. OVERVIEW OF DEMOGRAPHICS IN PNG

Around eighty-seven per cent of Papua New Guinea's (PNG) approximately eight million people live in the rural areas represented by a diverse and highly fragmented population with over 800 distinct languages. Population densities outside of major urban centres and the Highlands area are very low although if access to and use of arable land is considered actual densities are quite high. Even though PNG has experienced very high per capita growth rates in excess of 8% for a number of years now, the benefits are not very widespread as of yet and PNG has poverty rates in excess of 30%.

As of 2010, access to electricity is available to slightly over 13% of all households mainly in urban areas while the majority of the population who live in highly spread out locations do not have any access to electricity. Access to electricity is seen as a basic social need and an important driver of development to improve living standards as a basic social need. Women and children are particularly disadvantaged by this very low access, as electricity is seen as critical for complementing basic education needs and providing competent health facilities. The PNG Government recognises this as a major development priority and is one of the objectives of the Vision 2050 development plan.

PNG's background information is similar to the Philippines because virtually all the renewable energy sources in the Philippines are also found in PNG. The only notable differences between the two economies are the population size, the industries and setup of institutions with its legal entities, policies and regulations, which are more advanced in the Philippines than in PNG. PNG's guiding principles for Low Carbon growth are aligned with the Sustainable Development Goals (SDGs) and the PNG Energy Sector Development Programme (PNGESDP) which houses the National Electrification Roll Out Plan (NEROP) projects with households electrification access targets to reach 70% by 2030 and the PNG V2050 with target for PNG to be powered 100% from renewables by 2050.

PNG decided to use the Philippines template to progress our PNG Background information sooner because of its similarity and noting the short lead time before the PRLCE meeting in PNG. Furthermore, we intend to use this document as a basis to plan and progress our work into the future. We also aspire to use it to develop our institutional structures and set-up and align it better to suit the current socio-economic situation of the economy. We also aim to use this preliminary base data to position and prepare ourselves better for the future as the LC programme is reviewed.

2. ENERGY SITUATION

2.1 Primary Energy Supply

The economy's total primary energy supply (TPES) in 2014 reached 2.479 MTOE, 6.4% higher than the 2013 level of 2.321 MTOE (*Figure 1.1*). Total indigenous energy production decreased by 0.7% from 0.576 MTOE in 2013 to 0.598 MTOE in 2014 relative to TPES. Net imports grew by 3.5%, from 1.680 MTOE in 2013 to 1.882 MTOE in 2014.

PNG's energy situation is characterised primarily by a high reliance on imported fuels. In 2014 (*Figure 1.1*), oil remained as the economy's major energy source, accounting for 44% of the primary energy supply mix, followed by petroleum products with 32.0% then by geothermal/solar with 15%, natural gas with 6% and hydro with 3% share. In 2013 (Fig 2), Oil remained the major energy source, but this time accounting for 58.5% of the primary energy supply mix, followed by petroleum products with 17% then by geothermal/solar with 16%, natural gas with 5% and hydro with 3% share.

Therefore, there is an imminent need to act now and reduce the heavy reliance on imported fossil fuels by diversifying the supply fuel mix and at the same time increase the efficient use of current fossil fuel power generation sources. PNG has abundant indigenous renewable energy sources in hydro, solar, biomass, biogas, biofuel, wind, geothermal, ocean wave and tidal.

The government's export of oil to support the economy in the 1990's was a short-term measure. Similarly, as a natural gas producing economy, the government is doing the same for natural gas by exporting LNG. Challenges will remain in the short−term, but planning and implementing suitable measures today will enable substantive reductions in the medium to long - term. This will improve PNG's macro - economic stability by making it less vulnerable to volatile international fuel prices and high import payments.

PNG's main energy commodity exported is LNG, which is currently exported to Asia, especially Japan. On the other hand, biomass remains the traditional fuel for cooking in the rural and peri-urban areas whilst LPG use is common in the urban setting. In terms of renewable energy contribution, hydropower continues to be the major electricity producer whilst other promising energy sources such as geothermal and solar are yet to make a significant contribution. Wind energy source also looks promising but is suitable for certain Maritime Provinces and coastal locations. More wind speed data assessment and monitoring (resource mapping) needs to be established for each specific site.

Figure 1.1: Total Primary Energy Mix (In Percent), 2014

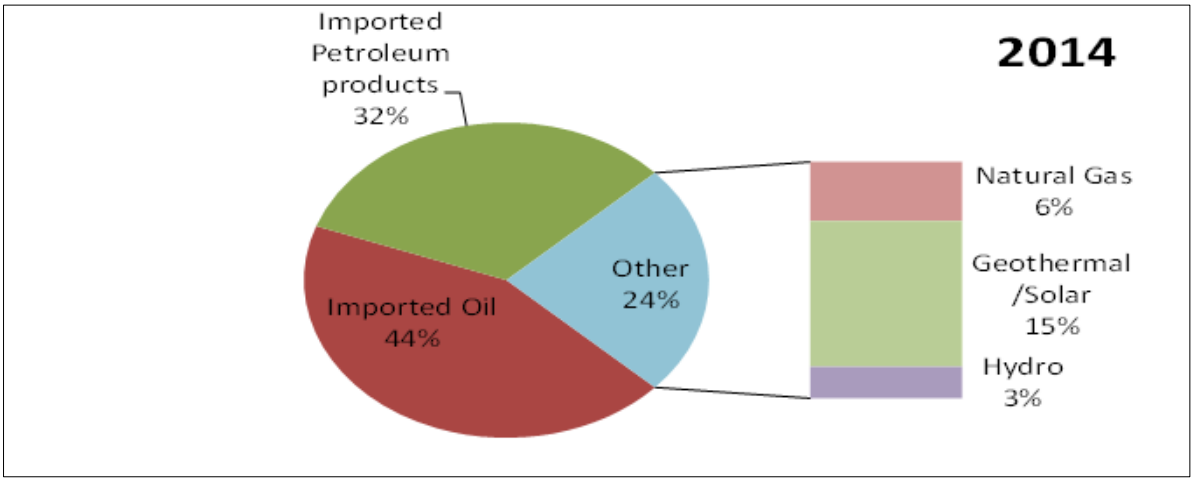
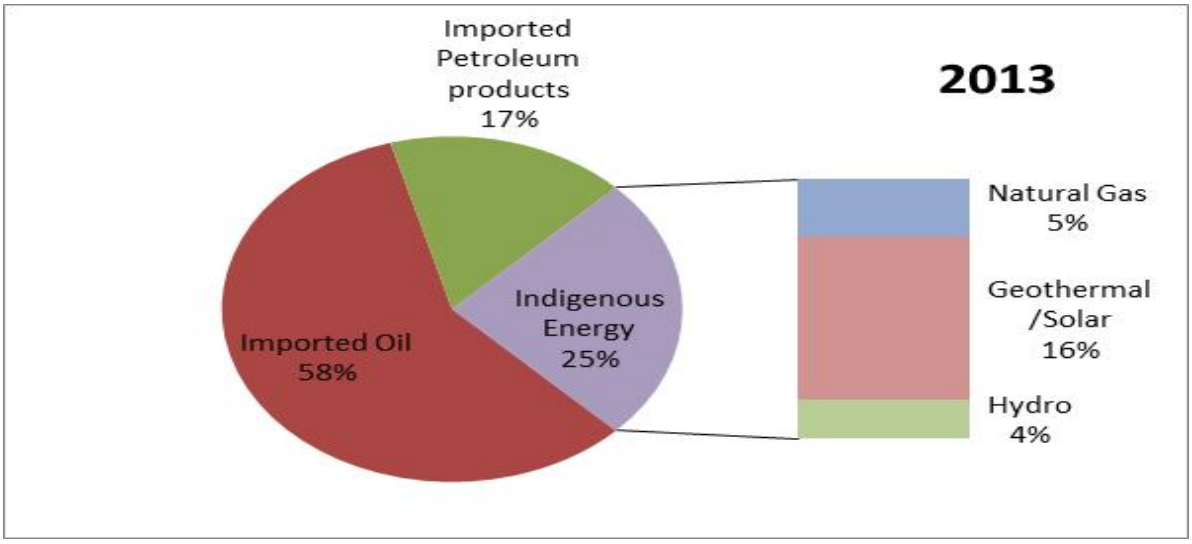


Figure 1.2: Total Primary Energy Mix (In Percent), 2013



2.1.1 Indigenous Energy (Domestic Energy Supply)

Total indigenous energy production decreased from 0.7%—1% from 2.479 MTOE in 2014 from 2.321 MTOE in 2013 relative to TPES (*Figure 1.2*).

Table 1: Local Energy Production in MTOE, 2013, 2014

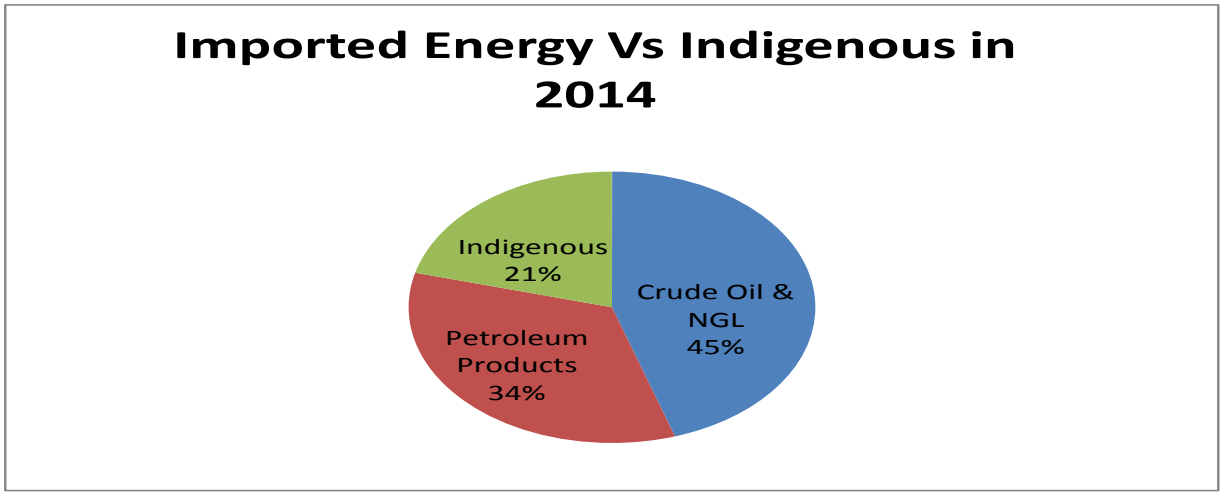
	ENERGY SOURCE	2013	2014
Fossil Fuels	**Oil**	0.799	0.819
	Natural Gas	0.127	1.502
Renewable Energy	**Geothermal/Solar**	0.363	0.363
	Hydro	0.086	0.088

2.1.2 Imported Energy Supply

Net energy imports in 2013 accounted for 72.4% of the TPES. In 2014, net energy imports accounted for 84.5% or 12.1% increase relative to TPES from the 2013 level. Net imported energy in 2014 is comprised of nearly 100% oil and oil products.

There are ethanol exports by Ramu Agro Industries Ltd but are not captured in the Energy Balance Table. We are determined to capture these information and others for inclusion into our Energy Balance Tables to better reflect the Energy Supply and Demand in PNG. There is also keen interest for biodiesel use in the transport sector to ease demand on oil imports.

Figure 1.3: Net Energy Products Importation, 2014

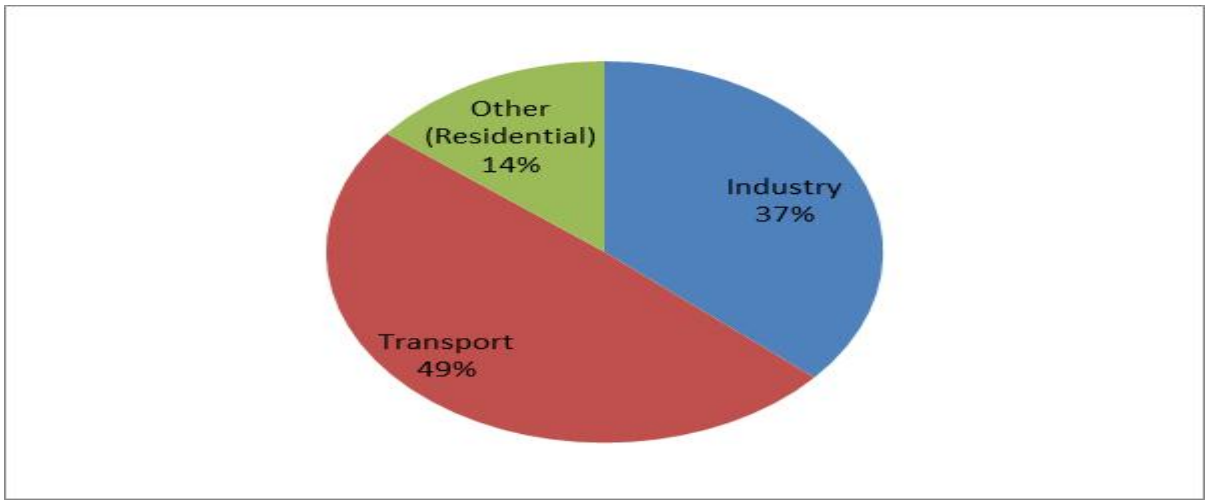


2.1.3 Total Final Energy Consumption

Total final energy consumption (TFEC) in 2014 reached 1.194 MTOE, a 5.1% increase from the previous year's level of 1.133 MTOE.

By sector uses of the TFEC, in 2013 the Transport sector remained as the biggest energy-consuming sector with 49% share of the total final energy demand, followed by industry with 37% and residential with 14%.

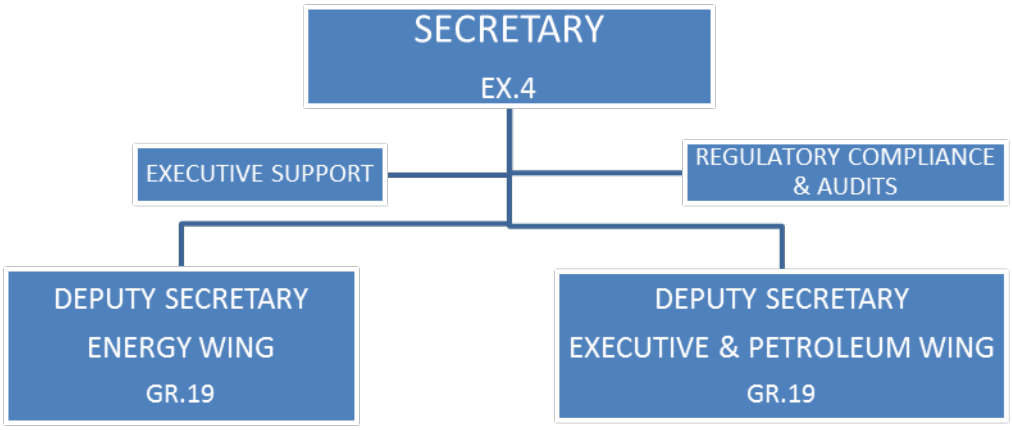
Figure 1.4: Total Final Energy Consumption by Sector, 2014



3. ENERGY SECTOR: STRUCTURES AND STAKEHOLDERS

3.1 Department of Petroleum and Energy Management

Figure 1.5: Department of Petroleum and Energy Management Structure



For matters relating to approval by the head of the organisation, the Acting Deputy Secretary Energy Wing and the Acting Deputy Secretary - Executive shall present it to the Secretary for his/her decision.

The following are the functions of the two main divisions of the Department:

3.2 Petroleum Wing

3.2.1 The activities of the Petroleum Wing are to:

(i) Promote exploration for petroleum resources

(ii) Encourage commercial production of petroleum and the development of downstream petroleum industries

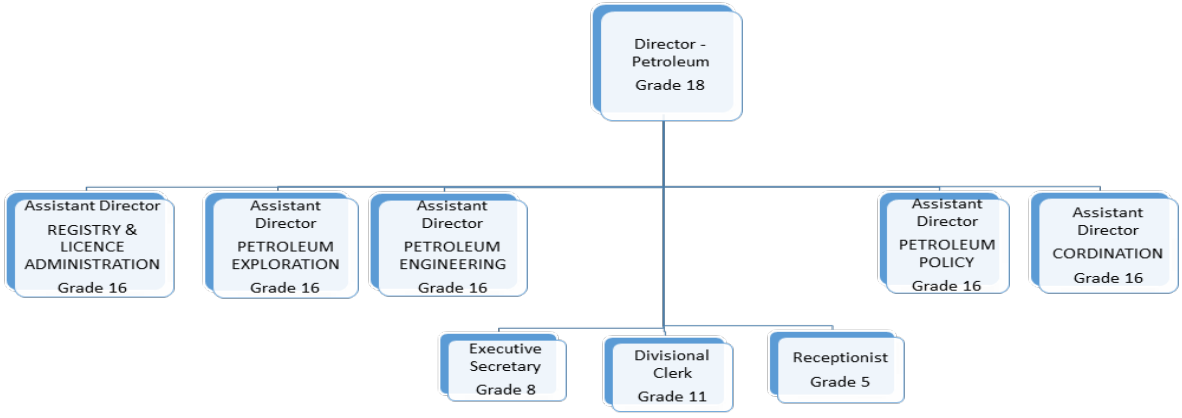
(iii) Negotiate petroleum agreements

(iv) Administer the legislative and fiscal regime legislated by the State and

(v) Carry out research, formulate policy and advise on petroleum related matters

3.2.2 The Management Structure of Petroleum Wing

Figure 1.6: Structure of Petroleum Wing



3.2.3 Other Related Organisations with special relation with Department of Petroleum and Energy

Kumul Consolidated Holdings, KCH (formerly IPBC) was formed by the Government of Papua New Guinea under an Act of Parliament (2002, amended in 2012) for the benefit of the State, to act as the trustee, owner and all-encompassing authority for the State owned assets and enterprises. KCH under its energy sector has embarked on delivering new major hydroelectric projects identified as critical to the long-term energy security for the economy. The Ramu 2 Project (180 MW) launched in December 2016 is one such project. Other projects in the different study and design stages include the Naoro Brown Hydropower Project (60 MW), Karimui Hydro Dam Study (1 800 MW) completed in January 2016, POM IPP Project, Port Moresby Transmission Upgrade Project and the Purari Hydro Project (2 500 MW).

Kumul Petroleum Holdings Limited (KPHL) is Papua New Guinea's national oil and gas company (NOC). The NOC was created by an Act Parliament through the Kumul Petroleum Holdings Limited Authorization Act 2015, which replaced NPCP Holdings Limited.

Through Kumul Petroleum Authorization Act 2015, KPHL is mandated to protect and maximise the value of the economy's petroleum assets such that it can contribute to the maximum wealth for its ultimate shareholders; the seven million plus people of Papua New Guinea. Since its inception in 2009 as NPCP Holdings, the NOC was operating as a commercial entity with its core commercial interest being its participation in the PNG LNG Project.

KPHL is currently responsible for managing the State's 16.57% equity in the US $19 billion PNG LNG Project through its subsidiary Kumul Petroleum (PNG LNG) Limited; becoming the 3rd largest partner in the largest single investment made by the economy to date.
KPHL has the potential to be like Petronas because it has high oil and gas resources and exploration potential in the economy that it will always have an option for 20.5%

The Konebada Petroleum Park Authority (KPPA) was set up by the government under the KPPA Act 2009 as a "free trade zone". The role of KPPA is to facilitate, regulate and manage the park which includes planning and coordinating development through engagement of current and future stakeholders and bring in investment. When the land is declared as free trade zones, it comes with tax incentives to lure investors and ultimately act as a one-stop shop for foreign and domestic investment purposes. The concept is similar as in Vanimo, Madang and the Sepik Special Economic Agriculture Zone.

3.3 Energy Wing

3.3.1 The activities of the Energy Wing are to:

(i) Promote and implement a National Energy Policy and other energy policies,

(ii) Promote better management of the economy's energy and water resources through appropriate planning and

(iii) Provide recommendations on the development of the public and private energy and water sector development.

3.3.2 Planning and Market Development Division

This is the Division tasked to formulate and implement government policies, programs and regulations relating to the exploration, development and production of indigenous petroleum, coal resources, and renewable energy resources and related product and market development.

3.3.3 Rural Electrification Division

This is the Division that carries out project implementation and implement government policies and programs relating to the feasibility studies of mini-hydro's, solar, wind, geothermal, ocean currents and other renewable energy sources.

3.3.4 Regulation and Licensing Division

This Division is mandated to issue generation licenses and other licenses and regulate them under the Electricity Industry Policy (EIP) and also assist PPL by setting up of its four area bases. Also as highlighted in the EIP, the understanding is that the Technical Regulation role will eventually come to this Division from PPL.

