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PAPUA NEW GUINEA ELECTRIFICATION PARTNERSHIP

OFF-GRID MARKET ASSESSMENT

About

ABOUT USAID-PEP

The United States Agency for International Development (USAID) Papua New Guinea (PNG) Electrification Partnership (PEP) Activity is a five-year (2020–2025) project partnership with the Government of Papua New Guinea (GoPNG) to advance the country's journey to self-reliance by contributing significantly to achieving the goal of connecting 70 percent of PNG's population to electricity by 2030. RTI International implements the project in collaboration with Oil Search Foundation, Energy Security Group, Delphos International, Fraym, Kaizen, Hawaii Natural Energy Institute and NEOS Advisory. USAID-PEP is part of the United States Government's Indo-Pacific Strategy, particularly the Asia Enhancing Development and Growth through Energy (EDGE) Initiative, which supports market-based energy policy and reforms, the modernization of energy infrastructure, and expanded access to affordable, secure, and reliable energy supplies.

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Acronyms and Abbreviations

AC	Alternating Current
ADB	Asian Development Bank
AIFFP	Australian Infrastructure Financing Facility for the Pacific
APEC	Asia-Pacific Economic Cooperation
ANZ	Australia and New Zealand Banking Group
C-Center	Community Center
CEDAW	Convention on the Elimination of All Forms of Discrimination against Women
CEPA	Conservation and Energy Protection Authority
CIPE	Center for International Private Enterprise
COVID-19	Coronavirus Disease 2019
CSO	Civil Society Organization
DDA	District Development Authority
DFAT	Australian Department of Foreign Affairs and Trade
DHS	Demographic and Health Surveys
DNPM	Department of National Planning and Monitoring
DPE	Department of Petroleum and Energy
DPM	GoPNG Department of Personnel Management
EIA	Electricity Industry Act
EIP	Electricity Industry Policy
ESPIMC	Energy Sector Program Implementation Monitoring Committee
EUPRIP	Energy Utility Performance and Reliability Improvement Project
GBV	Gender-Based Violence
GDP	Gross Domestic Product
GESI	Gender and Social Inclusion
GGGI	Global Green Growth Institute
GIS	Geographic Information Systems
GoPNG	Government of Papua New Guinea
GW	Gigawatt
HDI	Human Development Index
IBRD	International Bank for Reconstruction and Development
ICCC	Independent Consumer and Competition Commission

IEC	International Electrotechnical Commission
IFC	International Finance Corporation
IMF	International Monetary Fund
IPBC	Independent Public Business Corporation
IPP	Independent Power Producer
JICA	Japanese International Cooperation Agency
KCH	Kumul Consolidated Holdings
km	Kilometer
KPHL	Kumul Petroleum Holdings Limited
kVa	Kilovolt-Ampere
kW	Kilowatt
kWh	Kilowatt Hours
LLG	Local-level Government
LNG	Liquified Natural Gas
MFAT	New Zealand Ministry of Foreign Affairs and Trade
MMO	Mobile Money Operator
MMR	Maternal Mortality Rates
MP	Member of Parliament
MSME	Micro-, Small, and Medium-Sized Enterprise
MTDP	Medium-Term Development Plan
MTF	Multi-Tier Framework
MW	Megawatt
MWh	Megawatt Hour
NEA	National Energy Authority
NGO	Nongovernmental Organization
NEMU	National Electrification Management Unit
NEP	National Energy Policy
NEROP	National Electrification Roll-Out Plan
NISIT	National Institute of Standards and Industrial Technology
NRECA	National Rural Electric Cooperative Association
NZAID	New Zealand Agency for International Development

OGS	Off-Grid Solar
PAYGO	Pay-As-You-Go
PEP	Papua New Guinea Electrification Partnership
PFM	Public Financial Management
PGK	Papua New Guinean Kina
PNG	Papua New Guinea
PNGHDL	PNG Hydro Development Limited
PNGPC	PNG Ports Corporation
POM	Port Moresby
PPA	Power Purchase Agreement
PPL	Papua New Guinea Power Limited
PPP	Purchasing Power Parity
PUE	Productive Use of Energy
PV	Photovoltaic
QV	Quality-Verified
RCFI	Rural Community Financial Institution
REDD+	Reducing Emissions from Deforestation and Forest Degradation
ROGEP	Rural On-Grid Extension Project
SE4All	Sustainable Energy for All
SHS	Solar Home System
SIP	Service Improvement Program
STARS	National Strategy for Responsible Sustainable Development for PNG
STREIT	Support to Rural Entrepreneurship, Investment, and Trade
TAM	Total Addressable Market
TEIP	Town Electrification Investment Program
TWh	Terawatt Hour
UNDP	United Nations Development Programme
USAID	The United States Agency for International Development
USB	Universal Serial Bus
V	Volt

Executive Summary

Executive Summary

Since the year 2000, Papua New Guinea (PNG) has made steadfast strides to improve energy access. The Government of Papua New Guinea (GoPNG) places a high priority on addressing climate issues and mobilizing climate finance, and it sees the implementation of advanced energy technologies and creating an enabling environment as a pathway to do just that. While GoPNG's efforts such as the Vision 2050 plan pave a path forward, reducing risks to drive further private sector investment will be critical to ensure the sustainability of the energy sector.

As of 2020, approximately 15 percent of the PNG population has access to electricity through the grid, which is a modest improvement from 2.6 percent in 1996. PNG presents a difficult context to pursue large-scale electrification via a national grid due to a largely rural and remote population as well as populations dispersed across the country's many scattered islands—many with limited or poor access to roads. These factors have contributed to the low grid access rate, but as total costs of owning renewable energy systems have decreased in recent years, individual user- and community-based models for energy access have become significantly more viable. In 2017, IFC estimated that more than 60 percent of the population had adopted a solar product in a few short years (mainly solar lanterns) and left behind the alternatives of kerosene, candles, and dry cell batteries. This development is a positive first step in the PNG off-grid market, which demonstrates customers' willingness to adopt new products.

Most products to date have included solar lanterns, which offer limited benefits beyond improved lighting, and households with a solar lantern are generally not considered to be electrified[1]. Low-quality products have also flooded the market, which has undermined consumer confidence in the sector. Systems that provide higher levels of energy access are less affordable for consumers, which represents a major challenge that stakeholders need to understand and address. This report aims to improve this understanding through research and geographic information systems (GIS) analyses that pinpoint promising areas for off-grid electrification.

This report aims to improve this understanding through research and geographic information systems (GIS) analyses that pinpoint promising areas for off-grid electrification.

With its National Electrification Roll-Out Plan (NEROP) and Vision 2050, GoPNG set the goal of achieving 70-percent electrification by 2030 and 100-percent electrification by 2050. This shows that off-grid electrification in PNG is not merely a short-term opportunity that the grid will eventually replace—it has the potential to grow into a long-term industry that will contribute to GoPNG's energy access goals. Although the off-grid sector is at an early

[1] This report uses the World Bank Multi-Tier Framework to define access to energy, which is detailed in the Off-Grid Market section.

stage in PNG, favorable economics for off-grid technologies worldwide and hundreds of companies and products that companies have developed for the off-grid market in the past decade suggest that the sector is poised for growth through the next decade.

Off-grid electrification presents a viable alternative to providing baseline electricity services where grid extension is cost-prohibitive or technically prohibitive. In addition, grid extension faces several other challenges: the difficult terrain of the country, regulatory uncertainty, foreign exchange challenges, and long project development timelines for the additional generation capacity that is necessary to support additional household connections. These challenges present an opportunity for stakeholders developing the off-grid energy sector, which can readily deploy renewable energy solutions more quickly at lower capital and operational costs. For the purposes of this report, the off-grid market primarily focuses on three key areas: mini-grids, standalone residential solar systems (hereafter referred to as solar home systems [SHS], Tier 1 at minimum), and productive use of energy (PUE) products. Sites best suited for on-grid development are defined as those within 10 km of the existing on-grid infrastructure.

Mini-grids. For communities that are not connected to the local electricity grid, mini-grids are most relevant for areas with a relatively concentrated electricity demand since they require more investment relative to SHS in terms of generation and distribution assets. For a mini-grid to be viable in a location, it must have a certain household or customer density. Many mini-grids already exist in PNG but almost exclusively use fossil fuels.

Stakeholders in PNG are starting to explore renewable energy mini-grids (primarily solar and hybrid gas systems). GoPNG's NEROP identifies 437 locations as priority areas. Key gaps for mini-grid development include unclear regulations; low clarity on willingness and ability to pay for energy services (which affect business models for mini-grid developers); very high costs of equipment related to high transport costs to remote locations; project development issues regarding land ownership; and difficulty installing, operating, and maintaining, and protecting systems from vandalism in these locations. GoPNG is in the process of developing regulations, and donors are supporting demonstration projects to build out and validate business models for mini-grids. This report lays out a set of criteria for choosing promising mini-grid locations and combines it with a GIS analysis incorporating population and socioeconomic characteristics to help stakeholders identify promising locations to develop mini-grids.

Without proper maintenance, design, and quality components, mini-grids break down over time. Individuals often dismantle degraded systems into parts for reuse or sale. PNG Power Limited (PPL) established and operated 26 mini-grids, known as Community Centers or C-Centers, which aimed to provide localized power to communities not within the reach of the country's three main grids. However, as a result of years of improper upkeep, PPL has decommissioned many of these C-Centers.

Solar Home Systems. SHS have great potential in PNG for off-grid electrification in rural regions where there is low expected electricity demand due to the small population size of a community, limited institutional demand, and other logistical and financial reasons. In these settings, SHS are often the least-cost option for households because their total lifetime cost is lower than alternatives. Trained on-site professionals are not necessary to install SHS; rather, SHS products afford customers the ability to "plug and play."

Creating viable financing options for SHS will be key to increasing sales over the next several years. SHS financing models, such as pay-as-you-go financing (PAYGO), that allow customers to purchase and pay off systems over time could benefit both service providers and end-users. Such models allow customers to pay for equipment in affordable installments; and with greater affordability, more potential households can purchase SHS. PAYGO providers can mitigate the risk of customers missing a payment by integrating remote deactivation technology into these systems.

To integrate PAYGO in PNG, providers must adapt to local frameworks. Although mobile money (i.e., transferring money digitally, as enabled by mobile phones) has proven to be a successful model of PAYGO financing elsewhere, it is in a nascent stage of market development in PNG. Implementing PAYGO financing can be complex and may require dedicated business structures and adequate capacity to operate and maintain. Moreover, the upfront costs and long customer payback period of PAYGO financing often require a company to access external financing sources, which presents a challenge due to the currently low private investment levels in PNG.

Challenges for SHS include many of the same issues facing the broader electric sector, such as access to foreign exchange and the deficiency of working capital to sustain constant product flow. GoPNG can address these supply-side challenges in the SHS market by developing fiscal and monetary policies that increase access to foreign exchange and facilitating access to finance for companies. Meanwhile, the high cost of transportation in PNG creates another challenge for SHS companies. This can disincentivize SHS companies from reaching last-mile customers, especially if these customers are unable to bear the additional costs of last-mile transport. GoPNG can provide subsidies to decrease the overall costs of SHS companies or otherwise incentivize companies to reach all consumers.

On the demand side, consumers face issues related to product affordability and low reliability. While prices have come down significantly, consumers have limited financing options in what they can afford to buy upfront. Many consumers are only able to afford the most basic and often poor-quality products. Many consumers, therefore, have the misperception that all off-grid products are low-quality with short lifespans, as compared to traditional sources of lighting such as dry cell batteries, candles, and kerosene. People with these misperceptions are less likely to buy additional off-grid solar products. Targeted subsidies and financing plans can make off-grid products more affordable, while stricter regulations on the importation and sale of non-quality-verified products can reduce the availability of low-quality products.

Productive Use of Energy. PUE technologies offer electrification solutions to address issues by providing energy—both electric and non-electric (in the forms of heat or mechanical energy)—for activities that enhance citizen income and welfare.

For example, solar irrigation systems can improve crop yields, and cold storage systems can reduce food spoilage. This market assessment primarily analyzes PUE solutions related to the three economic activities of agriculture, livestock, and fishing and discusses PUE equipment and use cases that are directly applicable to rural businesses in these sectors. Common uses for PUE technologies in rural communities globally include farming, mining, private enterprise, health, and education. The current PUE market in PNG is comprised of end-users from the government, the agricultural sector, and the National Department of Health. Many of the country's emerging PUE end-users seek PUE products for agricultural activities. Agricultural activities contributed to 17 percent of PNG's gross domestic product (GDP) in 2020, which is comparatively higher than the average contribution of other countries in the East Asia and Pacific Islands Regions, which was 8.4 percent in 2020. There are key issues that plague the PUE market. There are no manufacturers of PUE products in PNG due to the high cost of manufacturing, the small market, and the absence of local supply chains for manufacturing. Further, the number of distributors and resellers is limited due to the scarcity of available financing options. Addressing this factor will be key to advancing the PUE market over the next five to ten years. Other key issues include affordability to end users and access to markets.

Electrification Potential across PNG. NEROP projects that in order to reach GoPNG's electrification goal of 70 percent by 2030, grid expansion and densification will have to provide 43 percent of total connections, assuming 16 kWh per month of electricity demand from all off-grid consumers in order to estimate the affordability of electricity and evaluate on- versus off-grid potential.[2]

This report builds on the NEROP analysis by including socioeconomic considerations that differentiate households and household electricity demand in different regions based on their estimated wealth and monthly expenditures. This report's GIS analysis accounts for the spatial heterogeneity of off-grid potential by leveraging socioeconomic data from two sources: the most recent Demographic and Health Surveys (DHS) program survey in PNG and PPL electricity demand data by province. This report's GIS analysis is consistent with NEROP projections that stand-alone Tier 1 SHS will serve 25 percent of households by 2030. This report also finds that Tier 3 mini-grids could serve the remaining 24 percent of households (with eight percent identified as high potential and 16 percent as viable). This analysis can help potential mini-grid investors and developers identify promising regions for further consideration.

[2] NRECA International, "Papua New Guinea National Electrification Rollout Plan (NEROP) Implementation Strategy and Investment Plan: Final Report 2020."

Purpose

Purpose

The purpose of this market assessment is to provide potential investors, off-grid developers, and other relevant stakeholders with information about the electricity sector in Papua New Guinea as well as the country's political, financial, and socioeconomic landscape. This report describes the current status of both on-grid and off-grid energy development in PNG, and provides an assessment of the market potential for mini-grids, solar home systems, and productive use of energy products. A detailed geospatial analysis that identifies communities best suited for each type of electricity development based on household socioeconomic characteristics is also presented. Those interested in better understanding the growth potential and challenges associated with PNG's power sector will benefit from this report.

Country Context

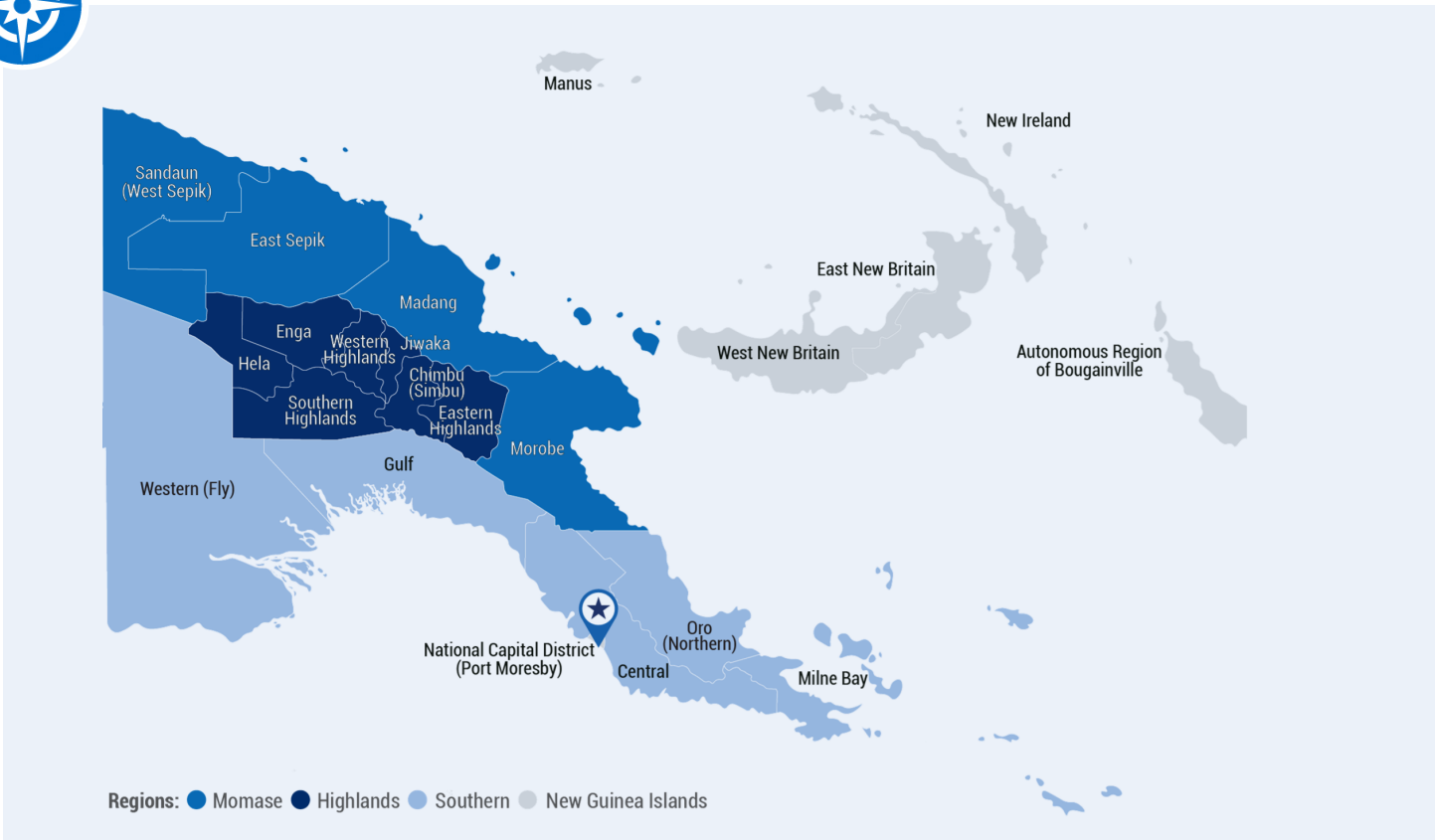
Country Context

PHYSICAL FRAMEWORK

Papua New Guinea occupies the eastern half of the island of New Guinea, located in the South Pacific Ocean, and shares a border with Indonesia. It has 22 provinces in four major regions: the central Highlands Region, the Islands Region, the Momase Region on the northern coast, and the Southern Region, which contains the national capital Port Moresby (see Figure 1). The area of PNG covers more than 462,800 square kilometers, making it the third-largest island country in the world.[3]

PNG enjoys a tropical climate and diverse flora and fauna. However, its location along the Ring of Fire means that earthquakes, volcanic eruptions, and other natural disasters are regular occurrences. Grid connectivity is a particular challenge, as its geography includes more than 600 individual islands, with steep elevations and thick rainforest cover across the main island.[4] While grid connectivity is low, with estimates of 15 percent, sales of off-grid solar products have grown steadily and, according to projections, are continuing to grow.[5]

FIGURE 1. MAP OF PAPUA NEW GUINEA'S REGIONS, PROVINCES, AND PROVINCE CAPITALS



[3] Asian Development Bank, "Financing Sustainable Growth in Papua New Guinea."

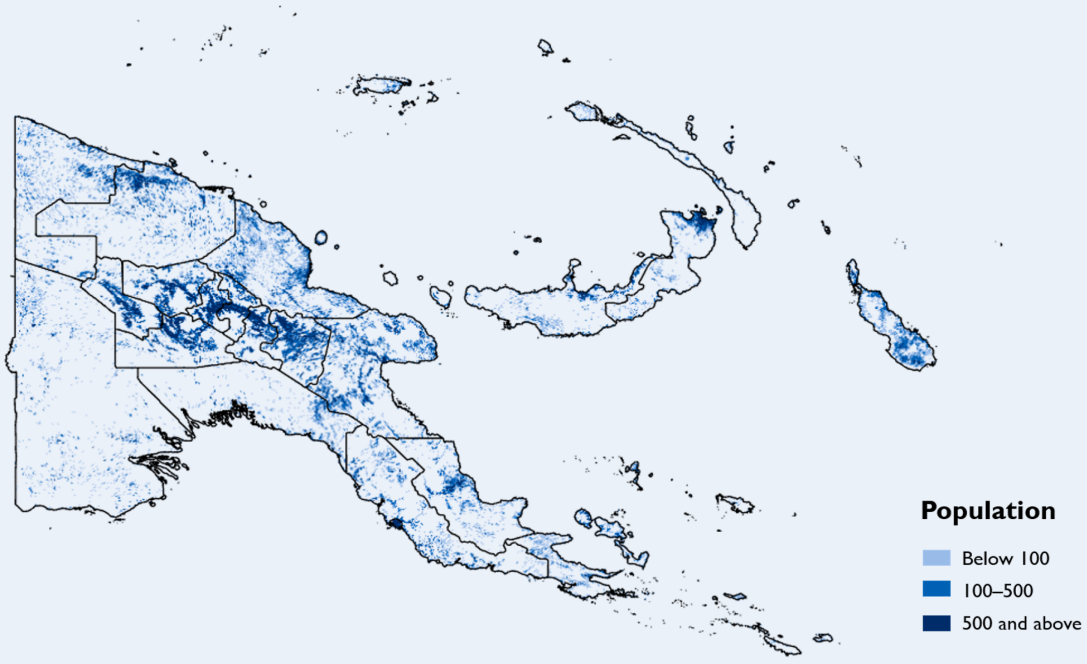
[4] International Finance Corporation, "Going the Distance: Off-Grid Lighting Market Dynamics in Papua New Guinea."

[5] International Finance Corporation.

SOCIOECONOMIC OVERVIEW

Papua New Guinea is home to both the largest population and the largest economy in the Pacific.[6] It is one of the most culturally diverse countries in the world, with hundreds of distinct ethnic groups among its population of 8.8 million. It has an estimated 840 distinct indigenous languages, making it home to roughly 12 percent of the world's spoken languages and one of the most ethnically diverse countries in the world.[7] This, alongside the challenging mountainous terrain, contributes to the isolation of different villages and groups, further enforcing PNG's status as one of the least densely populated countries in the world.[8]

FIGURE 2. POPULATION ACROSS PROVINCES OF PAPUA NEW GUINEA



Source: Facebook Population Database, 2018; USAID-PEP, 2021.

The country's economy includes export-oriented extraction and subsistence agriculture. PNG produces significant quantities of oil and natural gas; precious metals such as gold, copper, and silver; and agricultural products such as coffee, palm oil, vanilla, and seafood. Mineral extraction accounts for two-thirds of export earnings, which totaled $11 billion in 2019 (see Figure 3).[9] The majority of the population lives in rural, isolated areas, with minimal infrastructure or services,[10] and 80 percent of the people that live outside of urban areas rely on subsistence agriculture.[11] Analysts have noted the paradox that PNG has one of the world's

[6] Asian Development Bank, "Financing Sustainable Growth in Papua New Guinea."

[7] Carmen Ang, "Ranked: The Countries with the Most Linguistic Diversity." World Economic Forum.

[8] International Finance Corporation, "Going the Distance: Off-Grid Lighting Market Dynamics in Papua New Guinea."

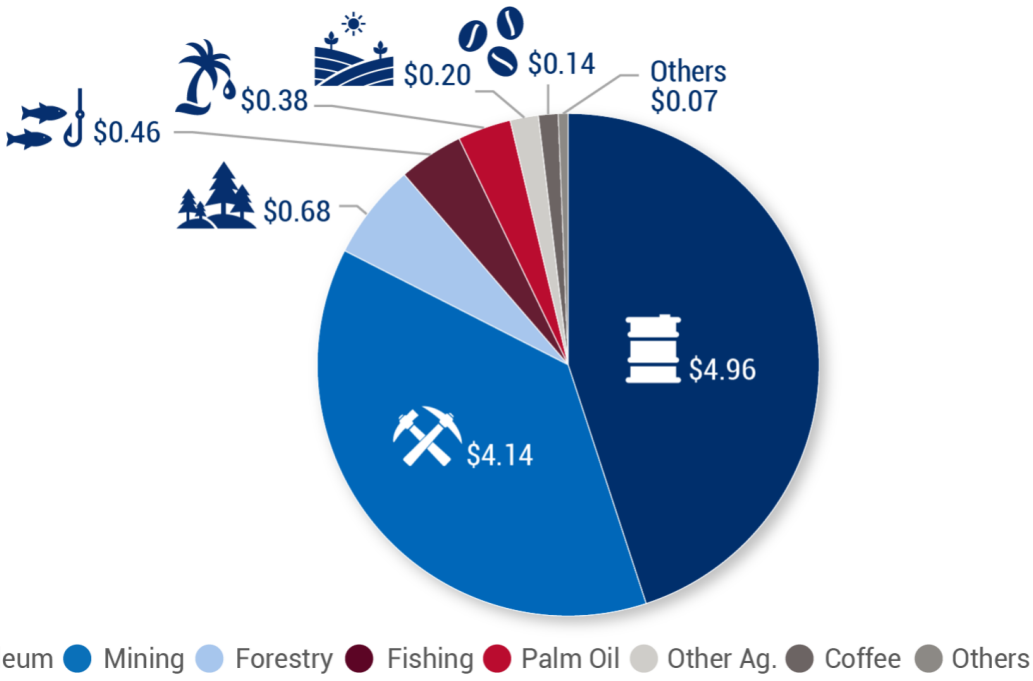
[9] CIA World Factbook, "Papua New Guinea - The World Factbook."

[10] Global Green Growth Institute, "Green Growth Potential Assessment of Papua New Guinea."

[11] CIA World Factbook, "Papua New Guinea - The World Factbook."

highest current account surpluses and conducts a significant amount of international trade, but it still lags in foreign exchange inflows, tax revenue, and economic and social development.[12] This is largely because only a fraction of the export proceeds from the extractive industry flows back into the country, which is sufficient to cover operational costs in the industry and meet financial obligations to the National Government, Provincial Government, and landowners. The extraction industry is largely foreign-owned and enjoys privileges, such as holding bank accounts overseas for procurement purposes. Therefore, there is little or no buildup in foreign reserves. The cost of imported goods continues to rise, and the cost of import replacement and domestically produced goods are also increasing because of the high import content (i.e., the share of a country's imported inputs used in its exports). The lack of foreign exchange has been a concern for off-grid companies in particular and poses a risk for the attainment of GoPNG's target of achieving 70 percent of household connections.

FIGURE 3. BREAKDOWN OF EXPORTS FROM PNG BY TRADE VALUE (BILLIONS OF U.S. DOLLARS)



Source: Observatory of Economic Complexity (OEC) Database, 2019.[13]

Table 1 gives an overview of socioeconomic indicators in PNG. According to the International Monetary Fund (IMF), PNG's GDP per capita was ranked 142nd in the world in 2021,[14] placing it as a lower-middle-income economy between many of its neighboring countries in the Pacific and above many countries in sub-Saharan Africa. However, the population does not yet have an even distribution of wealth. According to the Gini Index, a measure of inequality in income distribution, PNG ranked as the 13th most unequal country.[15] There is a wealth divide between subsistence farmers and richer urban residents, with much greater wealth

[12] James, "One Country, Two Economies."

[13] The Observatory of Economic Complexity (OEC), "Papua New Guinea (PNG) Exports, Imports, and Trade Partners."

[14] International Monetary Fund, "Report for Selected Countries and Subjects."