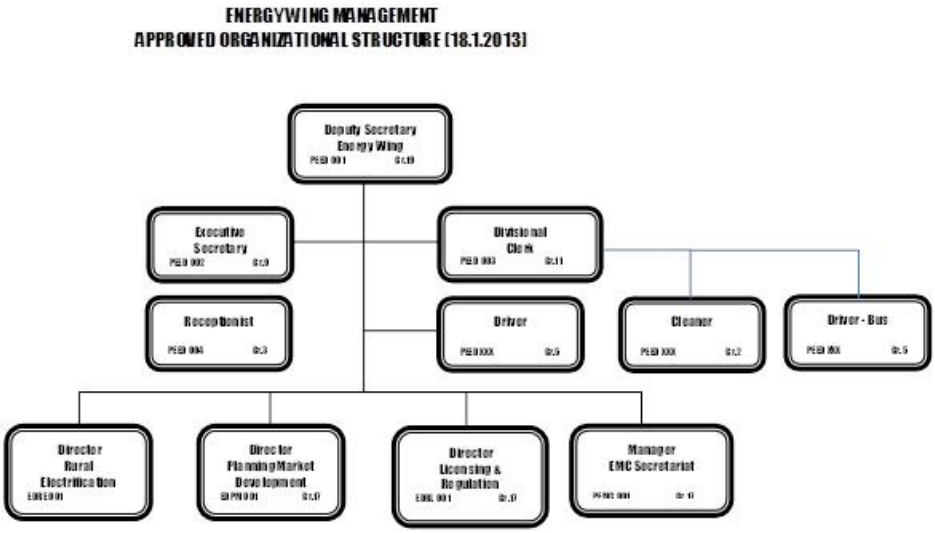
3.3.5 Electricity Management Committee Secretariat

The Electricity Management Committee (EMC) was established under the endorsement of the EIP by virtue of the National Executive Council (NEC)'s decision. Its function is to supervise the implementation of the EIP and simultaneously encompassing the development of energy projects and electricity markets and identify opportunities for different stakeholder partnerships and participation. It is tasked with the responsibility in rolling out the National Electrification Roll Out Plan (NEROP) in the urban and rural areas, plan industry restructuring to establish a competitive, market-based environment, ensures adequate, efficient and reliable supply of electricity, and formulates plans, programs and strategies relative to grid and off – grid electrification.

3.3.6 The structures of the respective arms of the Energy Wing under the Electricity Industry Policy

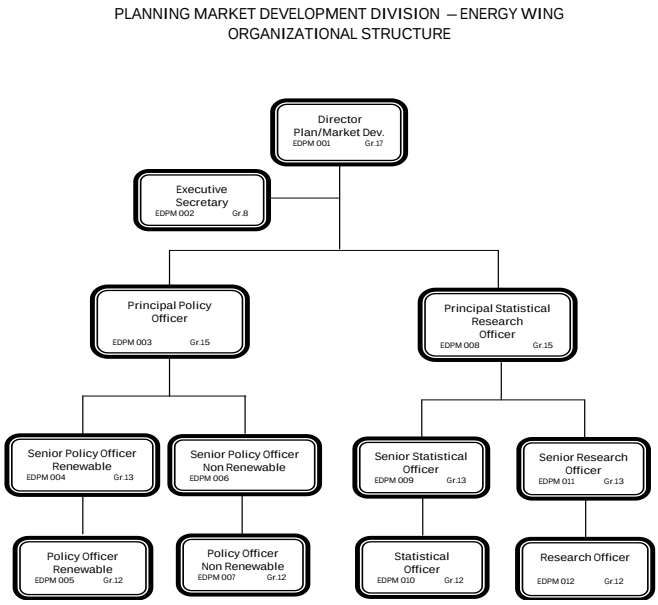
(i) The Structure of Management of Energy Wing

Figure 1.7: Structure of Energy Wing Management



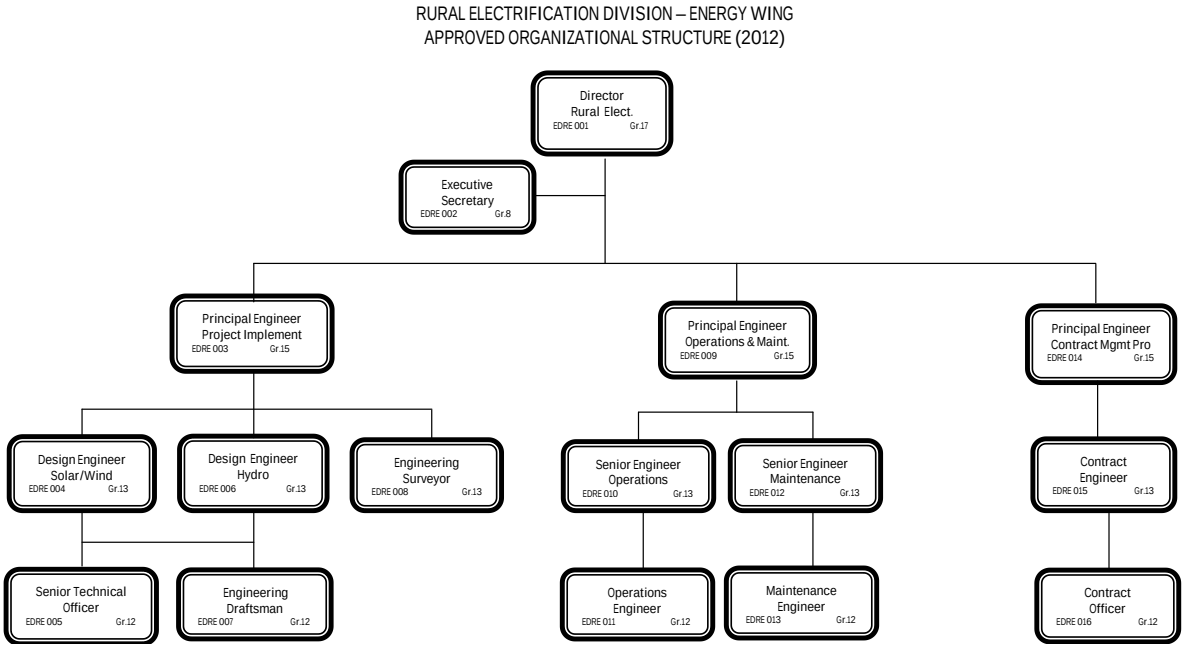
(ii) Planning Market Development Division

Figure 1.8: Structure of Planning Market Development Division



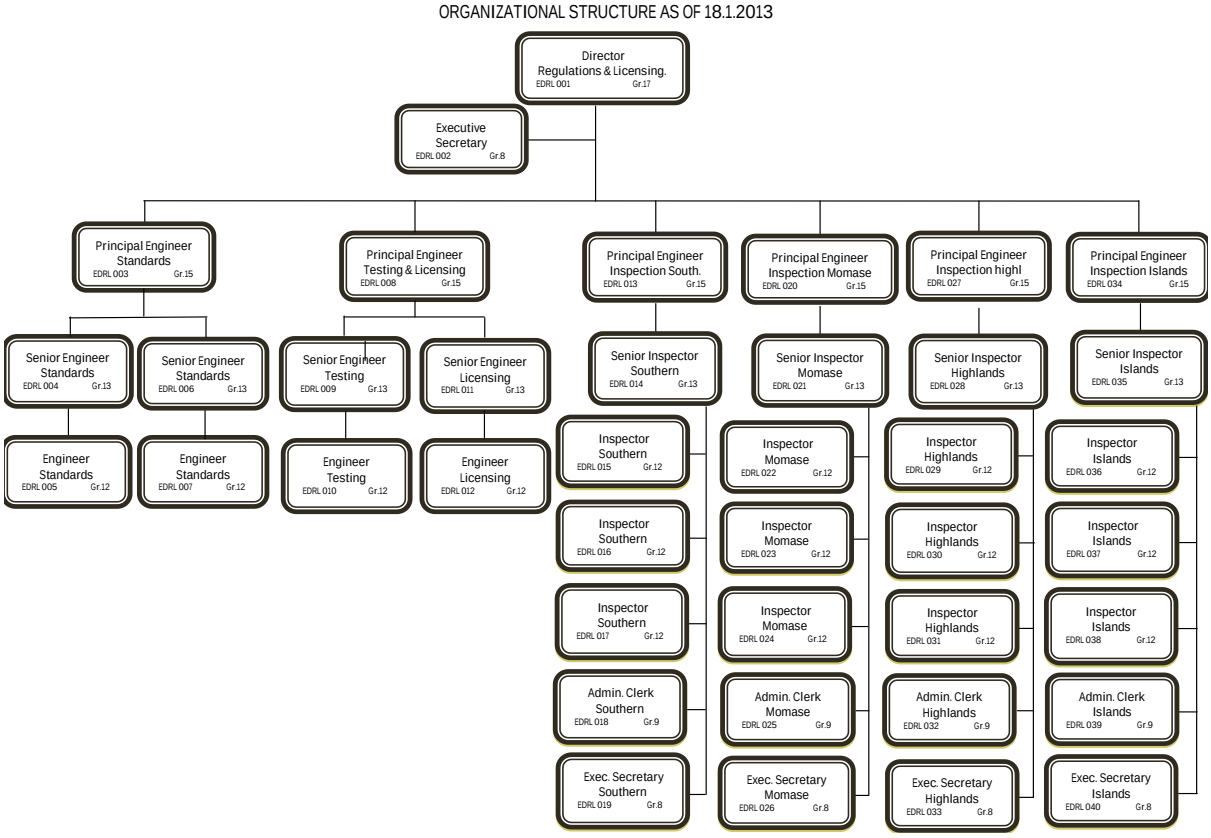
(iii) Rural Electrification Division

Figure 1.9: Structure of Rural Electrification Division



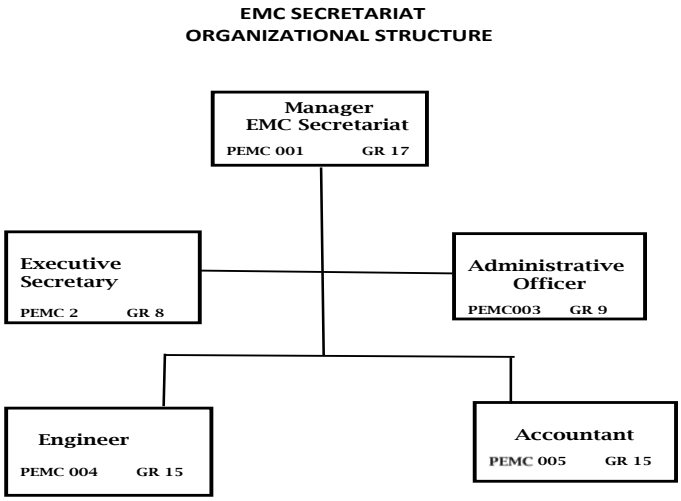
(iv) Regulation and Licensing Division

Figure 1.10: Structure of Regulation and Licensing Division



(v) Electricity Management Committee Secretariat

Figure 1.11: Structure of Electricity Management Secretariat



Unfortunately, all the vacancies in the above Divisions were not filled up since 2011. The budget for salaries was also removed by the government in 2016. Currently, EMC has a staff of four (4), Regulation and Licensing Division has one (1), Rural Electrification Division has four (4), Planning Market Development Division has two (2) and the Energy Wing management has two (2). Of the 77 positions created, only thirteen (13) are occupied or transferred from the previous structure.

3.3.7 Other Related Organisations with special relation with Energy Wing

PNG Power Ltd (PPL) is a state-owned vertically integrated company created under PNG Power Act 2002. PPL is the economy's main utility that provides electricity to all consumers. PPL has been granted the following licences by the Independent Consumer and Competition Commission (ICCC): (1) Generation, (2) Transmission, (3) Distribution and (4) Retailing of electricity PPL operates three separate urban grids (isolated) and 14 other independent provincial systems. In addition, there are a number of C-Centres and privately owned facilities in rural areas. The three separate urban grids operated by PPL are:

(i) Port Moresby System:

The Port Moresby system serves the National Capital District, the commercial, industrial and administrative centre of Papua New Guinea. The Port Moresby system also serves surrounding areas of the Central Province. The total installed capacity under the Port Moresby System is 116.2 MW (the Rouna Hydro Power Stations – 62.2 MW, Moitaka thermal power station – 30 MW, and Kanudi Power Station (diesel, privately owned) – 24 MW).

(ii) Ramu System:

The Ramu system serves the load centres of Lae, Madang and Gusap in the Momase Region and the Highlands centres of Wabag, Mendi, Mt Hagen, Kundiawa, Goroka, Kainantu and Yonki. The economy of the regions supplied by the Ramu system is based on mining, oil, gas, coffee, tea, timber and light industrial productions. The main source of generation is the Ramu Hydro Power Station (at Yonki) with an installed capacity of 75 MW, and a run-of-river Paunda station in the Western Highlands Province with 12 MW installed capacity. Power is also purchased when required from the privately owned Baiune Hydro Power Station at Bulolo in Morobe Province, and varies between 1 to 2 MW depending on availability. Transmission line outages, energy and peak demands are met by diesel plants at Madang, Lae, Mendi and Wabag. These plants serve as stand-by units.

(iii) Gazelle Peninsula System:

The Gazelle Peninsula system serves the townships of Rabaul, Kokopo and Keravat to service Gazelle's economy based on copra, coconut oil, cocoa, timber and fishing. The Gazelle Peninsula system is powered by a 10 MW hydropower system at Warangoi, Ulagunan Diesel Power Station with 8.4 MW, and 0.5 MW from Kerevat Diesel Power Station.

(iv) PPL's Provincial Systems:

PPL has fourteen (14) independent provincial systems (stand-alone systems) that can be developed and expanded into separate small grid systems. These mini grids can be made ready to integrate in to the larger grids like POM, Gazelle and Ramu in the near future. It is known that these provincial systems are diesel operated and PPL attempts by to replace all these diesel systems due to the high fuel, operation and maintenance costs and in light of PNG's commitment to climate change and low carbon energy. These diesel plants are good candidates for green climate fund assistance to offset their emissions.

There are also good potential hydro power sites within the Ramu grid system that could be developed to replace the diesel power systems in the Ramu grid system which are very expensive to operate and maintain. These potential hydro sites could attract green climate funding assistance to offset all the emissions for replacement with renewable energy sources. These are shown in Table 2 below.

Table 2 – Fuel consumed by Ramu grid diesel power plants in 2014

Station	Unit No.	Site Plate Rating	Energy Generated (K Kwhr)	Fuel Consumed (Litres)	Fuel Cost (PGK)	SFC of Fuel (Kwhr litres)
Milford	3	2,400	35,000.00	12,392.00	32,838.80	2.8244
	4	2,400	1,465,065.00	417,366.00	1,081,868.76	3.5103
	5	3,000	646,700.00	220,543.00	584,438.95	2.9323
	6	3,095	2,052,590.00	668,140.52	1,754,344.39	3.0721
	7	3,095	0.0	0.0	0.0	0.0000
	8	3,095	0.0	0.0	0.0	0.0000
	9	3,095	0.0	0.0	0.0	0.0000
	10	3,095	0.0	0.0	0.0	0.0000
	11	3,095	0.0	0.0	0.0	0.0000
	12	1,710	19,145.00	6,733.33	17,270.46	2.8433
Total			4,218,500.00	1,325,174.85	3,470,761.36	3.04
Taraka	1	1,440	398,970.00	106,246.00	277,302.06	3.7552
PPL	2	1,440	1,092,617.00	261,561.00	677,398.95	4.1773
	3	1,440	71,014.00	18,844.00	49,182.84	3.7685
	4	1,440	890,099.00	214,566.00	560,992.98	4.1484
	5	1,440	612,822.00	224,637.00	584,906.87	2.7281
	6	1,440	886,734.00	224,472.00	586,350.85	3.9503
	7	1,440	1,040,179.00	279,249.00	725,926.09	3.7249
Total			4,992,435.00	1,329,575.00	3,462,060.64	3.7504
Taraka	1	1,100	2,570,215.00	650,675.69	1,861,447.73	3.9501
(Aggreko)	2	1,100	2,769,521.00	683,064.56	1,939,452.31	4.0546
	3	1,100	2,732,550.00	694,835.65	1,974,928.82	3.9327
	4	1,100	1,996,833.00	505,733.84	1,447,348.72	3.9484
	5	1,100	2,364,105.00	609,036.89	1,721,868.45	3.8817
	6	1,100	2,676,355.00	692,478.52	1,970,255.76	3.8649
	7	1,100	2,870,744.00	731,614.29	2,088,616.38	3.9238
	8	1,100	2,927,910.00	754,780.74	2,154,921.45	3.8792
	9	1,100	1,828,016.00	431,144.61	1,206,275.14	4.2399
	10	1,100	2,728,733.00	701,148.64	1,980,942.76	3.8918
	11	1,100	2,393,918.00	660,162.39	1,857,878.26	3.6263
	12	1,100	2,182,597.00	582,590.75	1,652,960.44	3.7464
Total			30,041,497.00	7,697,266.57	21,856,896.22	3.9117
Madang	2	1,340	0.00	0.00	0.00	0.0000
	3	1,500	0.00	0.00	0.00	0.0000
	5	3,300	1,697,240.00	545,499.00	1,495,421.45	3.1114
	7	616	313,826.25	120,808.65	329,461.08	2.5977
	8	1,120	848,500.00	283,518.40	777,170.29	2.9928
	9	1,120	934,137.50	130,334.70	347,138.39	7.1672
	10	1,820	931,719.00	290,211.00	832,805.45	3.2105
	11	1,820	0.00	0.00	0.00	0.0000
	12	1,820	2,124,959.40	708,295.60	1,980,055.59	3.0001
Total			6,850,382.15	2,078,667.35	5,762,052.25	4.41594
Mendi	4	1,360	519,794.40	173,264.80	572,982.84	3.0000
Total						
Wabag	1	345	0.00	0.00	0.00	0.00
	2	230	0.00	0.00	0.00	0.00
	3	624	0.00	0.00	0.00	0.00
	Leased	1,000	1377825	404986.9	1345169.55	3.4021
Total				404986.9		
Goroka	1	1,440	275,646.00	82,994.00	266,118.15	3.3213
	2	1,440	229,643.00	65,720.00	219,952.24	3.4943
Total			505,289.00	148,714.00	486,070.39	3.4078
Kundiawa	1	1,440	14,071.00	2,542.00	8,897.00	5.5354
Total			48,519,793.55	13,160,191.47	36,964,890.25	

Source: (NEWJEC JICA Report, 2016)

4. RENEWABLE ENERGY (RE) RELATED NATIONAL PLAN/TARGET OF PNG VISION 2050

4.1 Goals, Objectives and Targets/Roadmap

The DSP 2010 - 2030 seeks to increase the RE-based power capacity of the economy to 100% renewables by the year 2050. To reach the 2030 level under the Electricity Industry Policy and the National Electrification Roll Out Plan, we need to triple the current capacity of mixed supply of 800 MW to 2 500 MW as suggested by the ANZ Bank Insight of Nov 2014. It is also possible that we can do the inevitable by ensuring that we concentrate our efforts to develop and implement renewable energy based power supply to meet the 2050 statement in PNG Vision 2050.

We would also need to overcome and replace the current thermal generation as well by aligning our efforts to ensure that the Low Carbon power supply we are embarking to install are efficient and reliable in meeting our vision in 2030 and beyond to 2050.

4.2 In the proposed National Energy Policy, it was intended that for Renewable energy, the following shall be carried out:

- Institutionalise a comprehensive approach to address the challenges and gaps that would prevent and/or delay wider application of RE technologies in a sustainable manner and
- Outline the action plans necessary to facilitate and encourage greater private sector investments in RE development.
- Ensure an Energy Efficiency and Conservation Policy is endorsed by Cabinet
- Ensure an Energy Efficiency and Conservation Law is endorsed by Cabinet and passed by the Parliament
- Ensure a Renewable Energy Policy is endorsed by Cabinet and
- Ensure a Renewable Energy Law is passed by Cabinet and Parliament to develop all the renewable energy resources in PNG and thus prepare to feed into the three (3) grids of Port Moresby, Ramu and Gazelle.

4.3 The Electricity Industry Policy and National Electrification Roll Out Plan

The National Electrification Roll Out Plan is a good plan which was supported by the World Bank and the government of PNG. The lead agency is the Department of Petroleum and Energy (Energy Wing). To realise the goals of the PNG Vision 2050, the following shall be carried out:

On a per technology basis, the Renewable Energy Plan intends to deliver the following:

(i) For geothermal, the Gazelle grid is poised to be extended and cover West New Britain Province. An additional 95 MW should be added to the Gazelle grid by 2030 and another 110 MW to the Ramu Grid by 2050;

(ii) Increase hydropower capacity by 1 483 MW by 2030 and further 3 680 MW by 2050 for the Pom and Ramu grids;

(iii) Deliver additional 62 MW biomass power to Ramu grid by 2030 and a further 34 MW by 2050;

(iv) Add 30 MW wind power capacity for Pom and Ramu grids by 2030 and a further 20 MW by 2050;

(v) Add new 65 MW solar power capacities by 2030 and pursue the achievement of a further 35 MW by 2050;

(vi) Develop the first 5 MW Ocean energy facility for the economy by 2022, which is to be connected to the Pom grid.

However, this plan may change in the course of time. For example, if hydro is expensive then, other alternative renewable energy sources in abundance and less expensive technologies could be deployed as the preferred option. However, the balance of the proposed power plants must be maintained in order to reach the 100% renewables by 2050.

The RE Plan is initially focused towards the addition of RE-based capacity for power generation. The estimates for the expected capacity additions are based on the PNG V2050 and the forthcoming RE Law. The entry of the above-cited RE-based capacities is highly dependent on the successful implementation of the REP as well as the policy and incentive mechanisms in the proposed RE Law. Particular attention shall be given to the timely conduct of grid impact studies required for all facilities connecting to the grid and conforming to the Grid Code and Third Party Access Code (TPAC). This is because PPL three grids are not big enough to handle large connections at any one time. The government has sought to introduce the Grid Code (mechanism for enhancing the decentralisation of the electricity generation and the TPAC for how IPP's are governed to be associated with the utility (PPL).

We resolve to do the following:

- Promote the Renewable Energy resources for electricity generation and other development uses in which the government had set the target of 100% by 2050. (PNGV 2050)
- Our Government regards this target as adequate. We will therefore perfect the current legislation, progressing in the design and implementation of alternative promotion mechanisms, as well as building Pilot Projects.

- With the measures defined in this strategy, we hope to have more of RE projects in our energy mix in the next decades as a scaling up method.
- We strive to aim for hydroelectricity to achieve greater than 50% share of the energy mix in the same period, with the remaining share coming from others sources.
- We will adhere to COP 21 and GHG reduction (2015)
- We intend to strive to reform the DPE into a National Energy Authority (NEA)
- We reaffirm our commitment to stand by the Government and World Bank on NEROP [2011] and resolve to progress it.
- We reaffirm our resolve to pass appropriate Policies and Bills to NEC and PARLIAMENT – e.g. Passing of Renewable Energy Bill (2017) and National Energy Authority Bill (2017) and Energy Efficiency and Conservation Policy and Bill 2018 etc.

4.4 The National Energy Policy Nine (9) Principles

Our draft National Energy Policy, which has been reviewed by all stakeholders, will be deliberated by the NEC and to be passed by the end of 2017. It is being revised and ready for submission to NEC and Parliament. The following are the 9 principles as listed below:

Principle 1 - Strengthen institutional capacity and recruit right human capital to manage the energy sector.

(a) Establish the National Energy Authority (NEA) as per NEC Decision 145/2013 dated 1st May 2013)

(b) Ensure adequate resources including infrastructure are made available to NEA

(c) Foster co-operative arrangements between the Department of Provincial Affairs and Local level government, Provincial governments, District Development Authority's, Special Purpose Authority's by virtue of the National Energy Policy shall take ownership of the path of electrifying the Provinces and Local Level areas under their jurisdiction by provisions made in 1995 where energy (electricity production and sale) was developed under the Organic Law on Provincial and Local Level Government, (OLP&LLG).

(d) The National Energy Policy with its accompanying National Energy Plan and sub policies and plans shall be made public to create widespread understanding, awareness and support for reform objectives and current practises amongst key stakeholders including government agencies, industry participants, consumers, and the community at large.

(e) All higher level and technical institutions shall include energy related subjects in their curriculum.

Principle 2 - Develop an integrated planning process for sustainable energy supply and use in both the Energy, Electricity Service Industry (ESI) and the hydrocarbons industry.

(a) Promote the development of appropriate regulatory guidelines including standards to meet the needs of producers, suppliers and users

(b) Promote the National Electrification Roll-Out Plan (NEROP) for Grid extension and off-Grid standalone power supply system

(c) Promote one hundred percent electricity usage from renewable energy sources by 2050.

(d) Promote energy data reporting both in supply and demand across all sectors.

Principle 3 - All energy resources will be developed by the State for the betterment of all citizens.

(a) The State should be an active participant in the development of all energy resources

(b) The State should empower landowner participation in the development of all energy resources ensuring land owner interest in this project is equitable.

(c) The State will review and define properly in law, the ownership and beneficial interest of its citizens in all energy resource development.

Principle 4 - Promote a conducive environment for long term sustainable economic solutions in the supply of all energy sources.

(a) Ensure appropriate legal and financial frameworks are in place for energy sector development by private sector participants.

(b) Promote public-private partnership in energy sector development.

Principle 5 - Encourage involvement of the private sector in the development and provision of energy services.

(a) Provide incentives for private sector investment through appropriate fiscal regimes.

(b) Promote a competitive energy and electricity market environment for the expansion of Independent Power Producers (IPPs) and distribution.

(c) Promote the efficiency and robustness of the Electricity Service Industries (ESI) through market reforms

(d) Promote corporatisation and commercialisation mechanisms for power utility and Independent Power Producers (IPP's) to facilitate improvements in power production, transmission, distribution and retail by relevant entities.

(e) Government shall continue to play an important role in the regulation of retail competition, including issues of prices control and market ownership in the Electricity Supply Industry (ESI) and allow for a lower tariff for rural electricity users based on Long run marginal cost (LRMC). Any control mechanisms in Independent Consumer and Competition Commission (ICCC) shall be gradually transferred to (ERC) when it is established.

Principle 6 - Ensure energy resources are developed and delivered in an environmentally sustainable manner.

(a) Minimise the adverse impact of energy production, distribution and consumption within the framework of the Environmental Act and other appropriate legislation and laws including Environment Impact Assessment (EIA) of energy projects

(b) Support international action on reduction of greenhouse gases and ozone depleting substances from energy standpoint

(c) Promote and support efforts in the conservation and maintenance of forests and appropriate marine resources, aquifers as carbon sinks.

Principle 7 - Promote efficient systems and safety in energy supply in all sectors (transport, residential, commercial, industrial and agriculture).

(a) Ensure minimum energy performance standards for electrical equipment, and adoption of building energy codes and other Standards for safety

(b) Ensure safe transportation of energy products and wastes.

(c) Promote solar power, solar thermal systems and LPG for residential, commercial and public institutions.

Principle 8 - Diversify the development and utilisation of energy resources for the economy's well-being and economic prosperity.

(a) Promote electricity generation for domestic needs from diversified energy sources and gas developers to commit 0.5TCF of gas to support the government's Domestic Market Obligation.

(b) Promote the introduction of renewable fuels (biofuels) for use in the transport and power generation sector.

Principle 9 - Promote energy efficiency and conservation measures and wise use of energy.

(a) Draft and enforce an Energy Efficiency Policy within one year of NEA's creation

(b) Promote energy efficiency measures in all sectors (industrial, residential, agriculture and transport) of the economy in end use of equipment and appliances.

(c) Promote minimum energy performance standards and appliance labelling to all electrical equipment and appliances in collaboration with PNG Customs Services (PNGCS), National Institute of Standards and Industrial Technology (NISIT), Independent Consumer and Competition Commission (ICCC) and other relevant stakeholders.

(d) Promote the concept of energy efficient buildings in accordance with Building Act and Regulations

(e) Promote energy audits in factories and industrial locations and demand-side management programmes in all sectors of the economy.

The Department of Petroleum and Energy along with PPL shall be in the forefront to carry out the implementation of the NEROP and the RE Based power development in the economy as it is inevitable that the Low Carbon development moves fast due to Climate Change issues.

Land acquisition and use in PNG is a major concern and a barrier to development by the predominant landowners. To ease tensions in land use issues, the option to engage landowners or communities as being part and parcel owners of any project can circumvent land use issues, which is seen as a significant barrier to grid extension (construction) and off – grid installations in PNG.

The NEROP will focus on grid connections as priority, and then will move to off-grid installations. It is emphasised that the aggressive development of RE resources shall be balanced with the need to provide an adequate, reliable, affordable and high quality power.

Table 3: RE Based Capacity Installation Target, PNG

SECTOR	INSTALLED CAPACITY (MW)	TRIPLING EXISTING CAPACITY BY 2030 AND COVER THERMAL					2030 TARGET 2500 MW	DOUBLING 2030 TARGET TO 2050 (5000MW)					2050 TARGET 5000 MW
		2011 - 2014	2015 - 2018	2019 - 2022	2023 - 2026	2027 - 2030		2031 - 2034	2035 - 2038	2039 - 2042	2043 - 2046	2047 - 2050	
HYDRO		255.0	25.0	394.0	900.0	164.0	1483.0	654.0	826.0	0.0	2200.0	0.0	3680.0
BIOMASS		0.0	30.0	0.0	32.0	0.0	62.0	0.0	2.0	30.0	2.0	0.0	34.0
SOLAR		0.0	0.0	50.0	0.0	15.0	65.0	15.0	5.0	15.0	0.0	0.0	35.0
WIND		0.0	0.0	10.0	10.0	10.0	30.0	0.0	20.0	0.0	0.0	0.0	20.0
OCEAN		0.0	0.0	5.0	0.0	0.0	5.0	0.0	5.0	0.0	0.0	0.0	5.0
GEOTHERMAL		0.0	0.0	5.0	40.0	50.0	95.0	0.0	20.0	0.0	50.0	40.0	110.0
TOTAL PNG		255.0	55.0	464.0	982.0	239.0	1740.0	669.0	878.0	45.0	2252.0	40.0	3884.0

The expected milestones over the period 2014 to 2030 are reflected in Table 4. The expected milestones over the period 2031 to 2050 are reflected in Table 18.

Table 4: REP Milestones

Sector	Target indicative Addition Capacity (MW)	Others
HYDRO	1064	Complete 394 MW by 2022, Add 900 MW by 2026 and add another 164 MW by 2030
BIOMASS	32	Add 30 MW by 2018 and another 32 MW by 2026
SOLAR	32	Add 50MW by 2022 and add another 15 MW by 2030
WIND	30	Completion of 10MW installations by 2022, 2026 and 2030
OCEAN	5	Complete a 5MW pilot project in Milne bay by 2022

4.4 Renewable Energy Plan (REP) Development Framework

The REP presents the overall approach to accelerate the development and utilisation of the RE resources in the economy. The framework for its development is shown in *Figure 1.6*.

4.4.1 The first work shall be the drafting of the Renewable Energy Law or Bill in the second half of 2017 and to be submitted to Cabinet and Parliament for approval.

4.4.2 In support of the above, UNDP in PNG has embarked on a project for funding by GEF with Climate Change Development Authority (CCDA) as the executing agency.

4.5 NEW PROJECT (2017)

Project Description

Concurrent with this Low Carbon Energy project, PNG is determined to get assistance from the Green Climate Fund (GCF) to enable it to develop some more renewable energy projects like those mentioned below through its (National Designated Agency) NDA and Accredited Entities (AE) that are based in the economy. Preliminary requirements for the GCF include the preparation of concept notes with costs and the likely GHG emissions avoidable. The submission for funding for detailed feasibility studies is then submitted to GCF Board. As a start the likely five projects are:

- Port Moresby's Wind and Solar Project with Department of Petroleum and Energy to lead
- Geothermal projects in East and West New Britain Provinces with Mineral Resources Authority to lead
- Markham Solar Project and possibly biomass with Department of Petroleum and Energy as the lead
- University of PNG (UPNG) Solar Project with UPNG as the lead
- Moreguina Hydro Power Project with Department of Petroleum and Energy as the lead.

In addition to the ones above, the DPE's Energy Wing will be having discussions with all the AE's operating in the economy such as the United Nation Development Programme, the World Bank and the Asian Development Bank to include some new projects after CCDA was notified. These projects are likely to be:

Table 5: Projects that will have impacts in different areas

No	**Type of assistance sought**	**Description**
1	GATOP - Scaling-up Hydropower development project for Climate Resilience in Morobe Province by adaptation	(Upgrade to 2 MW from 600 kW)
2	Homa Paua hydro power development project in Hela Province by mitigation - SHP. Project proposal	(30 kW)

4.6 PNG Energy Sector Development Project (National Electrification Roll Out Plan) NEROP

Project Description

The NEROP was a World Bank funded project which commenced in 2015 and completed in 2016. With the introduction of the Green Climate Fund, some of the projects identified in the NEROP can be funded using this facility. Whilst the NEROP targets Grid connection or extension as priority, some of the preferred generation sources are diesel, especially in areas where alternative renewable energy sources can be costly to develop. . For the off-grid option, the government may look at power projects that have been built by the Missions, NGOs and others and assist them to rehabilitate or upscale them to improve and maximise their power output. The Gatop micro hydro power project in the Finschafen area of the Morobe Province is one such example of a scheme built by the Lutheran Church to power the small community of Gatop

4.7 Renewable Energy Policy and Institutional Framework Development

The Renewable Energy Policy (REP) is based on the relevant work programs encapsulated in the PNG Vision 2050 Statement. The statement refers to drive a possible sectoral sub-programs for each of the RE resources such as geothermal, hydro, biomass, biogas, biofuel, wind, solar, and ocean. The government anticipates to cover all renewable energy resources in the forthcoming RE Law. Each sectoral sub-programme follows a roadmap which serves as a guide for the achievement of the PNG V 2050 statement. The ANZ Bank Insight statement predicts and firms a tripling of current power capacity to 800 MW by 2030 if the National Electrification Roll Out Plan is to be realised. This means a target of 2 400 MW by 2030. We do also note to initiate the displacement of current thermal plants when we progress into 2030.

After 2030, there might be another doubling of the 2030 capacity to 5 000 MW as population and industrial demand pushes the capacity requirement upwards.

We are also conscious of the development of the RE programme by taking into account market penetration targets of a particular RE resource. The programme indicates the milestones over the (2018–2050), a 32-year planning and action period. This programme can be realised through the realisation of which depends on the implementation of the following types of activities and plan as shown in Table 3. Only then, PNG will be able to achieve its aims outlined in PNG V2050 of being a 'smart, wise, fair, healthy and happy society' and one of the top 50 economies in the world by year 2050.

4.8 RE Industry Services

This is geared towards facilitating private sector investments in the energy sector. Assistance to the RE Developers shall start from the registration process up to the implementation of the various stages of their respective RE Service/Operating Contracts. Close monitoring of the contracts shall be undertaken to ensure that appropriate interventions are within DPE's or NEA's control, and as authorised by law, are provided in a timely manner to avoid delays in the implementation of their respective work programs. Aside from technical assistance, DPE or NEA may also provide advisory services in the areas of market development, business matching, as well as on the various policy and incentive mechanisms to ensure that the RE projects come on stream and comply with the requirements under the proposed RE Law.

4.9 Resource Development

Efforts towards harnessing the huge RE resource potential of the economy shall be improved. Among others, these may include:

(a) resource assessment (mapping), either nationwide or in a particular area/location;

(b) conduct of various studies such as those on the market, socio-economic and environmental impact or pre-feasibility of specific RE projects on its own or in partnership with interested groups/ organisations; and

(c) optimisation studies on the development and utilisation of RE resources. To expand the market for RE studies and/or on its non-power applications, specifically for those of biomass and geothermal energy shall also be undertaken.

4.10 Research, Development and Demonstration (RD&D)

Applied research and development (R&D) shall be undertaken to determine the viability of adapting certain RE systems, technologies or processes in the PNG setting, in areas where there is no or limited local experience. As may be warranted, demonstration or pilot projects

shall be implemented to showcase the feasibility of those technology or process. For instance, a demonstration project on Ocean current generation shall be conceptualised under the Ocean Sector Sub Programme and a pilot geothermal energy project in West New Britain.

4.11 RE Technology Support

The improvement of the quality, performance and cost of local RE systems towards greater consumer protection and their competitiveness with conventional systems shall be further pursued. Among others, these may include:

(a) the development of standards for locally manufactured/fabricated equipment or component such as wind towers, PV inverters, etc. and

(b) the establishment of a registration or rating programme for engineering service providers. Capacity building activities shall also be conducted to enhance the skills and knowledge of RE stakeholders. DPE or NEA shall work closely with partners from the private sector (i.e. local RE manufacturers and engineering service providers), training institutions and the academe in the development and implementation of the appropriate projects/activities.

The specific projects and activities in each sector shall vary depending on the challenges and gaps facing each sector as well as the expressed needs of the stakeholder groups being served. The cross-cutting activities are grouped into the Policy and Programme Support Component. This involves common activities which require a coordinated and integrated approach to implementation. Policy support mainly involves the continuation of efforts towards the formulation, implementation and monitoring of the mechanisms, rules and regulations prescribed by the proposed new RE Law. Programme support, on the other hand, will cover common activities which need to be undertaken to ensure the smooth implementation of the REP. Each sectoral sub-programme, however, shall also indicate specific areas where policy and programme support may be required.

4.12 Sectoral Sub-Programmes

Each sectoral sub-programme includes an overview of the sector, the roadmap and the various action plans which address the specific needs of the said sector. As earlier mentioned, the DPE or NEA formulated the initial draft of each sectoral sub-programme based on its knowledge and understanding of the challenges and gaps faced by the sector. The work programme presented now is what DPE envisaged for a few short activities until consultations from each subsector will be worked through to justify each of them through wider consultations of each project or activity that may be adjusted depending on the progress of work (e.g. from Resource Development to R&D and Demonstration).

4.12.1 Geothermal Energy Sector Sub-Programme

Geothermal energy comes from the natural heat of the earth. This heat is stored in rock and water within the earth and can be extracted by drilling wells at depths shallow enough to be feasible. The economy's geothermal resources are known to be of high quality since PNG lies in the proximity of the Pacific Rim of Fire. Geothermal wells are scattered all over the northern part of the economy. There is intention to first develop a 5 MW pilot project then a 40 MW in West New Britain Province, followed by a 50 MW plant in East New Britain Province. The economy's first geothermal plant was established at the Lihir Gold Mine with a 56 MW capacity. The economy's possible proven reserves might be 4 000 MW as indicated by the Icelander group. (See Table 19)

Although Lihir Gold Mine's geothermal plant of 56 MW was installed in late part of 2000, it cannot be added to any grid because it is on the island of Lihir. As stated above, there is now a proposal for a pilot project of 5 MW and then eventually a 40 MW power plant in West New Britain Province but both power plants cannot be added to the Gazelle grid. PPL will have to investigate the option to connect the Gazelle grid when the West and East New Britain road link opens up. There are also plans for Ramu grid to be connected by a geothermal plant from Madang and Port Moresby to be serviced from either the Oro or Milne Bay Province.

Table 6: Targeted Geothermal Capacity Addition (MW), By Grid

GRID	GEOTHERMAL	Commissioning Years											Total Capacity Addition to 2050 MW	% Share
		2011 - 2014	2015 - 2018	2019 - 2022	2023 - 2026	2027 - 2030	Total Capacity Addition to 2030 MW	2031 - 2034	2035 - 2038	2039 - 2042	2043 - 2046	2047 - 2050		
POM	EXISTING CAPACITY MW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RAMU		0.0	0.0	0.0	0.0	20.0	20.0	0.0	20.0	0.0	0.0	40.0	60.0	54.5
GAZELLE		0.0	0.0	5.0	40.0	50.0	95.0	0.0	0.0	0.0	50.0	0.0	50.0	45.5
TOTAL PNG		0.0	0.0	5.0	40.0	50.0	115.0	0.0	20.0	0.0	50.0	40.0	110.0	100.0

Table 7: Geothermal Sector Work Programme

Type of Activity	Work Program	
RE Industry services	1	Review of applications for action on the extraction of the resource by EMC
	2	Meeting with DNPM & ADBI and EMA & Geothermal Technical Working Group and CCDA task Force on the 5 MW Pilot Project
Resource Development	1	Invite EMA of Japan to construct a pilot 5 MW plant in West New Britain Province of a modular set up that can be enlarged to 40 MW
	2	Calculate emissions savings from two diesel plants this 5 MW will save
Resource Development ,RD & D	1	Technical cooperation between MRA, DP & E, DPE and EMA for the project
	a	Mapping & Database program of identified locations
	b	Pilot study and Feasibility study
	2	Research on harmful acids
RE Technology Support	1	Establishment of Geothermal Center or training institution for a start either in country or overseas
Policy and Program Support Related Activities	1	Drafting of Geothermal Energy Policy Development
	2	Drafting of Geothermal Energy Policy Guidelines
	3	Improvement and updating of Geothermal resources database

4.12.2 Hydropower Energy Sector Sub-Programme

Hydropower is the most dominant source of RE-based (electricity supply) capacity in the economy today. PNG has vast hydro resources with an estimate by a Consultant (Shawinigan) putting the potential capacity at around 15 000 MW. The Naoro Brown hydro of 80 MW will be added to the POM Grid in 2018/2019. Total installed capacity of hydropower in the economy is 230 MW. This accounts for 50% of the 580 MW total capacity rating for the economy. Full resource mapping of hydropower should confirm the 15 000 MW capacity in the economy.

Table 8: Targeted Hydropower Capacity Addition (MW), By Grid

GRID	HYDRO	Commissioning Years											Total Capacity Addition by 2050 MW
		2011 - 2014	2015 - 2018	2019 - 2022	2023 - 2026	2027 - 2030	Total Capacity Addition by 2030 MW	2031 - 2034	2035 - 2038	2039 - 2042	2043 - 2046	2047 - 2050	
POM	EXISTING CAPACITY MW	145.0	25.0	84.0	200.0	0.0	309.0	200.0	826.0	0.0	2200.0	0.0	3226.0
RAMU		100.0	0.0	310.0	700.0	164.0	1174.0	454.0	0.0	0.0	0.0	0.0	454.0
GAZELLE		10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL PNG		255.0	25.0	394.0	900.0	164.0	1483.0	654.0	826.0	0.0	2200.0	0.0	3680.0

The overall thrust of the Hydro Sector Sub-programme is the intensification of efforts to develop the huge untapped hydro resource potential of the economy. The provision of services to the hydro sector participants shall be sustained over the long-term 2017-2030 and further into 2050 to ensure that the targeted hydro capacity addition is met and over time gradually displace the current thermal generation and work towards 100% renewables by 2050. The sector's work programme, by type of activity, is listed in Table 9.