[15] CIA World Factbook, "Gini Index Coefficient – Distribution of Family Income."

among the 15 percent of the population that does not rely on subsistence agriculture. In 2018, the poorest half of the country earned only 13 percent of the national income, while the richest ten percent earned over 40 percent of national income. The top one percent earned roughly 15 percent of national income.[16] In rural and off-grid areas, the median household income is 650 kina every fourteen days, which is equivalent to approximately 1,400 kina or $400 per month.[17]

TABLE 1. PAPUA NEW GUINEA SOCIO-ECONOMIC INDICATORS

SOCIO-ECONOMIC INDICATOR	SUMMARY
Population (2019)	8,776,109 (51.04% male residents, 48.95% female residents)[18]
Population growth rate (2019)	1.95%[19]
Urban and rural populations (2019)	13.25% urban, 86.75% rural[20]
Population density (2018)	19 people per km^2 [21]
Urban population growth (2019)	2.57% annually[22]
GDP (2019 US dollars)	$2,829 per capita ($24.83 billion overall)[23]
GDP (2019 international purchasing power parity [PPP])	$4,548 per capita ($39.91 billion overall)[24]
GDP growth rate (2019)	5.9%[25]
Population living below National Poverty Line (2017)	37.5%[26]
Life expectancy at birth (2018)	64.26 years[27]
Languages spoken	Hiri Motu (official), Tok Pisin (official), English (official), 839 indigenous languages[28]
Main exports	Liquefied natural gas, oil, gold, copper ore, nickel, cobalt, timber, palm oil, coffee, spices, seafood[29]

16 World Inequality Database, "Papua New Guinea Income Inequality, 1980-2019."

17 International Finance Corporation, "Going the Distance: Off-Grid Lighting Market Dynamics in Papua New Guinea."

18 The World Bank, "Population, Total - Papua New Guinea | Data." The World Bank.

19 The World Bank, "Population Growth (Annual %) - Papua New Guinea | Data."

20 The World Bank, "Rural Population (% of Total Population) - Papua New Guinea | Data."

21 The World Bank, "Population Density (People per Sq. Km of Land Area) - Papua New Guinea | Data."

22 The World Bank, "Urban Population Growth (Annual %) - Papua New Guinea | Data."

23 The World Bank, "GDP (Current US$) - Papua New Guinea | Data."

24 The World Bank, "GDP, PPP (Current International $) - Papua New Guinea | Data."

25 The World Bank, "GDP Growth (Annual %) - Papua New Guinea | Data."

26 Asian Development Bank, "Poverty Data: Papua New Guinea."

27 The World Bank, "Life Expectancy at Birth, Total (Years) - Papua New Guinea | Data."

28 CIA World Factbook, "Papua New Guinea - The World Factbook."

29 CIA World Factbook.

The majority of Papua New Guineans are employed in the informal sector, which provides some income to an estimated 90 percent of households in PNG.[30,31] Subsistence agriculture is the principal economic activity for 80 percent of people living outside of urban centers,[32] though the number of households growing cash crops has risen. Other work in the informal sector includes selling, distributing, producing, and manufacturing goods and providing services in informal market areas, such as streets and roadsides. The government has been making efforts since the early 2000s to develop laws that promote and protect the informal economy in both urban and rural areas.[33]

Only an estimated 15 percent of the total workforce participates in formal employment at a private company or for the public sector.[34] In PNG, formal sector workers are often rural residents who have migrated to cities or urban centers in search of work to provide for their rural families. The youth population is particularly underrepresented in the formal sector: people between the ages of 15 and 24 make up only two percent of formal sector employees.[35] Meanwhile, there are two times more men in the formal economy than women.

Figure 4 shows each province's human development index (HDI), an internationally comparable measure of health, education, life expectancy, and income, as of 2018. Overall, the country has a medium-low level of development, with an HDI of 0.54. Internationally, it ranks 155th out of 189 countries in human development, just above Uganda and Benin and just below Pakistan and Cameroon. This is somewhat lower than expected based on its GDP per capita. Countries with similar per-capita incomes, such as Cambodia, Bangladesh, and Cameroon, have generally higher rankings in human development.[36] In most provinces, the health component of HDI is highest, averaging 0.68, the education component averages 0.43, and the income component averages 0.45. In the Highlands Region, the provinces of Hela, Enga, and Southern Highlands have the lowest average development levels, while the National Capital District, containing Port Moresby, has the highest.

[30] Business Advantage International, "Doing Business in Papua New Guinea 2020/21."

[31] Commonwealth Foundation, "Enhancing Localisation of the Papua New Guinea Informal Economy Act."

[32] The World Bank, "Reinforcing Resilience."

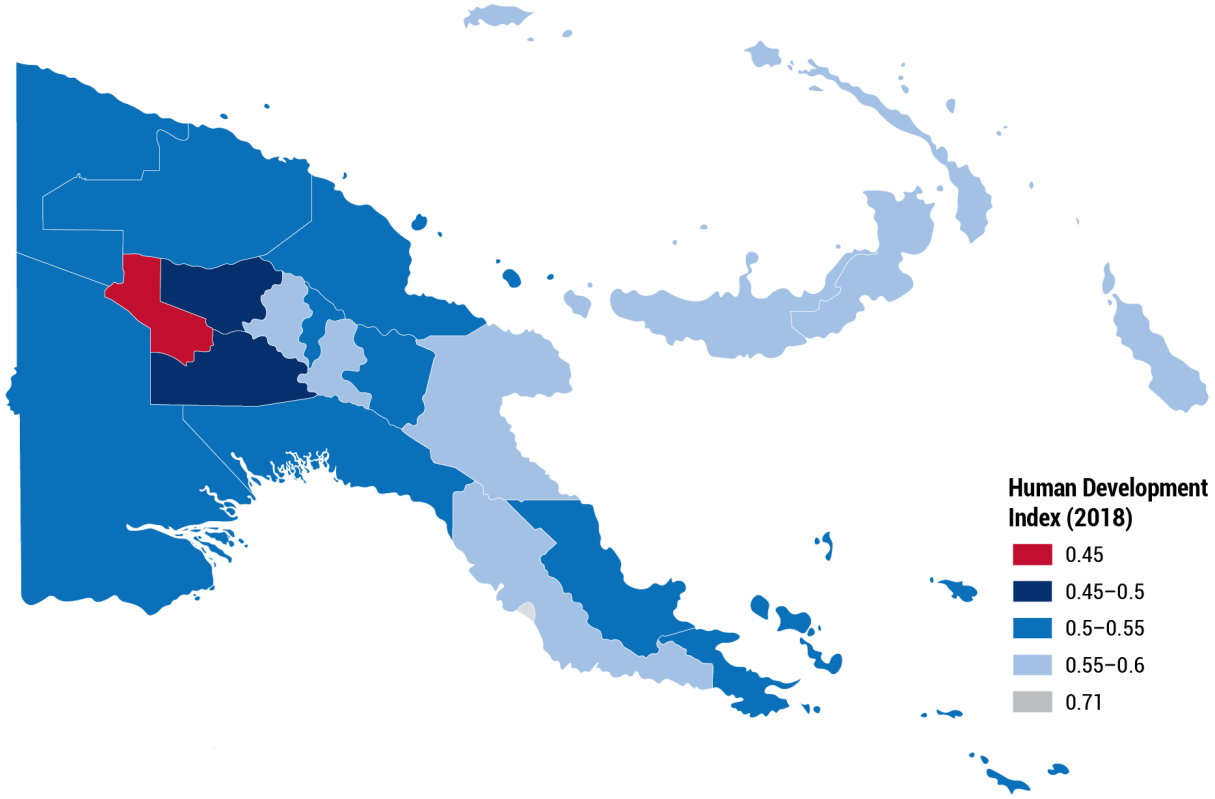
[33] Commonwealth Foundation, "Enhancing Localisation of the Papua New Guinea Informal Economy Act."

[34] Business Advantage International, "Doing Business in Papua New Guinea 2020/21."

[35] Business Advantage International.

[36] United Nations Development Programme, "Human Development Data Center."

FIGURE 4. HUMAN DEVELOPMENT INDEX BY PROVINCE, 2018

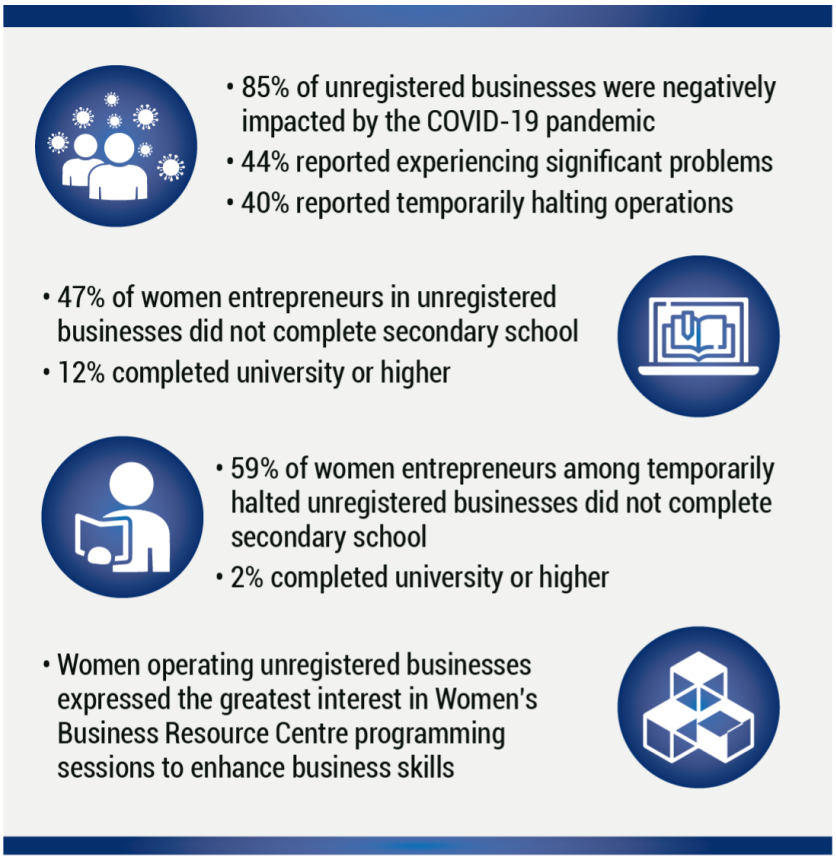


Source: Global Data Lab Subnational Human Development Index.

COVID-19 IMPACT ON THE INFORMAL ECONOMY

Coronavirus disease 2019 (COVID-19) has had negative effects on economic conditions for men and women, particularly those in the informal sector. 90 percent of households derive some part of their incomes from micro-, small, and medium-sized enterprises (MSMEs) in the informal economy. A study in 2020 by the Center for International Private Enterprise (CIPE) on women-owned or co-owned business shed light on the COVID-19-related challenges of MSMEs, women-owned and otherwise. The study showed that women entrepreneurs face a high risk of business suspensions and closures relative to their male counterparts. Before the pandemic, many businesses relied heavily on moving supplies, accessing markets, and responding to consumer demand. However, border closures, domestic lockdowns, and continued uncertainties have had significant impacts on the ability of businesses to trade and operate. Figure 5 provides a snapshot of the COVID-19 pandemic's impact on the informal economy in PNG. COVID-19 has also exacerbated the deficiency of foreign currency, which affects the ability of businesses to procure products manufactured outside of PNG.

FIGURE 5. SNAPSHOT OF THE INFORMAL SECTOR IN PNG AND THE IMPACT OF COVID-19



GENDER CONSIDERATIONS AND POLICIES

Human Rights Watch has deemed PNG to be "one of the most dangerous places in the world to be a woman," as more than two-thirds of women in PNG will be victims of domestic violence in their lifetimes.[37] Violence against women related to charges of witchcraft or sorcery is also common in some parts of the country. To deal with these entrenched issues, GoPNG has passed a series of laws, policies, plans, and regulations designed to quell violence and reduce discrimination against women, many with the support of donors over the past two decades. Donors have funded extensive activities related to family and sexual violence, child protection, access to justice, and women's participation in electoral processes. Donors have developed a Gender and Social Inclusion (GESI) policy, which national and provincial government agencies implement through a joint coalition led by GoPNG Department of Personnel Management (DPM). Women have representative structures in the governmental system called the National Council of Women and the Provincial Council of Women, which have been involved in recent legislation, such as the National Council of Women Act, 2014. Every province has a Council of Women, which places a women's representative on the Provincial Assembly, the elected provincial government structure. Despite all these measures, there is still much work to do as women still face structural discrimination and violence in their daily lives.

[37] Human Rights Watch, "Papua New Guinea."

Notable policy documents related to or including gender aspects are listed in Table 2.

TABLE 2. PNG POLICIES AND STRATEGY DOCUMENTS RELATED TO GENDER

PNG POLICY	DESCRIPTION
PNG Vision 2050	The PNG Vision 2050 is a 40-year comprehensive development plan. It contains the foundations of the new national service-delivery framework, which has been driving reforms since 2010. This framework focuses on bottom-up planning, with both top-down and bottom-up leadership. The framework involves the full range of PNG-led service developments from across all levels of government, partnerships with civil society and NGOs, donor support as determined by the Go-PNG, and private sector engagement in creating wealth and building PNG's resource base. At its center is the concept of decentralized service delivery.
National Strategy for Responsible Sustainable Development for PNG (StaRS), 2015–2030	StaRS is the GoPNG's own long-term sustainable- development plan, aimed at improving the ranking of PNG on the Human Development Index (HDI) to 50th by 2050.
Medium Term Development Plan III 2018 -2022 (Volume 2)	The Medium-Term Development (MTDP) translates the StaRS vision into action through a five-year rolling plan for each of the 22 PNG provinces. The country is currently implementing the MTDP III (2018-2022). The plan sets strategies, targets, deliverables, and estimated costs of implementation until 2022.
PNG Gender-based Violence Strategy 2016–2025	The PNG National Strategy on Gender Based Violence (GBV) 2016-2025 is the GoPNG's framework to prevent and respond to GBV. The Strategy seeks to institutionalize, strengthen and harmonize multi-sectoral and multi-level coordination across national and provincial governments and external stakeholders. The aim is to achieve zero tolerance toward gender-based violence by 2050, as per PNG's Vision 2050.
PNG GESI Policy 2013	The National Public Service Gender Equity and Social Inclusion (GESI) Policy assists National Public Service agencies, officers, and employees to embrace the GESI principles of respect, equity and diversity, which are enshrined in the constitution. Furthermore, it allows agencies to introduce inclusion and equity initiatives in the workplace.
PNG Demographic Health Survey 2016-2018	The PNG Demographic and Health Survey (PNG DHS) is a national survey on demographic and health indicators in PNG. The report provides data on fertility, family-planning practices, infant mortality, maternal and child health, knowledge and awareness of HIV/AIDS, domestic violence, and other related health issues. The indicators are important when developing policy and programming around gender and health.

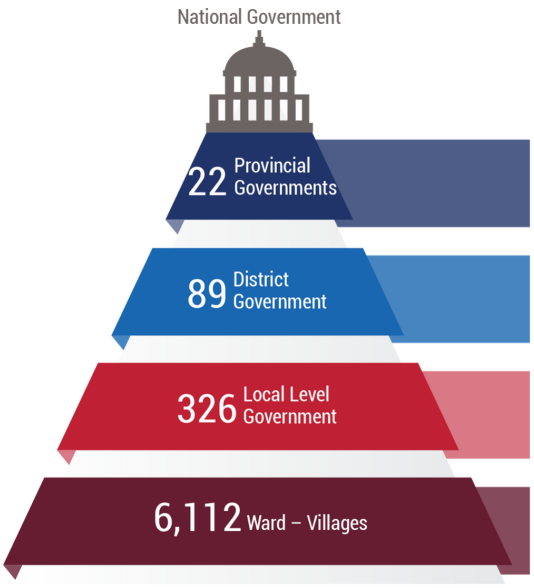
TABLE 2. PNG POLICIES AND STRATEGY DOCUMENTS RELATED TO GENDER	
PNG POLICY	DESCRIPTION
2011 PNG Government Convention on the Elimination of All Forms of Discrimination against Women (CEDAW) Report	In line with the UN Convention on the Elimination of Violence Against Women (CEDAW), in which the GoPNG is a signatory, PNG has undertaken legislative reforms to repeal laws that discriminate against women. One such milestone is the passing of the Women's Protection bill in the autonomous region of Bougainville, making PNG the second country in the world to have this law.
PNG Development Cooperation Policy 2016	The policy outlines the process of development cooperation in PNG and ensures that donor agencies and development partners implement projects that are enshrined in the Medium-Term Development of PNG's goals and directives, in order to support the GoPNG to achieve its key policies and strategies.
PNG Health Gender Policy 2014	The goal of this policy is to ensure that policy makers integrate a strong gender perspective into the health sector, and promote health and gender equality in an equitable way. This is to be accomplished through legislation, policies, and programs.
National Youth Policy 2020–2023	The National Youth Policy sets the foundation for the coordination of all youth-program interventions in various sectors in PNG. The policy defines youth as people between the ages 12–30, and the policy aims to mobilize the growing number of youth in the country to contribute toward the development of PNG.

POLITICAL LANDSCAPE

In 1975, PNG gained independence from Australia and established itself as a constitutional parliamentary democracy. Its unicameral Parliament has 111 Members of Parliament (MPs) with 22 that represent provinces and 89 "open seats" that represent districts.[38] It is part of the British Commonwealth and, thus, the British Monarch is the official head of state with a Governor-General as her representative. This system is similar to that of other Commonwealth countries in terms of the generally symbolic role that these officials play. In PNG, the Governor-General appoints the Prime Minister based on a vote of Parliament. The Prime Minister is the head of government and leader of the country.

The national government holds legislative power for federal matters, and provinces and local-level governments (LLGs) distribute allocated resources among their constituents. Figure 6 shows the government structure in PNG.

FIGURE 6. GOVERNMENT STRUCTURE



Historically, the Prime Minister's power has been tenuous due to the changing alliances of political parties and the risk of no-confidence votes that lead to the Prime Minister's dismissal. Since independence, only two of nine Prime Ministers elected by Parliament have finished their terms. The Parliament has voted out three of them by no-confidence votes, and three have resigned to avoid such a vote.[39] The Constitution allows a grace period of 18 months for new Prime Ministers before the Parliament can make a no-confidence vote. In November 2020, the current Prime Minister James Marape adjourned Parliament, which resulted in avoiding a no-confidence vote. GoPNG expects to hold the next election in June 2022.

The Office of Rural Development (ORD) holds the funds that drive provincial, district, and local development, which MPs can access for such targeted activities as electrification in coordination with implementing agencies (e.g., PPL). These funds feed into Service Improvement Programs (SIPs), which include Provincial Services Improvement Programs, District Services Improvement Programs, and LLG Service Improvement Programs. Each district's joint district priority committee decides on the selection of priority projects. However, some sources cite inadequate oversight over these ORD-controlled funds, which has earned them a reputation as "slush funds."[40] Such challenges have the potential to undermine efforts toward electrification goals; therefore, the oversight of these funds and selection of sustainable activities is a priority for advancing off-grid energy.

[38] Michigan State University, "Papua New Guinea."
[39] Kabuni, "What It Takes to Change a Prime Minister in PNG."
[40] Guande, "Better Monitoring Needed to Transform Slush Funds into Development Funds in PNG."

FINANCIAL LANDSCAPE

PNG's finance sector is advancing but remains limited in scope. As with other countries in the region, PNG's economy is only moderately monetized, with the local population relying on a combination of banknotes printed by the central bank and bartering of goods.

The country's ratio of broad money – a measure of the amount of money circulating in an economy – to GDP is still below 50 percent as of 2017. PNG's fiscal deficit, which averaged 3.9 percent from 2015 to 2019, faced the significant challenges of stagnating real[41] revenues due to weak economic conditions and lower revenues from the mineral and petroleum sector. During the same period, recurrent expenditures, especially the public sector wage bill (or the total amount paid in wages by the public sector), continued to rise. While GoPNG contained the deficit at 2.5 percent of GDP in 2017 and 2.6 percent of GDP in 2018, under a fiscal consolidation strategy, it widened to 4.9 percent of GDP in 2019. This was in the context of a continued weak revenue trend as well as a more expansionary fiscal policy, driven by an increase in capital expenditures and clearances of arrears. China has had a growing influence in PNG, and GoPNG is estimated to owe China $588 million (24 percent of PNG's total external debt). China has invested heavily into the energy sector with an estimated $880 million out of $4.88 billion total investments in PNG going into energy.[42]

Foreign exchange issues affect both on-grid and off-grid electricity generation. Unfortunately, companies and other entities can have difficulty accessing foreign currency in PNG for several reasons. First, they cannot freely convert funds associated with any form of investment into any currency. The Bank of Papua New Guinea, the country's central bank, requires that institutions in PNG hold all funds in the Papua New Guinean kina (PGK). In 2016, when GoPNG announced this rule, it caught many businesses off guard. For the businesses that initiated the appeals process to keep their non-PGK accounts, the authorities did not grant any such appeals. Second, in 2014, the Bank of Papua New Guinea introduced measures that only allowed trading of the kina in tight bands (i.e., with a price floor and price ceiling) to stabilize the currency. This effectively linked the kina to the U.S. dollar, causing dollars to become cheaper overnight and driving a spike in demand far surpassing supplies that exporters held locally. This led to foreign exchange shortages, though the central bank more recently began to allow PGK to depreciate against the U.S. dollar. Third, foreign exchange flows in PNG are linked primarily to commodity markets, particularly liquified natural gas (LNG), making it highly susceptible to fluctuating international natural gas prices. The need for accessible foreign currency has led to delays and lost business opportunities for distributors, particularly smaller ones because PNG banks tend to prioritize larger customers.

Overall, the environment for private sector growth, including regulatory regimes, needs reform. The financial sector is underdeveloped, and businesses of all sizes find it hard to access finance. Capital markets are poorly developed. While PNG has comprehensive laws

[41] Adjusted for inflation.

[42] Sarah O'Dowd, "The Belt and Road Initiative in Papua, New Guinea."

and institutions in place, governance remains weak compared with other regional economies. Weak management and technical expertise, limited financial resources, and inadequate performance management constrain the capacity of government agencies to implement reform measures. Although there have been improvements in public financial management (PFM), government entities still require strengthening and capacity development, particularly when it comes to procurement, payroll management, and subnational PFM systems, which are critical for expenditure control. Fiscal and debt management remains a central challenge, compounded by the volatile nature of the economy and revenues from the resource sector. The government needs to increase the transparency and frequency of reporting on debt liabilities. Strengthening financial institutions and building a robust financial system that can sustainably provide financing for growth will result in broadening access to finance.

COVID-19 IMPACT ON THE OVERALL FINANCIAL LANDSCAPE

The COVID-19 pandemic has significantly stressed the PNG economy. The Asian Development Bank's forecast for 2020 puts PNG's growth at -2.9 percent and estimates that government revenues will fall by 20 percent relative to pre-COVID-19 expectations. Lower commodity prices, weaker external demand, disruptions to international trade and supply chains, border closures, suspended international flights, and the impact of a hard lockdown that lasted for approximately one month have all depressed growth and reduced revenue expectations. The government announced a 5.7-billion-kina ($1.5-billion) stimulus package to mitigate the impacts of COVID-19, including a 600-million-kina ($162-million) fiscal response; and development partners also provided financial and technical resources. The social and economic impacts of COVID-19 related to financial insecurity are wide-ranging, exacerbating unemployment, food insecurity, and gender-based violence. The health system is fragile and unable to accommodate a substantial escalation in cases.

Energy Sector

Energy Sector

OVERVIEW

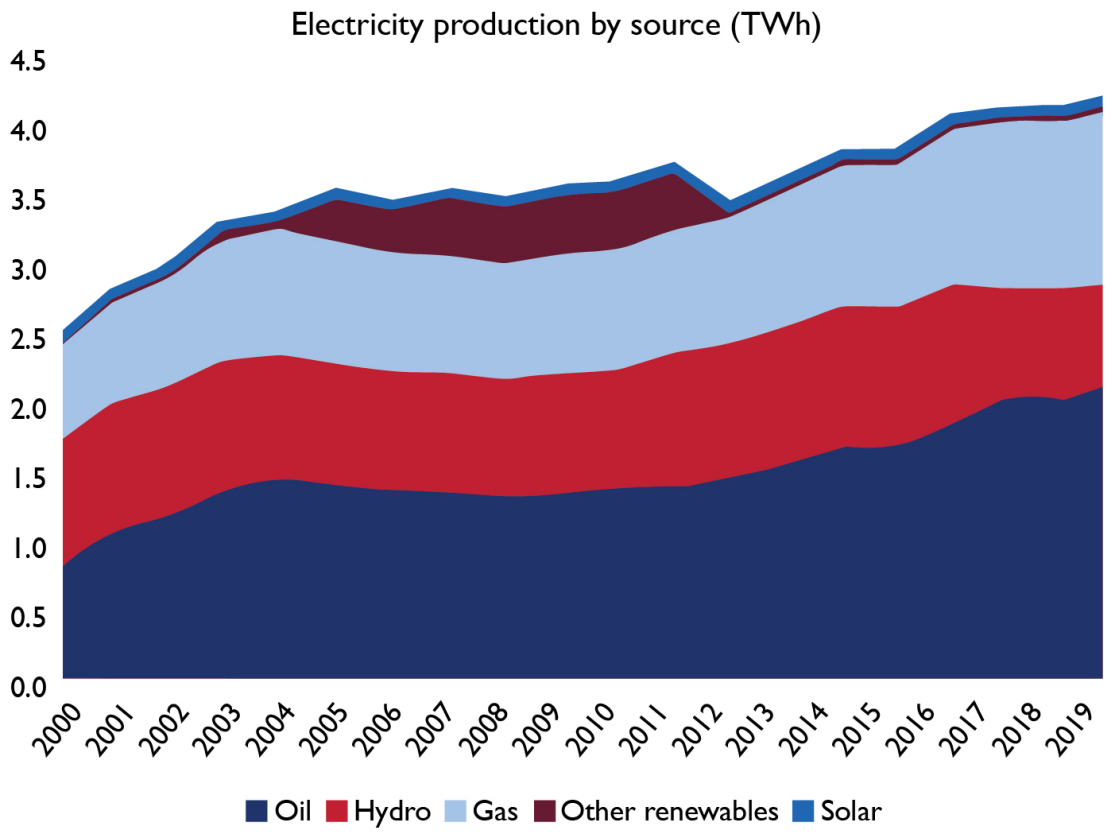
In Papua New Guinea, only 15 percent of the country's total population is connected to the national grid. Grid connection varies significantly by PNG's urban-rural divide: an estimated 40 percent of urban households are grid-connected while only an estimated 11 percent of rural households are so.[43] Due to PNG's isolated geography and geology, the country's on-grid connections include three distinct primary grids (Port Moresby, Ramu, and Gazelle Peninsula), 26 provincial grids that PPL operates, and many regional mini-grids that local governments own. Meanwhile, an estimated 60 percent of the population owns at least one off-grid solar product, such as a solar home system or solar lantern.[44] This number varies by province, with more off-grid product ownership in the Islands Region and less in the Highlands Region.[45]

Oil, gas, and hydropower dominate on-grid electricity production in PNG (Figure 7). Many of PNG's largest energy companies are oil and gas producers. Meanwhile, biomass and geothermal constituted a notable portion of electricity production between 2004 and 2012, primarily for use in resource mining and processing industries.

The Lihir Geothermal Plant is an example of a large electricity producer that a mining company, Lihir Gold Limited, built and operates. However, due to shifts in generation sources by these companies (for example, geothermal generation capacity by Lihir Gold decreased from 56 megawatts [MW] in 2010 to 13 MW in 2020),[46,47] geothermal and biomass have since become a small fraction of PNG's energy sources. Solar has contributed a minor amount to the country's electricity mix since 2005, with production rising to about 2,300 MWh each year since 2016, primarily as off-grid generation.[48] The Asia-Pacific Economic Cooperation (APEC) projects significant increases in energy production by 2050, with planned expansions of LNG and renewables. Renewables are a promising generation source for meeting future electrification goals, from solar power for basic applications such as phone charging and lighting of rural households to biomass and geothermal electricity generation for energy-intensive industries like those involved in agricultural processing and resource extraction.