Table 9: Hydropower Sector Work Programme

Type of Activity	Work Program	
RE Industry services	1	Review and Endorsement of Applications by EMC
	2	Encourage BOOT concept for PPA and IPP's to flourish by PPL.
Resource Development	1	Invite VSIPP's /SIPP's in mini-pico hydro for locals to participate in LC energy supply systems for their income and well being
	2	Develop Guide books on hydropower operations
Resource Development, RD & D	1	New technology and design of hydropower
RE Technology Support	1	Establishment of standards and best practices
Policy and Program Support Related Activities	1	Work on Renewable Energy Policy and Bill
	2	Work on Rural Electrification Policy

4.12.3 Biomass Energy Sector Sub-Programme

Biomass resources refer to natural or processed plants and plant materials, trees, crop residues, wood and bark residues, and animal manure or any organic or biodegradable matter that can be used in bioconversion process. The economy generates substantial volumes of waste residues which could be utilised as fuel. Biomass resources also include biofuels.

PNG is desirous to draft a Biofuels Law similar to that of the Philippines, which may either be included with the Biomass Law. This is because of the need for fuel blending to support the transport sector especially the use of two types of biofuels, namely, biodiesel as blend with diesel fuel and bioethanol with gasoline. These two key liquid fuels are produced from agricultural crops and other renewable feed stocks. Despite this substantial potential, biomass utilisation in the economy is mostly for non-power applications, such as biofuels in the transport sector, fuel wood in the household and commercial sectors and waste residues in agro-industries. New biomass power capacity is 30 MW proposed as an IPP for grid connection by 2018.

Biomass Sector envisions an addition of 90 MW biomass power capacity to spread along the Markham plains to year 2039 (Table 10) to the grid by 2042. This a good project because it helps locals with income from tree plantings and harvest for the power plant.

Table 10: Targeted Biomass Capacity Addition (MW), By Grid

GRID	BIOMASS	Commissioning Years											Total Capacity Addition to 2050 MW
		2011 - 2014	2015 - 2018	2019 - 2022	2023 - 2026	2027 - 2030	Total Capacity Addition to 2030 MW	2031 - 2034	2035 - 2038	2039 - 2042	2043 - 2046	2047 - 2050	
POM	EXISTING CAPACITY MW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RAMU		0.0	30.0	0.0	30.0	0.0	60.0	0.0	0.0	30.0	0.0	0.0	30.0
GAZELLE		0.0	0.0	0.0	2.0	0.0	2.0	0.0	2.0	0.0	2.0	0.0	4.0
TOTAL PNG		0.0	30.0	0.0	32.0	0.0	62.0	0.0	2.0	30.0	2.0	0.0	34.0

Table 11: Biomass Sector Work Programme

Type of Activity	Work Program	
RE Industry services	1	Review and Endorsement of Applications by EMC
	2	Encourage BOOT concept for IPP to enter into agreement with PPL
Resource Development	1	Research and adopt suitable waste to energy project.
RD & D	1	RD & D on new biofuel blend
	2	Have a National Accreditation laboratory
RE Technology Support	1	Establishment of standards and best practices by working with NISIT on standards for Suitable fuel blend or adopt suitable ones
Policy and Program Support Related Activities	1	Review and finalise Biofuel/Biomass Policy and Law
	2	Propose new policies on waste to energy
	3	Work on Renewable Energy Policy and Bill

4.12.4 Wind Energy Sector Sub-Programme

The economy is said to have a very good wind resource potential, albeit, there is need to have more wind resource assessment done in this sector. The World Bank funded wind assessment work is in progress but very slow in the installation of the wind masts and metering equipment. There exists some known wind study data dating back to the 1980s but was not continued to date. The UNDP proposed project reveals that it is possible to generate with power density of at least 400 W/m2 and transmission line cost of not over 25% of levelised cost of combined generation and transmission costs. We now wait for a full wind resource assessment study of the whole economy that might reveal more potential sites for wind energy generation. DPE will ensure that all renewable energy resource assessment be carried out to verify the economy's RE's resource capacity.

Table 12: Targeted Wind Capacity Addition (MW), By Grid

GRID	WIND	Commissioning Years											Total Capacity Addition to 2050 MW	% Share
		2011 - 2014	2015 - 2018	2019 - 2022	2023 - 2026	2027 - 2030	Total Capacity Addition to 2030 MW	2031 - 2034	2035 - 2038	2039 - 2042	2043 - 2046	2047 - 2050		
POM	EXISTING	0.0	0.0	10.0	0.0	10.0	20.0	0.0	10.0	0.0	0.0	0.0	10.0	50.0
RAMU	CAPACITY	0.0	0.0	0.0	5.0	0.0	5.0	0.0	5.0	0.0	0.0	0.0	5.0	25.0
GAZELLE	MW	0.0	0.0	0.0	5.0	0.0	5.0	0.0	5.0	0.0	0.0	0.0	5.0	25.0
TOTAL PNG		0.0	0.0	10.0	10.0	10.0	30.0	0.0	20.0	0.0	0.0	0.0	20.0	100.0

The Wind Energy Sector Sub-Programme (WESP) can support the following policy thrusts of the PNG Energy Plan:

(i) ensuring energy security;

(ii) pursuing effective implementation of energy sector reforms; and

(iii) implementing social mobilisation and cross-sector monitoring mechanisms. The sub-sector set the following activities to fulfill its goals.

Table 13: Wind Sector Work Programme

Type of Activity	Work Program	
RE Industry services	1	Review and Endorsement of Applications by EMC/PPL
	2	Strengthen linkage with NEROP
	3	Work plan should be for short term so that a revised work plan when we are in a better position can be drawn up of medium and long term
Resource Development	1	Continue resource assessment, mapping and database setup
Resource Development, R D D	1	Continue with Port Moresby Wing and Solar project with CCDA/GCF
	2	Calculate GHG Emissions potential to eliminate diesel power generation source.
RE Technology Support	1	Establishment of standards and best practices
	2	Capacity building of staff
	3	Invite manufacturing skills setup in country
Policy and Program Support Related Activities	1	Continue to draft the Renewable Energy Policy and Bill to develop this subsector
	2	Draft better guidelines for industry uses
	3	Invite many players to take part in large IPP projects with PPL.

4.13.5 Solar Energy Sector Sub-Programme

Most of the solar energy applications in the economy are found in the rural areas, due in part to the rural electrification initiatives initiated by many stakeholders like politicians, the national and local government units.

Solar energy applications in the rural areas are mostly photovoltaic (PV) stand-alone systems which range from 20-90 watt-peak (W-p) individual solar home systems to community-based

lighting applications (e.g. streetlights, village centers, and schools). Technological advances in solar have allowed telecommunication companies to use PV as back-up power supply in their remote cell sites in urban areas. Solar energy is also used to supply thermal energy for water heaters in the residential and commercial sectors. Based on the GEF Proposed project by UNDP on behalf of agencies in PNG. PNG has an average daily insolation of 5 kilowatt hour per square meter (kwh/m2).

The solar energy sector aims to achieve a target of additional 65 MW of solar power capacity, which is a start of the Solar programme by 2030 and an additional 35 MW capacity to 100 MW by 2050. However, this might change if hydro proves to be too expensive to build, and the government opts for alternate cheaper generation sources like wind, solar, biomass and so forth that are developed to meet the requirements of triple the current capacity to 2030 and double the 2030 capacity to reach 2050 target and fully meet the economy's requirement of 100% renewables by 2050.

Table 14: Targeted Solar Capacity Addition (MW), By Grid

GRID	SOLAR	Commissioning Years											Total Capacity Addition to 2050 MW	%Share
		2011 - 2014	2015 - 2018	2019 - 2022	2023 - 2026	2027 - 2030	Total Capacity Addition to 2030 MW	2031 - 2034	2035 - 2038	2039 - 2042	2043 - 2046	2047 - 2050		
POM	EXISTING	0.0	0.0	30.0	0.0	5.0	35.0	5.0	0.0	5.0	0.0	0.0	45.0	45.0
RAMU	CAPACITY	0.0	0.0	10.0	0.0	5.0	15.0	5.0	0.0	5.0	0.0	0.0	25.0	25.0
GAZELLE	MW	0.0	0.0	10.0	0.0	5.0	15.0	5.0	5.0	5.0	0.0	0.0	30.0	30.0
TOTAL PNG		0.0	0.0	50.0	0.0	15.0	65.0	15.0	5.0	15.0	0.0	0.0	100.0	100.0

The Solar Energy Sector Sub-Programme (SESP) is envisioned to support the following policy thrusts of the PNG Energy Plan:

(i) ensuring energy security;

(ii) pursuing effective implementation of energy sector reforms; and

(iii) implementing social rnobilisation and cross-sector monitoring mechanisms. Below are the scheduled activities and programs with their corresponding schedule of implementation.

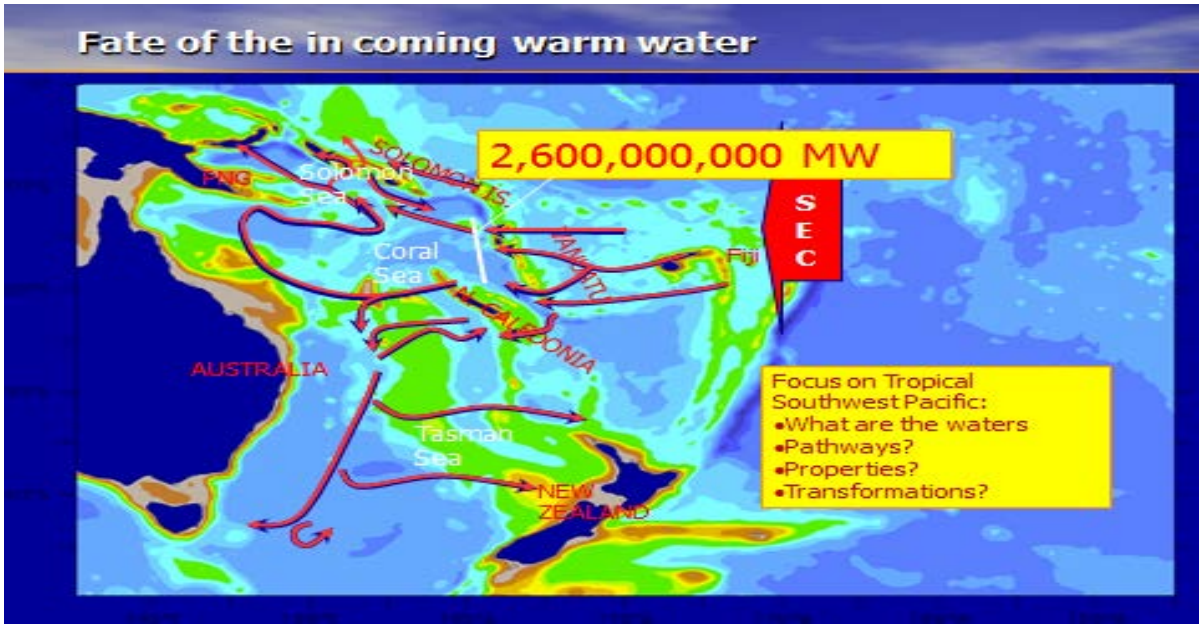
Table 15: Solar Sector Sub-Programme Projects and Schedule of Implementation

Type of Activity	Work Program	
RE Industry services	1	Review and Endorsement of Applications by EMC/PPL
	2	Strengthen linkage with NEROP
	3	Work plan should be for short term so that a revised work plan when we are in a better position can be drawn up for medium and long term
Resource Development	1	Continue with Port Moresby Solar and Wing project with CCDA/GCF
	2	Calculate GHG Emissions potential to eliminate power generation from diesel source.
Resource Development, R D D	1	Continue with Port Moresby Solar and Wing project with CCDA/GCF
	2	Calculate GHG Emissions potential to eleiminate power generation from diesel source.
RE Technology Support	1	Establishment of standards and best practices with NISIT
	2	Capacity building of staff
	3	Invite manufacturing skills setup in country
Policy and Program Support Related Activities	1	Continue to draft the Renewable Energy Policy and Bill to develop this subsector
	2	Draft better guidelines for industry uses
	3	Invite many players to take part in large IPP projects with PPL.

4.13.6 Ocean Energy Sector Sub-Programme

While the economy is endowed with vast ocean resource potential, there have been very limited activities in this sector. This is primarily because of the high investment cost for its exploitation. A study is currently being conducted by the University of PNG in the Milne Bay Province as a pilot project. The DPE or NEA shall maintain a close watch and provide assistance in order to help develop this project. The Ocean Energy Sector envisions the operation of the economy's first ocean energy facility by post 2019 to 2022 period. Throughout the planning period, the DPE or NEA shall intensify efforts to assist and advise interested investors in exploration and development of the untapped ocean energy resource potential. The DPE or NEA shall keep a close watch on developments abroad to identify opportunities for technology transfer. Currently there is a pilot project by the University of Papua New Guinea in Milne Bay Province. The DPE or NEA shall assist the University of Papua New Guinea to ensure this pilot project gets off the ground with financial assistance in the research pilot phase. Identified energy capacity by Ocean is well above the 2.6 billion MW for our combine region so there is huge potential to tap into this resource.

Figure 1.12: Image of Ocean Energy Resource Capacity



Source: Courtesy of Professor Kaluwin Chalapan UPNG July 2017

Support activities like capacity building and mentoring of sector participants' personnel as well as the establishment of standards and best practices, shall be sustained throughout the planning and action period (2017-2050). Programme support activities, such as technical cooperation with relevant agencies, e.g. PPL, DPE and DP&E and all Universities, shall likewise participate. The grid that this power supply shall feed into is the POM grid if PPL can connect Milne Bay to the POM Grid. The sector's work programme is listed in Table 17.

Table 16: Targeted Ocean Capacity Addition (MW), By Grid

GRID	OCEAN	Commissioning Years											Total Capacity Addition to 2050 MW	%Share
		2011 - 2014	2015 - 2018	2019 - 2022	2023 - 2026	2027 - 2030	Total Capacity Addition to 2030 MW	2031 - 2034	2035 - 2038	2039 - 2042	2043 - 2046	2047 - 2050		
POM	EXISTING	0.0	0.0	5.0	0.0	0.0	5.0	0.0	5.0	0.0	0.0	0.0	5.0	100.0
RAMU	CAPACITY	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAZELLE	MW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL PNG		0.0	0.0	5.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	5.0	100.0

Table 17: Ocean Sector Work Programme

Type of Activity	Work Program	
RE Industry services	1	Review and Endorsement of Applications by EMC/PPL
	2	Strengthen linkage with NEROP
	3	Work plan should be for short term so that a revised work plan when PNG is in a better position can be drawn up of medium and long term
Resource Development	1	Assist UPNG with Ocean Pilot project
	2	Calculate GHG Emissions potential to eliminate power generation from diesel source operating in Milne Bay Province.
	3	Assist PPL to have an independent grid from its own system in Milne Bay and with Plans to hook up with Pom grid.
Resource Development, R,D D	1	Begin collaboartive efforts with University of PNG on the Milne Bay Project
	2	Calculate GHG Emissions potential to eliminate power generation from diesel source.
RE Technology Support	1	Establishment of standards and best practices
	2	Continue to search international developments in this resource
Policy and Program Support Related Activities	1	Continue to help draft the Renewable Energy Policy and Bill to develop this subsector
	2	Draft better guidelines for industry uses
	3	Invite many players to take part in large IPP projects with PPL.

4.13.7 Investment Requirements

The targeted RE based Indicative capacity addition of 5 084 MW will mainly be financed and undertaken by the private sector and will entail a total investment of PNG Kina 13.90 Billion (equivalent to around US $4.3 Billion). Table 18 presents the breakdown of the requirement by resource.

Over on top of this amount, an estimated PNG Kina 496.8 Million have already been committed by the private sector for the development of 499 MW. This comprises of 419 MW projects in the hydropower and biomass (30) with solar 30 MW and wind with 20 MW. A new total of PNG Kina 13.90 billion shall be required for the development of the indicative projects of 5 084 MW.

Table 18: Investment Requirements for RE Projects by Resource Also Showing Indicative Capacity Addition to 2030 and Balance by 2050

No	RE RESOURCE	Committed Projects	Estimated Investment Requirement US$M for committed projects	Estimated Investment Requirement PNGK for indicative projects to 2030	Indicative Capacity (MW) to 2030	No	Estimated Investment Requirement US$M for indicative projects to 2030	Estimated Investment Requirement PNGK for indicative projects to 2030	RE RESOURCE	Indicative Capacity (MW) to 2050	Estimated Investment Requirement US$M for indicative projects to 2050	Estimated Investment Requirement PNGK for indicative projects to 2030
1	HYDRO	419	279.3	901.1	1064	1	709.3	2288.2	HYDRO	3680	2453.3	7914.0
2	BIOMASS	30	37.5	121.0	32	2	40.0	129.0	BIOMASS	96	120	387.1
3	SOLAR	30	100.0	322.6	32	3	106.7	344.1	SOLAR	35	116.7	376.3
4	WIND	20	80.0	258.1	10	4	40.0	129.0	WIND	20	80.0	258.1
						5			OCEAN	5	33.3	107.5
	SUBTOTAL	499	496.8	1,602.7	1138	6	896.0	2890.3	GEOTHERMAL	110	600.0	1935.5
									SUB TOTAL	3946	3403.3	10978.5
									GrandTotal	5084	4299.3	13868.8

Table 19: Data Sources Of RE Based Energy Sources

RE RESOURCES	REMARKS
Geothermal	Icelandic group estimated capacity to be around 4000 MW . (UNDP stated potential to be about 21.92 TWh/year, Current installed capacity is 52.8 MW).
Hydropower	Potential is about 15,000 MW; Current installed capacity <230 MW?
Ocean Thermal Energy Conversion (OPPL)	Prof K. Chalapan of UPNG estimates potential for PNG as a fraction of the massive 2.6 Billion MW that is available in the South Pacific Ocean between Australia, New Zealand and all PIC countries. (UNDP stated Very limited knowledge of potential (also for tidal energy or wave energy)).
Wind Energy	No estimates yet; Wind mapping activities currently underway by World Bank.
Solar Energy	Papua New Guinea has huge potential for solar energy utilization. UNDP estimates potential of 1,244 TWh/year. Government funding for village solar PV power generation systems carried out by PPL and OCCD.
Biomass Energy	Main practical biomass energy potential is in logging and agricultural areas, using either the crop output or residues. Some palm oil mills are utilizing oil processing waste as fuel, the same as what is being done in sugar mills.
Biogas Energy	Few palm oil mill are utilizing the palm oil mill waste to generate biogas energy to power their operations. New Britain Palm Oil Limited (NBPOL) has installed 3 MW methane biogas power plant in its palm oil mill. Others such as Hargy Oil Palm Limited are also planning to adopt similar technologies to generate electricity from its palm oil mill wastewater treatment.

5. CLIMATE CHANGE DEVELOPMENT AUTHORITY (CCDA)

5.1 Designated National Authority (DNA) and transition into CCDA

The Department of Environment and Conservation (DEC) was the primary government agency responsible for the conservation, management, development, and proper use of the economy's environment. All subsequent activities of CDM under the Department of Environment and Conservation (DEC) as the Designated National Authority (DNA), are now handled by the Climate Change Development Authority.

5.2 CDM Updates and/or Green Climate Fund

In 2008, Lihir Gold Mine got its application for CDM funding of the mines geothermal power supply of 56 MW. The Energy Wing is now working closely with CCDA to solicit funds from the Green Climate Fund to finance some of its renewable energy projects through AE's.

5.3 Transition of DEC into Climate Change Development Authority and Conservation, Environment Protection Authority (CEPA)

Currently, the Climate Change Development Authority by virtue of the Climate Change Development Authority Management Act 2010 gives the control of Climate Change issues with CCDA whilst CEPA deals with environment and its safeguards.

Table 20: Climate Change Road Map 1992 – 2016

History of Climate Change in PNG…

History of Government Intervention on Climate Change…

Year	Events
1992	PNG was a Party to the first UN Conference on Environment and Development hosted by Brazil in Rio de Janeiro. This gives birth to the Climate Change Convention, the Kyoto Protocol (1997), Agenda 21 and the Convention on Biological Diversity.
1993	PNG Signed the UN Framework Convention on Climate Change in June and ratified it in April.
1997	PNG **signed the Kyoto Protocol** when it was adopted in Kyoto, Japan on 11th December 1997.
2000	PNG **ratified the Kyoto Protocol**, also completed its Initial National Communication.
2002	PNG submitted its **Initial National Communication** to the UNFCCC.
2005	PNG and Costa Rica introduces avoided deforestation into the UNFCCC negotiation process. Kyoto Protocol entered into force on 16th February 2005. PNG Chair CfRN.
2007	PNG ensures REDD+ be part of the **Bali Action Plan** or Roadmap.
2008	GoPNG established OCCES in September.
2009	Launching of the **Vision 2050** in November.
2010	Establishment of OCCD and the endorsement of the **Climate Compatible Development Strategy** and its Interim Action Plan. Start of Sectoral Policies reforms.
2014	The **National Climate Compatible Development Management Policy** endorsed by Cabinet in July. Work on draft Climate Change Bill starts.
2015	• **Climate Change (Management) Act 2015** endorsed by Parliament in July, and certified on 20th November. • PNG submit its **Intended National Determined Contributions**. • PNG signed the **Paris Agreement** – REDD+ was captured as a standalone in **Article 5**.
2016	• **UNFCCC Paris Agreement (Implementation) Act 2016** endorsed by Parliament • PNG Government invited Green Climate Fund to establish office in PNG.

6. REFERENCES

- 2013 and 2014 Key Energy Statistics for PNG – APERC on behalf of APEC
- 2015 National Energy Policy Task Force
- 2016 ECA Report on NEROP
- NEWJEC JICA REPORT 1 2015 on Ramu Power Upgrade
- NEWJEC JICA REPORT 2 2015 on Ramu Power Upgrade
- UNDP GEF submission

APEC PEER REVIEW

ON LOW CARBON ENERGY POLICIES (PRLCE)

Part II: Peer Review Team Report

1. OVERARCHING FINDINGS

ACHIEVEMENTS AND CHALLENGES

Achievement 1: A number of energy policies have been developed and are in the process of obtaining cabinet's approval.

Papua New Guinea has quite a lot of achievements in terms of formulating policies. Building-up from the absence of any policies from early years, several policies, specifically on energy, have now been formulated to grow the economy and improve the quality of life in PNG. The policies attempt to cover wider range of areas to address the increasing requirements in the energy sector and these are either for implementation and or in the process of obtaining cabinet's approval. For example, the National Energy Policy (or "NEP" which will restructure the energy sector), and Biofuel Policy are awaiting cabinet's approval; polices on Public and Private Partnership, Renewable Energy, and Rural Electrification among others, are for implementation.

Achievement 2: Additional 1 655 MW of power generation planned to come online in phases over the next ~30 years.

In a bid to increase electricity access to its people, the government has planned for an additional 1 655 MW of power generation to come online in phases over the next 30 years. This will be realised through the entry of new independent power producers (IPPs) in power generation. A more comprehensive discussion on electricity generation targets and achievements can be found in the succeeding parts of the report.

Achievement 3: Electrification started from areas closer to urban areas with gradual expansion of PPL's grid system.

The government was able to provide electricity in urban areas where building infrastructure is easier. Though only 13% of the total population has access to the electricity, this is gradually increasing with the expansion of PPL's grid system, through land acquisition by PPL and the entry of IPPs in the electricity generation market.

Achievement 4: Some off-grid rural electrification initiated by private enterprises such as mining companies. Government can encourage these companies to utilise RE for such off-grid electrification.

While electricity access is mostly limited to urban areas currently, some off-grid rural areas have also been able to obtain electricity by initiatives from private enterprises such as mining

companies. For example, the 56 MW geothermal power plant on the island of Lihir was developed by the Lihir Mining Company for their own use. Though the geothermal power plant is not interconnected to any grid due to its location, excess power generated is sold to nearby rural residents. In a way, such companies help provide off-grid electrification to rural areas in PNG.

Challenge 1: Maintaining political will to expedite energy development

While several PNG government agencies work hard to formulate relevant energy policies, stronger political will is needed to progress these policies to the implementation stage and expedite energy development. For example, the NEP has been formulated since 2006 but still yet to be approved by the cabinet at the time of peer review.

Challenge 2: Public attitude and perception

As PNG's rural communities face multiple pressing needs (e.g. water supply, sanitation, road building, health issues, education, economic development etc.), electricity may have been undervalued. This causes a misalignment with the government's objectives for increasing electricity access and may hence impede wider developments.

Challenge 3: Poor accessibility and high cost

PNG has a rugged terrain with limited road infrastructure, and fragmented demand where over 80% of the population lives in rural areas. This makes it difficult and costly for the economy to develop infrastructure for grid access.

Challenge 4: Low income levels

While PNG has experienced very high per capita growth rates of more than eight per cent on average since 2005, the benefits are not very widespread as seen from PNG's poverty rates of more than 30% (Department of Petroleum and Energy, 2017). In addition, more than 80% of the population lives in rural areas with low income levels.

Challenge 5: Lack of trained personnel in the sector

PNG lacks human resources capacity in the energy sector. Currently, technical and vocational schools do not have sufficient courses to equip students with relevant skills pertaining to this sector. The government recognises this dilemma and is now introducing energy studies (as of 2017) in the technical and vocational curriculum to meet this shortfall in the industry.

Challenge 6: Lack of funding/investments

On top of the challenges related to the living conditions in PNG, technical challenges such as the lack of trained personnel, funding and investment also affect the rate of electricity development in the economy.

RECOMMENDATIONS

Recommendation 1: Conduct survey

In order for PNG to move towards its targets, these challenges should be taken as opportunities by the government. The government should take small steps in implementing policies, such as conducting a "needs assessment survey" first to find out the needs and priorities of the people, especially in rural areas. It is vital to find out their priorities, ability and willingness to pay for the services before the government can make an informed decision on the need for setting up energy infrastructure.

Recommendation 2: One step at a time

Another step that the government could take is to assess the most efficient way of utilising its available resources. The government has set ambitious targets to energise the economy by tapping on all its renewable resources concurrently from now to 2050. To facilitate the achievement of the targets, the government could adopt a more structured process in phasing out its level of commitment over the development of renewable resources. This involves prioritising one or two renewable resources at a time.

For example, given PNG's large hydro resource potential, the government should concentrate its efforts over the next few years to lead the development of the economy's hydropower resources to encourage success. At the same time, since there is already a good level of private sector involvement in bioenergy, the government may consider taking a back seat and instead play a supportive role in this aspect. After laying the foundation and building up momentum for hydro and bioenergy, it may then be a good time to focus resources on wind and solar energy, and finally followed by geothermal and ocean energy.

Recommendation 3: Tariff review – Government should, with inputs from PNG Power Limited (PPL), work towards setting a tariff level that reflect actual costs to support sustainable development of energy projects.

Meanwhile, in order to support the sustainability of energy projects, the government should review its electricity tariffs. With inputs from PPL, the government should work towards setting a tariff level that reflect actual costs of supplying electricity (including capital cost of energy infrastructure and running cost).

Recommendation 4: Capacity building

Recommendation 5: Training – Assess the requirements of its workforce and review the need for training across the board, including knowledge transfer from foreign investors to the locals.

One of the low hanging fruits is for the government to devote more resources, both technical and financial, to enhance the capacity of agencies in implementing policies or action plans, such as the rural electrification unit of PPL and the Climate Change Development Authority, which play important roles in the energy sector. There are also several technical assistance programmes on capacity building offered by international donor agencies, which the PNG government can explore.

Similarly, the respective units of the government responsible for energy development should assess the requirements of its workforce and review the need for training across the board. The government needs to strengthen its collaboration with stakeholders. As foreign companies operate most of the energy infrastructure in PNG, it would be beneficial for PNG if knowledge transfer from these foreign companies could form part of the contract or agreement.

Example: Operating/Service Contract in the Philippines

A service contract is formed between the government and energy developers, which provides for technical capability enhancement for the local technical staff (DOE, the Philippines, 2017a).

Recommendation 6: Education and public communications

Recommendation 7: Awareness raising – The Department of Petroleum and Energy (DPE) to collaborate with relevant agencies to develop and circulate information, education campaign (IEC) on the energy policies/projects.

Another challenge that PNG should address is the lack of public awareness on the benefits brought about by electricity. It must be highlighted to the communities that electricity is of more value than currently realised as it enables and enhances other services e.g. health (refrigerated medicines, and better communication with urban centres) and education (e.g. through lighting and the internet). As the rural communities are already used to living without electricity, electrification may not be their priority. Therefore, the government should create a programme for massive education and public communication to improve fundamental understanding on the benefits of electricity and convey that the benefits of electricity would outweigh its costs (e.g. efficient electric lighting replacing kerosene lighting is an example of a direct benefit). In particular, local provincial governments need to play active roles in raising awareness due to diverse language and culture.

DPE should collaborate with the relevant government agencies in PNG to develop and implement information and education campaign (IEC) on the government's policies and projects on energy.

Example: Power Patrol in the Philippines

The Filipino government created the *Power Patrol* in the late 90s, with the households in small villages as the target to 1) respond to the need of ensuring a continuous, adequate, and economic supply of energy with the end in view of ultimately achieving self-reliance in the economy's energy requirements; and 2) to promote and adopt energy conservation, renewal, and efficient utilisation of energy so that our energy supply and resource can keep pace with economic growth and economic development (DOE, the Philippines, 2017b).

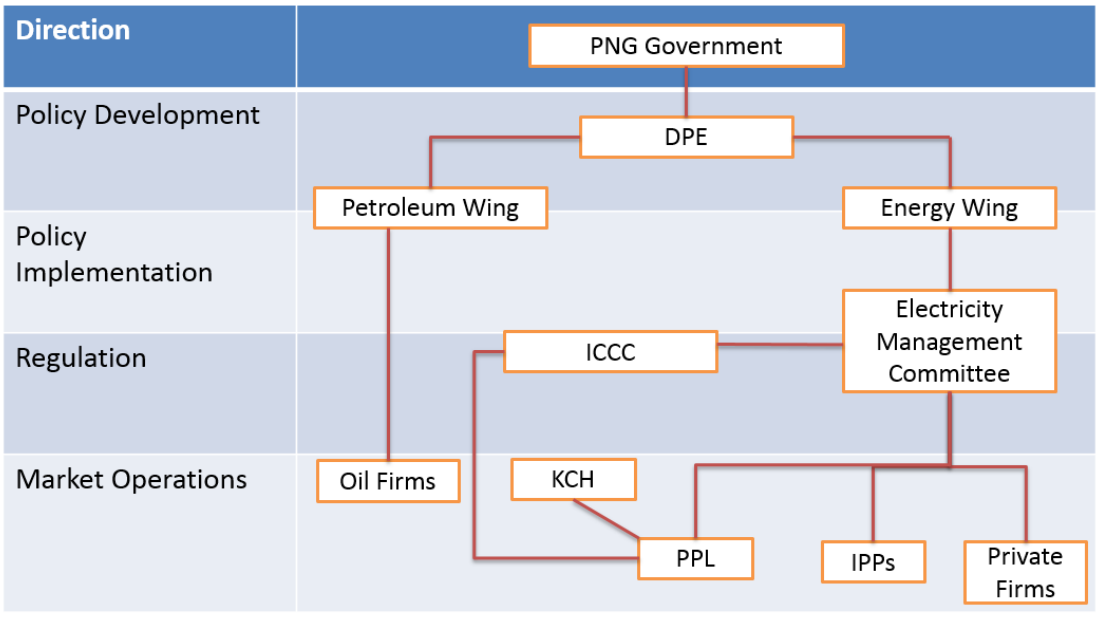
2. INSTITUTIONAL CONTEXT

ACHIEVEMENTS AND CHALLENGES

Achievement 1: PNG has clearly established a lead agency for energy development, with well-defined roles and functions within the agency

DPE oversees the energy development in Papua New Guinea (PNG). There are two main divisions within the DPE – the Petroleum Wing and the Energy Wing. The Petroleum Wing is dedicated to matters relating to PNG's petroleum resources while the Energy Wing is in charge of planning and implementing all other energy policies including renewable energy (RE) policies. The Energy Wing of the DPE also leads the development and implementation of the National Electrification Rollout Programme (NEROP), an important project that lays out the roadmap for PNG to achieve its target of increasing electricity access to 70% of households by 2030. *Figure 2.1* shows the institutional arrangements for the energy sector in PNG.

Figure 2.1: Institutional Arrangements for Energy Sector in PNG



ICCC = Independent Consumer and Competition Commission
IPP = Independent Power Producer
KCH = Kumul Consolidated Holdings
PPL = PNG Power Limited

Source: Presentation slides by DPE

Achievement 2: Good collaboration between DPE, the Department of Public Enterprises and PNG Power Limited (PPL), which facilitated the establishment of the NEP 2016 – 2020

The establishment of the NEP 2016-2020 (Department of Public Enterprises and Department of Petroleum and Energy, 2015), as the economy's first energy policy since political independence in 1975, was a significant milestone for PNG. It charts out the energy development strategies, including RE development plans, which seek to improve the quality of life for its citizens in support of the PNG Vision 2050.

The NEP was jointly published by DPE and the Department of Public Enterprises, demonstrating good collaborative efforts between the agencies. Furthermore, the two agencies also worked closely with state-owned power company PPL to understand its available assets and planned projects, and incorporate its inputs into the NEP. Such collaboration between the government and relevant stakeholders is vital to the formulation of practical development plans for the energy sector.

Achievement 3: Successful organisation of multi-stakeholder PRLCE workshop

DPE successfully organised the PRLCE workshop, which was well-attended by all relevant RE stakeholders including the Climate Change and Development Authority (CCDA), Department of Public Enterprises, Department of National Planning and Monitoring, PPL, private companies, academia, etc. The workshop thus presented a good platform to discuss PNG's energy plans and RE issues, with inputs from different stakeholders' perspectives.

Challenge 1: Manpower shortage and lack of official mandate

Despite the important role played by the Energy Wing in the DPE, it is seriously under-staffed with only 13 out of 77 positions filled. While the current team is very capable, there is insufficient manpower to handle the large volume of work required to progress towards the government's ambitious energy targets. This would adversely affect work productivity and efficiency, and potentially derail the progress of projects handled by the Energy Wing. Regardless of the reasons for not addressing this in the past, it is now pertinent for the Energy Wing of DPE to be fully staffed and resourced to ensure timely progress of various projects and action plans.

In addition, many government officials are designated as 'acting officials'. The lack of formal mandates has hindered their ability to perform their duties at times, especially when liaising with foreign counterparts. This has also affected the morale of officials who are not recognised for performing beyond their actual designations.

Challenge 2: Government agencies are fragmented and tend to lack good coordination

Critical functions of the energy sector are vested in different institutions, causing some overlaps and confusion.

Challenge 3: Insufficient consultation and communications with stakeholders

During the PRLCE workshop, the PNG stakeholders also participated actively in the Question-and-Answer (Q&A) sections following each presentation by a PNG representative. There were a number of questions fielded from one PNG stakeholder to another, seeking clarity on the developments in various energy sectors. This suggests that usual communication and consultation among the different energy stakeholders may not have been sufficient.

RECOMMENDATIONS

Recommendation 8: Ensure sufficient human resources to drive energy policies

In order to ensure that there are sufficient human resources to drive energy policies, the central government should restore the budget for the vacant positions in DPE and allow more time for recruitment. At the same time, DPE should make it a priority to commence recruitment to fill the positions as soon as the budget is approved. Without enough staff, any government organisation cannot function properly. This is also in line with the first principle of the NEP, which seeks to "strengthen institutional capacity and recruit right human capital" for the energy sector. It may also be useful to second staff from other agencies with good capacity to the DPE to assist with the implementation of certain projects or policies. For example, PPL could second some of its staff to the DPE to help set up the new rural electrification division. This would help improve communication between the agencies (as the secondees would have pre-existing relationships within PPL), and would also assist with the technical planning work that the rural electrification division is likely to encounter.

Recommendation 9: The PNG Government should allocate enough budget for RE and other energy policies including personnel expenditure.

If PNG has insufficient revenue to finance important government expenditure, several options could be considered, such as the implementation of tariffs.

Example: Special Duties and Taxes in Japan

Japan introduced a special purpose duty on petroleum imports to finance energy policy budget including personnel expenditure. Such special duty is easy to collect and also discourages consumption of imported petroleum, enhancing energy security and low-carbonisation of energy system. However, if such special duty is difficult to implement due to international commitments, special purpose sales tax on fuels could be introduced. Japan introduced special sales tax on gasoline (though not for energy policy budget but for road construction).

Recommendation 10: Many government officials are designated as "acting" officers. This situation should be made known to higher officials (maybe at the ministerial level) and rectified in order to give clear mandate to the relevant officials.

Recommendation 11: Communications across government agencies should be improved to ensure that each agency is aware of what another agency is doing. In the long run, there should be further streamlining across government agencies. It is important to provide individual agencies with a clear division of responsibilities so that resources can be deployed effectively.

Recommendation 12: DPE should foster closer contact with all RE stakeholders. It might be better to create a standing committee on RE policy for closer links and communication between relevant government agencies.

Recommendation 13: More consultation with private companies during the development of market policies, and more public engagement prior to rolling out public infrastructure plans.

It may be useful to develop market-based energy policies (e.g. electricity tariff review) following consultation with the private sector to shape practical policies. In order to gain buy-in from the masses regarding infrastructure developments (e.g. as part of the rural electrification plan), DPE should also engage with the public to ensure that the objectives are clearly communicated and the process clearly explained.

3. RENEWABLE ENERGY GOALS, TARGETS AND STRATEGY

ACHIEVEMENTS AND CHALLENGES

Achievement 1: PNG has set an ambitious renewable energy goal of 100% by 2050, and an intermediate target of serving all new load with renewable energy by 2030.
These overall goals define success for the development of energy resources in PNG, and enable the prioritisation of individual projects and programs. Without these overarching goals, prioritising near-term actions can be difficult.

Achievement 2: PNG is considering an 'all of the above' approach to sources of energy, investigating natural gas, solar, wind, geothermal, hydro, ocean, and biomass.
Unlike many island economies, PNG has a variety of energy resources that can support the prosperity of its economy. The Peer Review Team learned of power projects, whether existing or in construction, ranging from biomass to hydro with storage and natural gas. Other resources, such as solar, wind, and geothermal, are under varying degrees of study. These resources have the potential to complement each other as PNG pursues its energy and economic development goals.

Achievement 3: PNG also has an ambitious goal of enabling 70% of its population to access electricity by 2030.
This goal aligns with several global aspirations embodied in, for example, the United Nations Sustainable Development Goals and the Millennium Development Goals. Electricity becomes valuable when it powers equipment that improves economic productivity or quality of life, so it will be important to link this electricity access goal with economic or social outcomes.

Challenge 1: PNG has not communicated any targets for improving the reliability of electricity service or reducing costs to ratepayers.
During the presentations at the peer review, several commenters noted that the supply of electricity from the existing grid suffers from a lack of reliability, and others noted that electricity tariffs would not support economic development. The Peer Review Team experienced at least one unplanned outage during its week in the capital, Port Moresby. Without diminishing their importance to energy security, economic development, and sustainability, renewable energy goals should be pursued with consideration of the reliability and affordability of electricity supply.

Challenge 2: Less than 15% of the population has access to electricity, and a similarly low percentage of the population lives in urban areas.

Private capital tends to flow to electric systems with predictable sources of revenue, a stable number of customers, and timely payments from large users, including government customers (Dan Aschenbach, 2015). Increasing rural access can be costly and logistically challenging, and present uncertain returns in the face of competing infrastructure priorities.

Example: Mobilisation of Public Funds in the United States to Electrify Rural Areas

In the early 1900s, as investor-owned utilities built electricity grids in metropolitan areas of the United States, rural areas remained without access to electricity. From 1930 to 1945, several central government programs increased access to electricity in rural America from 10% of farms to nearly 45% (National Museum of American History, n.d.). This was made possible by direct financial support from the federal government to cooperatively-owned distribution utilities. The National Renewable Energy Laboratory of the United States Department of Energy has found the mobilisation of public funds to be critical in more recent electrification efforts in other parts of the world (Terri Walters, 2015). Similarly, the World Bank estimates that US $35 billion per year is needed to achieve universal access by 2030, but notes that donor contributions for electricity access amount to approximately US $700 million per year (World Bank, 2010a).

RECOMMENDATIONS

Recommendation 14: PNG should focus attention and resources on a near-term action plan to develop the lowest cost renewable resource available near load centres.

PNG is blessed with a variety of energy resources. Presenters provided information to the Peer Review Team on activities spanning the full range of potential energy resources for PNG. The Peer Review Team visited one large hydroelectric project development site near Port Moresby, learned of a biomass project serving New Britain, and discussed how the University of Papua New Guinea could host a sizeable solar project.

While resources such as ocean thermal or geothermal may benefit PNG in the future, presently available commercial technology at relatively low costs can improve quality of life in PNG in the near term. Given the institutional issues addressed earlier in this report, focusing on a few priority projects may result in the biggest impact, making the most of both donor funds and PNG government expertise. Channelling efforts and resources towards success in one or two areas can be the foundation for success in other areas. As a point of reference. *Figure 2.2* shows an estimate of power generation costs from the National Renewable Energy Laboratory (NREL) of the United States Department of Energy.