[43] The World Bank, "Preliminary Findings from a Multi-Tier Framework (MTF) Household Survey in PNG."
[44] International Finance Corporation, "Going the Distance: Off-Grid Lighting Market Dynamics in Papua New Guinea."
[45] The World Bank, "Preliminary Findings from a Multi-Tier Framework (MTF) Household Survey in PNG."
[46] Bertani, "Geothermal Power Generation in the World - 2005-2012 Update Report."
[47] Gleeson et al., "Lihir Operations: Aniolam Island, Papua New Guinea."
[48] Ritchie and Roser, "Energy - Papua New Guinea."

FIGURE 7. ELECTRICITY PRODUCTION MIX IN PNG BY YEAR



*Notes:

- Y-axis measured in terawatt hours (TWh), which is equal to 1,000 gigawatt hours
- Other renewables include geothermal, biomass, and hydrogen
- Source: Our World in Data, based on BP Statistical Review of World Energy & Ember (2021)

Solar and wind resource availability vary greatly throughout PNG due to its mountainous terrain. Solar resources are greatest in the Western Highlands as well as parts of Hela, East Sepik, and Madang.[49] Meanwhile, the Western Province and the islands have lower solar potential. However, solar resource availability is still relatively high in PNG and viable for many applications across the country, at more than 1,200 kilowatt hours (kWh) of generation per kilowatt (kW) of installed capacity across much of the country.[50] Overall, wind potential is relatively low in PNG as much of the country has average windspeeds below the minimum threshold for wind generation.[51] However, there are areas across PNG with substantial wind resource potential, such as in Western Province and the flatter northern part of the main island, including Sandaun and East Sepik. In addition, there are lowland corridors between mountains with high wind potential—for instance, between the Finisterre Range in northeastern New Guinea and the Bismarck Range in the Western Highlands.

[49] The World Bank, "Global Solar Atlas."

[50] The World Bank.

[51] The World Bank, "Global Wind Atlas."

There is also significant hydropower potential in PNG due to high rainfall across many parts of the country.[52] Although there have been no detailed studies in PNG to estimate hydropower potential, the commonly cited technical potential is 15 gigawatts (GW).[53] Kerema, Alotau, Kimbe, Wewak, Vanimo, Buka, Arawa, Kavieng, and Tari are all urban centers with existing electric transmission infrastructure that have a high potential for new hydropower generation.[54]

THE NATIONAL ENERGY AUTHORITY

In 2017, the Department of Petroleum and Energy (DPE) introduced the PNG National Energy Policy (NEP) 2017-2027[55] which called for the establishment of an energy entity, the National Energy Authority (NEA), to be solely responsible for Economic and Technical Regulation, the development and implementation of a National Energy Policy and the implementation of the NEROP.

The NEA Act passed in April 2021 and was full adopted in July 2021. The NEA Act seeks to expedite the development and application of regulations related to all activities in electrification. The purpose of the NEA is to serve as an umbrella agency for establishing service standards for transmission and distribution networks; setting electricity tariffs; service quality standards, regulating, and issuing licenses and permits to electric sector participants; and enforcing electrical standards and license conditions. Moreover, the National Energy Act states that both the economic regulatory powers of the electric sector that the Independent Consumer and Competition Commission (ICCC) currently performs and the technical regulatory powers that PPL currently performs will transfer to NEA.

In April 2021, GoPNG repealed the relevant provisions under the Electricity Industry Act (EIA) that empowered ICCC to perform technical[56] and economic regulation. The National Electrification Management Unit (NEMU) is responsible for building NEA's capacity, and managing and implementing NEROP. NEMU will be staffed by international experts, and national staff will understudy them. GoPNG expects that the national staff will take over from the international experts after a period of three to five years. NEMU will report to the NEA Managing Director. NEA in turn will report to the Ministerial Steering Committee through both the Department and Agencies Committee and the Energy Sector Program Implementation Monitoring Committee (ESPIMC). USAID-PEP partner countries will have representation on ESPIMC. Figure 8 shows the management structure under NEA and NEMU, and Figure 9 shows the NEMU structure.

[52] International Hydropower Association, "2018 Hydropower Status Report."

[53] International Hydropower Association.

[54] Government of Papua New Guinea, "Fossil Fuel Abatement for Diesel-Based Power Systems: An Action to Meeting SDG 13 through Sustainable Electricity."

[55] It should be noted that several versions of the National Energy Policy exist. The National Energy Policy 2016-2020 and National Energy Policy 2017-2027, both introduced by the Department of Petroleum and Energy, are accessible online. Various reports refer to the National Energy Policy 2018–2028 (Engelmeier and Gaihre, 2019). According to the Global Green Growth Institute, the DPE confirmed that the National Energy Policy 2018-2028 is identical to the National Energy Policy 2017-2017 (GGGI, 2019).

[56] The technical regulatory powers were delegated to PPL by ICCC because it did not have the technical capacity to perform this function.

FIGURE 8. NATIONAL ENERGY MANAGEMENT REPORTING STRUCTURE

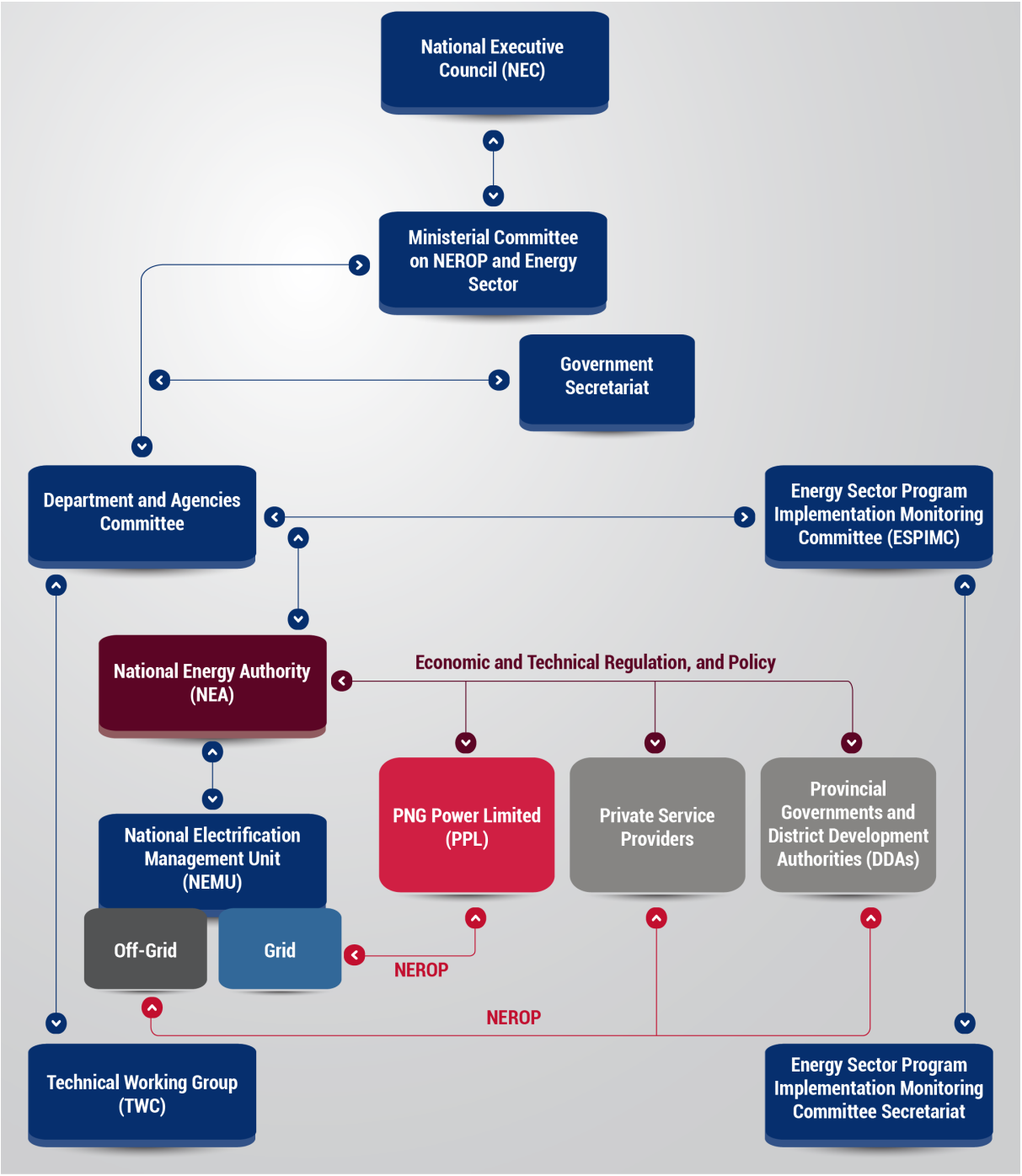
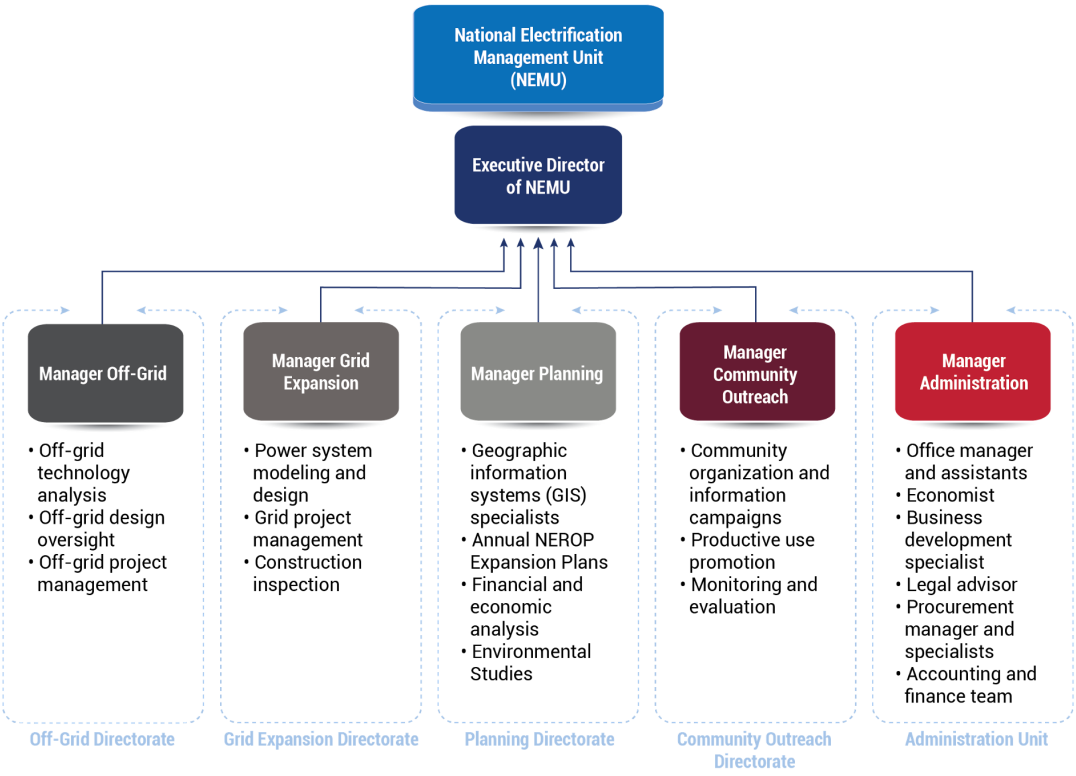


FIGURE 9. NEMU STRUCTURE



OTHER KEY STAKEHOLDERS

The PNG energy sector is comprised of many other government entities, industry players, international partners, donors, and development finance institutions. In addition to NEA, the national utility PPL is the most important stakeholder and has the mandate for on-grid electrification, which is defined as electrification within ten km of PPL's existing grid. Table 3 includes a list of these stakeholders, and Annex 1 includes more details. Table 3 includes only major companies in the on-grid sector, while Table 15 in the Solar Home System Market subsection of the Off-Grid Market section of this assessment includes off-grid companies.

TABLE 3. KEY PLAYERS AND STAKEHOLDERS IN PNG'S ENERGY SECTOR

PNG GOVERNMENT INSTITUTIONS	PRIVATELY-OWNED COMPANIES	INTERNATIONAL DONORS AND DEVELOPMENT FINANCE INSTITUTIONS
National Energy Authority (NEA)	Zenith Energy Ltd.	Asian Development Bank (ADB)
PNG Power Limited (PPL)	NiuPower Limited	Australian Department of Foreign Affairs and Trade (DFAT)

TABLE 3. KEY PLAYERS AND STAKEHOLDERS IN PNG'S ENERGY SECTOR		
PNG GOVERNMENT INSTITUTIONS	PRIVATELY-OWNED COMPANIES	INTERNATIONAL DONORS AND DEVELOPMENT FINANCE INSTITUTIONS
Department of Petroleum and Energy (DPE)	PNG Biomass	Japanese International Cooperation Agency (JICA)
Department of Treasury (DoT)	PNG Hydro Development Limited (PNGHDL)	New Zealand Ministry of Foreign Affairs and Trade (MFAT)
Department of National Planning and Monitoring (DNPM)	PNG Forest Products (PNGFP) Hydro	United Nations Development Programme (UNDP)
Kumul Consolidated Holdings (KCH)	POSCO International	United Sates Agency for International Development (USAID)
Kumul Petroleum Holdings Limited (KPHL)	New Britain Palm Oil	World Bank Group
Independent Consumer and Competition Commission (ICCC)	Shenzhen Energy Hydro-power Development Co Ltd.	International Finance Corporation (IFC)
Conservation and Energy Protection Authority (CEPA)		
National Institute of Standards and Industrial Technology (NISIT)		

CURRENT ON-GRID ELECTRICITY GENERATION INFRASTRUCTURE

In recent years, different entities have reported different values for the total generation capacity in PNG, in some cases presenting conflicting values within the same document. In the National Energy Policy 2017-2027, PNG's Department of Public Enterprises cites both 797 MW and 580 MW of installed capacity in the same document.[57] In more recent documents, 580 MW is more commonly cited (e.g., in 2019 World Bank reported that the country had *about* 580 MW)[58,59]—this report assumes 580 MW to be the correct value.

[57] Department of Public Enterprises, "PNG National Energy Policy 2016-2020."

[58] The World Bank. "Project Information Document/Integrated Safeguards Data Sheet" 2019.

[59] The addition of the breakdown of generation sources in the World Bank report equals 282 MW, as shown in the table, but the report itself reports "about 580 megawatts" (italics added)

Both PPL and independent power producers (IPPs) operate generation facilities with PPL operating over 300 MW of on-grid and approximately 100 MW of mini-grid generation.[60,61] IPPs and private sector generators own and operate the rest of the country's generation, supplying electricity to PPL-operated grids, industrial facilities, and rural communities.[62] IPP generation capacity is estimated to be 280 MW.[63] Table 4 shows the estimated capacity by generation type as of 2016, the most recent available estimate of countrywide generation. The on-grid electricity transmission infrastructure in PNG (defined as PPL-owned/operated grids) is comprised of three primary grids and 26 smaller grids.[64] The three primary grids are: the Port Moresby grid, or POM grid, located in the capital of Port Moresby; the Ramu grid located through the Markham Valley from Lae to the Highlands and Madang; and the Gazelle Peninsula grid on the northeastern island of New Britain. The Port Moresby grid has an installed capacity of about 250 MW, primarily from the 61 MW Rouna hydropower cascade stations, three gas-fired plants (25 MW, 58MW and 45 MW), and a 41 MW diesel power station.[65] The Ramu grid has about 178 MW of installed capacity, including the 78 MW Ramu 1 hydropower plant, 42 MW of smaller hydropower stations, a 30 MW HFO plant owned and operated by an IPP, and several small diesel plants, which PPL operates, that make up for any shortfall and serve as backup generation.[66] Finally, the Gazelle Peninsula grid uses a PPL-operated 10 MW hydropower station and 12 MW of diesel-based power plants.[67]

TABLE 4. GENERATION CAPACITY BY TYPE, 2019

TYPE	CAPACITY (MW)	PERCENT (%)
Hydropower	230	40
Diesel	217	37
Natural Gas	82	14
Geothermal	53	9
Total	**582**	**100**

The 26 smaller grids (C-Centers), which PPL operates, deliver power to urban areas across the country.[68] These independent grids are isolated due to the rough terrain and long distances

[60] The World Bank, "Papua New Guinea Least Cost Power Development Plan Update."

[61] International Finance Corporation, "Assessment of Generation Assets and Fuel Supply Options in Selected Mini-Grids in Papua New Guinea."

[62] Department of Public Enterprises, "PNG National Energy Policy 2016-2020."

[63] The World Bank. "Project Information Document/Integrated Safeguards Data Sheet" 2019.

[64] NRECA International, "Papua New Guinea National Electrification Rollout Plan (NEROP) Implementation Strategy and Investment Plan: Final Report 2020."

[65] The World Bank, "Delivering Affordable, Sustainable and Reliable Power to Papua New Guineans: Key Challenges and Opportunities in the Power and Domestic Gas Sectors."

[66] The World Bank.

[67] Isaka, Mofor, and Wade, "Pacific Lighthouses: Papua New Guinea."

[68] NRECA International, "Papua New Guinea National Electrification Rollout Plan (NEROP) Implementation Strategy and Investment Plan: Final Report 2020."

between urban centers in PNG that make interconnectivity difficult and uneconomical. Many of these C-Centers require refurbishment and do not provide reliable power. As such, PPL holds several power purchase agreements (PPAs) with IPPs to supply power to these provincial grids.[69]

In addition, there are small, rural electricity systems that local authorities operate at government administration centers across PNG. While official accounts are unclear as to how many centers exist, some reports count approximately 150 of these smaller systems.[70] As these systems are generally greater than ten km from the existing grid, they are considered part of the off-grid infrastructure, which this assessment details in the Off-Grid Market section.

In total, there are an estimated 7,000 km of transmission and distribution infrastructure across the country, of which roughly 4,100 km are medium-voltage transmission lines.[71] Ramu has the largest grid network with 720 km of transmission gridlines, followed by POM at 170 km and Gazelle at 75 km. The remaining 3,000 km of infrastructure include PPL-owned or privately owned mini-grids distributed throughout the country.

Table 5 shows tariffs for on-grid generation for residential, commercial, and industrial customers. In 2013, GoPNG set tariff rates and froze them. Because tariff rates have not increased since 2013, the sector has encountered challenges related to PPL's financial viability. PPL uses a pre-pay service called Easipay, which allows customers to prepurchase units of electricity to use. When the pre-purchased quantity runs out, the meter automatically switches off until the customer buys more electricity. As with similar systems in other parts of the world, this system saves PPL money and reduces losses by reducing the need to collect bills from smaller and residential customers. As of 2018, 88 percent of total PPL customers (including industrial, commercial, and domestic) used Easipay. Of the domestic customers, 94 percent used Easipay.[72]

TABLE 5. ON-GRID ELECTRICITY TARIFFS UNDER THE EASIPAY SYSTEM

CUSTOMER TYPE	COST	UNIT
Industrial	63.31	toea*/kWh
Commercial	96.27	toea/kWh
Residential	69.68	toea/kWh
Public Lighting	165–580	kina/year

* toea = 1/100th of a kina

[69] The World Bank, "Project Information Document/Integrated Safeguards Data Sheet for Energy Utility Performance and Reliability Improvement Project (P167820)."

[70] Isaka, Mofor, and Wade, "Pacific Lighthouses: Papua New Guinea."

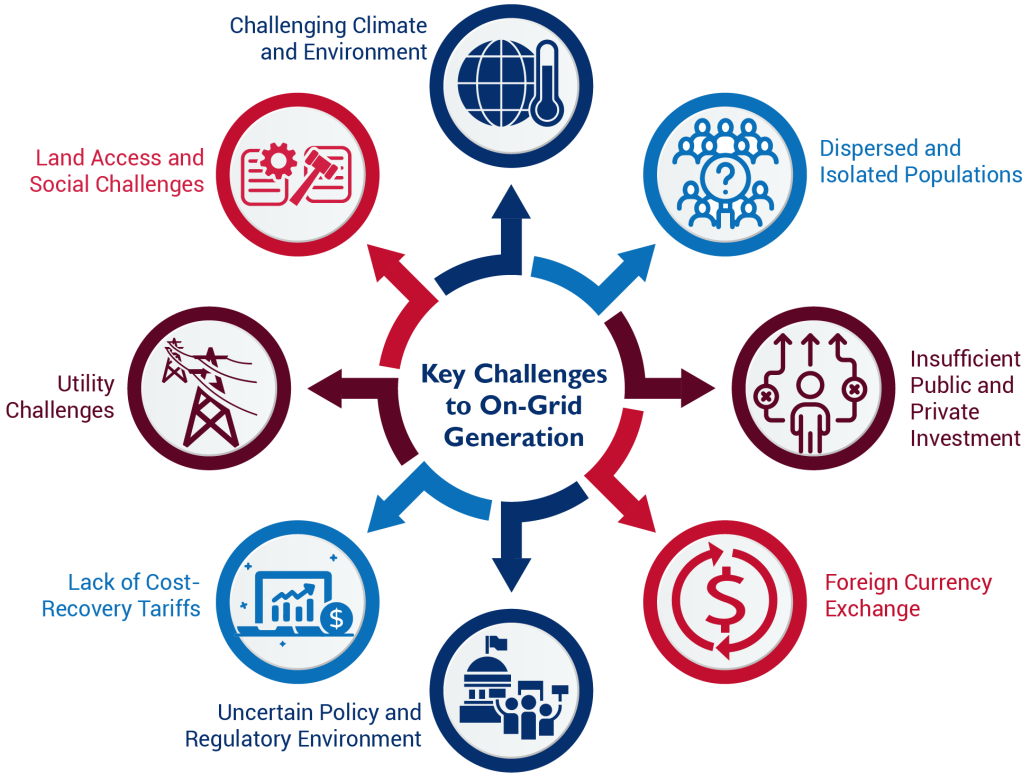
[71] Economic Consulting Associates, "PNG National Electrification Rollout Plan: Energy Sector Development Project (ESDP) Closing Workshop."

[72] PPL Billing Data. PPL, 2018.

CHALLENGES FOR ELECTRIFICATION IN PNG

PNG's electric sector faces many geographic, social, economic, and other challenges that have led to high on- and off-grid generation costs, low grid penetration, and low on-grid reliability. Figure 10 and the following section present some of the key challenges for electrification in PNG.

FIGURE 10. KEY CHALLENGES TO ON-GRID GENERATION IN PNG



Challenging Climate and Environment. PNG is a mountainous country with mostly rugged terrain, which makes the construction of roads and transmission lines to remote communities particularly costly.[73] Infrastructure is also difficult to maintain because the country is especially vulnerable to natural disasters, including earthquakes, volcanic eruptions, tsunamis, cyclones, river and coastal floods, landslides, and droughts.[74]

Dispersed and Isolated Populations. The population of PNG is dispersed over hundreds of islands. Even on the main island, the terrain isolates many communities from the main electric grid infrastructure. These remote communities are often small with low energy demand, which makes the cost of electrification per capita expensive.[75]

[73] Maxwell, "A Case for Low-Cost, Renewable Green Energy to Power Up Papua New Guinea."

[74] Global Logistics Cluster, "Emergency Preparedness: Operational Logistics Continency Plan."

[75] Maxwell, "A Case for Low-Cost, Renewable Green Energy to Power Up Papua New Guinea."

[76] Asian Development Bank, "Energy Sector Assessment CAPE PNG."

Insufficient Public and Private Investment. Current funding in PNG (which comes mostly from public sources) is insufficient for both the routine maintenance of electric infrastructure and capital investments in new infrastructure.[76] This has led to frequent unplanned maintenance and the derating of existing equipment, resulting in power outages and low reliability. The government relies heavily on funding from donors and investors for new infrastructure, but such private investment faces challenges due to an absence of policies and risk-mitigation instruments to overcome the perception of risks at the national and utility level.[77] Additional private financing is necessary for PNG to meet its electrification targets. There is also a need to develop cost-recovery tariffs, which would provide additional revenue to PPL to improve its ability to invest in capital projects as well as operations and maintenance.

Foreign Currency Exchange. Foreign currency is another major challenge for energy sector development in PNG. Due to the highly illiquid international market for the kina (i.e., it is difficult to convert kina to ready money), many quality-verified (QV) manufacturers only accept the U.S. dollar.[78]

Utility Challenges. The national utility PPL suffers from power theft, tampering with meters and other equipment, and frequent outages for its commercial, industrial, and residential customers. These challenges have contributed to the mounting debt that PPL owes to service providers (i.e., losing approximately 25 million kina per month on average in revenue). Customers suffer from low power voltages and unpredictable outages deviating from PPL's posted schedule. Further, transmission and distribution infrastructure are ageing, and insufficient line clearance presents a risk of fires that can cause damage to commercial and residential buildings.

Uncertain Policy and Regulatory Environment. Regulatory uncertainty is a problem in PNG that has led to inefficiencies in the electric sector and contributed to the high costs of electricity generation. For example, entities still produce electricity through expensive, imported oil rather than using the cheaper domestic potential of hydropower and natural gas, and project implementers have not necessarily achieved cost savings through competitive procurement processes.[79] There are considerable inconsistencies between existing policies and regulations in the electric sector, which has led to the weak enforcement of regulations.[80] This environment of regulatory uncertainty has also impacted the country's ability to attract private investment.

Lack of Cost-Recovery Tariffs. Since ICCC's establishment in 2002, it has adopted a cost-reflective tariff-setting approach (i.e., the building block model), which combines all costs from PPL's network throughout the country (i.e., the regulated asset base, weighted average cost of capital, depreciation, and operating expenses). ICCC then combines these total costs with the demand forecast for the five-year regulatory control period to determine tariffs. PPL plays a consultative role on tariffs to ICCC/NEA and has been pushing for higher tariffs. Moreover,

[77] Asian Development Bank.

[78] International Finance Corporation, "Going the Distance: Off-Grid Lighting Market Dynamics in Papua New Guinea."

[79] The World Bank, "Delivering Affordable, Sustainable and Reliable Power to Papua New Guineans: Key Challenges and Opportunities in the Power and Domestic Gas Sectors."

[80] Global Green Growth Institute, "Green Growth Potential Assessment of Papua New Guinea."

because ICCC's determination in 2012 showed an unwanted increasing price path, since 2013, GoPNG has halted further tariff increases.

PPL faces significant management and financial issues which limit its ability to invest in capital projects and increase electricity access through an on-grid connection. Frequent power cuts occur due to the lack of generation capacity and lack of fuel. PPL has also endured frequent turnover among management, having had eight heads of the utility (resulting in eight new strategic directions) since 2015.[81] Due to these existing constraints, opportunities for increasing access via on-grid connections may be mostly limited to donor-funded initiatives in the short term.

Land Access and Social Challenges. Access to land and its use as collateral remains limited. Tribes, clans, and land-owning groups own 97 percent of all land through customary claims. Since it is not possible to buy customary land, companies and other entities often secure access for private sector investments through special agricultural and business leases, which the government negotiates with landowners. Landowners enter into contracts with private companies and the government to receive royalties from energy production. However, companies and other entities may find it challenging to locate and negotiate with multiple owners of large areas of land, so parties do not always resolve landowner claims before projects proceed. This often leads to disputes between citizens, private companies, and the government.[82] Land ownership is one of the greatest barriers to large-scale infrastructure development across all sectors in PNG.

CUSTOMER SEGMENTS

Understanding types of customers and their characteristic needs is important to ensuring the proper procurement of off-grid products in a way that benefits the most people. Key customer segments, as PPL defines them, include:

PPL charges customers that apply for grid-connected electricity services at a domestic rate, a general supply rate, an industrial rate, or a streetlight rate.

- **Domestic Customers.** Domestic customers consume or intend to consume electricity that entities supply exclusively for household purposes (which does not fall into general supply or industrial customer segments).
- **Industrial Customers.** Industrial customers consume or intend to consume more than 200 kilovolt-ampere (kVA) of electricity regardless of their end-users.
- **General Supply Customers (Commercial Customers).** General supply customers have a demand of less than 200kVA and do not consume electricity for their households or other domestic purposes.
- **Streetlights.** Streetlighting rates are charged to the person, city authority, or provincial government that is responsible for providing streetlights to a community. Annual streetlight charges and the associated rates are based on the general supply rate.

[81] Kenneth, Gorethy, "PNG Power Chief Bekker Resigns after Nine Months in Job – 8th MD to Quit."

[82] Westbrook, "In Papua New Guinea, Exxon's Giant LNG Project Fuels Frustration."

DOMESTIC CUSTOMERS

Domestic or residential customers currently make up roughly 20 percent of PPL's on-grid electricity demand in PNG.[83] There is significant electric demand potential in the residential sector in PNG. Only 15 percent of the population has access to the national grid, which is primarily in urban centers.[84] Meanwhile, an estimated six percent of the population lives within one km of the grid but does not have electricity access, and an estimated 80 percent lives in rural towns and villages that are more than one km from the existing grid.

Data from PPL from 2014 indicate that the annual average on-grid electricity demand is 1,900 kWh per household in urban areas.[85] Electricity consumption in urban households includes the use of standard devices, such as mobile phones and other appliances, such as air conditioning, electric stoves, microwave ovens, and washing machines.[86] A USAID-PEP conducted GIS analysis estimates that approximately 660,000 households live within one km of the grid, while 188,000 of these households are expected to be "likely to connect" to the grid based on household wealth.[87] The estimated total addressable market (TAM) for these "likely" new on-grid connections from grid extension is around 248 million PGK per year[88] or $70 million per year.[89] Moreover, there is an opportunity for further developing the generation and distribution capacity among existing on-grid customers, as over half of the households connected to the grid (roughly 90,000 in 2019) have unreliable electricity supply.[90]

INDUSTRIAL CUSTOMERS

PNG's industrial sector predominantly includes large-scale resource extraction projects, such as petroleum and natural gas as well as gold and copper mining, which are the major consumers of electricity in the industry. The timber and agricultural (i.e., coffee, palm oil, cocoa, tea, rubber, and sugar) industries also contribute to the sector's electricity demand. An estimated 28 percent of on-grid electricity demand comes from the industrial sector,[91] though many companies and projects generate their own electricity and do not depend on PPL. For instance, the Ok Tedi mine in the Western Province runs the Ok Menga hydropower plant as well as backup diesel generation for its electricity requirements. Projections estimate that industrial sector energy demand will increase 21 percent between 2016 and 2050, though

[83] PPL billing data from 2018.

[84] International Finance Corporation, "Going the Distance: Off-Grid Lighting Market Dynamics in Papua New Guinea."

[85] NRECA International, "Papua New Guinea National Electrification Rollout Plan (NEROP) Implementation Strategy and Investment Plan: Final Report 2020."

[86] Lovo et al., "Renewable Energy Technologies as 'Saving Graces' for Pacific Island Nations Fighting Climate Change."

[87] USAID Demographic and Health Surveys (DHS) 2018 data.

[88] This uses the PPL tariff rate for domestic customers of 69.68 toea/kWh. Source: https://www.pngpower.com.pg/images/misc/Tariff3May2013.pdf.

[89] This uses an exchange rate of US $0.28 per 1 kina.

[90] International Finance Corporation, "Going the Distance: Off-Grid Lighting Market Dynamics in Papua New Guinea."

[91] Asia Pacific Energy Research Centre, "APEC Energy Demand and Supply Outlook - 7th Edition."

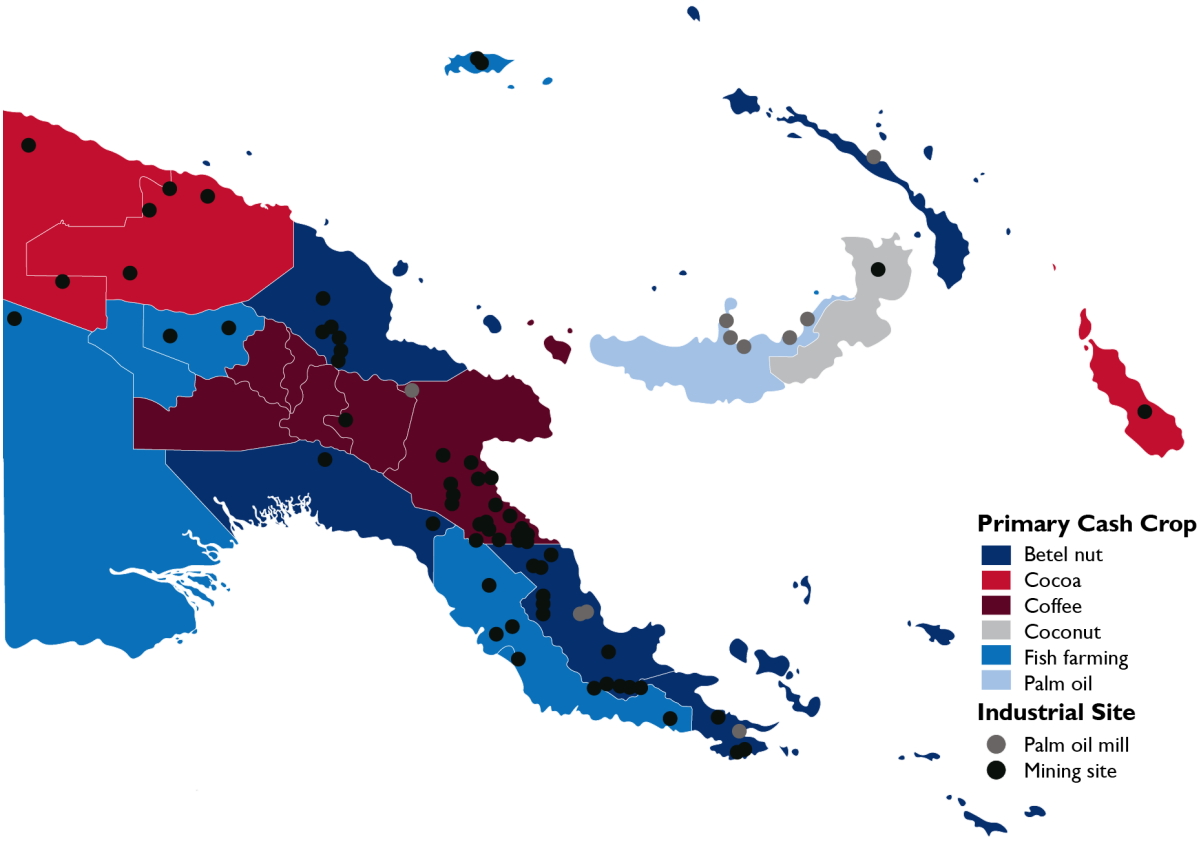
roughly two-thirds of that will be demand for petroleum and not just electricity.[92]

Figure 11 shows the primary cash crop produced in each province as well as the locations of mining sites and palm oil mills across the country. The majority of mining sites are located in the Morobe, Central, and Oro Provinces. Meanwhile, West New Britain, which produces palm oil as its primary cash crop, maintains many of the country's palm oil mills.

GENERAL SUPPLY CUSTOMERS

General supply customers in the commercial sector comprise a large portion of on-grid electricity demand in PNG, with a little more than 50 percent of total demand coming from what PPL calls the "general supply."[93] Electricity demand from this sector primarily goes to buildings, particularly for lighting, air cooling, and water heating. The commercial sector is located mostly in urban centers. Projections show that commercial sector energy demand (which includes electricity, kerosene, and liquified natural gas) will grow at 4.8 percent per year until 2035.[94]

FIGURE 11. PROVINCES' PRIMARY CASH CROPS, MINING SITES, AND PALM OIL MILLS



Source: USAID Demographic and Health Surveys (DHS) 2018 data.

[92] Asia Pacific Energy Research Centre.

[93] PPL billing data from 2018.

[94] Asia Pacific Energy Research Centre, "APEC Energy Demand and Supply Outlook - 5th Edition."

ELECTRIFICATION TARGETS

GoPNG set the goal of achieving 70 percent electrification by 2030 (as detailed in NEROP) and 100-percent electrification by 2050 (Vision 2050).[95,96] The approach of the rollout plan for achieving these goals is two-pronged: (1) extend and intensify the existing grid infrastructure and (2) finance and develop new off-grid infrastructure to reach households where grid extension is not cost-effective (i.e., least-cost).

The NEROP report identifies 283,141 potential connections through densification by 2030; 684,089 potential connections through expansion and densification of expansion; 26,607 potential connections through mini-grid deployment; and 605,055 potential connections through SHS.[97] Achieving these potential connections would result in an estimated 43 percent of the population with access to the grid in 2030 and 70 percent of the population with access to electricity.[98] The total estimated cost of electrification between 2021 and 2030 is $729 million.[99]

The NEP 2017–2027,[100] the overarching policy document for the energy sector, lays out detailed plans for energy sector development in PNG to achieve these electrification targets, signaling significant reforms that the government wants to make in the sector. KCH, which is the parent company of PPL, will initiate the process of restructuring PPL. The restructuring plan includes the formation of NEA.

In addition to the electrification target, under Vision 2050, PNG aims to reach 100-percent electricity generation from renewables by 2050 and reduce emissions levels by 90 percent from 1990 to 2050. The NEP outlines strategies for taking advantage of PNG's high renewable resource potential to increase geothermal, hydropower, biomass fuel, solar, and wind generation. Despite these goals, the NEP also introduces long-term plans to intensify data collection efforts for oil and gas to increase investment and promote coal exploration as an option for low-cost electricity generation.[101]

[95] NRECA International, "Papua New Guinea National Electrification Rollout Plan (NEROP) Implementation Strategy and Investment Plan: Final Report 2020."

[96] The Independent State of Papua New Guinea, "PNG Vision 2050."

[97] NRECA International, "Papua New Guinea National Electrification Rollout Plan (NEROP) Implementation Strategy and Investment Plan: Final Report 2020."

[98] NRECA International.

[99] NRECA International.

[100] It should be noted that several versions of the National Energy Policy exist. The National Energy Policy 2016-2020 and National Energy Policy 2017-2027, both introduced by the Department of Petroleum and Energy, are accessible online. Various reports refer to the National Energy Policy 2018–2028 (Engelmeier and Gaihre, 2019). According to the Global Green Growth Institute, the DPE confirmed that the National Energy Policy 2018-2028 is identical to the National Energy Policy 2017-2017 (GGGI, 2019).

[101] Department of Petroleum and Energy, National Energy Policy 2017-2027.

ENERGY POLICIES AND REGULATIONS

Since the 1990s, GoPNG has passed many energy sector plans, policies, and regulations. Figure 12 visualizes the timeline and Table 6 provides further details.

FIGURE 12. RELEVANT ENERGY PLANS, POLICIES, REGULATIONS, AND LEGISLATION TIMELINE

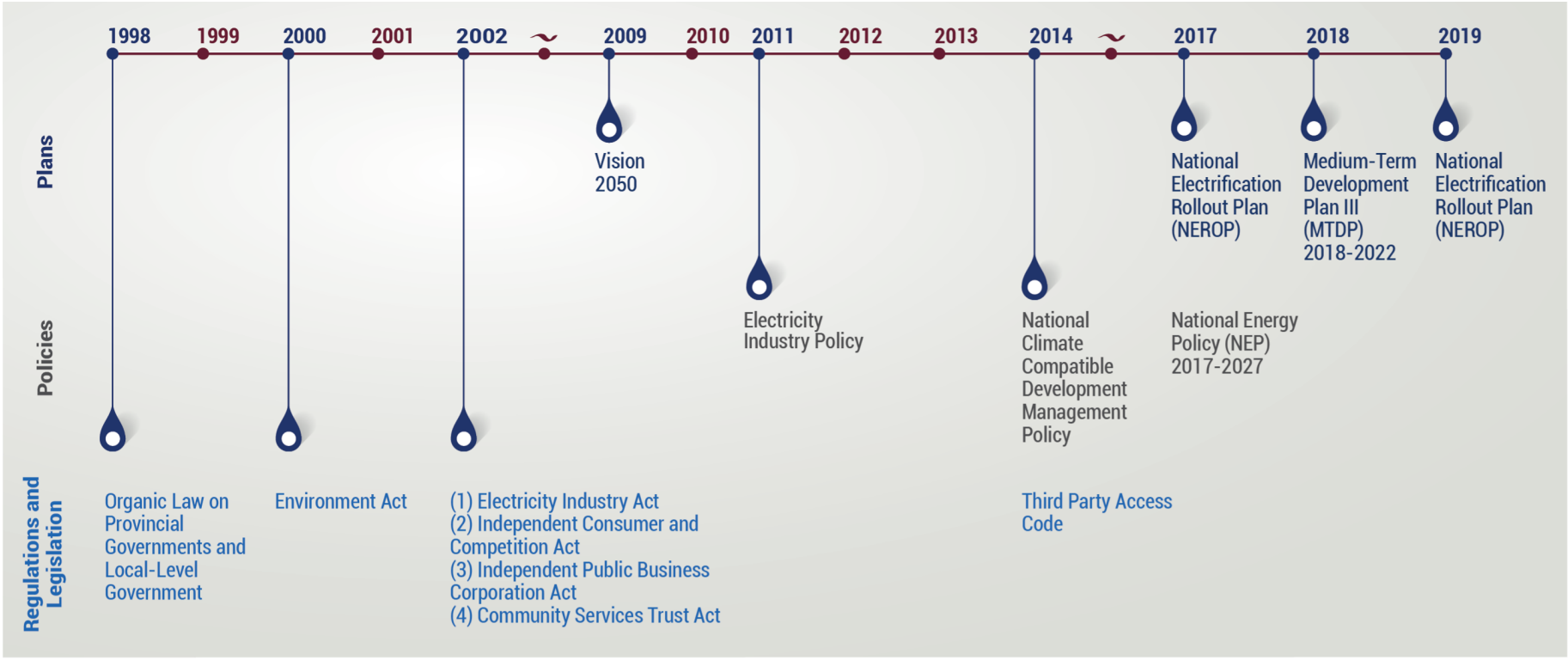


TABLE 6. RELEVANT ENERGY PLANS, POLICIES, REGULATIONS, AND LEGISLATION		
NAME	YEAR OF INTRODUCTION	DESCRIPTION
POLICIES AND PLANS		
Vision 2050	2009	Long-term strategy with seven focus areas: human capital development, wealth creation, institutional development and service delivery, security and international relations, environmental sustainability and climate change, cultural and community development, and strategic planning and integration.
Electricity Industry Policy	2011	National policy to put in place structures and processes to achieve affordable and reliable electricity for as many citizens as possible. This policy provides the current institutional framework for rural electrification in PNG. It has not had any updates since its creation in 2011.
National Climate Compatible Development Management Policy	2014	Strategy for increasing mitigation and adaptation measures across all sectors of the economy, including decreased dependence on fossil fuel technologies in the electric sector.
National Electrification Roll Out Plan (NEROP) and its Implementation Strategy and Investment Plan	2017, 2019	The World Bank, Columbia University, and the National Rural Electric Cooperative Association (NRECA) supported GoPNG to design this plan to reform and expand the electricity sector. It includes detailed geospatial analyses of existing electric infrastructure and population distribution as well as economic assessments of grid expansion and grid intensification options. [102,103]

[102] The Earth Institute, Columbia University, "Preparation of National Electrification Rollout Plan and Financing Prospectus."

[103] NRECA International, "Papua New Guinea National Electrification Rollout Plan (NEROP) Implementation Strategy and Investment Plan."

TABLE 6. RELEVANT ENERGY PLANS, POLICIES, REGULATIONS, AND LEGISLATION		
NAME	YEAR OF INTRODUCTION	DESCRIPTION
POLICIES AND PLANS		
National Energy Policy (NEP) 2017–2027	2017[104]	National policy and least-cost strategies for the energy sector to meet national and provincial development needs. Aligns with the goals of Vision 2050 and draws support from NEROP. Introduced NEA and EnerCom in 2017 and created them in 2021.
Medium-Term Development Plan III (MTDP) 2018–2022	2018	A five-year development strategy that defines the policy directions and priority areas for investment within different sectors for the years 2018–2022. Released every five years under the mandate of the PNG Planning and Monitoring Responsibility Act, it translates Vision 5050 into more specific implementation programs.
REGULATIONS AND LEGISLATION		
Organic Law on Provincial Governments and Local-level Government	1998	Grants authority to provincial and local governments to regulate electricity and other utilities within their own jurisdictions.
Environment Act	2000	Regulates activities that can impact the environment, such as the building of new infrastructure.
Community Services Trust Act	2002	Protects the welfare and advancement of underprivileged groups through the requirement that government and non-government agencies must fund infrastructure development in rural areas.
Independent Public Business Corporation Act	2002	Establishes the Independent Public Business Corporation of PNG to hold certain assets as a trustee for the state, including all shares of PPL.

[104] It should be noted that there are several versions of the National Energy Policy. The National Energy Policy 2016-2020 and National Energy Policy 2017-2027, both introduced by the Department of Petroleum and Energy, are accessible online. Various reports refer to the National Energy Policy 2018–2028 (Engelmeier and Gaihre, 2019). According to the Global Green Growth Institute, the DPE confirmed that the National Energy Policy 2018-2028 is identical to the National Energy Policy 2017-2017 (GGGI, 2019).

TABLE 6. RELEVANT ENERGY PLANS, POLICIES, REGULATIONS, AND LEGISLATION		
NAME	YEAR OF INTRODUCTION	DESCRIPTION
REGULATIONS AND LEGISLATION		
Independent Consumer and Competition Act	2002	Establishes the Independent Consumer and Competition Commission (ICCC) to promote competition and fair trading, regulate prices for certain goods and services, and protect consumer interests. Regulates the electricity and petroleum industries and their pricing.
Third-Party Access Code	2014	Requires that ICCC reviews and approves any PPAs between PPL and an IPP before they sign them.
Electricity (Industry) (Amendment) Act	2020	Establishes an electricity commission to regulate the generation, supply, and sale of electricity as well as related purposes and activities.

DONOR ENERGY PROGRAMS

Donors have been active in PNG's energy sector for many years with key contributions from the World Bank, ADB, UNDP, JICA, Australia's DFAT, New Zealand's MFAT, and USAID. Annex 4 of this document includes a complete list of current projects relevant to rural electrification or off-grid energy.

Off-Grid Market

Off-Grid Market

OVERVIEW OF THE OFF-GRID MARKET

Due to a population that is overwhelmingly rural with low access to the grid, PNG is a promising market for off-grid solutions. Unlike many countries that have a single, unified electrical grid, PNG has multiple small grids that cover major population areas. Unfortunately, COVID-19 has negatively affected growth in PNG's off-grid electricity market. The pandemic led to border closures and disruptions in international trade and supply chains, which decreased the availability of and increased prices for off-grid products and parts. Meanwhile, lower commodity prices and weakened external demand led to an economic slump across the country, lowering households' ability to pay for electricity and off-grid solar products. In response, the government announced a 5.7-billion-kina ($1.5-billion) stimulus package across multiple industrial sectors to mitigate the impacts of COVID-19. However, it is not yet known how this stimulus package will impact off-grid development.

To reach the government's target of 70-percent electrification by 2030, NEROP estimates that the off-grid market will best serve 27 percent of the population, or over 630,000 households.[105] The renewable off-grid market has high potential due to the widespread availability of solar and hydropower resources across the country. However, the off-grid market in PNG is nascent, and stakeholders have conducted few site-specific feasibility studies to date. For purposes of this Market Assessment, off-grid electrification and associated technologies include both mini-grids and SHS.

Analysis conducted by USAID-PEP shows tremendous potential for mini-grid development in PNG (Figure 13) based on population settlement patterns and socioeconomic characteristics.[106] Many of these households are in one of the 437 communities that NEROP has identified as viable sites for mini-grid development,[107] but additional communities with sufficient household density are also identified as potential candidates for mini-grids.[108] USAID-PEP distinguished mini-grid sites into high-potential (greater than 320 households) or viable (100–320 households) sites. Based on the number of households in these identified sites, the total addressable market (TAM) for mini-grid development and SHS for

[105] NRECA International, "Papua New Guinea National Electrification Rollout Plan (NEROP) Implementation Strategy and Investment Plan: Final Report 2020."

[106] The USAID-PEP analysis is based on Facebook 2018 population data and PNG electric grid maps by the World Bank. High potential communities are defined as those with more than 320 households within a two-by-two-km gridded area (which is slightly different than the NEROP definition, as described in the next footnote). Viable communities are those with 100-320 households.

[107] NEROP identifies "viable" sites as those where PPL grid expansion costs were deemed too high, and clusters of households exceeded a lower limit of 100 connections within a radius of approximately one km. A maximum radius of one km was selected to ensure that more costly and complicated medium voltage distribution was not required to connect the households in the mini-grids.

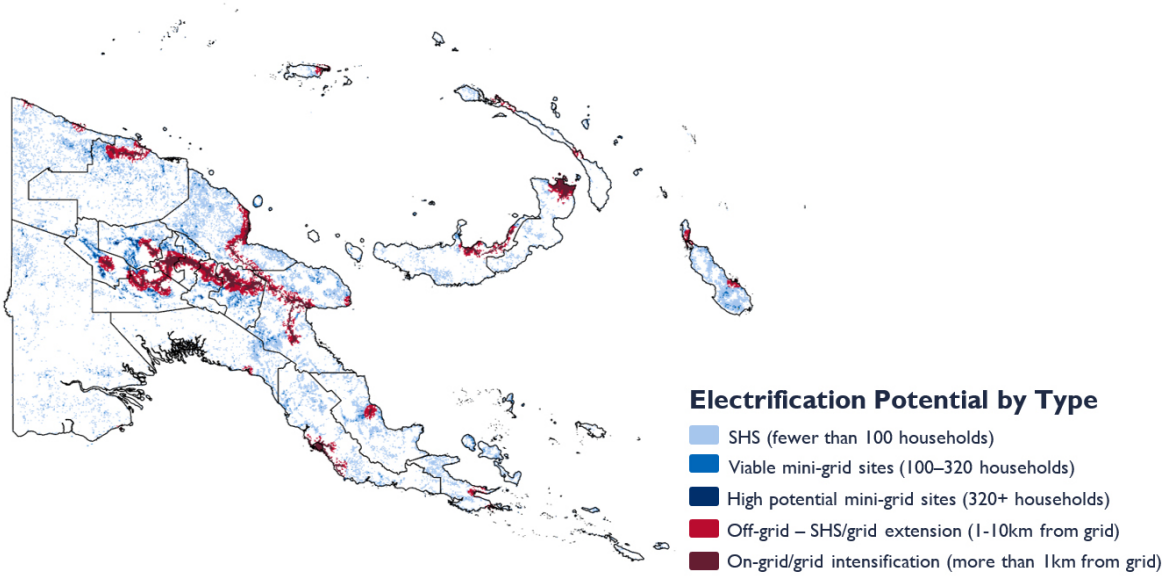
[108] This market information is based on characteristics of mini-grids across the world. While this information can assist in the process of exploring potentially viable areas for mini-grid electrification, it does not reflect any formal electrification plans. USAID-PEP encourages stakeholders to take further action to confirm the viability of potential mini-grids and align plans with those of GoPNG.

all households (including those identified as more or less likely to adopt) is estimated at around $71 million per year.[109] This calculation assumes households are willing to spend 295 kina per year on electricity access. From the percent of households that USAID-PEP identified as best-served by mini-grids vs. SHS, this breaks down to a TAM of around $35 million each for mini-grids and SHS (Table 9). The TAM might be higher if households are willing to pay more for more reliable electricity.

No comprehensive studies have been conducted to-date to estimate the willingness-to-pay of rural PNG residents for access to electricity. A report by the International Finance Corporation (IFC) Lighting Program estimates that off-grid households spend on average $16 per month on lighting based on survey data. The IFC Lighting Program used this as a proxy for willingness-to-pay.[110] Meanwhile, the World Bank and the Energy Sector Management Assistance Program (ESMAP) began conducting an on-going study to examine the electricity access and energy expenditures of 2,635 households across PNG.[111] They found that "off-grid energy solution users" (i.e., those who rely on candles, kerosene, and dry-cell batteries) spend on average 166.6 kina ($47) per year on electricity, or approximately 13.9 kina ($3.94) per month.

In this current report, to capture household expenditure as a proxy for willingness-to-pay, USAID-PEP uses data collected by the International Food Policy Research Institute (IFPRI) for their Papua New Guinea Household Survey of Food Systems in 2018. The annual average household expenditure on energy-related products is estimated to be 295 kina ($84) or approximately 24.5 kina per month; this number is assumed to represent the average household connecting to mini-grids and solar home systems. The next section discusses willingness-to-pay in PNG in more detail.

FIGURE 13. POPULATIONS BEST SUITED FOR ON-GRID, MINI-GRID, OR SOLAR HOME SYSTEM SOLUTIONS



Note: Each site in this analysis is defined as a two-by-two-km grid.
Source: USAID Demographic and Health Surveys (DHS) 2018 data.

[109] This uses an exchange rate of US $0.28 per 1 kina.

[110] International Finance Corporation, "Going the Distance: Off-Grid Lighting Market Dynamics in Papua New Guinea."

[111] The World Bank, "Preliminary Findings from a Multi-Tier Framework (MTF) Household Survey in PNG."

EXPECTED DEMAND OF HOUSEHOLDS AND WILLINGNESS/ABILITY TO PAY FOR ENERGY

As previously mentioned, data on willingness to pay is limited in PNG, but there is significant concern from stakeholders on households' ability to pay for energy, especially for rural communities with poor access to markets. GoPNG and other institutions have looked at expected energy usage and calculated spending based on this. For example, the NEROP estimates that the monthly average demand for new customers will be 16 kWh per month.[112]

Prototypical characteristics of off-grid solar products and systems:

Solar lanterns:

- Less than 3 W
- MTF Tier 0 Service

Stand-alone solar home systems:

1. At least 3 W
2. MTF Tier 1 Service

Mini-grids:

3. At least 200 W (per household connected)
4. MTF Tier 3 Service or higher

This estimate uses the lower end of results from IFC's survey on monthly expenditures for lighting and then applies the ICCC-approved PPL tariff. USAID-PEP expands on this estimate by leveraging PPL billing data and DHS data to estimate electricity demand for different segments of rural communities.

In PNG, there are at least two broad segments of rural households with distinct electricity demand requirements. First are rural residents who work in the informal economy, mainly as subsistence farmers, and constitute 97 percent of the rural population. For this group, energy consumption is low and is primarily for lighting a few 8 W lightbulbs at night, charging one or two mobile phones, and, for some, charging a Wi-Fi device or laptop.[113] These households' expected energy needs correspond to Tier 1 in the World Bank's Multi-Tier Framework (MTF) for electricity access, for which rechargeable batteries and SHS are sufficient to power low-load appliances.[114] USAID-PEP estimates that these households require 20 W peak load.[115] The second group is comprised of formally employed professionals who work as nurses, teachers, local government officials, and church pastors. Average professional rural residents use more electricity because they tend to own more appliances such as refrigerators and televisions. These households tend to use standalone solar packages with backup batteries to power these appliances.

According to a survey conducted across PNG between 2017 and 2019, on average, these "professional" rural households require around 1.2 kW of peak power capacity.[116]

[112] NRECA International, "Papua New Guinea National Electrification Rollout Plan (NEROP) Implementation Strategy and Investment Plan: Final Report 2020."

[113] Lovo et al., "Renewable Energy Technologies as 'Saving Graces' for Pacific Island Nations Fighting Climate Change."

[114] Mikul Bhatia and Nicolina Angelou, "Beyond Connections: Energy Access Redefined."

[115] This represents two 8-W bulbs and a 4-W charger being used at the same time as a rough estimate for peak load need.

[116] Lovo et al., "Renewable Energy Technologies as 'Saving Graces' for Pacific Island Nations Fighting Climate Change."

The survey focused on rural communities surrounding Lae in the Morobe Province, where rural households may be wealthier than in other provinces due to their proximity to the city; therefore, these estimates may be on the higher end of rural demand. These consumers' energy needs correspond to MTF Tier 3 or higher and would be best served by mini-grids.[117] The NEROP and MTF define mini-grids as suitable to provide Tiers 3 and 4 access to communities, while SHS should provide at least Tier 1 access to households.