Figure 1.2: Estimate of power generation costs from its Annual Technology Baseline

Technology		CF Range		CAPEX Range		OPEX			LCOE Range	
		Min. (%)	Max. (%)	Min. ($/kW)	Max. ($/kW)	Fuel Costs ($/MWh)	Fixed O&M ($/kW-yr)	Variable O&M ($/MWh)	Min. ($/MWh)	Max. ($/MWh)
Dispatchable										
Coal	PC	55%	85%	$ 3,859	$ 3859	$ 20	$ 32	$ 5	$ 71	$ 97
	IGCC	55%	85%	$ 4,141	$ 4,141	$ 20	$ 53	$ 7	$ 80	$ 109
	CCS-30%	55%	85%	$ 5,341	$ 5,341	$ 22	$ 68	$ 7	$ 97	$ 135
	CCS-90%	55%	85%	$ 5,906	$ 5,906	$ 26	$ 79	$ 9	$ 112	$ 154
Natural Gas	CT	7%	30%	$ 864	$ 864	$ 32	$ 12	$ 7	$ 70	$ 173
	CC	56%	87%	$ 1,032	$ 1,032	$ 21	$ 10	$ 3	$ 36	$ 42
	CC-CCS	56%	87%	$ 2,154	$ 2,154	$ 24	$ 33	$ 7	$ 58	$ 73
Nuclear		92%	92%	$ 5,979	$ 5,979	$ 6	$ 102	$ 2	$ 80	$ 80
Biopower		52%	52%	$ 3,889	$ 3,889	$ 3	$ 108	$ 5	$ 130	$ 130
Geothermal		80%	90%	$ 5,055	$ 13,480	$ 0	$ 155	$ 0	$ 64	$ 183
CSP with 10-hr TES		42%	59%	$ 8,133	$ 8,133	$ 0	$ 66	$ 4	$ 130	$ 181
Non-Dispatchable										
Wind	Land-based	11%	47%	$ 1,573	$ 1,713	$ 0	$ 51	$ 0	$ 40	$ 179
	Offshore	31%	50%	$ 3,891	$ 8,331	$ 0	$ 131	$ 0	$ 105	$ 271
Photovoltaic	Utility	13%	27%	$ 2,014	$ 2,014	$ 0	$ 13	$ 0	$ 67	$ 134
	Commercial	11%	18%	$ 2,465	$ 2,465	$ 0	$ 18	$ 0	$ 124	$ 204
	Residential	12%	20%	$ 4,025	$ 4,025	$ 0	$ 24	$ 0	$ 180	$ 298
Hydropower		60%	66%	$ 3,895	$ 7,261	$ 0	$ 77	$ 0	$ 69	$ 126

Source: National Renewable Energy Laboratory, http://atb.nrel.gov/

Recommendation 15: PNG should engage with rural communities to develop a remote, off-grid power system as part of delivering other public services, such as health, mobile banking, agricultural marketing, or remote education.

Electricity becomes valuable when it powers equipment that improves the productivity or quality of life of those with access to it. An electrification programme may be more impactful if it is linked with well-articulated purposes, such as access to health services, remote education or agricultural marketing. This would enable engineering solutions tailored to the electricity access needs in different communities, balancing the cost of providing access with the expected benefit.

Donor funding is not often available for cross-sectoral projects, and coordinating discrete funding streams from different donors at different times would be challenging for PNG officials. Long-term government commitment to delivering quality of life improvements in PNG is important to support its electrification efforts.

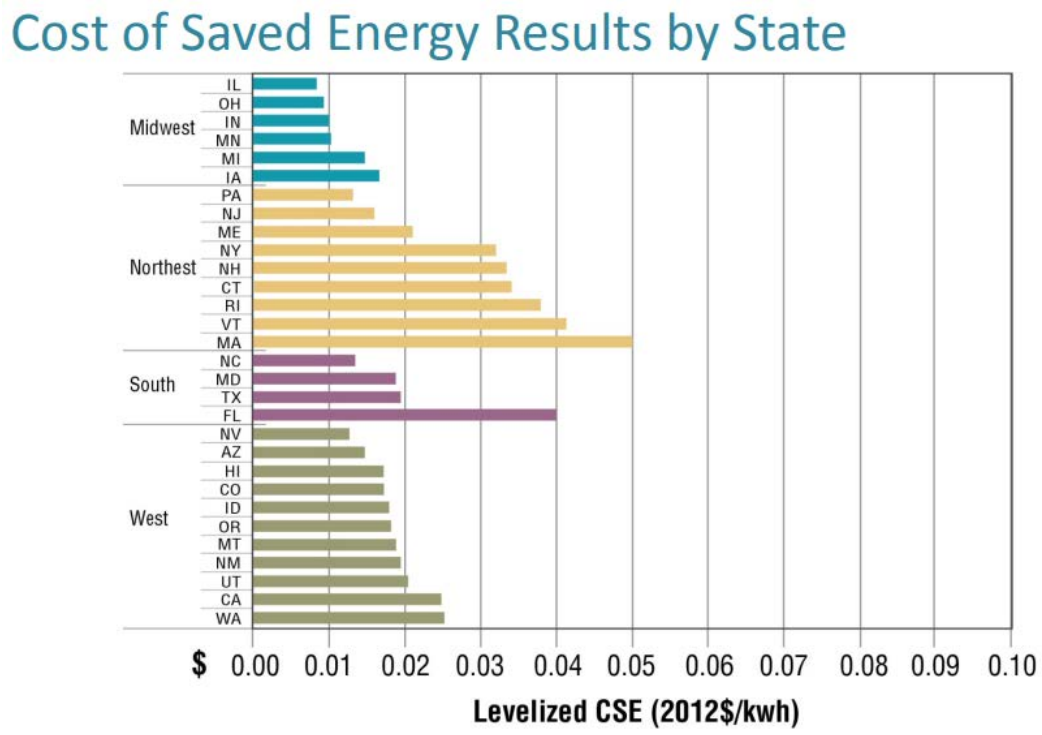
Example: Successful Electrification from Viet Nam, Laos, Bangladesh and Tunisia

Viet Nam, Laos, and Bangladesh enjoyed some electrification success recently, attributed in part to a sustained commitment to long-term goals by the national government (World Bank, 2010a). Tunisia achieved its electrification goal through a cross-sectoral approach that emphasised health and education over forty years.

Recommendation 16: PNG should prioritise new renewable energy and energy-efficient technologies as part of its energy development strategy.

Promoting energy-efficient technology, such as through preferential customs treatment or consumer outreach efforts, will help optimise capital-intensive investments in power generation and grid infrastructure. Energy efficiency programs in the United States are estimated to cost US $0.021 per kWh saved (see *Figure 2.3* below), which is lower than the cost of producing electricity and lower than electric rates paid by consumers.

Figure 2.3: Estimates of the Cost of Saved Energy (CSE) in the United States



Source: Lawrence Berkeley National Lab, http://emp.lbl.gov/publications/program-administrator-cost-saved

In comparison, the most recent cost estimates for power generation technology show the cheapest option is natural gas combined cycle at a range of US $0.036—$0.042/kWh. While new generating equipment and grid upgrades will be part of the economic development of PNG, energy efficiency efforts can complement the relatively capital-intensive investments in power supply.

4. REGULATION AND INFRASTRUCTURE

ACHIEVEMENTS AND CHALLENGES

Achievement 1: PNG has established the authority for economic regulation of the electricity sector in its competition agency, Independent Consumer and Competition Commission (ICCC).

This type of regulation can be used to ensure that electricity system costs are incurred in a prudent fashion and allocated to the appropriate electricity consumers. It can also support the provision of additional energy services in a cost effective manner.

Achievement 2: Many energy-related policies are in draft form, awaiting priority setting from the new government.

As discussed in the Overarching Findings, much of the needed groundwork has been laid for a supportive policy environment, enabling the newly-elected government to quickly set priorities for the development of the electricity system in PNG.

Challenge 1: Some issues, such as biodiesel standards and community benefits from hosting energy infrastructure, have not been fully addressed.

PNG does not have significant supply chain related to manufacturing of energy technology or energy-consuming consumer appliances, such as refrigerators. For power generation, several presenters noted that securing the land necessary for larger energy projects can be difficult in PNG, in part because there are varying expectations of fair compensation for hosting these projects.

Challenge 2: Concerns with the reliability and quality of electric service and the condition of the electricity grid.

In order to attract and retain commercial and industrial customers, power quality and system reliability need to meet expectations. Unplanned outages and other system fluctuations can also damage expensive consumer appliances. In addition, there was some uncertainty as to the level of non-technical losses and electricity theft, which can negatively impact system operations.

RECOMMENDATIONS

Recommendation 17: PNG should rely on internationally-recognised standards when establishing new regulations covering the performance of technology.

The development of new regulations regarding the performance of technology requires appropriately trained staff, laboratory resources, and sustained engagement with local manufacturers. Given the current supply chain and consumer market in PNG, the efforts of other APEC economies to regulate their manufacturers and set internationally-recognised product standards can be applied in PNG to the benefit of its consumers. In addition, relying on standards developed by larger economies for globally-competitive firms will help harmonise these standards within APEC. Harmonising these standards with those in other APEC economies will help protect PNG consumers from any sub-standard equipment excluded from other APEC economies, and set expectations for any new businesses in PNG.

Recommendation 18: PNG should consider establishing performance standards for electricity providers, such as benchmarks for reliability and line losses, to complement economic regulation.

Government-owned utilities are often insulated from allocative efficiency encouraged by private capital flows. Similarly, the financial penalties imposed on poor-performing investor-owned utilities are not typically imposed on state-owned enterprises. In regulating the electricity sector and the performance of PNG Power Ltd, economic regulation can be the foundation for the improvement of electric service in PNG. It will be necessary to understand the costs and benefits of new energy services in order to set expectations for the performance of service providers in safely meeting the demand of customers for new technology, such as distributed energy. These performance standards could also cover the benefits that should flow to a community hosting a power project, borrowing lessons learned from community benefits agreements around the world.

Recommendation 19: PNG should analyse latent demand for electricity so that capital-intensive energy infrastructure investments can be optimised to meet customer needs in non-electrified areas.

Expansion of electric generating capacity is expected to reach 2 500 MW by 2030; however, the numbers behind this calculation were not available for the Peer Review Team. Whether this level is appropriate depends on macroeconomic variables such as population and economic development, as well as electric system variables, such as capacity factor and technical losses. To avoid overbuilding the electric system at the expense of other capital-

intensive projects important to PNG, the capacity expansion of the electric system should be estimated with caution and consideration of all relevant factors.

Compared with peers in Asia and Africa, the 2 500 MW estimate might provide much more electricity than needed for PNG's demand. If population grows at 2.5% each year to 2030, and assuming the 70% electrification goal is met, then PNG will need to supply electricity to approximately 7.7 million people. *Figures 2.4a and 2.4b* show the electricity consumption per capita of GDP across APEC economies. If electricity consumption rates are comparable to the Philippines and Indonesia, the generating capacity needed to serve this load might be less than half the 2 500 MW figure shared with the review team. A better understanding of the assumptions used in reaching the 2 500 MW estimate would help determine whether that level of capacity is an appropriate infrastructure planning goal.

Figure 2.2a: Electricity consumption per capita against GDP per capita

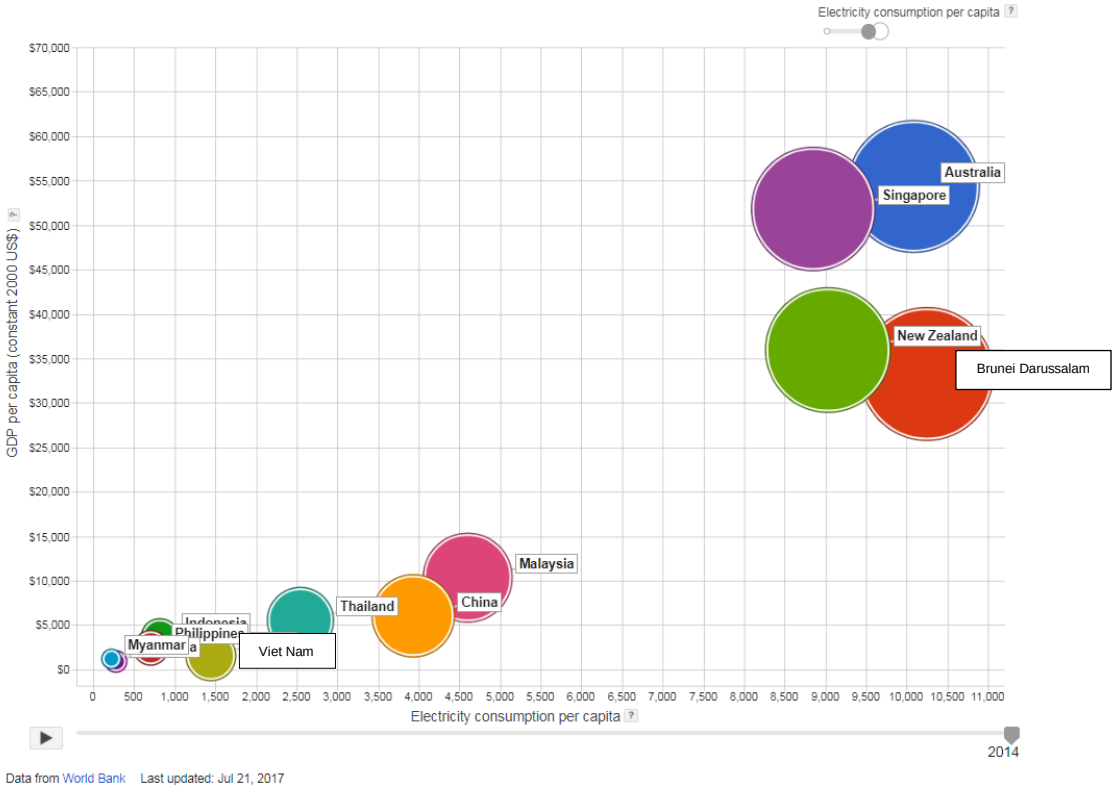
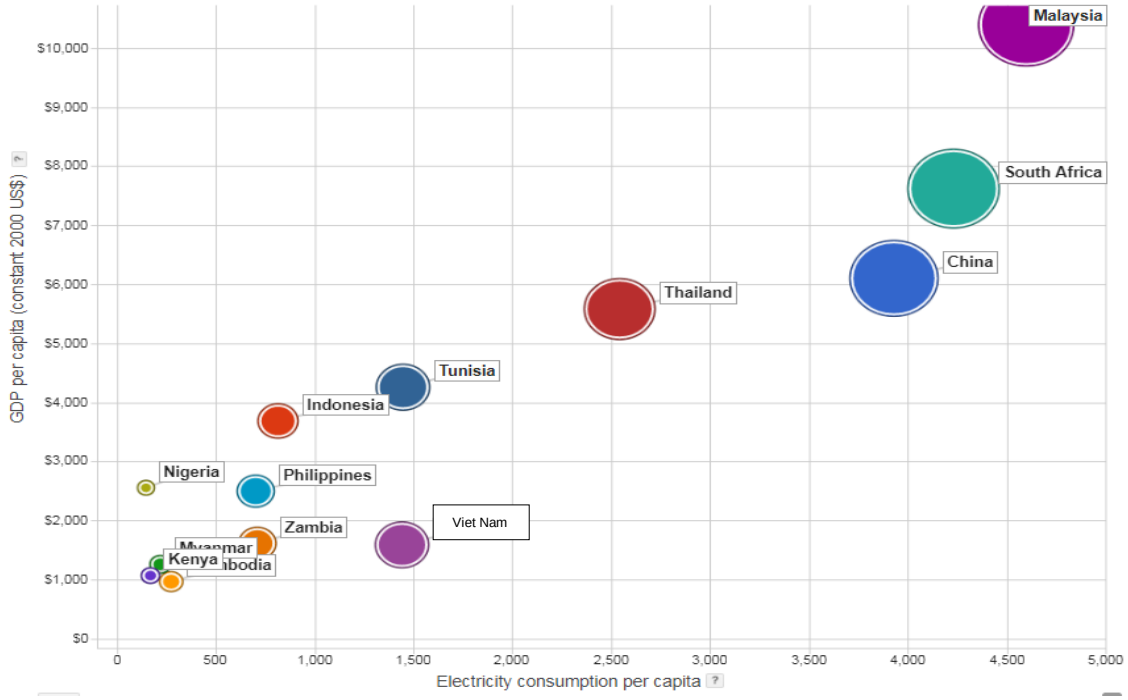


Figure 2.3b: Electricity consumption per capita against GDP per capita



Source: World Bank, 2017

Recommendation 20: PNG should consider whether electrification policies should be implemented by a dedicated entity or programme, such as a programme within DPE, to enable PPL to focus on meeting reliability needs in load centres and with new industrial customers.

The experiences of the Philippines, the United States, Bangladesh, and Costa Rica indicates that specific organisations dedicated to rural electric service can effectively achieve higher electrification goals. Such electrification efforts can be cooperatively run by the communities themselves. On the other hand, Laos, Mexico, Thailand, and Tunisia relied on publically-owned utilities to achieve electrification goals. Experience from India, Tanzania, and Ghana highlight the potential for public-private partnerships in achieving rural electricity access. The World Bank found the following common elements in successful electrification efforts:

(1) An understandable and transparent system to prioritise the areas to receive electricity and the projects to be selected,

(2) A long-term commitment that accounts for local factors, such as supply chain and human capital,

(3) Simplified regulatory requirements on rural systems that ensure safety without imposing undue costs, and

(4) An approach that takes into account other conditions for sustainable rural development (World Bank, 2010a).

These elements extend beyond the design and operation of a centralised electricity grid. PNG should consider these elements in designing an effective electricity access programme with appropriate regulatory requirements.

5. BIOENERGY—BIOFUELS, BIOMASS

ACHIEVEMENTS AND CHALLENGES

In terms of bioenergy (biofuels and biomass), Papua New Guinea (PNG) has been using biomass resource mainly for residential cooking due to high price of liquefied petroleum gas (LPG) and limited access to electricity (13% as of 2010). Recently PNG has pursued biomass for electricity generation to achieve 100% renewable electricity target in PNG Vision 2050. However, PNG's plan on biofuel utilisation is still limited in research scale.

Achievement 1: Available biomass feedstock at industrial scale

There already exist industries for sugarcane and oil palm plantations, which provide feedstock for bioenergy application, e.g. biomass power plant and biofuel. However, production of both ethanol and palm oil are limited to food applications and export.

Achievement 2: Already plan and on-going project for bioenergy utilisation

To achieve PNG Vision 2050, the NEP has been drafted with nine key principles. One of the principles (Principle 8) explicitly promotes the introduction of biofuels for use in the transport and power generation sector. Moreover, a biomass power plant of 62 MW has been planned by 2030 with additional 34 MW of capacity expected by 2050. These biomass plans are supported by Oil Search (PNG) Ltd, PNG's largest company with over 80 years of investment history and a key player for wood-fuelled IPP (Independent Power Producer). In addition, two biogas power plants from palm oil effluent has been privately commissioned for carbon-credit purposes, with many more coming up in the near future.

Achievement 3: Technical capacity building for biofuel project

At the research and demonstration level, the local university Pacific Adventist University conducted a pilot study in 2010 to convert used cooking oil (UCO) within the campus to biodiesel. The study has since been later expanded to involve local restaurant for UCO collection. Arising from the project, technical personnel, necessary equipment and public awareness for biodiesel usage will be able to support the drafting of biofuels law for biofuel blending in transportation sector within the Biomass Energy Sector Sub-Programme of National Electrification Roll Out Plan (NEROP).

Challenge 1: Lack of specific targets/mechanisms for biofuel usage in transportation sector

Despite a high fraction of energy used in transportation, i.e. 49% in 2013 total final energy consumption (Department of Petroleum and Energy, 2017); PNG lacks specific targets for biofuel usage in transportation sector. This is in contrast to the clear renewable targets set for electricity. With available biofuel feedstock (both sugarcane for bioethanol and oil palm for biodiesel), appropriate mechanisms should be introduced to convert this biofuel feedstock into biofuel for economical local usage. Furthermore, since the car industry in PNG mainly relies on the import of both new and used cars, discussions with car makers and local dealers are necessary for biofuel promotion.

Challenge 2: Lack of technical standards/guidelines for biofuel promotion

Unlike biomass/biogas power plants, where large companies have invested in technology and training technical personnel, biofuel has not caught the attention of private sector. Currently, only one university project with limited resources in funding and technical knowledge have explored this field. PNG government can help to support the university initiative by incorporating biofuel into the national agenda in order to catch interest from private sector.

RECOMMENDATIONS

Recommendation 21: Take best practices from other APEC economies regarding biofuel implementation

With successful implementation of biofuel for transportation in many APEC economies, PNG can consult other economy stakeholders to learn more about the best practices. For instance, national standards and guidelines for biofuel (bioethanol and biodiesel) should be developed from adopting existing international/regional standards to ensure workability and consistency. In addition, relying on standards developed by larger economies for globally-competitive firms will help harmonise these standards within APEC. Harmonising these standards with those in other APEC economies will help protect PNG consumers from any sub-standard equipment excluded from other APEC economies, and set expectations for any new businesses in PNG. PNG government should also conduct formal consultations with car makers/local dealers for technical support, as well as potential local producers of biofuel. Appropriate pricing schemes or government incentives may need to be introduced to kick-start biofuel programme, e.g. tax exemption on biofuel blending.

6. HYDROPOWER AND OCEAN ENERGY

ACHIEVEMENTS AND CHALLENGES

Achievement 1: Hydropower is the most dominant source of RE in PNG

Hydropower is the most dominant source of RE-based capacity in PNG. In 2014, oil remained as PNG's major energy source, accounting for 44% of the primary energy supply mix, followed by petroleum products with 32% then by geothermal/solar with 15%, natural gas with 6% and hydro 3% (Department of Petroleum and Energy, 2017). Based on this, there is a need to reduce the heavy reliance of PNG on imported fossil fuels by diversifying the fuel mix.

Achievement 2: Hydro and ocean energy are considered as contributors to PNG's target of 100% RE by 2050

The PNG Development Strategic Plan (PNGDSP) 2010–2030 seeks to increase the RE-based power capacity of PNG to 100% renewables by 2050. The RE Plan intends to increase the hydropower capacity by 1 483 MW in 2030 and further to 3 680 MW by 2050 from Port Moresby and Ramu grids.

Challenge 1: Absence of policy on hydropower and ocean energy development (micro, mini, large, ocean) i.e. incentives, guidelines, etc.

PNG lacks policy on the development of hydropower and ocean energy. The policy should guide the investors on how to develop hydropower and ocean energy potential sites. Furthermore, it should provide both fiscal and non-fiscal incentives to encourage private sector and foreign investments in hydropower and ocean energy development.

Challenge 2: Lack of resource assessment on hydropower and ocean energy potentials (limited data available and lack of experts)

Data on hydropower and ocean potential sites are very limited. There is an estimated potential capacity of 15 000 MW hydropower in PNG. However, data is very limited and potential sites need to be validated. On the other hand, there have been very limited activities in ocean energy sector. One reason is due to the high investment cost for ocean energy development. Furthermore, majority of the potential sites are located in areas where there is little or no demand. Therefore, developing the resource might not be economical. Local experts are also very limited.

RECOMMENDATIONS

Recommendation 22: Enact a law that provides policy direction and incentives on developing hydropower and ocean resources

In order to intensify and encourage the development of hydropower resource and ocean energy potentials, enactment of a law or a policy direction is needed. The policy or law should guide the investors on how to develop hydropower and ocean energy potential sites. It should also provide both fiscal and non-fiscal incentives to encourage private sector and foreign investments in hydropower and ocean energy development

There is a need to conduct resource assessment of hydropower and ocean energy potential sites. This is necessary to guide investors on the sites which are ready for development. PNG can seek both technical and financial assistance from international donor agencies.

To complement the programme, local capacity building should be included.

7. SOLAR AND PV

ACHIEVEMENTS AND CHALLENGES

Achievement 1: Solar energy application is still in its infancy in PNG, though some stand-alone solar PV systems have been applied in rural areas and remote telecommunication stations.

Existing solar energy applications in PNG are mostly found in rural areas due to rural electrification programs initiated by many stakeholders like politicians, the national and local government units. Most applications are stand-alone PV systems, ranging from 20–90 W individual solar home systems to community based lighting applications. Telecommunication companies have also adopted PV as back-up power to their remote cell sites in urban areas, and solar thermal water heaters could sometimes be found in the city. However, the application of solar PV is still uncommon in PNG.

Achievement 2: The University of PNG (UPNG) recognises the need for further research in solar energy and have proposed the establishment of a solar project at its campus.

The University of PNG Centre of Renewable Energy was established in 2015, aiming to increase research activities, awareness and training to encourage renewable energy applications. Also, according to the PNG Climate Change and Development Authority news bulletin, UPNG has submitted a solar energy project proposal for the consideration of the Green Climate Fund in January of 2017. The project is expected to be installed at the campus, and will include solar electricity production for campus buildings and electric vehicles. If the UPNG campus project is successful in its goals of achieving carbon neutrality, it may be possible to replicate the model to other campuses.

Achievement 3: High solar energy installation target of 50 MW by 2022 is commendable.

The Solar Energy Sector Sub-Programme (SESP) set an aspirational target of establishing 50 MW of solar installed capacity by 2022, and 100 MW by 2050. According to the APEC Peer Review Background Information document, these targets may increase if large-scale hydropower is evaluated to be too expensive to build and the economy opts to increase installed capacity of other renewable energy sources such as solar, wind or biomass. The SESP is envisioned to support the PNG Energy Plan in ensuring energy security, pursuing effective implementation of energy sector reforms, and implementing cross-sector monitoring mechanisms.

Challenge 1: Clear guidelines and project development mechanisms are required.

Although PNG has drafted the NEP that lists the development of sustainable energy solutions as a core principal, practical promotion mechanisms have not yet been determined. Due to high initial cost of setting up solar PV systems, it is important to accelerate initiatives on solar energy to provide clearer directions, particularly in formulating clear guidelines in project development and establishing implementation mechanisms.

Challenge 2: Difficulties in land acquisition for large-scale solar farms.

The economy of PNG relies primarily on subsistence farming and smallholder cash cropping of coffee, cocoa and copra, implicating that land ownership is fragmented. However, the installation of solar farms requires large areas of land. Negotiation with landowners thus prove to be a challenge. In addition, farm owners generally resist leasing out arable land for the construction of solar farms. Clear guidelines for land acquisition would need to be developed, and business models that integrate solar energy generation with agricultural development should be discussed.

RECOMMENDATIONS

Recommendation 23: Establish solar energy demonstration projects at school campuses.

By establishing demonstration projects at school campuses, the government of PNG could field test the technical feasibility of solar PV system applications in urban settings while circumventing the issue of private land acquisition. The data generated from the demonstration system could be analysed for future study, and technology training and promotional materials could be derived from the demonstration project. Finally, according to the training materials, experts could train technical personnel or the local industry in solar energy utilisation.

It is recommended that small solar demonstration systems with data monitoring mechanisms be installed in five to ten schools to support lighting or cooling services. School staff and students must be encouraged to participate in the demonstration system design and installation process, to allow the locals to have hands-on experience in solar energy systems. Under the school environment, the demonstration project could involve local academia and energy industry to jointly explore the best solar energy solution for PNG, and eventually generate a comprehensive solar energy training programme. The training programme should include contents such as introduction to solar PV system architecture, basic solar PV system installation site assessment, technology and economic evaluation of solar PV systems, and most importantly the operation and maintenance of a solar energy system.

Through the implementation of demonstration projects, the government of PNG could collect information on solar energy system installation related to cost, technical or institutional barriers in integrating renewable energy systems to the utility grid, and survey local industry support resources. These reference data could help the government of PNG to establish concrete guidelines, promote the use of solar energy and encourage the development of a local solar energy support industry.

Recommendation 24: Design stand-alone solar lighting system pilot projects for rural villages and develop a sustainable financial model.

About 85% of the population of PNG resides in fragmented rural areas where extension of the utility grid is difficult and costly. Due to PNG's superior solar irradiation condition, it is recommended that the government of PNG develop stand-alone solar systems for rural electrification, and develop a sustainable financial model to generate sufficient revenue to support long-term operations and maintenance of the power supply system.

The government of PNG could commence by identifying one to two rural villages per province as pilot sites, and collect local power demand information through on-site surveys. The pilot projects should contract with reliable system providers and technical assistance teams for the design and installation of the pilot systems. Capacity building workshops on basic system maintenance and troubleshooting should also be offered to local villagers to ensure system upkeep in the following years of system operation.

Through the implementation of the pilot projects, the willingness to pay for electricity of local villagers should be examined. Then, a financially recoverable business model should be proposed together with the evaluation of relevant approaches to financing and/or government subsidies of rural energy systems. Power tariff collected from the villagers could be used as funding for future power supply system maintenance work to ensure long-term operation of the power supply station and ensure the sustainability of the project.

It is also recommended that the project assist local villagers in forming a management committee to supervise ongoing system operations, maintenance and tariff collection. To ensure that the pilot villages have the right capability to operate and maintain the power system, the power management committee and local villagers should be encouraged to participate actively throughout the inception of the pilot project.

Example: Solar PV Mini-grid Systems for Lighting in Myanmar Rural Area

A successful stand-alone solar energy project was completed in mid-2017 in Myanmar Rural Area in the Magway and Sagaing Regions. The mini-grid system generates a centralised power supply with solar energy, providing households and public facilities with electricity for lighting through a newly established distribution network. Local villagers were involved throughout the planning and construction of the pilot project. A series of technical capacity building sessions were also offered to the villagers, and a power management committee was formed. The pilot project is designed such that the power management committee receives regular power tariff revenue from village households for maintaining the mini-grid. With the success of this project for rural electrification, the Myanmar government is currently planning a series of stand-alone solar PV mini-grids.

8. GEOTHERMAL ENERGY

ACHIEVEMENTS AND CHALLENGES

Achievement 1: Geothermal resources have been technically proven

PNG's first geothermal plant was established in Lihir Gold Mine with a capacity of 56 MW. Therefore, the resource has been technically proven. Based on an Icelandic group estimate, PNG has a potential of 4 000 MW.

Achievement 2: Geothermal considered as contributor to PNG's target of 100% RE by 2050

The PNGDSP 2010–2030 seeks to increase the RE-based power capacity of PNG to 100% renewables by 2050. The RE Plan intends to add 95 MW from geothermal to Gazelle grid by 2030 and another 110 MW to Ramu Grids by 2050.

Challenge 1: Absence of policy on geothermal energy development i.e. incentives, guidelines, etc.

Geothermal development is capital-intensive, and PNG lacks policy on the development of geothermal energy. The policy should guide the investors on how to develop geothermal energy potential sites. Furthermore, it should provide both fiscal and non-fiscal incentives to encourage private sector and foreign investments in geothermal energy development.

Challenge 2: Lack of resource assessment on geothermal energy potentials (limited data available and lack of experts)

Data on geothermal potential sites are very limited. Only surface data (surface manifestations) are available. There is an estimated potential capacity of 4 000 MW based on estimated provided by an Icelandic group. However, data is very limited and potential sites need to be validated. Furthermore, majority of the potential sites are located in areas where there is little or no demand. Thus, developing the resource might not be economical. Local experts are also very limited.

RECOMMENDATIONS

Recommendation 25: Enact a law that provides policy direction and incentives on developing geothermal energy resources

In order to intensify and encourage the development of geothermal resource, enactment of a law or a policy direction is needed. The policy or law should guide the investors on how to develop geothermal potential sites. Furthermore, it should provide both fiscal and non-fiscal incentives to encourage private sector and foreign investments in geothermal energy development. There is a need to conduct resource assessment of geothermal potential sites. This is necessary to guide investors on the sites which are ready for development. PNG can seek both technical and financial assistance from international donor agencies. To complement the programme, local capacity building should be included.

9. WIND ENERGY

ACHIEVEMENTS AND CHALLENGES

Achievement 1: Inclusion of wind power in its development strategies

While there is no commercial scale grid-connected wind power in PNG currently, wind power has been included as one of the development strategies in the PNG Vision 2050. PNG has set targets for installed wind capacity to reach 30 MW by 2030 and 50 MW by 2050 to diversify the RE applications in PNG.

Achievement 2: Wind resource assessment

The World Bank funded wind resource mapping study started in 2014 and will be completed by 2018. Interim reports on mesoscale modelling (World Bank, 2015a) and site identification (World Bank, 2015b) were published. Regions in PNG with relatively higher wind resources have been identified. Upon completion of the study, a more complete picture on the availability of wind resources in PNG will be available, which will then reveal the true potential and the scale of economic development of wind power in PNG.

Challenge 1: Conflicting information

Based on the background information provided by PNG, the economy is noted to have good wind resources but no concrete data was available to support the claim. According to data from the 1980's, it is possible to have a wind generator installed in Port Moresby. However, a study conducted by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) indicated that wind resources in PNG may not be sufficient to vastly develop wind power. These contradicting information, together with the lack of comprehensive wind resource assessment, make it difficult to evaluate the practicality of wind power target set in the Vision 2050. A more insightful evaluation can only be done after the completion of the wind resource mapping study funded by the World Bank.

Challenge 2: Uncertain return on investment of wind power projects

With no existing projects in PNG, the financial sector may not show great interest in wind power developments, which are often viewed as risky investments due to high initial costs and long payback period. Incentives need to be considered in order to raise their interest, which will be discussed in the recommendations.

Challenge 3: Lack of experience and professional working in wind power

Currently, there is no commercial scale grid-connected wind turbine installed in PNG, and no information regarding stand-alone off-grid installation. PPL, as well as private sectors have limited experience in construction and operation of wind turbine/farm in PNG. Relevant professionals working in this area are also lacking. This will pose great challenges in developing wind power in PNG.

Challenge 4: Land accessibility and environmental issues

The installation of onshore wind turbine/farm needs a vast area, particularly for a wind farm. Although the land underneath the wind farm can be cropped or farmed, it still depends on the willingness of landowners. As 97% of the land in PNG is occupied by landowners, problems may arise due to the accessibility of land for any potential wind power project. On the other hand while offshore wind turbine/farm installations can circumvent landownership issues, the high capital cost of developing offshore options must be considered. Furthermore, the levelised cost of electricity (LCOE) for offshore wind farms, though decreasing, will still be much higher than that of onshore wind farms (PD Ports, Clean Energy Pipeline, 2014). Finally, environmental issues, such as noise and visual impact, may cause concern to local people. The project also needs to get through the respective environmental legislation before approval.

RECOMMENDATIONS

Recommendation 26: Early planning of wind turbines installation

It takes about three to four years to commission a wind power project from the planning stage. Therefore, PNG is recommended to start planning as soon as the results of wind resource mapping is proved to be positive so as to catch the target completion timeline in 2022 for the first 10 MW of wind power in Port Moresby. A sizable wind farm project should establish a grid code, which defines the requirements of a wind farm connected to the national grid to ensure safe, secure and economic operation. Therefore, PNG may need to consider the grid code at early stage.

Recommendation 27: Offering of incentives to private investors

As mentioned, the initial cost of developing a wind power system is high. In order to attract the interest of private investors, more incentives should be considered, such as tax rebates, tax concessions on RE equipment, higher return rate and so on.

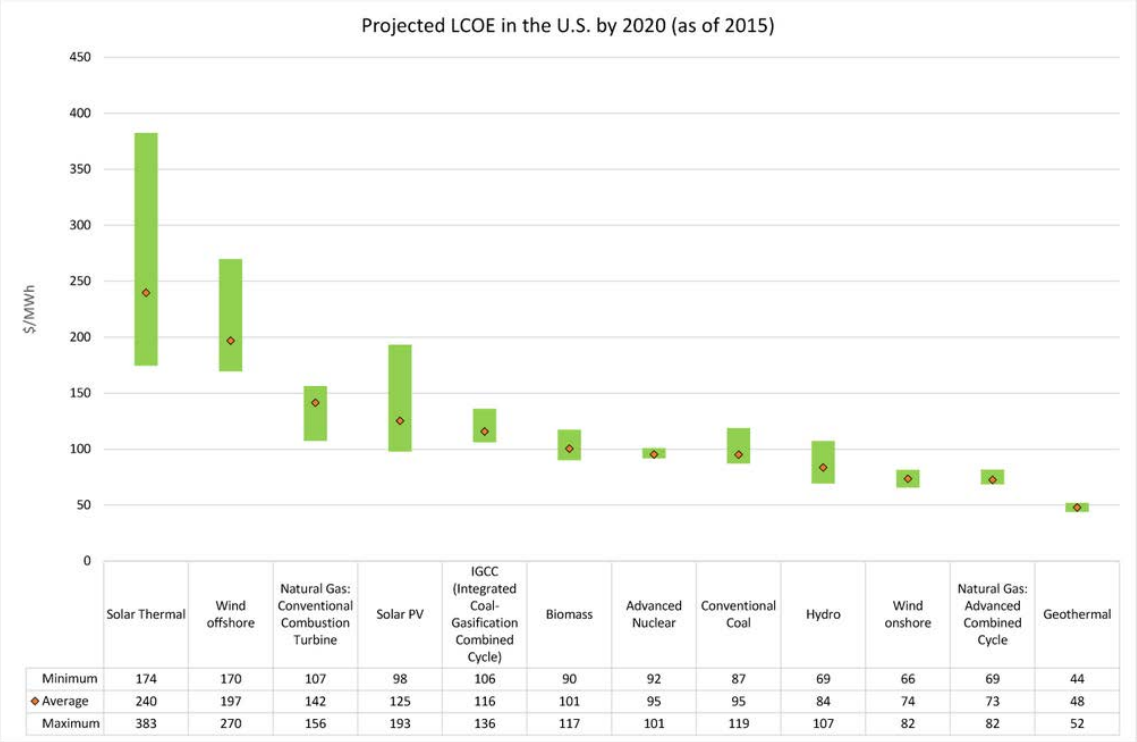
Recommendation 28: Construction of off-grid wind turbines

Construction of standalone off-grid wind turbine is comparatively easy and has fewer constraints as compared to grid-connected wind power. PNG has around 600 islands and many of them are still un-electrified. Private sectors should be encouraged to engage in construction of off-grid wind turbines, particularly in remote areas with sufficient wind resource but not connected to the national electric grid.

Recommendation 29: Enhancement of scale of target installation

As the LCOE for wind power is normally quite low as compared with other renewable power (see *Figure 2.5* below), PNG can consider expanding the scale of installation after getting more experience from the initial construction phase. This may be particularly useful in the event the target solar uptake cannot be met. It is not difficult to expand wind power provided that the wind power density of the potential site is greater than 400 W/m2. In the market, the largest available power capacity of wind turbine is 8 MW that has a tower height of 140 m and swept area of 21 000 m2. Given sufficient wind resources, building two to three wind turbines of medium capacity can fulfil the development target.

Figure 2.5: Projected LCOE of Renewable Energy in the U.S.



	Solar Thermal	Wind offshore	Natural Gas: Conventional Combustion Turbine	Solar PV	IGCC (Integrated Coal-Gasification Combined Cycle)	Biomass	Advanced Nuclear	Conventional Coal	Hydro	Wind onshore	Natural Gas: Advanced Combined Cycle	Geothermal
Minimum	174	170	107	98	106	90	92	87	69	66	69	44
Average	240	197	142	125	116	101	95	95	84	74	73	48
Maximum	383	270	156	193	136	117	101	119	107	82	82	52

Source: (Wikipedia, 2015)

Recommendation 30: Encourage communication with various stakeholders

As the construction of the wind power projects would likely involve negotiations with landowners, more communications with landowners and various stakeholders are highly recommended in order to develop a win-win situation. The messaging could be focused on exploring the feasibility of creating a better environment for the landowners and the villagers, profit sharing for the project and so on.

Recommendation 31: Government support for research and training

It has been highlighted that there is not much government support for local research on RE in terms of research funding, particularly in the area of wind power. Therefore, it is recommended that the PNG government provide more financial support and collaborate with local universities on wind power research. As there are insufficient wind power/RE professionals, government should also support universities and tertiary institutions to provide more vocational courses and trainings related to wind power and other RE to train up more professionals in this area.

10. POWER SUPPLY SYSTEM, SMART GRID, PRIVATE PARTICIPATION

ACHIEVEMENTS AND CHALLENGES

Achievement 1: PPL has developed adequate human capital

PPL has developed good institutional capacity (both technical and managerial). PPL has also recognised that, as consequence of its capability, it will have a key role in influencing and developing PNG's energy policy. There is also good capability within the DPE but it appears to have insufficient resources for the challenges ahead (particularly rural electrification).

Achievement 2: The Naoro-Brown hydro project could offer a model for further IPPs

PNG is making very good progress on encouraging independent generation. The Naoro-Brown Edevu hydro project is a very good example of PNG putting together a project that is 'investable' by parties from outside PNG. The land and other economy-specific challenges were resolved prior to the project being tendered, thus lowering risks for developers.

Challenge 1: The future generation portfolio (more renewables) will require different skills and capabilities from the current predominantly diesel-based system

Just as diesel generators depend on fuel supply, renewable generation is reliant on the availability of the underlying renewable resources. Instead of simply dispatching diesel generation, PPL will have to understand the second-to-second, day-to-day and seasonal variability of renewable resources (e.g. 'one in one hundred year' drought risks affecting hydropower) and have the right type of generation to respond to these changes in renewable resource availability. PPL will therefore need to have an increasing focus on developing flexible generation options.

Challenge 2: Understanding the full implications of increasing electricity access/renewable electricity targets

It appears that PPL is starting to understand the implications of increasing electricity access and renewable generation targets. The targets are very ambitious. It is likely that further work will be required in this area so that PPL can inform the government of the resources required to deliver on the current targets.

Challenge 3: Changing operating environment

PPL and DPE are facing a changing operating environment. Some of the changes include:

- Reducing costs of new technologies (e.g. PV) such that private sector investment occurs rapidly.
- Potential rapid increase in demand (on existing networks) from new commercial connections, and growth in existing residential connections.
- Potential change in intra-day demand patterns and requirements.

Challenge 4: Affordability of electricity

While ambitious targets have been set for rural electrification, there remain funding challenges:

- Rural communities are unable to afford electricity (except for the most basic needs such as lighting).
- The cost of rural electrification are typically higher than grid-scale supply where hydro generation is available.
- The existing uniform national electricity tariff discourages private sector involvement in rural electrification.

RECOMMENDATIONS

Recommendation 32: The investment focus should move from individual 'least-cost generation projects' to a 'least-cost generation portfolio' approach.