TABLE 7. SIMPLIFIED MULTI-TIER FRAMEWORK LEVELS (WORLD BANK)[118]

	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Power Capacity	Less than 3 W	At least 3 W	At least 50 W	At least 200 W	At least 800 W	At least 2000 W
Hours of Service (Daily Availability)	Less than 4 hours	At least 4 hours	At least 4 hours	At least 8 hours	At least 16 hours	At least 23 hours
Reliability	More than 14 disruptions per week			At most 14 disruptions per week	3-14 disruptions per week	At most 3 disruptions per week with total duration of less than 2 hours
Quality	Households experience voltage problems that damage appliances				Voltage problems do not affect the use of desired appliances	
Affordability	Cost of a standard consumption package of 365 kWh per year is more than 5% of household income			Cost of a standard consumption package of 365 kWh per year is less than 5% of household income		

For another data point for willingness to pay, this report used data collected by the International Food Policy Research Institute for their Papua New Guinea Household Survey of Food Systems in 2018.[119] This study surveyed more than 1,000 rural households in East Sepik, West Sepik, Madang, and the Autonomous Region of Bougainville primarily for the purpose of exploring poverty and food security; household expenditures were also included. Notably, expenses for batteries, firewood, kerosene, electricity/gas, and lamp/torch/solar panels were collected. Very few respondents reported expenditures on firewood (seven respondents out of 1,026), kerosene (11 respondents), or electricity/gas (15 respondents) so these were not

[117] Mikul Bhatia and Nicolina Angelou, "Beyond Connections: Energy Access Redefined."

[118] Mikul Bhatia and Nicolina Angelou.

[119] International Food Policy Research Institute (IFPRI), "Papua New Guinea Household Survey on Food Systems, 2018."

considered, but 57 percent of respondents reported expenses on batteries and 59 percent reported an expense in the lamp/torch/solar panel category which give important clues to what the population is using for lighting or energy and how much they are spending. Of the 57 percent of respondents reporting battery expenditure, average monthly expense was 13.87 kina ($4.13). While this does not present a complete picture of energy spending, it shows that a significant portion of the population may be able to spend over $4.00 per month on energy and could be willing to spend this money on a solar product instead of batteries (especially if financing mechanisms allow paying off of a system over time). The other key insight provided by this study was on capital expenses that households made related to lighting under the "lamp/torch/solar panels" expense category for the last one year. This category could include several different products: dry cell battery-powered lanterns, small "torches" (flashlights), SHS, or larger solar panels. Based on the IFC report that showed over 60 percent of the population owned a solar product, it can be inferred that a significant number of these represent solar products, although it is impossible to know with the data available. Regardless, 59 percent of respondents to the IFC survey reported an expense in this category over the past year with an average expense of 123 kina ($37.54) which demonstrates that the rural population is willing to invest a relatively significant amount in lighting products. Total annual spending on energy-related products estimated by IFPRI – including electricity, batteries, kerosene, firewood, lamps, torches, and solar panels – is broken down by quintiles in Table 8.

TABLE 8. ANNUAL ENERGY EXPENDITURES OF RURAL HOUSEHOLDS BY QUINTILES (ELECTRICITY, BATTERIES, KEROSENE, FIREWOOD, LAMPS, TORCHES, SOLAR PANELS)[120]

	FIRST QUINTILE (LEAST SPEND-ING)	SECOND QUINTILE	THIRD QUINTILE	FORTH QUINTILE	FIFTH QUINTILE (MOST SPENDING)
Total expenditure per year (USD)	0	7.32	21.95	53.05	251.94

*The IFPRI analysis sampled a total of 1,026 households. Each quintile represents 20 percent of the 1,026 surveyed households.

**The IFPRI household survey was not designed to be nationally representative but attempted to capture as wide of a spatial range as possible. The survey included rural households in East Sepik (Maprik), Sandaun / West Sepik (Nuku), Madang (Middle Ramu) districts, and the Autonomous Region of Bougainville (Buin and Siwai areas of Southern Bougainville).

Table 9 presents the off-grid market potential by demand segment based on the size of communities and the projected electricity demand in these communities from USAID-PEP's GIS analysis, with further details in Annex 3.[121] This estimate represents the potential market

[120] International Food Policy Research Institute (IFPRI).

[121] These numbers are different from the previously cited numbers on solar product penetration because they only consider Tier 1 and higher SHS (GOGLA data), which only make up a small percentage of total solar product sales.

size if each household were served by the most appropriate modality as identified by the GIS analysis. The GIS analysis identifies the most appropriate modality for each community based on its size and the estimated demographics of the community. However, the timing of the uptake of mini-grid development can impact the SHS market potential in the near term, for which the GIS analysis cannot fully account. For instance, if mini-grid deployment is delayed, it is likely that some households would opt to become SHS customers instead of waiting for a mini-grid to arrive. The SHS Market section of this document explores the current SHS market using the total population, given the uncertainty around timing for the uptake of mini-grids.

TABLE 9. OVERVIEW OF OFF-GRID MARKET POTENTIAL IN PNG BY SEGMENT

	SOLAR MINI-GRIDS	SOLAR HOME SYSTEMS[122]
Number of Potential Households	419,000	437,000
Current Market Penetration (Percent of Total Households)	<1%	~5%
Total Addressable Market (USD)	$34,609,000	$36,096,000

Source: USAID-PEP analysis based on population data from Facebook, DHS household surveys, and PPL billing data.

OTHER POTENTIAL OFF-GRID CUSTOMERS

In addition to the residential off-grid market's demand for electricity, the non-residential off-grid market also has significant potential demand for electricity. In rural areas, healthcare facilities, schools, shops, and farms can all benefit from off-grid solar systems to power lights, refrigerators, water heaters, and irrigation systems. Many of these entities can act as anchor customers to make mini-grids more viable for residential consumers. For example, small businesses and telecom towers are both often used as an anchor customer for rural communities. Mini-grids with anchor loads can help offset the costs of electricity generation for residential consumers by cross-subsidizing residential power demand, assuming certain criteria are met. Specifically, the distance from the anchor customer to residential customers is important, as geographically disbursed customers may increase overall costs due to the need for more distribution infrastructure. Institutional customers located near residential customers and with sufficient revenues to pay for power consumption are ideal anchor loads for mini-grid development.

CURRENT STATUS OF MINI-GRID DEVELOPMENT IN PNG

An MTF Tier 3 mini-grid is an off-grid system that involves small-scale power generation and serves a limited number of consumers via a distribution grid that can operate in isolation from the main grid.[123] The power generation of a mini-grid can come from diesel generators,

[122] The SHS Market section of this document includes further relevant details. The calculation of market penetration considers QV Tier 1 and above products only using sales data showing 2.8 percent market penetration over the past year (GOGLA) and assuming that there was at least 2.2 percent penetration in 2019 (i.e., a 27 percent growth over a year); this is an indicative value.

renewables (solar photovoltaic [PV], hydro, wind, biomass, etc.), or a hybrid of renewable and diesel generation. A mini-grid may also include an energy storage system, which may use lead-acid battery technology, lithium-ion battery technology, or other energy storage technologies.

In PNG, PPL operates 26 regional grids ("C-Centers") outside of the three main grids of Port Moresby, Ramu, and Gazelle Peninsula.[124] All of the 26 PPL-owned regional grids run on diesel generator power except for the Kimbe and Bialla systems, which use a combination of hydro and diesel generators.[125] All of these operate at significant losses due to the high cost of generated power in comparison to their tariffs.[126] Table 10 presents a summary of these regional grids.

TABLE 10. PPL-OWNED REGIONAL GRIDS

REGION	POWER STATION	GENERATION TYPE	PEAK LOAD (MW)[127]	ESTIMATED CONNECTIONS[128]	SYSTEM LOSSES (%)[129,130]
Bougainville	Buka	Diesel	1.9	2,463	13.2
	Arawa	Diesel	0.9	314	-
East Sepik	Wewak	Diesel	4	2,207	11.4
	Maprik	Diesel	0.7	337	16.7
Gulf	Kerema	Diesel	0.5	350	7.1
Hela	Tari	Diesel	0.7	632	-
Manus	Lombrum/ Lorengau	Diesel	1.7	1,630	9.4
Milne Bay	Alotau	Diesel	2.7	1,103	14
	Samarai	Diesel	0.04	62	39.5

123 Alliance for Rural Electrification, "Off-Grid Electricity Systems."

124 NRECA International, "Papua New Guinea National Electrification Rollout Plan (NEROP) Implementation Strategy and Investment Plan: Final Report 2020."

125 PNG Power Ltd, "Information Handbook."

126 NRECA International, "Papua New Guinea National Electrification Rollout Plan (NEROP) Implementation Strategy and Investment Plan: Final Report 2020."

127 International Finance Corporation, "PNG Mini-Grid Development Program: Inception Report."

128 International Finance Corporation.

129 Estimated based on historical demand from 2000-2015.

130 PNG Power Ltd, "Fifteen Year Power Development Plan: 2016-2030."

TABLE 10. PPL-OWNED REGIONAL GRIDS

REGION	POWER STATION	GENERATION TYPE	PEAK LOAD (MW)[127]	ESTIMATED CONNECTIONS[128]	SYSTEM LOSSES (%)[129,130]
Morobe	Fin-schhafen	Diesel	0.2	184	13.7
New Ireland	Kavieng	Diesel	1.9	929	8.4
Oro (Northern)	Popondet-ta	Diesel	1.7	1630	10.4
	Divune	Hydro	3		
Sandaun (West Sepik)	Vanimo	Diesel	2	284	12.1
	Aitape	Diesel	0.3	163	9.1
West New Britain	Bialla	Diesel	5	2253	10.4
	Lake Hargy	Hydro			
	Kimbe	Diesel			20.1
	Ru Creek	Hydro			
Western	Daru	Diesel	0.8	559	23.2

In addition, there are an estimated 150 mini-grids located in provincial centers across PNG. These are primarily smaller, rural, diesel or hydropower generators that provincial governments own and operate. Historically, PPL and provincial governments have passed back and forth the responsibility for the C-Centers and, therefore, have not properly maintained many of them.[131]

Industrial companies often build and operate mini-grids that support industrial demand for projects related to mining, timber, or petroleum, though many of these mini-grids also support demand from the economic centers that arise from and surround an industrial site. These mini-grids tend to include hydropower, diesel, and other fossil fuel generators. Communities in areas without industrial demand are not able to benefit from this type of mini-grid development. The number of private mini-grids is undetermined, including most of those for mining and industrial sites (as well as those connected to populations near those sites, such as the OK Tedi and Lihir Gold mines).

Solar mini-grids are rare in PNG. Two known examples of existing renewable energy mini-grids include an 80-kW solar-battery-diesel hybrid mini-grid that powers the Kompiam hospital and staff housing (which the Engan Provincial Government funds) and a 250-kW hydro mini-grid that powers the Kudjip Hospital (which the Government of Australia funds).[132]

[131] Port Jackson Partners, "Powering PNG into the Asian Century."

[132] Lyons, "Australian GP Dr David Mills Faced Incredible Challenges When Working to Establish Vital Primary Healthcare Services and Training in Papua New Guinea."

PPL is in the process of constructing a solar mini-grid on Samarai Island with technical assistance from UNDP. The Government of Australia's *Pawarim Komuniti* program is also currently funding the construction of several solar mini-grids.

CURRENT OFF-GRID PRODUCT OWNERSHIP

As of 2019, approximately 60 percent of households in PNG owned off-grid solar (OGS) products, including Tier 1 SHS and Tier 0 devices, such as solar lanterns.[133] In the second half of 2020 alone, the International Electrotechnical Commission (IEC)/VeraSol[134] QV OGS product sales totaled 67,000 units, the highest number ever recorded in PNG.[135] However, these sales are still a fraction of the total off-grid products sold in PNG. Meanwhile, the same timeframe included sales of 1,737 units of off-grid solar appliances, including TVs, fans, water pumps, and refrigeration units. This represents a six-percent increase in sales compared to the same time in the previous year. Despite the increase in total OGS product sales, less than five percent of all households across PNG own Tier 1 SHS, which are more expensive than Tier 0 devices. An estimated 51 percent of OGS products currently in use are Tier 1 products, and 46 percent are Tier 0 products such as one-light systems.[136] The market penetration of OGS products varies across the country.[137] Market penetration tends to be highest in villages near large port cities, possibly because of greater accessibility at lower costs, while communities farther from ports seem to have lower market penetration.

IN-COUNTRY TRANSPORTATION LOGISTICS

Specifically for mini-grids, long procurement timelines can negatively impact project profitability over the lifespan of the asset. PNG Ports Corporation (PNGPC) is a state-owned entity that operates and controls the authority over berthing, piloting, storing, and wharfing cargo services under the Department of Transport. In PNG, the primary ports receiving international cargo are Port Moresby, Lae, and Kimbe. Lae serves the Highlands Region through its network of roads, while Port Moresby serves areas in the Southern Region. Currently, as part of upgrade efforts, authorities relocated the Port Moresby port to Motukea Island. The new port intends to include more container-handling facilities and berths, reducing turnaround times and allowing ships and products to transit more quickly. Kimbe serves the Islands Region. A handful of smaller ports transport domestic cargo from the main island to the other islands.

Shipping internationally to PNG normally takes 25 days for full container load shipments and 45–50 days for "less-than-container-load" shipments (or categorically smaller loads) to arrive at Port Moresby or Lae.

[133] International Finance Corporation, "Going the Distance: Off-Grid Lighting Market Dynamics in Papua New Guinea."

[134] The IEC is a leading international standards organization that publishes quality standards for various solar products including standalone solar energy kits. These standards establish stakeholders and end-users understand the quality of products on the market.

[135] GOGLA, "Global Off-Grid Solar Market Report: Semi-Annual Sales and Impact Data, July - December 2020."

[136] GOGLA.

[137] International Finance Corporation, "Going the Distance: Off-Grid Lighting Market Dynamics in Papua New Guinea."

An imported product typically follows the transport process outlined in Figure 14. Shipping internationally to PNG normally takes 25 days for full container load shipments and 45–50 days for "less-than-container-load" shipments (or categorically smaller loads) to arrive at Port Moresby or Lae. Then, container clearance takes around three days, depending on the clearance agency's preparedness and documentation work.[138]

FIGURE 14. MOVEMENT OF IMPORTED PRODUCTS FROM MANUFACTURER TO END-USER

After customs clearance, either the warehouses hold the containers or transport them to distributors in the surrounding regions. Warehouses nearer to the port serve all international port destinations. Typically, the primary distributor imports and sells the imported items through branch offices and retail showrooms in town areas; whereas, mid-mile distributors cannot completely realize their potential, as they require financial support to advance their product acquisitions for pre-ordering the product. Large distributors often encourage only cash-and-carry sales because of lesser demand and volume.

Table 11 shows costs associated with transportation.

TABLE 11. COSTS OF TRANSPORTING PRODUCTS IN PNG (KINA)

FEE	LARGE 40-FT CONTAINERS	SMALL 20-FT CONTAINERS
Customs Documentation	30	30
Customs Clearance Agent	4,200	2,800
Wharfage Handling	4,300–4,600	2,800–3,300
International Ship and Port Facility Security	60	60
Terminal Container Handling	822	432

[138] Note: Most commonly from China.

TABLE 11. COSTS OF TRANSPORTING PRODUCTS IN PNG (KINA)		
FEE	LARGE 40-FT CONTAINERS	SMALL 20-FT CONTAINERS
Truck Transportation: Wharf to POM	1,200	850
Truck Transportation: Wharf to Highland Region / Mt. Hagen	16,000 without side loader 22,000 with side loader	12,000 without side loader 16,000 with side loader
Truck Transportation: Wharf to Highland Region / Mendi and Wabag	18,500 without side loader 24,500 with side loader	14,500 without side loader 18,500 with side loader
Container Return Charges	1,000	1,000
Container Return Penalty if not returned within the time limit	20 per day	20 per day

GENDER CONSIDERATIONS

Women in rural communities are often primary household managers, entrepreneurs, skilled agricultural producers, and consumers; however, across the world, they remain a grossly underserved group whose participation in the energy sector is, therefore, a top priority among stakeholders. Engaging women is particularly important in PNG, where 85 percent of the population lives in rural or remote areas with poor access to energy.

Community lighting and other off-grid electrification activities (e.g., PUE, as discussed in later sections) can notably contribute to the economic empowerment and safety of women. Women who operate their own businesses may benefit from the availability of community lighting near their shops and workplaces, which enables them to operate safely after dark. These extended work hours, in turn, allow women to earn higher incomes, improve their quality of life, and pursue further economic opportunities.

Better community lighting in areas that women commonly traverse can reduce the risk of crime, enabling communities to be more active at night and supporting the studies of both children and adults. Encouraging studying leads to improved educational outcomes, which can empower community members in the informal economy to integrate further into the formal economy. Communities can consider installing lighting around homes, productive spaces, and public areas for all social groups to support community relations.

Benefits of Community Lighting

- Reduces the risk of gender-based violence (GBV) and other threats
- Improves community members' ability to navigate physical hazards after dark (e.g., hillsides, waterways, bridges, sewers, vegetation, shelters, and dangerous animals)
- Ensures safe and dignified access to basic services
- Contributes to effective policing and emergency services

TABLE 12. PRODUCTS AND SUPPORT AREAS/FUNCTIONS		
NO.	PRODUCTS	SUPPORT AREAS/FUNCTIONS
1	Public solar lighting	Market areas and individual shop stalls.
2	Solar home system	Electrification of homes to run lighting, radios, fans, mobile phone charging, torchlight charging, and TVs (a lower priority in some households).
3	Solar cooker/solar-based electric cooker	Efficient cooking, thereby avoiding firewood.
4	Solar refrigeration equipment and ice maker	Supporting businesses to store food and cool drinks.
5	Water pump	Increased availability of drinking water. For farmers, it can also increase the availability of drinking water for livestock when surface water is low.

MINI-GRID MARKET

Historically, it has not been commercially viable for mini-grid developers to own and operate private mini-gids in PNG because of antiquated business models and monetization strategies. Currently, mini-grid developers only develop mini-grids in PNG for commercial purposes (e.g., mining, industrial facility) or with direct donor or government support. Key renewable energy mini-grids in development in PNG include:

- **The second round of the Government of Australia's *Pawarim Komuniti* program** – will support the development of three to five renewable energy mini-grids with grant funding.
- **The Government of Australia's Economic and Social Infrastructure Program (ESIP)** – through off-grid component Pawarim Komuniti, supports the upgrading of the PPL mini-grids of Maprik, Finschhafen, Vanimo, and Daru to solar-battery-diesel hybrid mini-grids. ESIP has tendered out feasibility studies of upgrades of two of these sites to progress this to construction.
- **UNDP** – provides technical support to PPL to develop an 80-kW solar PV plant for its Samarai mini-grid. The UNDP is also providing funding for two feasibility studies of hydro mini-grids in the Eastern Highlands.
- **The New Ireland Development Corporation** – the business arm of the New Ireland Province Government, which is funding the construction of three solar power plants for mini-grids at Kavieng (2 MW), Kronos (0.11 MW), and Namatanai (0.4 MW).[139]

Mini-grids require a certain household or customer density to be viable. The viability of mini-grids in a country or region is highly dependent on settlement patterns and socioeconomic indicators that determine demand for electricity and how much revenue the mini-grid can collect.

[139] Emiliano Bellini, "'You Can't Go Wrong with Solar.'"

The World Bank's MTF states that mini-grids can serve Tier 3 or higher households.[140] Similarly, topography, distance between customers, and resource availability dictate how much a system will cost to construct. Prefeasibility studies that narrow down site locations and detailed site assessments can help decrease construction costs. Meanwhile, well-developed business models and payment plans can help ensure that sufficient revenue is collected and a mini-grid is properly maintained throughout its lifetime. An important variable for mini-grid operators is understanding what demand looks like from different customer segments to be able to size a system properly and design pricing for different groups. Ideally, an anchor customer (or customers) will take a significant percentage of available energy, which can bring in significant revenue so that the revenue from households (which can be more variable) is less important. Further, these customers consume electricity during the daytime when residential customers consume less electricity—a factor that could improve the financial viability of mini-grids. Internationally, some mini-grid operators have used innovative models to lower costs such as providing a basic package to households that only require lighting and basic services such as phone charging for a set monthly cost or by utilizing rechargeable batteries that customers rent and return when the energy is finished. The PNG mini-grid market is very nascent and much of this market discovery still needs to be completed.

GoPNG can also promote regulations conducive to mini-grid development such as targeted subsidies and tax incentives. Costs to build and operate a mini-grid are generally higher than the grid so it is important for GoPNG and other stakeholders to have a thorough understanding of the economics to develop and operate a mini-grid in PNG and compare that to the amount a community is able to pay for the service. If the amount a community is able to pay is less than the amount to develop and operate a mini-grid, GoPNG and partners will need to consider subsidies to make up this difference. It will be crucial for regulations to consider these limitations and allow flexibility in tariffs as well as provide clear guidelines on compensation for a mini-grid operator if the national grid is extended into an area where a mini-grid exists. This will be key to facilitate investor confidence and investment in mini-grids in the coming years.

The rest of this section discusses the potential for mini-grids across PNG, the challenges, and the regulatory environment. Investor considerations and consumer financing options are presented in a later section of this report. A good resource for developers, investors, GoPNG, and other stakeholders to understand different aspects of mini-grid development (including planning and policy, design, economics, community engagement, ownership models, and financing) is USAID's Mini-Grid Toolkit.[141]

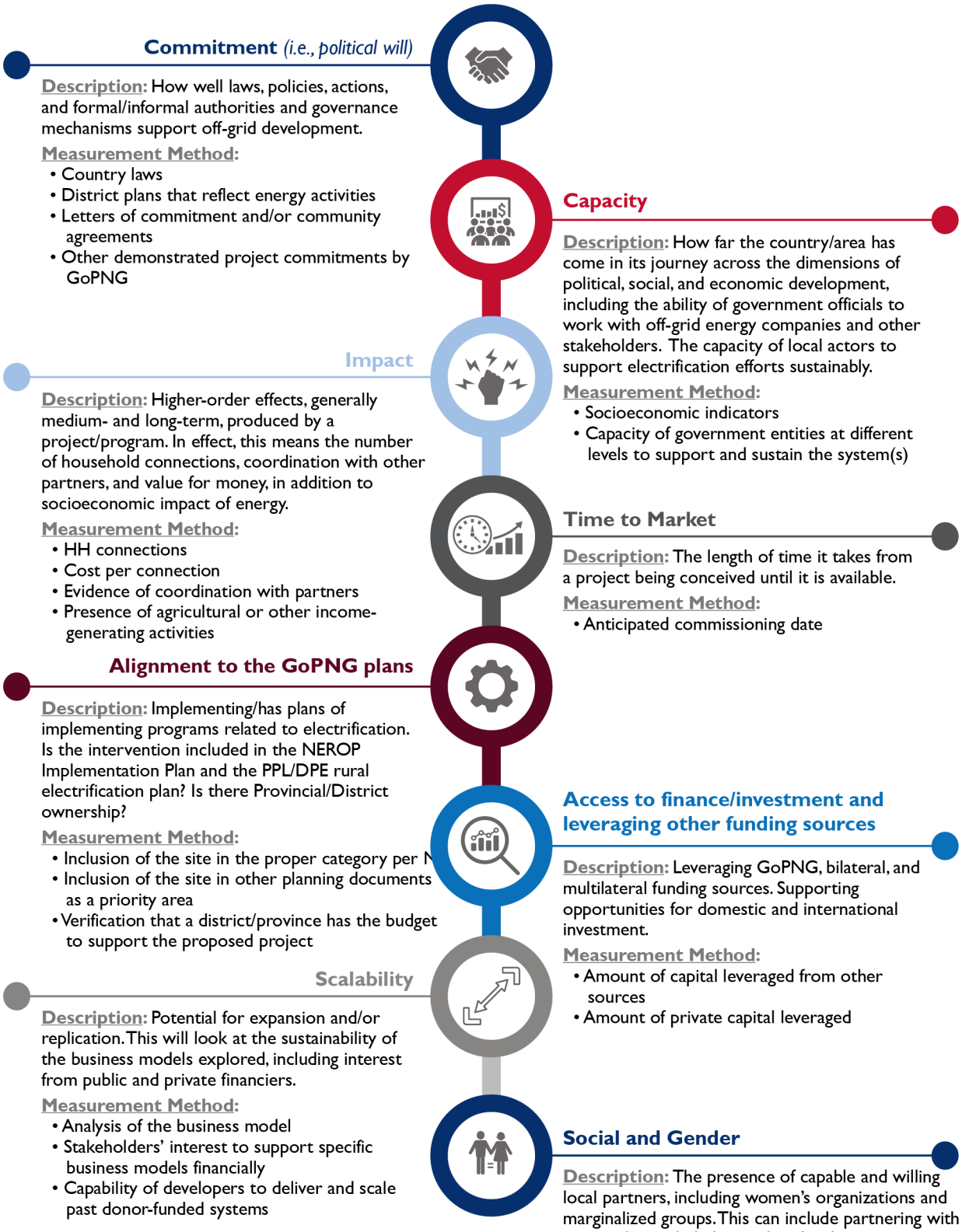
SELECTION OF SITES FOR MINI-GRIDS

USAID-PEP developed a set of selection criteria for mini-grids for Papua New Guinea that bring together political, economic, and financial considerations to prioritize sites for mini-grid development. It is presented in Figure 15 as a tool that stakeholders could use to make investment decisions in mini-grids.

[140] Mikul Bhatia and Nicolina Angelou, "Beyond Connections: Energy Access Redefined."

[141] US Agency for International Development, "Mini-Grids Support Toolkit."

FIGURE 15. SITE SELECTION CRITERIA



GEOGRAPHIC INFORMATION SYSTEMS ANALYSES AND VIABLE MINI-GRID SITES

As part of the NEROP report, GoPNG, PPL, and NRECA completed a GIS analysis (funded by the World Bank Group) to determine the least-cost option for electrifying different areas of the country, and GoPNG adopted the resulting plan as part of the NEA Bill. The GIS analysis identifies promising off-grid areas for mini-grid development and defines them as areas where clusters of houses "exceed a lower limit of 100–200 structures within a radius of approximately 1,000 meters."[142] The analysis aimed to keep the connection cost per household below $1,300. This analysis was a valuable first step in determining viable sites for mini-grids.

In this document, USAID-PEP's GIS analysis takes a step further by considering the socioeconomic characteristics of communities (in addition to topographic ones) to determine potentially viable areas for mini-grid development.

In this document, USAID-PEP's GIS analysis takes the analysis a step further by considering the socioeconomic characteristics of communities (in addition to topographic ones) to determine potentially viable areas for mini-grid development. USAID-PEP completed this analysis with existing data sources and can improve upon it with additional data sources in the coming years. The analysis is not intended to supplant the NEROP findings, which defined the areas that GoPNG is currently considering for mini-grids, but instead to provide market information for stakeholders on areas that could be viable for mini-grid developments in the future. USAID-PEP is also planning for this analysis to be accessible on an online platform in 2022 for stakeholders to explore characteristics of specific areas. USAID-PEP will update the online information periodically through 2025 to provide interested parties with up-to-date and localized information that can be difficult to ascertain from standard reporting practices.[143]

This analysis is particularly useful in the PNG context where transportation options are limited, and it is expensive to assess the feasibility of a particular site. As GoPNG looks to scale up mini-grids quickly, this information will play a key role for government planners as well as private sector developers and financiers to lower the overall cost of development by narrowing down the number of potential sites and providing a first-order estimation about the economics of building a system in a particular area.[144] The key results from USAID-PEP's analysis are shown in Figure 13, and Annex 3 presents the methodology note.

The NEROP GIS analysis identified 437 communities as viable mini-grid sites based on the number of households in each community.[145] USAID-PEP's GIS analysis leverages the socioeconomic characteristics of households to determine which communities have the highest demand potential based on asset ownership.