It is recommended that PPL use a portfolio approach in evaluating new generation options. While it is more complex, it better identifies the least-cost generation option for PNG. An important aim of all power systems is to provide electricity at the least cost. Complex trade-offs need to be made when deciding the type of electricity generation to build.

Power systems require electricity demand and supply to be matched instantaneously, since storage of electricity is very expensive. Managing a diesel-based power system is relatively easy – electricity can be easily generated to match demand whenever required because the generator can be easily ramped up or down. However, managing a power system based largely on renewables is much more challenging, as electricity generation is only possible when the renewable resource is available. Furthermore, each type of renewable generation has its unique seasonal, daily and even locational generation patterns. This means that the availability of renewable resources needs to be considered before deciding the type of plant to be built, such that the collective output of the renewable generation matches the expected demand patterns (to minimise the need for expensive diesel generation).

For example, hydropower generation must consider whether the annual rainfall patterns matches the seasonality of electricity demand and if not, whether hydro storage solutions could help to bridge the gap.

The most common way to calculate the cost of an electricity generation is by considering the Levelised Cost of Electricity (or LCOE), which looks at the lifetime electrical generation in comparison to the lifetime costs (capital and operating). A key assumption is that all electricity generated from a specific project is used. However, it must be cautioned that in reality, the LCOE of individual generation plant is less useful in electricity systems that have a moderate proportion of renewable electricity. This is because there are times of surplus electricity generated from renewables, which typically cannot be stored and is thus wasted as generation spills. For some technologies, this spill can be significant, even at relatively low proportions of renewable electricity penetration (this is already the case for solar PV in some Pacific Island economies). Therefore, using LCOE alone to compare generation options risks underestimating the actual generation costs of integrating some technologies into the power system. It is essential to factor in the cost due to generation spills, which requires assessing the entire generation fleet as a portfolio. In simple terms:

- The LCOE approach looks at a generation project in isolation, assuming that all of the possible generation will be used, and
- The portfolio approach considers the impact of a new generation project on the existing electricity system (both supply and demand), and allows for issues of generation being spilled, or more diesel 'back-up' generation being required.

Recommendation 33: Better understand the drivers of electricity demand

In most economies, electricity demand growth is based on three key factors:

- Social living patterns (i.e. the pattern of intra-day electricity use, which is typically different for residential and commercial sectors)
- The number and type of electricity connections (e.g. residential and commercial etc.)
- The wealth of the economy (i.e. gross domestic product, and consumer's ability to pay for electricity).

In economies which are not fully energised (e.g. Papua New Guinea, Vanuatu, Solomon Islands etc.) the number of electricity connections is driven by:

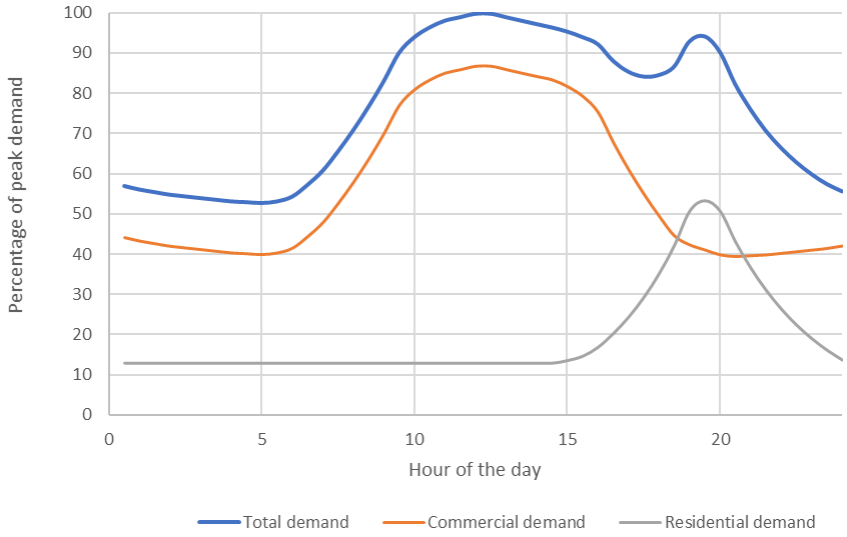
- Population growth (as in most other economies)
- The rate of connection of existing, but not yet connected, households.

Demand growth in the commercial and residential sectors typically follows different patterns. In the commercial sector, once a new commercial load connects to the network, it is likely to be relatively stable and will not show large growth over time. However, given PNG's rapidly developing economy, and that electricity supply is available in the main urban centres, connection rates (i.e. adding new commercial loads) have the potential to increase rapidly.

In the residential sector, electricity demand on the distribution network can increase very quickly if households become wealthier (i.e. increased buying power for more appliances). The overall shape of average daily demand in Papua New Guinea's Port Moresby network can be seen in *Figure 2.6* below. This actual total demand data has been disaggregated into the estimated average commercial and residential load components. The commercial load currently dominates the intra-day demand shape, as shown by the midday peak in demand.

It should be noted that the curve is based on average data, and hence the actual day-to-day variability on the residential load may be significantly more than the commercial loads (i.e. due to discretionary use of air conditioning, as experienced in other tropical economies). Therefore the residential peak may already be close to being the actual peak demand on very hot days.

Figure 2.6: Average daily electricity demand (total demand, and estimated residential and commercial components)



Source: Derive from data in UPNG's presentation to the Review Team

Overtime, as living standards increase, the residential demand could gradually dominate the intra-day demand shape on urban grids. This would arise through households buying air conditioners and other peak time appliances (cooking, television, lighting, etc.). Therefore, the residential load needs to be closely monitored because it has the potential to be the causer of peak demand in the near future. We can also see that residential load in off-grid systems will need careful design to match generation (e.g. PV) to the evening demand – typically storage will be required in the form of mini hydro or batteries (for PV).

A key point here is that it is necessary to forecast on-grid demand to allow the optimal type and amount of generation to be built. The same applies to off-grid systems, where the shape and magnitude of demand could change very quickly as communities adjust from having no

electricity, to a reliable electrical supply (and buy appliances as their income grows). For off-grid systems, it is not just the generation, but also whether a full network, micro-grid, or stand-alone household systems are used.

Recommendation 34: Start developing capability to assess the impacts of solar photovoltaic generation

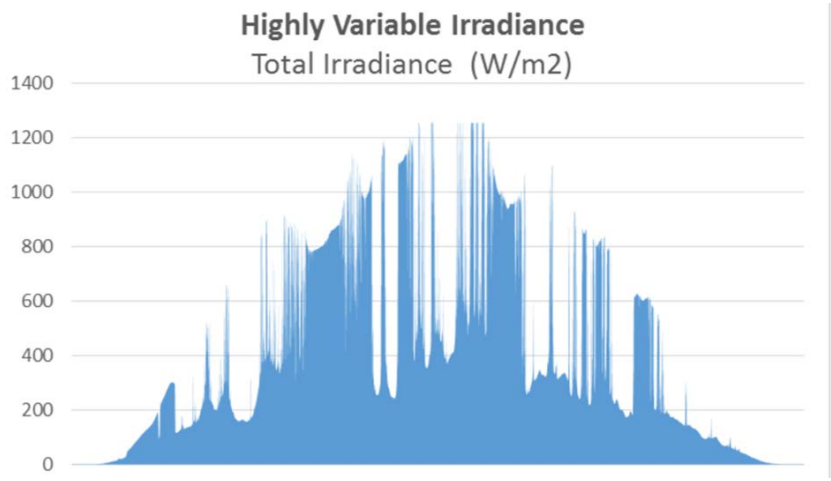
Solar photovoltaic generation could be connected to PPL's network in considerable quantities in coming years. This is because it is a relatively simple technology for the private sector (and donors) to develop. However, there is little, if any, policy guidance on the scale, type, and configuration of PV that can be added to the network.

During the PRLCE visit, the Review Team learnt that UPNG is considering to install a large solar PV array on their campus. If such a large PV array is installed in one location (such as the University), then it is likely to have significant adverse impacts on security and reliability of the power system. This could add overall economic costs for the electricity system, even though it resulted in lower electricity charges for the University.

The increase in system costs arises because the output of solar PV arrays is not constant – it fluctuates second to second as passing clouds block the array (see *Figure 2.7* below).

This is very significant or large arrays (as proposed for UPNG) as about 75% of the PV generation could be lost in a matter of ten or so seconds. It would be very challenging for the rest of the power system to cope with such a disturbance.

Figure 2.7: Variability of solar resource in cloudy conditions



Source: (Australia Renewable Energy Agency, 2015)

However, the issue is not about the number of PVs installed but the concentration of PVs in a single location. By dispersing the installation locations of the PVs (e.g. about a kilometre apart or more), geographic diversity means that not all arrays will be affected at the same time by the same clouds. This will significantly lower the net variability caused by solar PV on the

network. There are also other issues caused by solar PV such as steady state 'voltage rise' on networks, and dynamic voltage problems. Overall, it would be very useful for PPL to start developing the capability to understand these impacts of solar PV before the technology starts to be widely deployed in PNG grid systems.

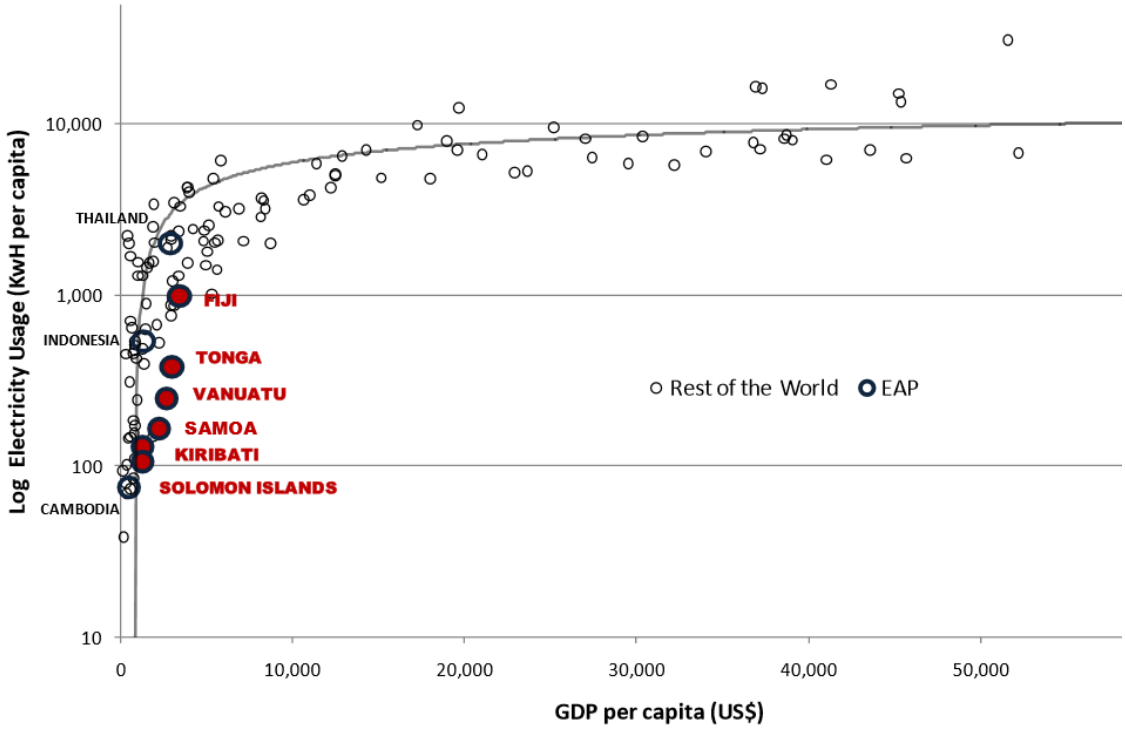
Recommendation 35: Better understand the affordability versus cost, and consumers' willingness to pay (particularly for rural electrification)

A key factor in the design of rural electrification systems is the ability of consumers to afford electricity. If consumers only want electricity for lighting (e.g. because this is all they can afford), then this will determine the type of electricity supply options that are most cost-effective.

However, it is important to not only consider the current electricity affordability, but also how 'affordability' may change over time (e.g. if electricity spurs industrial growth and employment that brings income to the community). This is shown by *Figure 2.8* below, where increasing GDP is highly correlated to increasing electricity consumption at a network level. By understanding the affordability of electricity, it is much easier to plan for rural electrification because:

- Least-cost supply options can be matched to community electrification needs
- The appropriate subsidies can be determined (i.e. the difference between the least-cost supply, its end uses and what the communities can afford)
- Long-term sustainability of electricity tariffs can be assessed (i.e. is enough revenue gathered from the flat electricity tariff to fund the on-grid and rural electrification projects at sufficient rate to achieve PNG's electricity access targets.)
- Whether a different tariff structure may be required, rather than a flat national tariff (this would provide a better investment signal for private sector projects in terms of rural electrification).

Figure 2.8: Chart showing increasing wealth is correlated to increasing electricity consumption



Source: World Bank Data (chart from Vanuatu National Energy Roadmap)

Recommendation 36: Consider moving to more cost-reflective pricing structures in the medium term (temporally, and spatially)

PPL's current electricity pricing is similar to that of many economies in that it is a simple flat tariff that does not vary over time. However, this does not reflect the true cost of electricity production, which varies over time depending on the generation and network costs. It is useful for prices to better reflect the cost of providing electricity service at different locations and different times of the day so that:

- Any parties investing in embedded generation (e.g. PV) see the right price signal to encourage only efficient investment.
- Encourage investment in the most efficient end-use technologies where this is lower-cost than providing additional electricity supply
- Encourage efficient consumption decisions.

11. GREENHOUSE GAS MANAGEMENT

ACHIEVEMENTS AND CHALLENGES

Achievement 1: Strong government will on GHG mitigation

PNG is a global leader in pushing climate change negotiations forward. It is a member of many Multilateral Environmental Agreements (MEA) including the Rio+20, the United Nations Convent to Combat Desertification (UNCCD) and Convention on Biological Diversity (CBD). Over the past two decades, the PNG government has also demonstrated good efforts to address global climate change issues. For example, PNG ratified the UNFCCC in 1993 and Kyoto Protocol in 2002. It is also the first economy responding to the Paris Agreement (COP 21) in 2015. In 2009, PNG launched its Vision 2050 of which it committed to reduce GHG emissions significantly with good forest management and through the development of renewable energy resources. In 2010, PNG government announced the PNGDSP 2010–2030 to advance specific agendas of the Vision 2050. In 2015, PNG established the Climate Change and Development Authority (CCDA) to implement the Climate Change (Management) Act 2015. All the above demonstrated the determination of the PNG government in reducing GHG emissions.

Achievement 2: Market driven projects for CDM transactions

Clean development mechanism (CDM), as defined in the Kyoto Protocol, provides emission reduction projects with certified emission reduction (CER) units which may be traded in emission trading schemes. CDM can assist developing economies in meeting their sustainable development objectives. Some CDM projects had been successfully registered in PNG, including the New Britain Palm Oil Methane Capture Biogas Energy Generation Project, Oil Search Limited's Flare and Vent Gas Conservation Project and the PNG Power Limited's Divune Hydropower Project.

Challenge 1: Unbalanced GHG emissions from LULUCF and non-LULUCF sources

Available data indicated that 95% of the GHG emissions in PNG comes from LULUCF, while only five per cent comes from other sources including energy (non-LULUCF). To reduce emissions from LULUCF, PNG will work with UNDP to implement the economy's REDD+ programme which is aimed at reducing emissions from deforestation and forest degradation, and increasing forest carbon stocks. Tackling the remaining GHG emissions from non-LULUCF sources will be mainly done through reducing fossil-based energy utilisation by improving energy efficiency and adoption of renewable energy. It should be cautioned that

due to the disproportionately large contribution to GHG by LULCF, any effort made in reducing emissions from non-LULUCF sources through RE and energy efficiency initiatives would easily be cancelled out by ineffective emission control measures for LULUCF sources.

Challenge 2: Aggressive targets of GHG reduction

Total GHG emissions in PNG are projected to increase in all sectors by 32% and three to five times for energy, transportation and oil and gas sector by 2030 due to economic and population growth. According to the Copenhagen Accord and the PNG Vision 2050, PNG would decrease its GHG emissions by at least 50% before 2030 while becoming carbon neutral before 2050. Therefore, substantial efforts need to be put in in order to achieve these aggressive targets.

Challenge 3: Unsuitable location of RE sources

There are abundant RE resources in PNG but many are located in remote locations with limited demand. It is not cost effective to construct long transmission lines from these remote locations to the main grid line.

RECOMMENDATIONS

Recommendation 37: Expedite the implementation of National Climate Change Policy, and formulation of NEP

The NEP proposed the following actions that can mitigate GHG emissions:

- PNG government will support international action on reduction of GHG
- Ensure minimum energy performance standards for electrical equipment and appliances,
- Adopt building energy codes for energy-efficient buildings
- Promote RE for residential, commercial and public institutions
- Promote the introduction of biofuels in transport and power generation sector
- Formulate and implement an energy efficiency policy
- Promote energy efficiency measures in all sectors in end use of equipment and appliances
- Promote energy audits in all sectors

These policies have long-term impact on mitigating PNG's GHG emissions and therefore should be taken as the top priority for implementation in PNG Government's agenda.

Recommendation 38: Greening road transport

Road transport sector constitutes a large proportion of GHG emissions from energy sources in PNG. Therefore, reducing its emission is considered to be of high priority. Promoting use of clean fuels for motor vehicles such as biofuels and energy-efficient public transport such as bus, tram and other mass transport are recommended. The use of biofuels for transport also fits the recommended biofuel policy for PNG stated earlier.

Recommendation 39: Turning waste into energy

It is highly recommended to increase energy recovery from waste, such as biomass waste and used cooking oil (UCO). There is good energy content in such waste; their disposal will not only waste energy and increase the burden of treatment facilities but also increase GHG emissions. Currently, a palm oil harvesting company in PNG, which is grid-connected, has used sludge from palm oil extracting process to produce biogas for electric power generation. The Pacific Adventist University of PNG also found it feasible to turn UCO from hotels to biodiesel. There are also other waste-to-energy technologies that the PNG government may consider, such as food waste to energy, wastewater treatment sludge to biogas and so on.

Recommendation 40: Provide more incentives for energy efficiency (EE) and renewable energy (RE) initiatives

Energy efficiency can improve the efficiency of energy generators and reduce energy consumption, while RE can substitute the use of fossil fuels. Both EE and RE initiatives can reduce GHG emissions and are common tools for GHG management. However, initial cost of implementing EE and RE may be high with long payback period depending on the technologies. To show its support, PNG government should consider providing incentives to private sectors for implementing EE and RE initiatives.

Recommendation 41: Raise the awareness of EE and RE.

Government and institutions should provide more training and publicity on EE and RE to raise awareness. Fundamental knowledge of RE and energy conservation concepts can be started in primary and secondary education. Relevant technologies and information can be uploaded on the websites of relevant government departments.

Recommendation 42: Encourage more sectors and NGOs to participate in market driven CDM projects to mitigate GHG emissions.

Currently, only a few projects are registered as CDM projects in PNG. As CDM transactions can help to mitigate the GHG emission, the PNG government should encourage more sectors and NGOs to participate in market driven projects for CDM transactions.

Recommendation 43: Adoption of GHG management tools

There are a number of GHG management tools that have been demonstrated to be useful to reduce GHG emission such as energy/carbon audit, energy efficiency and energy conservation. PNG government has policies on energy efficiency and energy conservation under the Climate Change (Management) Act 2015. However, it is neither common to have energy audits conducted in government and private sectors nor many professional energy auditors practicing in PNG. It is therefore recommended for PNG to promote energy or carbon audit, energy efficiency and energy conservation measures in the government, commercial and industrial sectors. Government and tertiary institutions should also provide training to equip energy professionals with the necessary skills to carry out these measures.

Recommendation 44: Develop and implement building energy codes for new buildings

Buildings account for about 30% of all energy consumption globally and constitute a significant share of GHG emissions in most economies. Building energy codes help ensure that new buildings use energy efficiently, and this can reduce building energy use. It is foreseeable that PNG will have more modernised buildings in the coming decades, particularly in major provinces and cities such as Port Moresby. In western economies where the building sector is one of the most energy-consuming sectors, relevant building energy codes have been developed in order to have green and energy-efficient buildings. Therefore. PNG should also consider developing building energy codes. This could be included in the NEP.

Example: Summary of Building Codes by the World Bank

A World Bank report (World Bank, 2010b) summarises the findings of an extensive literature survey of the experiences of implementing building energy efficiency codes in developed economies, and can be a good reference to PNG.

The following are the building energy codes in some economies/regions for reference as well:

- IEA Energy efficiency requirement in building codes, energy efficiency policies for new buildings (International Energy Agency, 2008)
- U.S. Building Code (U.S. Department of Energy, 2017)
- National Energy Code of Canada (National Research Council Canada, 2011)
- Australia: Building Code of Australia (Australia, 2017)
- Country Report on Building Energy Codes in Australia (Pacific Northwest National Laboratory, 2009)
- Japan: Energy efficiency building standards (Asia Business Council, n.d.)
- Hong Kong, China: Codes of practice for energy efficiency of building services installation (Electrical and Mechanical Services Department, 2015)

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