[142] NRECA International, "Papua New Guinea National Electrification Rollout Plan (NEROP) Implementation Strategy and Investment Plan: Final Report 2020."

[143] While this analysis reports mini-grid sites as viable for market information, USAID-PEP encourages companies and other parties to engage with local authorities to ensure alignment with local and national government plans.

[144] The analysis does provide an estimate of demand. USAID-PEP can provide these details for specific sites to stakeholders upon request, and ultimately, the analysis will be put on a platform online.

[145] For the NEROP report, costs were based on solar-diesel hybrid systems, but in some cases solar plus storage or hydro may be the most cost effective.

Case Study: Kandrian Community

The Kandrian community in West New Britain is an example community identified by this analysis for mini-grid development. This community is located 282 km from the existing grid, and its assumed connection rate if a grid were present is approximately 35 percent.[146] There are an estimated 470 households within this community (35 percent assumed connected = 165 households). In addition, there are two health centers and one school, totaling 1,400 kWh per month from institutional demand. Household and institutional demand together result in an estimated total community demand of 14,300 kWh per month. About 10 percent of the Kandrian community's total demand is estimated to come from institutional demand.

FIGURE 16. KANDRIAN COMMUNITY ANALYSIS

Kandrian community features

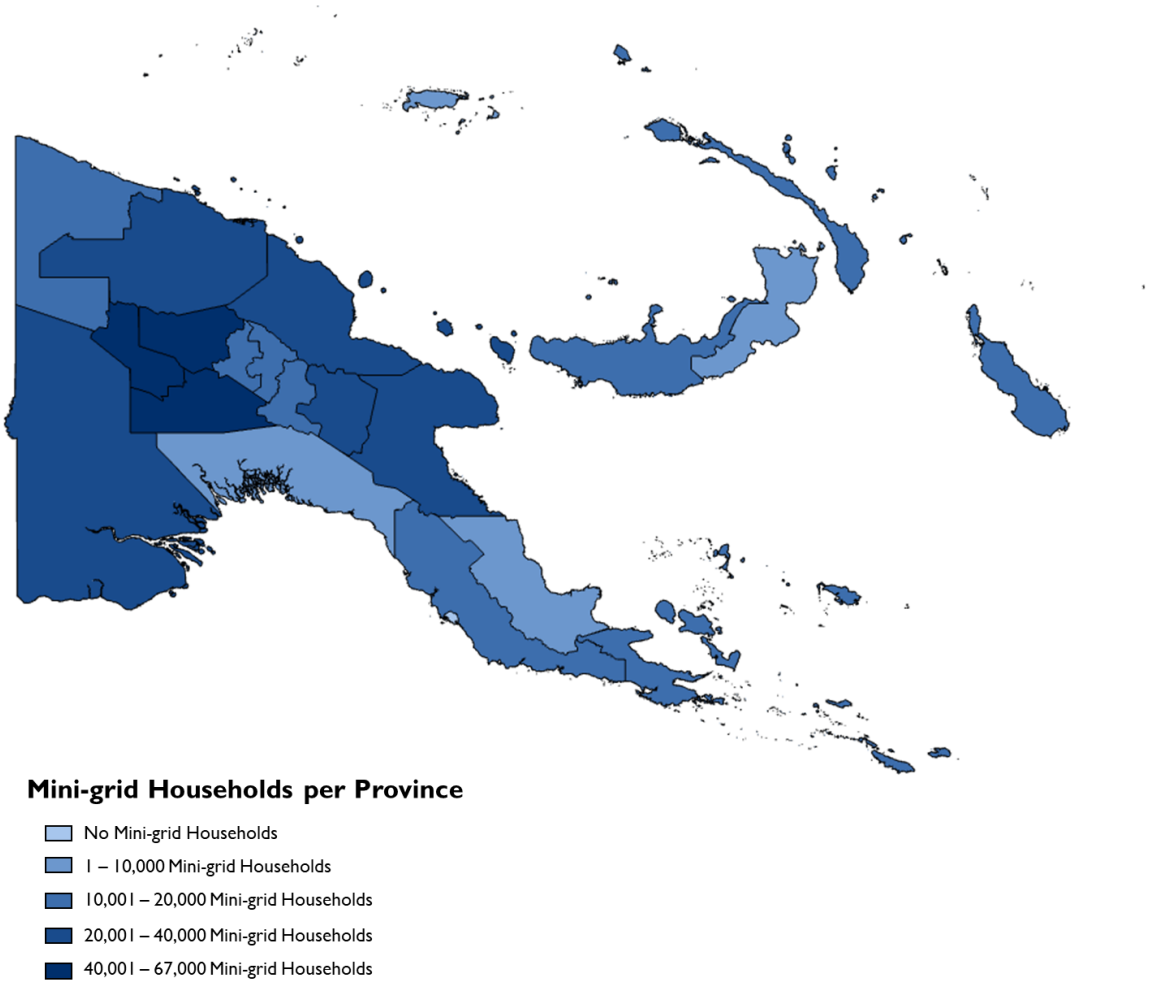
- Populated place
- Secondary road
- Tertiary road
- Airfield
- School
- Health center

Indicator	Value
Number of households	470
Total community demand[1]	14,300 kWh/month
Estimated connection rate[2]	35%
Distance to grid[3]	282km

As it will be important to cluster mini-grids to achieve economies of scale by mini-grid companies, USAID-PEP's GIS analysis looked at the provinces with the greatest number of households that fall within areas identified as mini-grid (see Figure 17). Not surprisingly, the highest potential provinces are in the Highlands Region which has the highest population density in PNG, but it is notable that the vast majority of provinces do have some potential mini-grid areas.

[146] Connection rate is calculated based on DHS regional averages disaggregated by wealth levels and urbanicity. Specifically, USAID-PEP calculated the percentage of households that had access to electricity in survey enumeration areas that had at least one household with electricity.

FIGURE 17. MAP OF HOUSEHOLDS IN MINI-GRID AREAS BY PROVINCE



While the GIS analysis in this report identifies the communities best suited for mini-grid development, it does not consider the timeline on which mini-grids will be deployed at scale, which is difficult to predict, as few commercially viable mini-grids have been deployed in PNG to date. Developing mini-grids in a commercially viable way requires financial support for the cost-sharing of capital requirements. GoPNG must establish clear regulatory guidelines, as PNG currently has no clear licensing, tariff-setting, or other technical and regulatory guidelines for mini-grids. These uncertainties mean that developers have no clear timeline to serve as a reference point for building mini-grids at scale. Depending on how quickly GoPNG and partners are able to overcome the aforementioned barriers, mini-grid deployment could be accelerated or delayed. NEROP used a relatively conservative approach and does not anticipate that private developers will build any mini-grids before 2023. Further, NEROP projects that private mini-grid developers will only develop 57 mini-grids by 2030, connecting 26,607 households at a total cost of $30,703,492. In terms of household cost, NEROP estimates that the 100 most attractive potential solar-diesel mini-grid sites will have an estimated average capital cost of $1,252 per household, with the lowest capital cost of these mini-grids at $964 per household.[147]

[147] NRECA International, "Papua New Guinea National Electrification Rollout Plan (NEROP) Implementation Strategy and Investment Plan: Final Report 2020."

KEY CHALLENGES AND POTENTIAL SOLUTIONS FOR FOR MINI-GRIDS

In addition to other energy sector-wide challenges discussed in the Challenges for Electrification in PNG subsection of this document, mini-grid developers face challenges specific to the mini-grid sector. Mini-grids require trained electricians to maintain them because—unlike SHS, which mostly run on low-voltage DC power—developers typically set up mini-grids as 240 V AC or 400 V 3-phase AC systems. Without proper maintenance, mini-grids tend to break down over time, which often result in local individuals dismantling systems into parts for reuse or sale.[148] Unfortunately, trained electricians are scarce in rural areas of PNG due to low levels of capacity and low wages.

Relatedly, the success of mini-grids depends on having employees trained in billing and collections, financial accounting, and governance. Without trained employees working under a well-developed ownership model, mini-grids can quickly become financially unsustainable. For instance, tariffs must be set to ensure adequate revenues to maintain a financial reserve for acquiring replacement parts.

To increase skilled labor in communities with mini-grid development potential, GoPNG and municipal governments can subsidize training programs for locals in electrical systems and financial accounting. Moreover, the government can require that mini-grid developers have well-developed long-term plans before beginning construction for collecting sufficient tariffs to pay for wages and other maintenance activities.

Another challenge that mini-grid developers face is that distribution and transportation costs for getting equipment to the remote and rural mini-grid sites are high in PNG, which adds to the overall costs of constructing mini-grids. One-fifth of the population lives farther than one km from the main road (Figure 18). Across the value chain, in-country transportation costs increase the cost of goods by 20 percent.[149] Many places across the country are not accessible via road, which further complicates the installation, operation, and maintenance of systems in these locations. Additionally, equipment is often not standardized across PNG,[150] requiring the transport of parts across long distances in areas without regional distribution centers that carry standardized parts.

To address this challenge, GoPNG can improve road infrastructure and connectivity to help alleviate transportation cost issues. Moreover, incentives that GoPNG can provide for private sector investment—including reducing upfront costs and ensuring sufficient revenue flow—in solar mini-grid development and upkeep are key to ensuring their success. Solar mini-grids with battery storage have an advantage over solar-diesel systems in this context because regular delivery of fuel is not required. As such, economic analyses could be conducted to better understand the costs of developing solar-diesel versus solar-battery systems in different communities across PNG.

[148] Global Green Growth Institute, "Green Growth Potential Assessment of Papua New Guinea."

[149] International Finance Corporation, "Going the Distance: Off-Grid Lighting Market Dynamics in Papua New Guinea."

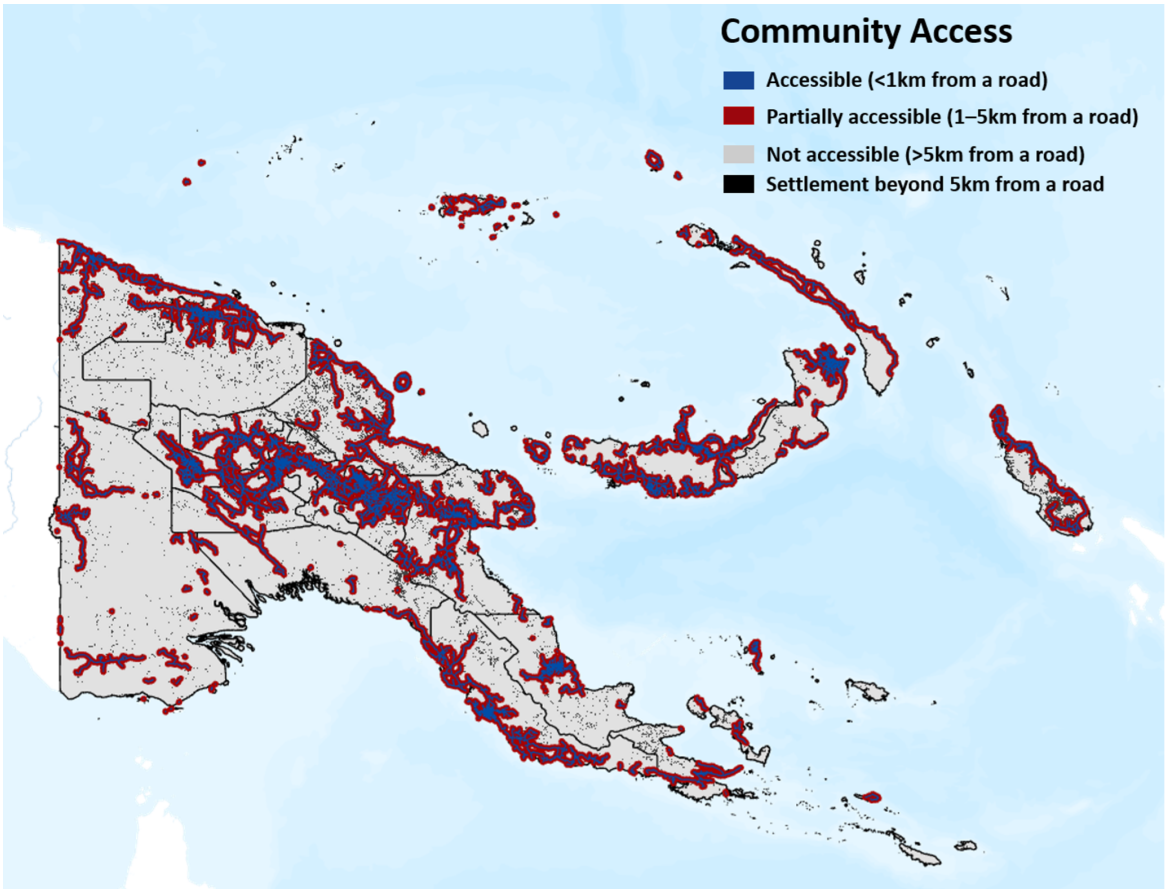
[150] Global Green Growth Institute, "Green Growth Potential Assessment of Papua New Guinea."

Site selection is another challenging but important aspect of mini-grid development because it can dictate the cost of building the system. In order for mini-grids to be affordable and successful, they must be located in areas with sufficient resource availability and electricity demand.

They must also be accessible at relatively low costs via well-developed road infrastructure. These requirements can be challenging in PNG because of the scarcity of existing data on resource availability and estimated demand and the high cost of traveling to remote communities for feasibility studies. Geospatial analyses such as the one conducted in this report help to identify locations with high-density communities and to estimate potential community electricity demand. By narrowing down candidate sites for further analysis, development costs for mini-grid developers can be reduced.

Interested stakeholders can look to USAID-PEP's Catalytic Energy Fund to enhance their understanding of potential challenges and solutions related to mini-grid development. The Catalytic Energy Fund will test and validate different business models, including innovative customer financing models, by providing capital for early-stage mini-grid deployments to give market participants data on willingness to pay, learnings from developing agreements with local communities, and a better understanding of financing gaps that might exist and subsidies that may be required to serve poorer, rural communities.

FIGURE 18. PNG COMMUNITY ACCESS TO EXISTING ROAD NETWORK



MINI-GRID REGULATIONS

PNG does not have well-developed mini-grid regulations, which has resulted in limited mini-grid deployment to date. However, GoPNG has recognized this gap and is developing an off-grid code with UNDP and the National Association of Regulatory Utility Commissioners (NARUC), supported by USAID. NARUC provided a series of trainings to ICCC on designing off-grid regulations from 2019-2020. As of June 2021, GoPNG and UNDP had sent the draft off-grid code to stakeholders for review. UNDP also initiated discussions with NEA, ran a workshop for NEA on the draft off-grid code guidelines, and made presentations on hydro and solar policy. UNDP expects to finalize the code so that NEA can convert the code into regulations before the end of 2021. Until UNDP and NEA complete these steps, developers face an uncertain environment, particularly for questions related to the economic viability of an investment (tariffs, exclusive rights to an area, and compensation if the grid encroaches on the service territory).

PPL Exclusive Zone. The Electricity Industry Policy (EIP) specifies that PPL has exclusive rights to retail electricity in areas where it currently supplies power and within ten km surrounding these network areas. The exception to this is for customers with greater than ten MW loads. This means that private mini-grid developers must develop them outside of this zone.

Licensing and Exclusivity. The EIP also requires tendering the power supply to rural areas to the private sector or PPL via a competitive process for capital subsidies. The NEROP includes a strong emphasis on private sector participation, and current regulations already allow private companies to establish new grids outside of PPL's exclusive area as long as ICCC grants them a license.[151] Authorities are discussing updating these licensing and exclusivity rights as part of new guidelines. The Minister of Energy will issue licenses for projects 10 MW and higher.[152] NEA will issue permits for projects less than 10 MW under a simplified process under the off-grid regulation, which bodes well for off-grid mini-grids.

Tariff Regulations. Currently, the tariff-setting process in PNG allows electricity providers to charge grid-specific tariffs under the EIP.[153] This benefits the sector. However, private developers face difficulties navigating this process for mini-grids, which has discouraged development. The proposed guidelines favor a method by which developers negotiate directly with communities to determine a fair tariff. However, this is still under negotiation, and there are questions about whether communities would have enough knowledge to negotiate a fair tariff. In 2021, GoPNG both passed the NEA Bill and repealed provisions under the EIA that empowered ICCC to carry out technical and economic regulations. These actions provided for the transfer of the economic and technical regulatory functions from both ICCC and PPL to NEA.

Technical Regulations. Prior to the NEA Bill, ICCC delegated technical regulations to PPL because ICCC did not have the technical regulatory expertise to perform this function. In 2011,

[151] The Earth Institute, Columbia University, "Preparation of National Electrification Rollout Plan and Financing Prospectus."

[152] This particular provision in the NEA Act has compromised the independence of the NEA. The plan is to amend this provision after the NEA Bill is certified.

[153] The Earth Institute, Columbia University, "Preparation of National Electrification Rollout Plan and Financing Prospectus."

as a result of the EIP, GoPNG established a Licensing and Regulation Division in the Energy Wing of DPE and transferred technical regulatory functions from PPL to the Energy Wing. However, GoPNG did not provide funding to fill the positions; therefore, these technical regulatory functions remained with PPL until the passing of the NEA Bill. With its creation, NEA is expected to play a key role as an independent party that will carry out technical regulatory roles as third-party retailers begin to enter the market.

ACTIVE MINI-GRID COMPANIES

Table 13 shows a list of companies involved in mini-grid development in PNG. These include companies that provide services for diesel and solar mini-grids as well as for other technologies. Because solar mini-grids are rare in PNG, companies that provide such services tend to rely on other lines of business for revenue. Companies that do operate solar mini-grids have generally been funded by an international donor or foundation.

TABLE 13. COMPANIES INVOLVED IN MINI-GRID DEVELOPMENT IN PNG

SERVICE	COMPANY	ENERGY SOURCE
Developer	PNG Biomass	Biomass
Developer*	Puma Energy	Diesel
Developer	Astra Solar	Solar
Developer	Solar Solutions	Solar
Engineering, Procurement, and Construction	Pacific Energy Consulting	-
Engineering, Procurement, and Construction	Certway Power Limited	-
Engineering, Procurement, and Construction	D.P. Engineering	-
Engineering, Procurement, and Construction	Christian Radio Missionary Fellowship (CRMF)	-
Engineering, Procurement, and Construction	Zenith Energy	-
Operation and Maintenance	Certway Power Limited	-
Operation and Maintenance	CRMF	-
Operation and Maintenance	Kiarivu Electrical Consulting Services	-

TABLE 13. COMPANIES INVOLVED IN MINI-GRID DEVELOPMENT IN PNG		
SERVICE	COMPANY	ENERGY SOURCE
Operation and Maintenance	Remco Engineering Ltd, Multi Electrical Services Ltd (MES)	-
Operation and Maintenance	Mortronix Technologies Ltd	-
Operation and Maintenance	Masip Engineering and Consultants Limited. (MEC)	-
Operation and Maintenance	Green Energy and Engineering	-

*The PNG Biomass project has gradually been decommissioned and provides little capacity to the grid to date, though it is still in operation.

SOLAR HOME SYSTEM MARKET

SHS have great potential in PNG for off-grid electrification in rural regions where there is low expected electricity demand due to the small size of a community, the lack of institutional demand in a community, or other reasons. In these settings, SHS are often the least-cost option for households because their total lifetime cost is lower than alternatives. Moreover, SHSs are easy for customers to install and operate and do not require trained on-site professionals.

IFC estimates the market for Tier 0 and Tier 1 off-grid lighting solutions to be $259 million per year over the next few years.[154] IFC projects that the year-over-year growth in demand for all OGS products (inclusive of Tier 0 and Tier 1 products) to be approximately seven percent. This includes demand from new customers and demand for upgrades from existing customers. Specifically for Tier 1 SHS, USAID-PEP estimates the market for SHS is $40 million per year. However, minimal information is available regarding the growth projections for Tier 1 products due to SHS's currently low market penetration.

A study estimated that Tier 1 SHS are four times cheaper than Tier 3 mini-grids on a per-kW basis.[155] In 2021, prices for QV Tier 1 (12–40 W) SHS in PNG ranged from $170 to $600 (610 kina to 2,100 kina) per unit in the main cities such as Port Moresby and Lae, depending on the size and features of the system and the appliances included with it.[156] Due to the high cost of transportation and logistics in PNG, these prices are higher in PNG than in sub-Saharan Africa. For instance, in SSA, the cost of Tier 1 4–25 W systems ranges from

[154] International Finance Corporation, "Going the Distance: Off-Grid Lighting Market Dynamics in Papua New Guinea."

[155] Global Green Growth Institute, "Green Growth Potential Assessment of Papua New Guinea."

[156] Based on price list from select distributors.

$100 to $250.[157] The high cost of Tier 1 SHS in PNG makes access to these systems out of reach for many households. The challenge of affordability and options for making SHS more affordable are discussed in the "Key Challenges and Potential Solutions for SHS" subsection of this document.

SOLAR HOME SYSTEM MARKET SIZE

Data collected by USAID-PEP from companies in PNG that sell QV products indicate that the market for Tier 1 and larger systems was approximately 50,000 from July 2020 to June 2021. Sales for all QV products (including all solar lanterns and solar home systems) were approximately 100,000 in that time. It should be noted that these numbers may not be exhaustive, and some bulk sales may be inflating this value compared to years past. Therefore, it is difficult to make projections using these sales numbers, but it does show that the PNG SHS market has reached a good size and hopefully further initiatives to promote affordability can increase the market size. The market size of generic products was not explored, but based on the IFC results from a few years ago, it is expected to be at least several times as large as the QV market (in terms of volume).

TABLE 14. SHS MARKET SIZE (JULY 2020 – 2021)

	SALES OVER A YEAR	APPROXIMATE MARKET PENETRATION FROM ONE YEAR OF SALES (ACROSS TOTAL POPULATION)[158]
Tier 1 and larger systems	50,000	2.8%

SOLAR HOME SYSTEM VALUE CHAIN

In PNG, sales for OGS products are almost exclusively on a cash basis with limited options for purchasing by credit. This is unlike many other countries where pay-as-you-go (PAYGO) or microfinance have provided options for customers to pay for systems in installments. Limited financing options combined with a low ability to pay in rural areas means that the sector is dominated by cheaper products (primarily Tier 0 lighting products) that are affordable on a cash basis for price-sensitive customers. This has created two distinct segments of the market that behave differently. QV products generally follow one procurement pathway and "generic" products that have no such testing and certification and are of varying quality follow another. Generic products have created quality concerns in the market generally, but their lower cost means that they continue to dominate the market. Generic products are estimated to have 82.5 percent of the market share.[159]

[157] International Renewable Energy Agency, "Pay-As-You-Go Models: Innovation Landscape Brief."

[158] Assumes 1,798,563 households from NEROP report.

[159] International Finance Corporation, "Going the Distance: Off-Grid Lighting Market Dynamics in Papua New Guinea."

The paths that these different products take end up having significant cost implications for QV products.[160] In general terms, generic products are more often bundled with other types of products during importation or further steps along the value chain. Taking advantage of this bundling also gives these products a price advantage compared to products that are shipped alone. The value chains of QV versus generic OGS products in PNG are discussed in the following sections as per the steps in Figure 19: manufacturing and assembly, sales and distribution, after-sales support, and end-of-life disposal.

FIGURE 19. SHS VALUE CHAIN STEPS

Manufacturing and Import

Most QV and generic OGS products sold in Papua New Guinea are manufactured in and imported from China. QV products are shipped primarily from Guangzhou or Shenzhen, while little is known about the ports of origin for generic products. The main ports of entry in PNG are Port Moresby and Lae. Even though Port Moresby has minimal road connectivity to the rest of the country, it is a primary port of entry for OGS products for various reasons. First, many importers and distributors are based in Port Moresby because the area itself has a large demand for OGS products. Second, the city is home to many bulk-purchase customers, such as the government, international NGOs, and other organizations. Lae, on the other hand, is the largest port in PNG. As such, it is better connected by road to the rest of the country and by marine routes to the other islands. OGS products have been increasingly shipped directly to Lae in recent years to reach the broader PNG market.

As previously mentioned, international shipping costs are particularly high in PNG. This is partly because the country has so few export goods, so cargo ships often return from PNG less than half-filled.[161] To get around this, importers of non-QV products often import their products in mixed containers that include a variety of other fast-moving goods. Meanwhile, importers of QV OGS products often wait until they have enough purchase orders to fill an entire shipping container. Unfortunately, this can take up to a few months, causing business to be lost to faster, generic product competitors. International transportation costs from China to PNG are estimated to increase the cost of OGS products by 15 to 20 percent.[162]

[160] It should be noted that there are non-QV products that are generally considered to be good quality and are distributed in a similar manner to QV products.

[161] International Finance Corporation, "Going the Distance: Off-Grid Lighting Market Dynamics in Papua New Guinea."

[162] International Finance Corporation.

Distribution and Sales

In addition to high international shipping costs, transportation and logistics costs within PNG are also expensive. Road transportation from Lae to other parts of the country adds an estimated 20 percent to the cost of both QV and generic OGS products.[163] Due to these logistical difficulties, most OGS products in PNG are sold in larger urban or provincial centers and directly in stores by retailers. Further, there is sufficient unmet demand in many of these peri-urban areas, so companies have little reason to sell products in the rural areas beyond them. QV products are rarely sold in district centers and small towns. At least 20 PNG businesses currently import and distribute QV OGS products, and the major ones are listed in Table 15. On the other hand, rural customers tend to rely on generic products sold in lot shops (i.e., local store owned by community members) in nearby towns because of the lack of available QV products.

After-Sales Support

QV product manufacturers provide a warranty for all of their products, but according to the IFC, warranties are not always passed on to customers in PNG.[164] As a result, QV products are rarely if ever returned to manufacturers for repair or replacement. Meanwhile, generic products do not generally come with warranties.

Overall, QV products were found to require half the number of repairs as generic products, so the useful lifetime of QV products is much longer.[165] Local electricians are often able to replace parts of generic products with reusable components from different products, but QV products are often designed to be replaced rather than repaired.

End-of-Life Disposal

Currently in PNG, there are no recycling options for solar PV modules and batteries.

ACTIVE OFF-GRID SOLAR COMPANIES

Table 15 shows manufacturers and distributors of QV OGS products in PNG. Green Light Planet, OvSolar, Orb Energy, Barefoot, Omnivoltaic Energy Solutions, d.light, and Niwa Solar are some of the popular brands that are aggressively pushing their products into new markets. The number of generic OGS products is not known.

[163] International Finance Corporation.

[164] International Finance Corporation.

[165] International Finance Corporation.

TABLE 15. SELECT MANUFACTURERS AND DISTRIBUTORS OF OGS PRODUCTS IN PNG	
INTERNATIONAL MANUFACTURERS THAT SELL IN PNG	
BRAND	**PRODUCTS**
Barefoot Power	Solar fans, solar laptop chargers, solar radios, solar lanterns, solar lights with Universal Serial Bus (USB) chargers, solar phone chargers, solar plug-and-play hubs, solar refrigerator
d.light	Solar fans, solar lanterns, solar lights with phone charger and radio, solar lights with phone charger and television
Greenlight Planet (Sun King Solar)	Solar lanterns, solar lanterns with phone chargers, solar lanterns with radios, solar lighting and plug-and-play hubs, solar lights with radio and television bundles
Niwa	Solar lanterns, solar lights with phone chargers, solar computers, solar televisions with fans and lights and phone charger bundles
Omnivoltaic	Solar panels only, solar fans, solar lanterns, solar lights, solar radio, solar refrigerators, solar televisions, solar televisions, solar lights with television bundles
Orb Energy	Solar water heaters, solar grid-connected systems with net metering, solar plug-and-play hubs
ovSolar	Solar lanterns, solar lanterns with phone charger, solar lights with television bundle
DISTRIBUTORS OF OGS PRODUCTS IN PNG	
COMPANY	**SALES POINTS**
Badili Hardware	Port Moresby
BNBM	Multiple locations across the country
Brian Bell Group	Port Moresby, Lae, Mt. Hagen, Kokopo, Kimbe
Chemica	Multiple locations across the country
Cool Stuff	Port Moresby (Vision City, Water Front), Lae (Andersons Eriku), Madang (Andersons Madang)
Fair Price (Courts)	Port Moresby and Lae
Hardware Haus (CPL Group) / Stop & Shop / City Pharmacy	Multiple locations across the country

TABLE 15. SELECT MANUFACTURERS AND DISTRIBUTORS OF OGS PRODUCTS IN PNG	
DISTRIBUTORS OF OGS PRODUCTS IN PNG	
Jedjay Limited	Multiple locations across the country through last-mile sellers; Islands Region and other mid-mile markets
NGF	Port Moresby , Lae
Nuigini Electrical Co. Ltd	Lae and Madang
OmniVoltaic	New Ireland Province as a base and distributes throughout NGI region - East, West New Britain, re-sellers also come from Buka and Manus
Origin Energy	Multiple locations across the country through retailers
OvSolar	Kavieng; other locations through NGF and Bisi Trading, including NGF Lae
Sola Paygo	Enga, WHP, Jiwaka, Simbu, EHP, Mendi, Port Moresby, Kimbe, Kokopo, Rabaul
Solar Solutions PNG	Port Moresby (sales and information center), Lae Distribution center (McDui Street)
Solar Tech Global	Port Moresby
Tininga Hardware	Mount Hagen
Titan Distributors	Lae

KEY CHALLENGES AND POTENTIAL SOLUTIONS FOR SHS

The residential solar systems (i.e., SHS) market has grown substantially in PNG over the past few years due to reductions in prices and increased availability, as well as efforts by the IFC's Lighting PNG program to increase SHS use. However, in many respects, the market remains nascent and faces challenges to its continued development. Small, cheap, and generic products (primarily lanterns) have largely driven the impressive 60-percent penetration. This demonstrates the demand for off-grid solar products in the market; however, energy sector stakeholders must overcome several fundamental challenges to achieve higher levels of service. These challenges include both supply- and demand-side issues.

Supply-Side Challenges

On the supply side, the SHS market faces many of the same issues faced by the broader electric sector, as described in the Challenges for Electrification in PNG subsection. These include issues of access to foreign exchange, which make it difficult for distributors to purchase products from international suppliers, and limited working capital to sustain constant product flow. Through developing fiscal and monetary policies that increase access

to foreign exchange as well as facilitating access to finance for companies, the government can address these supply-side challenges that the SHS market faces.

The cost of transportation to the end-consumer provides another supply-side challenge. High transport costs from the country of manufacture (predominantly China) as well as high in-country transport costs can disincentivize distributors and retailers from reaching last-mile customers. In fact, PNG's in-country transport costs are generally well above the rates in other countries, with local shipment costs being almost the same as the international shipping cost for a full container load (FCL). For instance, a 40-foot FCL from China costs an estimated 15,750 kina. Transportation from Lae to the Highlands and/or Hagen Regions is approximately 22,000 kina, and to Mendi/Wabag is approximately 24,500 kina. As most last-mile customers are unable to bear the additional costs associated with last-mile transport, distributors and retailers do not have any incentive to reach these customers. Unlike some countries where agents for off-grid companies are the main sales points and are often close by, distribution channels in PNG are much less likely to venture out to villages. This means that consumers often buy products while visiting larger towns, or friends or relatives bring them to villages. A person in a village with no means to travel may struggle to find off-grid products, particularly QV ones. To help reach last-mile customers, the government can provide incentives for SHS distributors and retailers that decrease overall costs.

Demand-Side Challenges

The SHS market faces various challenges on the demand side as well. The first is the issue of affordability. While prices have come down significantly, consumers have limited financing options in what they can afford to buy upfront. Many consumers are only able to afford the most basic and often poor-quality products. The Consumer Financing section explains these financing issues in more detail. Targeted subsidies can make off-grid products more affordable for low-income households. For instance, municipal governments could provide targeted subsidies for households below a certain income or asset ownership threshold to help with the purchase of SHS. Such a program would make SHS ownership more attainable for the poorest households. Meanwhile, SHS companies could employ financing schemes, such as the "lease-to-own" model, to reduce the upfront costs of purchasing a SHS for consumers.

The reliability or longevity of systems also presents a challenge. The market is flooded with low-cost, generally low-quality products, which may not even last six months or a year and may harm consumer confidence. For OGS systems, in general, only 17.5 percent of products are QV.[166] Generic products tend to have lower satisfaction rates than QV products, which can lead to lower confidence overall in SHS products and "spoil" the market. People may also think that all off-grid products are low-quality with short lifespans, as compared to traditional sources of lighting, such as dry cell batteries, candles, and kerosene. People with these perceptions will be less likely to buy additional off-grid solar products, let alone more expensive ones.

To address this challenge, GoPNG could impose stricter regulations on the importation and sale of non-QV products. Tax incentives to help QV products reach more customers and

[166] International Finance Corporation, "Going the Distance: Off-Grid Lighting Market Dynamics in Papua New Guinea."

targeted subsidies to decrease costs of QV products could also help increase the share of QV products being sold.

CONSUMER PAYMENT FOR SHS

The majority of people in PNG (approximately 80 percent of the population) are unbanked and thus depend primarily on cash, mobile money, and remittance networks for financing large purchases.

Mobile banking is gaining traction in the market, making banking services accessible even in remote areas. Energy sector stakeholders must advocate for greater efforts for financial inclusion and financial literacy to encourage more people to improve their access to finance. Aside from commercial banks, PNG also has savings and loan societies and licensed financial institutions, including microfinance institutions, money remitters, money changers, and foreign exchange dealers.

FIGURE 20. TYPES OF POTENTIAL PAYMENT SOURCES FOR SHS

Financial Institution. In PNG, the central bank, the Bank of PNG, regulates the banking sector. Four commercial banks operate in the country, predominantly the locally owned Bank of South Pacific. Other players include Australian-owned Australia and New Zealand Banking Group (ANZ), Westpac and the locally owned Kina Bank. While retail banking has considerably propagated its presence in PNG over the past years, there is still a great deal of opportunity for this sector to grow. For instance, for rural residents, conventional banking services remain difficult to access, as major banks still do not have a significant number of brick-and-mortar locations in rural areas. With 80 percent of the country unbanked, women and rural residents are especially excluded. Even as these banks grow and open more locations, the majority of rural Papua New Guineans are not engaged in business, and their incomes generally cover their own subsistence with little left over for savings. Rural banks generally provide cash services, while other financial services, such as loans, are inaccessible to the average person. This is because the average net income in rural areas is low. There are at least five micro-finance institutions (MFIs) active in PNG.[167] In other markets across the world, MFIs have been important partners to scale up off-grid products by providing affordable payments for SHS and other products. In PNG, this model also holds promise but has not had success thus far. The MFIs' noninvolvement until now may be due to their insufficient understanding of off-grid products and high interest rates.

[167] Bank of Papua New Guinea, "List of Licensed Banks and Financial Institutions."

Cash. Cash sales make up between 80–90 percent of off-grid solar energy system sales in PNG, primarily due to the lack of other options.[168,169] However, interviews have indicated that people in PNG complain about the need to travel to and from banks and post offices in urban centers to take out cash.[170] In rural areas, villagers rarely spend money except to pay for large expenditures, such as school fees, social obligations, and clothing.[171] For other goods, it is common for villagers to travel to larger communities with more formalized vendors.

Digital Money. The challenging nature of the banking system in PNG for consumers presents unique opportunities for the introduction and growth of mobile money systems. Digicel is the largest telecommunications provider in the country and has invested heavily in the development of a mobile money system known as CellMoni. Digicel has had success in developing a user base for CellMoni in urban areas, such as Port Moresby and Lae, which have formalized marketplaces. Digicel has already begun to implement electricity bill payments. However, there continue to be some challenges for the widespread adoption of mobile money in rural areas. First, many rural villagers have low demand for money because there is little to buy. Second, large parts of the country lack reliable mobile connections, which makes the use of digital money difficult. Third, there is a scarcity of mobile money agents who can provide enrollment and support for CellMoni in rural areas. Digicel has been addressing this issue by working with shop vendors as sub-distributors who provide Digicel/CellMoni management services alongside their other goods and services. By opening CellMoni kiosks as "stores in stores," Digicel has found a way of minimizing its own cost of expanding its number of registered agents by using existing rural vendors to market and manage their own financial services.[172]

As Digicel continues to expand its network of registered mobile money agents in rural areas, the large number of financial services that were previously unavailable are now increasingly available. While mobile money is still in the nascent stages in PNG, mass adoption of mobile money systems could catalyze growth across all rural livelihoods. Mobile money offers formalized personal accounting, the facilitation of transactions through increased volume and money velocity, and the ability to set up recurring payments for bills and financing.

Pay-As-You-Go. Mobile PAYGO business models give consumers access to electricity systems they might not otherwise be able to afford by allowing them to pay for products using a variety of payment mechanisms (such as mobile money transfer, scratch cards, and cash payments), ownership arrangements, and financing options. PAYGO is beneficial for both service providers and customers of off-grid renewables because it allows customers to pay for equipment and electricity consumption in small installments while allowing providers remote access to deactivate systems if payments are overdue. Currently, Sola Paygo is the only company in PNG that utilizes the PAYGO business model. PAYGO faces various challenges in PNG. For example, mobile money, which is necessary for PAYGO to succeed, is at a nascent market stage in PNG. Moreover, companies that utilize PAYGO often require external funding

[168] International Finance Corporation, "Going the Distance: Off-Grid Lighting Market Dynamics in Papua New Guinea."

[169] GOGLA, "Global Off-Grid Solar Market Report: Semi-Annual Sales and Impact Data, July-December 2020."

[170] Tillman Bruett and Janine Firpo, "Building a Mobile Money Distribution Network in Papua New Guinea."

[171] Tillman Bruett and Janine Firpo.

[172] Tillman Bruett and Janine Firpo.

due to the greater capital requirements necessary for establishing this business model, which can be difficult due to low private investment levels in PNG.[173] PAYGO can require complex systems and a network of resources to ensure risk is mitigated on both the distributor and consumer side. As such, there must be adequate capacity for the industry to grow.

Remittance Network. Wage-earners in the formal employment sector are the primary users of the remittance network in PNG.[174] These employees are often rural residents who have migrated to urban areas in search of employment. They send part or all of the income they earn home through trusted family members or the post office money transfer service.[175] Remittances can come in the form of cash or gifts of food, clothing, and electronics, such as OGS products. According to estimates, the majority of households in PNG receive some form of remittances from family members.[176]

TABLE 16. FINANCIAL INSTITUTIONS REGISTERED WITH CBL

INSTITUTION	DEFINITION	NUMBER
Commercial banks	Large banks providing traditional banking services to individual consumers and corporations	9
Rural community financial institutions (RCFIs)	Community-owned entities providing savings, checking, loans, direct deposits, money-transfer services, and payments of government salaries to consumers	12
Microfinance Institutions (deposit-taking)	Institutions providing small loans and savings accounts, mainly to traders and small businesses	1
Microfinance Institutions (non-deposit-taking)	Institutions providing small loans and not savings accounts	<5
Credit unions	Member-based institutions providing savings and credit extensions to rural areas	275
Informal village saving and loan associations	Saving clubs or groups that are not formally attached to the financial sector	1,450
Mobile money operators (MMOs)	Entities that provide payment services through mobile money accounts	2
Insurance companies	Companies that provide crop or health insurance	19

[173] Global Green Growth Institute, "Green Growth Potential Assessment of Papua New Guinea."

[174] International Finance Corporation, "Going the Distance: Off-Grid Lighting Market Dynamics in Papua New Guinea."

[175] Tillman Bruett and Janine Firpo, "Building a Mobile Money Distribution Network in Papua New Guinea."

[176] Tillman Bruett and Janine Firpo.

Productive Use of Energy

Productive Use of Energy

PUE products offer a variety of off-grid solutions to address electrification and business profitability by providing energy—both electric and non-electric (in the forms of heat or mechanical energy)—for activities that increase income and livelihoods of local business owners. In rural contexts, PUE activities commonly relate to the sectors of agriculture, enterprise, health, and education.[177]

PUE can have different definitions and sometimes is restricted to products that in some way contribute to income-generating activities. In this report, we use a broad definition that includes enhancing income generation and improving productivity—including health and education.

Renewable energy PUE systems have the potential to improve the economic development and livelihoods of PNG's off-grid communities by increasing agricultural productivity, improving food security, extending productive hours, and providing quality health services. Solar-powered systems for off-grid health centers and clinics provide better quality health services, extend the hours of operation, and increase the reliability of power throughout the day. In off-grid areas, healthcare facilities cannot address all community needs. There is excellent potential for Papua New Guineans to improve their livelihoods using agricultural PUE products.

Examples of Solar-Powered PUE Products

- Lanterns and Lighting Systems
- Water Pumps and Sprayers
- Processing Mills, Graters, Crushers
- Food Dryers, and Egg Incubators
- Refrigerators, Freezers
- Cooling Fans
- Mobile Phone Chargers

Currently, in PNG, there are no specific norms or guidelines in place for PUE in the off-grid sector. NEA, which is in charge of developing guidelines and regulations for the on-grid and off-grid markets, currently aims to release an on-grid code and guidelines. However, there is little information about guidelines for off-grid generation and its associated services. GoPNG's publication of official guidelines will assist the private sector and other interested investors to focus their efforts and investments. Also, access to funding, grants, and subsidies will be better targeted to making off-grid power and PUE products cheaper for everyone who uses them.

[177] Kapadia, "Productive Uses of Renewable Energy A Review of Four Bank-GEF Projects."

AGRICULTURAL AND FISHING SECTORS

AGRICULTURE

Agriculture is the backbone of PNG's economy, providing livelihoods for 80 percent of people living outside of urban centers.178

While commercial farms help provide food and other resources to communities in urban centers, the livelihoods of many rural families relies heavily on subsistence agriculture, livestock, fisheries, and forestry. Subsistence food production is the source of 83 percent of food energy and 76 percent of protein in PNG.[179]

Agriculture also accounts for 18.4 percent of Papua New Guinea's overall GDP. Sweet potato, coffee, cocoa, copra, palm oil, rice, and vanilla are some of the country's primary products. However, crop spoilage due to insufficient infrastructure and processing facilities has affected and continues to affect farmers' livelihoods. The agriculture and fishing sector share a close relationship and similar challenges. Poor rural households living in coastal areas are dependent on fishing and farming for their subsistence and livelihoods. However, climate change impacts, such as increased temperatures are leading to droughts that effectively reduce crop production, while the warming of the oceans is reducing the abundance of fish and catch potential. Meanwhile, economic factors such as underdeveloped infrastructure, inadequate distribution capabilities, limited equipment, and access to capital erode fishers' and farmers' abilities to enhance their incomes and overcome poverty.

PNG imports large amounts of rice, wheat, tomatoes, onions, and other products for everyday use, and GoPNG is attempting to improve local production through several pilot programs across the country. The majority of the rural population in PNG (60–85 percent) consumes sweet potatoes and other locally cultivated and accessible staple foods, fruits, and vegetables. By improving utilization of PNG's underutilized natural resources, such as water and land, GoPNG is aiming to increase the domestic production of crops, such as rice, thereby lowering PNG's import bill.

PNG has built an export market for palm oil, coffee, cocoa, and copra, but it has not been able to do so for other agricultural products. The government has recently expressed interest in diversifying the country's agricultural exports to become the "food basket of Asia."

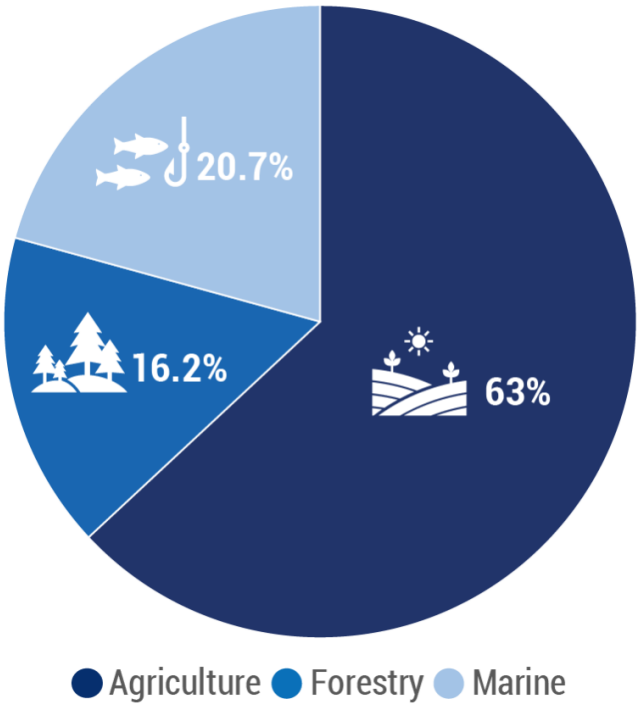
MARINE FISHING

Marine fishing is a significant but underdeveloped industry in PNG. Fishing contributes to only 20 percent of PNG's exports in the agriculture, forestry, and marine sector. Though the fishing industry has developed rapidly in recent years, PNG cannot yet capitalize on the full value of its exports, as it is unable to process a significant amount of them in the country.

178 The World Bank, "Reinforcing Resilience."

179 FAO, "Family Farming Knowledge Platform." Papua New Guinea. November 3, 2021.

FIGURE 21. DISTRIBUTION OF PAPUA NEW GUINEA'S AGRICULTURE, FORESTRY, AND MARINE EXPORTS, 2017[180]



Because of insubstantial infrastructure and incentives, large-scale fishing is not common in PNG. However, the small-scale fishing industry is a significant revenue generator for individuals.

Tuna fishing accounts for a large proportion of PNG's exports and is a significant source of exports in the Pacific region. However, PNG nationals' fishing is on a modest scale due to a limited amount of cold storage and processing facilities throughout the country. For example, Lae suffers from an unstable grid connection; this has led some companies to procure diesel generators to ensure reliable electricity supply.

A handful of marine processing companies have formed a joint venture with other foreign companies and are operating in PNG as a result of international aid and various initiatives by government-supported development programs. However, these companies have not expanded their investments due to frequent power outages, congestion at ports, land constraints, and other regulatory problems.

Table 17 lists some of the major marine processing companies operating in PNG.

[180] Bank of Papua New Guinea, "QEB Statistical Tables."

TABLE 17. MARINE PROCESSING COMPANIES AND DETAILS			
S.NO	MARINE PROCESSING COMPANY	LOCATION	DETAILS
1	Majestic Seafood	Lae	Joint venture between Frabelle Fishing Corporation, Century Canning Corporation (Philippines), and Thailand's Union Frozen Products
2	International Food Corporation	Lae	Malaysian company
3	Zhoushan Zhenyang		Chinese company
4	RD Tuna	Madang	Owned and run by the Philippines-based RD Group
5	Hailisheng Group	Lae	Chinese company
6	Nambawan Seafood Tuna	Lae	Joint venture between Filipino and Taiwanese firms

Key Challenges and Opportunities

A key issue in the market is that the majority of the cultivated crops and caught fish are located far from demand centers. Transporting these crops and fish requires suitable storage, processing, and transportation infrastructure, all of which are lacking in PNG. Currently, this issue has led to product spoilages and a loss of revenue. In addition, because the road and transportation infrastructure between rural areas and urban demand centers is underdeveloped, the cost of the final product ends up being higher due to the high cost of transportation.

Agricultural and Fishing Sector Challenges

- Limited transportation facilities
- Higher cost of the agricultural and fishing outputs due to aging or absent infrastructure
- Lack of farming or fishing equipment
- Limited availability of cold storage and processing equipment
- Droughts
- Limited access to credit and capital for finance options

Unavailable financing options are another barrier to agricultural and fishing sector development. Only 13 percent of the population has access to a bank, which makes getting a loan nearly impossible for a farmer. Without access to finance, farmers and fishers are unable to invest in equipment to increase their output or diversify their activities.

Other major challenges include social issues with agricultural production on clan-owned land and climate change impacts, resulting in food insecurity. Rainfall patterns have changed in recent years. Droughts have become more common, causing crop damage and food shortages.

PUE products can offer solutions to some of these livelihood and productivity challenges, as they have proven effective in sub-Saharan Africa in increasing food security through agro-processing, cold storage systems, farm equipment, and irrigation.

PUBLIC BUILDINGS

Public buildings for institutions like healthcare, public assembly, and schools stand to benefit significantly from PUE technologies as well. Major areas of energy consumption in these buildings come from lighting, heating/ventilation, and major appliances. In each instance, there are opportunities both for improving the performance of system components and the way they are controlled as a part of integrated building systems. Energy use in public buildings depends on a combination of sound architecture, a clear understanding of energy systems design, and effective operations and maintenance.

Water heaters and cold-storage solutions are responsible for up to approximately 20 percent of a building's energy use. Many of the PUE technologies designed to improve whole building energy performance can also increase the efficiency of these appliances. Improved insulation and other strategies can reduce energy losses from hot water distribution systems in public buildings. Water heaters with storage tanks have load-shifting capabilities and can provide other services important for optimizing the electricity usage of a mini-grid. Over the past several years, significant improvements and use cases have been made in cold storage technologies in places like sub-Saharan Africa and the Philippines. An increasing number of agricultural processing centers and households have realized gains by using cold storage devices and freezers. In the PNG context, these technologies can significantly improve operations of public buildings and provide reliable revenue power sources that improve local livelihoods.

HEALTH SECTOR

The need to consider linkages between energy and healthcare has gained urgency during the COVID-19 pandemic, whose immense challenges healthcare facilities can mitigate with PUE products. The health sector stands to gain considerably from the broader deployment of PUE—specifically, cold storage solutions for rural areas that are critical to healthcare services for storing medicines, blood, and vaccines. Remote healthcare clinics can further benefit from a combination of solar PV and battery storage as viable solutions for providing reliable off-grid power and addressing cold storage needs.

The adoption of solar and PUE products in PNG is still at an early stage, as the population has generally low awareness about how off-grid renewable energy can support PUE.[181]

[181] International Finance Corporation, "Going the Distance: Off-Grid Lighting Market Dynamics in Papua New Guinea."

EXISTING PUE MARKET

Various off-grid companies, wholesalers, distributors, retailers, and resellers have started focusing on solar products only in recent years. While the market has many players, many of them operate only in a limited capacity due to various challenges and regulations in the market.

PRODUCTIVE USE OF ENERGY PRODUCTS CURRENTLY AVAILABLE

The current PUE market in PNG is comprised primarily of end-users involved in government initiatives through the agricultural and health sectors. The National Department of Health uses solar-powered refrigerators for storing vaccines and medicines and blood-bank refrigerators in rural areas where electricity is not available. The Department of Agriculture and Livestock procures solar dryers for fruits and vegetables. Many of PNG's major up-and-coming PUE end-users seek PUE products for agricultural activities.

There are no manufacturers of PUE products in the PNG market due to the high cost of manufacturing, the small market, foreign exchange issues, and the lack of local supply chains for manufacturing. Moreover, the number of distributors and resellers is limited due to inaccessible and unavailable financing options.

The proliferation of PUE products in PNG is poised to grow alongside that of other available solar products. Though historical data in the PUE sector is sparse, the most commonly sold solar products in the country are SHS, solar lanterns, and torch lights (flashlights). Companies have not yet tested other products outside of SHS in the country with the PAYGO business model; PUE products could follow a similar business model in this regard.

The Brian Bell Group, one of PNG's leading distributors of solar products, has reported significant demand for solar sewing machines, refrigerators, and freezers. To date, this demand reportedly has stemmed from small business owners like farmers, fishers, and textile vendors. Some companies are starting to sell solar water pumps (e.g., Hardware Haus, Brian Bell) for agriculture and solar poultry incubators (e.g., Brian Bell). Meanwhile, the company Agsol is supplying solar-powered rice mills and processing equipment to farmers. While financing options for these systems has been limited to mostly cash purchases, some companies like Agsol provide after-sales support to increase customer confidence. Further, select OEMs that have presence in international markets offer warranties on their PUE products, typically lasting two to three years. Because the market is still nascent, companies currently in PNG are uniquely positioned to market and sell products based on immediate demand and market-driven needs.

BUSINESS MODELS FOR END-USER FINANCE

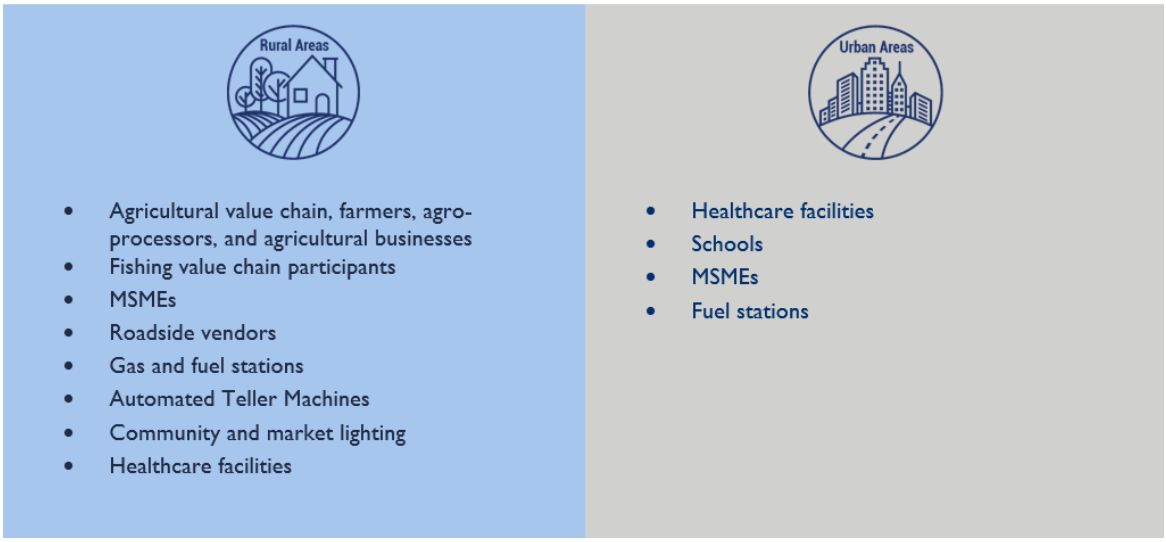
Apart from nonprofit organizations and government entities that offer these products to individuals to empower them, retailers offer some PUE technologies over the counter. Activities related to de-risking commercial investment and results-based financing (RBF) designs aim to incentivize companies to enter unconventional and challenging markets and promote commercial investment.

PAYGO is a notable financing model in some sub-Saharan countries that enables energy service providers or retailers to sell PUE technology to end-users in exchange for amortized payments over several installments.[182] In some cases, providers collect payments as end-users reach specific production yields and revenue targets. Though this model is still in its early stages in PNG, it has improved production targets for small-holder farmers and spurred other innovative business models and encouraged community ownership of PUE technology systems.

PUE BUSINESS OPPORTUNITIES

Figure 22 shows the target customers of PUE products. Key customer segments include crop farmers, fishers, poultry farmers, and healthcare workers.

FIGURE 22. TARGET CUSTOMERS OF PUE PRODUCTS



POTENTIAL PUE TECHNOLOGIES IN PNG

Solar Water Pumps. Communities across the globe have increasingly adopted solar water pump technology, which has encouraged cleaner, more sustainable access to water in locations with unreliable or unavailable access to electricity. Only 40 percent of the PNG population currently has access to clean drinking water.[183] Solar water pump systems generally consist of a submersible or surface pump, solar modules, and a controller. Submersible pumps generally draw water from bore wells, while surface water pumps draw water from nearby rivers, lakes, and ponds. A limited number of farmer communities and clans in PNG have adopted this solution.

Solar Food Dryers. Solar dryers remove moisture to increase the shelf life of crops, such as cocoa, coffee, tomatoes, bananas, and beans. These dried foods, which farmers can process, transform, and sell in various forms, such as flakes, powders, and slices, have immense demand across the world, promote food security, and help reduce food waste. Solar food dryers provide a way for farmers to bring in additional revenue.

[182] IRENA, "Innovation landscape brief: Pay-as-you-go models."

[183] The World Bank, "Papua New Guinea."

Solar Kiosks. Many countries in Southeast Asia and Africa have solar kiosks, as they have become popular for a variety of services, such as cool drinks, mobile phone charging, and battery charging for flashlights. While no company in PNG has yet piloted solar kiosks, companies in several African countries have successfully demonstrated their viability as sustainable business opportunities that support community development. Generally, for charging a mobile phone, a villager in PNG must travel to a town or urban area. For operators of solar kiosks, the service of fully charging one mobile phone generally costs one kina, while a cold drink costs two kina. A single kiosk has the potential to charge more than ten mobile phones per day and sell at least 30 cool drinks, which provides additional income to system owners.

Solar Cold Storage Containers and Ice Makers. In off-grid areas, demand is high for solar-powered cooling systems and containers to preserve and increase the shelf life of vegetables, fruits, and fish. Farmers and fishers generally cultivate and catch most agricultural and fish products far from demand centers and, therefore, benefit from solar containers near both harvest sites and market areas. Shipping also requires cold-chain facilities to prevent goods from spoiling quickly. Solar containers often come in ten-, 20-, and 40-foot sizes to suit the needs of a given supply chain. While installing a single container may be a costly investment, it can have a notable positive impact on the livelihoods of farmers and the economy of a community at large.

Solar Livestock and Poultry Incubators. Across PNG, off-grid poultry farmers can only sell eggs from their farms to customers and large corporations on a limited scale due to the undersupply of electricity and the high cost of raising chicks. Solar-powered poultry hatchers support off-grid farmers to increase their incomes by facilitating egg hatching, incubation, and production. A smaller incubator has a hatching capacity of about 40 eggs, so a farmer can sell 20 chicks in each lot for a profit of three kina per chick and retain 20 chicks to raise as hens.

VIABILITY OF SELECTED PUE PRODUCTS

Palm oil is one of PNG's most profitable crops, and its development has created jobs and other societal benefits. Through special agricultural and business licenses (SABLs), developers acquire land and receive funds to develop palm oil plantations. Though there have been questions on whether most developers are clearing forests with no intention of cultivating palm oil, it remains one of the most sought-after products in the country. Key parts of the harvesting phase are often done manually and can add weeks to the timeline of harvesting the plant to producing oil; this creates a business case for efficient automation PUE technologies. Table 18 estimates the approximate efficiency and revenue gains from utilizing a solar irrigation system.

TABLE 18. INPUTS AND VIABILITY CALCULATION FOR A SOLAR IRRIGATION SYSTEM FOR PALM OIL IN PNG[184]

PRICE OF PALM OIL[A]	AVERAGE YIELD IN PNG FOR PALM OIL (MT/HA PER YEAR)	EXPECTED INCREASE IN PRODUCTION[B]	REVENUE FOR 0.4 HA (1 ACRE) OVER ONE YEAR WITHOUT IRRIGATION[C]	REVENUE FOR 0.4 HA (1 ACRE) OVER ONE YEAR WITH IRRIGATION[D]	INCREASE IN REVENUE FROM IRRIGATION OVER ONE YEAR
3.5 PGK/kg	4.6	52%	6,440 PGK	9,789 PGK	3,349 PGK

[a] Average of 3-4 PGK/kg

[b] Calculated based on labor efficiency gains (included in reference materials)

[c] Assumes two live planting seasons based on average yield (standard for palm)

[d] Assumes planting seasons with increased production gains from leveraging PUE system

Coffee is also an important export for PNG with high return markets in 2020 including Spain, United Kingdom, Jordan, South Africa, and Sweden. Decreasing processing timelines for both caffeinated and decaffeinated coffee presents a strong business case to implement PUE technologies. Drying coffee beans can take 24–72 hours when done manually, but these times are slashed significantly when leveraging solar drying technology. Table 19 estimates the efficiency and revenue gains from implementing solar drying technologies to coffee production.

TABLE 19. INPUTS AND VIABILITY CALCULATION FOR A SOLAR FOOD DRYER FOR COFFEE IN PNG[185,186]

PRICE OF COFFEE[A]	AVERAGE YIELD IN PNG FOR COCOA (MT/HA PER YEAR)	EXPECTED INCREASE IN PRODUCTION[B]	REVENUE FOR 0.4 HA (1 ACRE) OVER ONE YEAR WITHOUT DRYING[C]	REVENUE FOR 0.4 HA (1 ACRE) OVER ONE YEAR WITH DRYING[D]	INCREASE IN REVENUE FROM IRRIGATION OVER ONE YEAR
11.5 PGK/kg	19.8	61%	91,080 PGK	146,639 PGK	55,559 PGK

[a] Average of 10.5 – 12.5 PGK/kg for both arabica and robusta coffee,

[b] Calculated based on labor efficiency gains (included in reference)

[c] Assumes two live planting seasons based on average yield (standard for coffee growers)

[d] Assumes planting seasons with increased production gains from technology implementation from PUE system

[184] Note: These calculations are provided as indicative estimates of viability based on publicly available information. Revenue increases and payback period can vary based on individual circumstances. The calculations demonstrate the usefulness of these products to the PNG market.

[185] International Trade Centre, "Market Demand Study for Papua New Guinea Coffee."

[186] Ludwig Aur Aba, Boniface Aipi, and Tanu Irau, "Supply Response of Coffee in Papua New Guinea."

Efficiency gains are weighed against baseline calculations derived from historic production and revenue yields of both palm oil and coffee for these specific examples. Based on current farming and processing methods that often involve manual irrigation and processing, automated technologies can improve product yields from anywhere between 50-70 percent depending on the crop.[187] For the case of coffee as an example, drying beans in the sun can take between six and fourteen days to a moisture content of 10-15 percent (the industry standard). Utilizing solar drying technology dramatically reduces this time, taking anywhere between 12-24 hours. Mechanizing this process also reduces the likelihood for contamination and enables higher yields from farm to packaging by up to an additional 12 percent.[188] Using conservative estimates within reported field data across the production process, expected yield increases were calculated for both palm oil and coffee when leveraging select PUE technologies.

DISTRIBUTION AND MARKETING STRATEGIES FOR PUE PRODUCTS

Churches have significantly contributed to the development of local communities. Some churches are currently operating health centers and schools and independently supplying electricity to nearby off-grid areas. Therefore, in any PNG community, companies, development partners, and other stakeholders benefit from reaching out to key church groups to raise awareness about QV products.

Currently, the inability of MSMEs to access financing is a major challenge that affects distribution. Development partners and energy sector stakeholders must evaluate successful business models to support MSMEs, build the capacity of MSMEs to market and finance QV products, and support their entry into new markets.

Table 20 estimates approximate payback periods for FuturePump SE1 and Lorentz solar irrigation systems that are used in PNG and other countries in Southeast Asia and Africa. Calculations assume that 75 percent of increased revenue gains could go toward paying for the system.

TABLE 20. PAYBACK PERIOD FOR SELECT SOLAR IRRIGATION SYSTEMS[189,190]

	FUTUREPUMP SEI	LORENTZ PS-CS-F
Cost of System	3,079 PGK	5,162 PGK
Estimated payback period	0.9 years	1.8 years

* Assumptions are detailed in the subsequent paragraphs below.

[187] Richard Michael Bourke, "Impact of Climate Change on Agriculture in Papua New Guinea."

[188] Matthew Grant Allen, Richard Michael Bourke, and A. McGregor, "Cash Income from Agriculture [in Papua New Guinea]."

[189] In person visits to Solar Solutions company in PNG.

[190] Nelson et al., "Oil Palm and Deforestation in Papua New Guinea."

For PUE systems used for profitable crops throughout the region, this calculation shows that payback periods can be fairly short if structured the correct way. A similar calculation for solar dryers for coffee is included in Table 21.

TABLE 21. PAYBACK PERIOD FOR SELECT SOLAR FOOD DRYERS[191,192]

	CONA SOLAR SOLAR DRYER	ANERSOL SOLAR DRYER C
Cost of System	4,734 PGK	2,372 PGK
Estimated payback period	2.1 years	1.6 years

* Assumptions are detailed in the subsequent paragraphs below.

These products notably are representative of systems used throughout the Southeast Asia region. Therefore, there may be additional variables to consider when operating in different environments. As more of these systems are deployed in PNG, more sophisticated financing structures will be devised. Of note, payback periods were calculated based on the technological specification sheets and weighed against average production yields in the region, based on FAO agricultural data. The calculations included in the table also correct for farm gate versus market price issues. Even if payback periods for these technologies stretched to three years, this still presents a reasonable business case over the course of the technologies 10–15-year lifespan.

In terms of other financing, distribution, and marketing strategies, PUEs are still a new model that will require more research to determine their viability in PNG. However, models that have been successful in countries like Uganda may offer effective strategies for similar deployment in PNG. For example, one successful nonprofit in Uganda provides accelerator funds to businesses that partner with PUE product manufacturers that have direct connections to end-users (e.g., smallholder farmers, local business owners, etc.) to offer partially financed PAYGO systems. In practice, only end-users with specific electricity or electrical equipment needs that generate adequate income utilize these systems. The PAYGO product provider collects an earnest money deposit, often in the form of a check, from the end-user to ensure compliance throughout the payment process; defaulting on payments or bounced checks are a punishable offense in Uganda. This incentivizes compliance at the risk of the end-user's credit-worthiness and future opportunities to access capital.

CHALLENGES IN THE DEVELOPMENT OF PUE MARKETS

Affordability. As financing options have been limited for many PUE technologies, high capital costs have been the major hurdle that prevents further proliferation of new technologies. Though these systems can often achieve payback in one to two years with moderate use, small business owners are not able to provide sufficient capital resources to justify such a purchase. Vendors must establish payment terms that allow small business owners to pay incrementally over a predetermined timeframe. The industry must also work with GoPNG to mobilize more subsidies for these systems; this will increase vendors' flexibility in terms of financing options.

[191] In person visits to Solar Solutions company in PNG.

[192] Kaoh et al., "More Resilient Cropping Systems for Food Security and Livelihoods in the Pacific Islands."

Unavailable PUE Guidelines. GoPNG has not yet established guidelines or business models to create an enabling environment for PUE products. Furthermore, the government has donated PUE products at regular intervals across the country under various programs, making it difficult for private vendors and suppliers to offer identical products directly to customers as they wait for government support programs to offer those products. Many development programs have also researched PUE use cases and goods, but none have yet raised awareness about the various PUE models and goods available in the PNG market.

Access to Remote Communities. Introducing PUE technologies can be challenging for communities that have limited distribution channels. Pairing PUE product manufacturers with local distributors can be a challenge due to their limited storage/shelf space, their unfamiliarity with products, and the sometimes-prohibitive costs of products. A further challenge is encouraging and teaching the community the economic benefit of PUE technologies over the lifespan of the product. A combination of procuring products that directly address the acute needs of smallholder farmers, business owners, and other PUE stakeholders as well as educating them on economic benefits is a hurdle that the PUE market must overcome.

Need for a Single Coordinating Agency. USAID, DFAT, MFAT, JICA, UNDP, the Energy Sector Council, and the New Zealand Agency for International Development (NZAID, delivered through MFAT) are all working on different schemes to raise the country's electrification rate. The potential duplication of efforts and lack of central coordination present major risks that could hinder developmental activities. There is also limited coordination between energy and other sectors, particularly agriculture, which is needed to promote projects/products that can contribute to broader sustainable development goals across sectors.

GENDER CONSIDERATIONS FOR PRODUCTIVE USE OF ENERGY

International development programs have extensively examined gender from maternal health to gender-based violence to the education of girls. In communities where women and girls already have achieved these basic needs, development programming has focused on skills development, access to finance, support for women-owned MSMEs, and other efforts aimed at increasing economic engagement.[193]

Gender inequalities correlate strongly to poverty and socioeconomic power distributions and especially pose challenges to women from lower socioeconomic backgrounds. Improving access to off-grid productive use appliances has a positive impact on women's economic empowerment.

For example, solar water pumps and mills can reduce the time women spend on household and farm chores, and other work that women traditionally do. These solutions reduce the need for manual labor tasks, such as getting clean water for cooking, irrigation, and cleaning

Women in PNG on average do 70 percent of household agricultural work but often do not receive recognition for their contributions due to the unstructured nature of such work. The majority

[193] Deloitte University Press, "Women, Energy, and Economic Empowerment: Applying a Gender Lens to Amplify the Impact of Energy Access."

of agricultural work is segregated by gender, and social norms frequently task women with labor-intensive and time-consuming tasks, such as harvesting, washing, and processing. This presents a significant value proposition for PUE technologies for women, as efficiency gained from PUE technologies occurs during the harvesting and processing stages. Beyond sales, men in PNG prefer to engage in high-level tasks such as planting, shading, planning, and trimming.

Given the important role of women in rural communities for the cultivation and marketing of key crops in PNG, a reliable power supply and efficient technologies could provide economic livelihood opportunities by adding value to produce that farmers would otherwise sell in its raw form at a lower cost.

PUE appliances can also perform some processing automatically, improving upon the traditional method of sorting and processing grains manually. Similarly, solar refrigerators can not only allow for more sales for small businesses and increased food preservation rates, but also allow women to have more time for other skill- and business-building activities.

These issues are not limited to rural populations. Urban planning and infrastructure decisions related to energy impact the daily lives of women and girls—including their mobility, their access to sanitation, streetlighting, and their choice of jobs and work hours.[194] In PNG, informal settlements within urban areas have limited access to the electricity grid. The opportunities that increased electrification efforts can afford local communities, particularly women, has already started to push distributors, end-users, and other industry stakeholders to translate their energy access into new opportunities for income generation and sustainable business development.

A 2019 report by UN Women found that PNG women depend on reliable energy in their business activities and that their livelihoods suffer from disruptions in the electricity supply.[195] The current supply of grid electricity is considered to be low capacity, unreliable, and often disconnected. The report found that prolonged power interruptions create considerable economic and social distress. Women make capital investments in electrical appliances that they use in their businesses as well as to improve their quality of life, and unreliable electricity access can negatively affect their business.

PUE technology implementation enables new opportunities for households and business development for women. Technologies that enable small-scale manufacturing like sewing, weaving, and ceramic-making significantly decrease production timelines and help owner/operators to focus on other tasks. Further research will be key to understanding what PUE markets are the most mature in PNG. Doing so can allow industry donors to nurture markets that have a short-term high value proposition while kick-starting others that have a slightly slower trajectory.

[194] UN Women, "Safe Spaces for Women, by Women, Bring Smart Infrastructure for All."

[195] Power to women (electrification) baseline survey. Report on Nine Mile (Quarry) settlement to suburb pilot site. UN Women. (2020).

Most of the women that were part of the UN Women study were solely or jointly responsible for paying household power bills. Those without electricity often spent up to 20% more on batteries, candles, firewood, and phone-charging costs, with lower-value outcomes and inherent risks (e.g., fires and security risks).

In the same survey, a total of about 35 percent of households that previously had access to power had been disconnected due to PNG power upgrades. Some of the disconnections may also have been due to the non-payment of electricity bills.

GENDER AND HEALTHCARE FACILITY ELECTRIFICATION

The lack of reliable power in health facilities can severely impede health service provision, affecting both the operation of health facilities and the quality of healthcare that patients receive.

Electrified healthcare facilities can operate for extended hours, which is particularly relevant for births. Reliable and consistent power directly correlates to increases in safe births, especially at night.[196] High numbers of home births have increased the rates of maternal and infant mortality. Furthermore, a study conducted by Solar Aid found a positive correlation between electric lighting during delivery and the improved detection of bodily tears and postpartum hemorrhages as well as fewer health issues with newborns, as compared to traditional fuel-based lighting.[197]

Evidence shows that fewer women visit healthcare facilities at all when electricity access is absent. External security lighting in a clinical context is also important to enhance safety for women and children who need to visit the facility at night. However, lighting is not the only key factor. With a continuous power supply, healthcare staff can better sterilize medical equipment and maintain hygienic standards. Electrification enables laboratory work and, hence, supports patient diagnoses. A stable electricity supply also allows for the continuous cooling of medical products, including blood donations, drugs, and vaccines.[198]

Cooking, heating, and cooling also play important roles in the safe provision of food and water to patients and are critical to reducing heat- and cold-related foodborne and waterborne diseases.

An inefficient or non-existent power supply affects the ability of a community healthcare facility in a rural and remote location to attract and retain skilled health workers. The majority of rural health facilities in PNG are poorly staffed. Many are run-down and lack basic services. Improving the power supply in communities and healthcare facilities increases the likelihood of retaining staff and improving the reliability and continuity of rural medical services.

[196] Efficiency for Access Coalition, "Off-Grid Appliance Market Survey: Perceived Demand and Impact Potential of Household, Productive Use and Healthcare Technologies."

[197] Strohmeier, "Why Sustainable Energy Matters to Children: The Critical Importance of Sustainable Energy for Children and Future Generations."

[198] Strohmeier.

RECOMMENDATIONS FOR THE ADOPTION OF PUE TECHNOLOGIES

Key issues in the PUE market stem from lack of affordability, underbanked communities, and difficulty accessing villages in disparate areas of the country. The economic development of a country relies in part on its resource productivity and exporting goods with high profit margins. As such, PNG's industry heavily relies on its agriculture, livestock, and associated agricultural manufacturing. Private investors historically have been apprehensive to invest in the country due to its inadequate policies and regulatory guidelines for the off-grid sector as a whole. Increasing coordination between donors through a centrally managed government organization may help reduce sector risk and provide a solid foundation for investors to develop profitable businesses. Further, there needs to be greater emphasis on developing appropriate subsidy schemes that encourage investment from private investors rather than GoPNG giving away products, which can erode the market.

There is a general need to raise awareness among potential end-users about PUE products and their benefits to local communities and business owners. Technologies such as solar-powered agricultural or agro-processing equipment could help improve the productivity of smallholder farmers and increase crop yields. Further, solar dryers, solar refrigeration systems (for preserving crops), and solar mills for crop processing can add value to farmers looking to enhance profits from their yields. Raising awareness about available solutions in the PUE product market, various technologies, potential business models, and financing options are low-hanging fruits that can serve as a steppingstone to building the PUE market. Other recommendations include:

Addressing access to finance and foreign exchange issues. Interviews with various private companies and organizations in PNG revealed the major challenge of purchasing products from overseas through U.S. dollars. Purchasing companies must endure a waiting period of several weeks to several months to process foreign exchanges. This issue has hindered the growth of new, innovative products deployed in both the on- and off-grid energy sector. Historically in similar markets, most of financing comes from international investors, specialized investment funds, and impact investors. There is also a need to inform and build the capacity of banks and financial institutions regarding PUE products to catalyze interest in participating in mutually beneficial business models such as PAYGO PUE.

Government, policy, and regulatory support. GoPNG must prioritize addressing policy and regulatory issues and policy support agencies to encourage the wider adoption of PUE products by end-users. This should not be limited to providing broad-based subsidies to the market, rather developing mechanisms to encourage manufacturers active in other countries to view PNG's market as a potentially lucrative opportunity. PUE product companies cite regulatory uncertainty as a major hurdle to address before entering the PUE market in PNG. Creating new monetization strategies will help reduce risks for manufacturers and distributors.

Sector-wide coordination. Private enterprises, governmental organizations, and investors should work together to establish, amend, and implement programs that are market-driven and prioritize sustainable business operations for end-users. This will make the PUE supply chain more robust and allow for increased resources surrounding capital expenditure, access to markets, after-sales support, and end-of-life disposal. Consequently, consumer confidence

will increase and demand for these products will grow. Further, coordination must occur between adjacent sectors such as water. It will be increasingly important to identify where in the value chain PUE technologies can bring the highest economic benefit to relevant sectors.

Technical assistance to private companies. Stakeholders should provide technical assistance to private companies and governmental organizations to build capacity and raise awareness about suitable and available products for the PNG market. Also, there is a need to provide technical trainings to technicians, engineers, and others in solar energy installation and maintenance. USAID-PEP is exploring ways to ensure the proper transfer of technical knowledge to all participants. There is also a need to raise more awareness about PUE business models that have proven successful in other countries and build the capacity of other participating organizations, which will help increase the adoption rate of off-grid PUE products.

Gender equity. Understanding the household and business demands on women and their characteristic needs are critical to supporting economic empowerment through their entrepreneurship and business ventures. GoPNG must prioritize gender equity issues for the development of the PUE market. Raising awareness about technologies, such as solar cookers, SHS, and other solar-powered devices, can empower women and their families to have a higher quality of life, boosting their economic contributions in various industries.

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Annexes

Annexes

ANNEX 1: KEY ENERGY SECTOR PLAYERS AND STAKEHOLDERS

GOVERNMENT INSTITUTIONS

National Energy Authority. In 2017, DPE introduced the PNG National Energy Policy 2017–2027, which called for the establishment of an energy entity, the National Energy Authority (NEA), to be solely responsible for the development and implementation of a National Energy Policy. In April 2021, GoPNG passed the NEA Bill to expedite the development and application of regulations related to all activities in electrification. The purpose of the NEA is to be an umbrella agency for establishing service standards for transmission and distribution networks, setting electricity tariffs, regulating, and issuing licenses to electric sector participants, and enforcing electrical standards. Moreover, the National Energy Act states that any control mechanisms in the electric sector that the Independent Consumer and Competition Commission (ICCC) manages will gradually transfer to the NEA. The National Electrification Management Unit (NEMU) responsible for managing the energy regulatory framework will report to the Ministerial Steering Committee, which will in turn report to the National Executive Council as part of the revised National Electrification Roll-Out Plan (NEROP).[199]

Department of Petroleum and Energy. DPE is the current overarching agency responsible for energy sector policy and planning. The DPE is comprised of three divisions: Petroleum, Energy, and Corporate Services. The primary aim of the Petroleum Division is to support efforts in developing PNG's known and potential petroleum resources through the administration and regulation of all petroleum projects in the country. The Energy Division of the DPE is responsible for advising the government on energy sector issues, data collection and analysis, and energy policy development.[200] Particularly, it heads the Electricity Management Committee (EMC), which is responsible for developing a National Electrification Roll-Out Plan (NEROP). This division is also responsible for power sector planning.[201] Lastly, the Corporate Services Division supports and facilitates the other two operational divisions, with a particular focus on the development of procedures and human resources. Under the PNG National Energy Policy 2017–2027, GoPNG will restructure DPE into NEA.

Department of Treasury. The Department of Treasury is responsible for providing sound economic policy advice to the government to support informed decision-making. The department is responsible for developing and implementing the government's annual and medium-term budget frameworks; providing economic, investment, and tax policy advice; and managing of the government's public debt. The Department of Treasury provides the policy guidance for the management of the performance of the PNG economy as it pertains to the development of the energy sector.

Department of National Planning and Monitoring (DNPM). The role of DNPM is to lead, plan, coordinate, and facilitate appropriate national and international initiatives that address and promote equitable and sustainable development of PNG in accordance with both a long-term

[199] Department of Public Enterprises and Department of Petroleum and Energy, National Energy Policy 2016-2020.

[200] Isaka, Mofor, and Wade, "Pacific Lighthouses: Papua New Guinea."

[201] Asian Development Bank, "Energy Sector Assessment CAPE PNG."

vision for the nation and the five principles of the National Constitution. DNPM acts as the key central agency advising GoPNG on matters relating to strategic development, development policy, development planning and programming, foreign aid coordination and management, and the monitoring and evaluation of national development projects and programs.

PNG Power Limited. PNG Power Limited (PPL) is a state-owned entity, which Kumul Consolidated Holdings holds in trust, and serves as the national electricity utility in PNG. The Electricity Commission Privatization Act established PPL to be the successor company of the Papua New Guinea Electricity Commission. PPL is a vertically integrated power authority, meaning that is responsible for the generation, transmission, distribution, and retailing of electricity. It operates the three interconnected transmission and distribution grids in the country as well as many provincial power systems,[202] providing power and services to residential, industrial, commercial, and government customers. Moreover, PPL has historically taken on the role of technical regulator for the electric sector, undertaking roles such as approving licenses for electrical contractors, providing certification for models of electrical equipment and appliances, and providing safety advisory services for major installations. Under the National Energy Policy, PPL will unbundle itself into distinct entities operating in the generation, transmission, distribution and retail, and regulations sub-sectors.[203] This unbundling effort is part of the government's initiative to improve regulatory oversight and increase industry competition in the electric sector.

Kumul Consolidated Holdings (KCH). KCH is the entity which holds in trust the government's non-petroleum and non-mining assets. KCH (formerly known as IPBC) was established in July 2002 under the Independent Public Business Corporation of Papua New Guinea Act 2002 (also known as the IPBC Act). KCH is mandated to hold all government-owned commercial assets in trust and to manage those assets to improve commercial performance and underpin economic development. KCH is not responsible for the government's mineral, oil, and gas assets. KCH is the holding company for nine state-owned enterprises (SOEs) that operate in agriculture, aviation, banking and financial services, insurance, maritime infrastructure, power that is PPL, post and logistics, telecommunications, and water and sanitation. KCH also acts as the manager of infrastructure projects throughout PNG, including hydroelectric power facilities, metropolitan sewerage systems properties, and port developments. KCH is a 100-percent state-owned statutory corporation.

Kumul Petroleum Holdings Limited (KPHL). Kumul Petroleum Holdings Limited (KPHL) is PNG's state-owned oil and gas company. The GoPNG Parliament created it through the Kumul Petroleum Holdings Limited Authorization Act of 2015 in order to protect and maximize the value of PNG's petroleum assets. A core commercial interest for KPHL is the ExxonMobil-operated PNG LNG Project, which has a capacity of 6.9 million metric tonnes per year, producing nine trillion cubic feet of natural gas over 20 years. KPHL manages the state's 16.57-percent equity in the PNG LNG Project and is the third-largest partner in this single largest investment that GoPNG has made to date. In addition, because KPHL is the legislated state nominee for oil- and gas-related projects, it can exercise its option for a 20.5-percent stake in every project. It is also involved in the Western Pipeline Project

[202] Isaka, Mofor, and Wade, "Pacific Lighthouses: Papua New Guinea."

[203] Department of Petroleum and Energy, National Energy Policy 2017-2027.

for aggregating stranded gas fields in the Gulf and Western Province, as well as the Port Moresby Power Project, to sell gas from the PNG LNG plant to the 50-MW power station.[204]

Independent Consumer and Competition Commission. The primary role of the Independent Consumer and Competition Commission (ICCC) of PNG is to administer and implement the ICCC Act of 2002 through price regulation, licensing, and industry regulation.[205] Under the NEA, the ICCC will no longer be responsible for establishing electricity tariffs and setting the prices of petroleum fuels. The ICCC will also no longer issue licenses to independent power producers and mining companies that own generation and distribution facilities.

Conservation and Environmental Protection Authority. In 1985, GoPNG established the Conservation and Environmental Protection Authority (CEPA), formerly called the Department of Environment and Conservation, to ensure the management of natural and physical resources in PNG and sustain environmental quality and human wellbeing.[206] Among biodiversity-conservation duties among others, CEPA is responsible for assessing the environmental impact of new gas development projects, hydropower infrastructure developments, and mining projects. CEPA also issues relevant environmental permits.[207]

INDUSTRY ASSOCIATIONS: ENERGY EXTRACTION

Papua New Guinea Chamber of Mines and Petroleum. The Papua New Guinea Chamber of Mines and Petroleum is a nonprofit industry organization comprised of members from the oil and gas and mining industries. The role of the chamber is to promote the growth of the mining and petroleum industries in PNG by being the primary source of information and representing the industries' interests to the government.

ExxonMobil. ExxonMobil, an American multinational corporation, operates the PNG LNG project and has an equity stake of 33.2 percent. It also has a 37.1-percent stake in the proposed Papua LNG venture and a 49-percent stake in the P'nyang gas field development proposal. In addition, the company has stakes in the gas resources at the Muruk field as well as several onshore and offshore exploration permits. This includes deep-water prospects where no entities have undertaken drilling to date.[208]

Oil Search Ltd. Oil Search Ltd. is an incorporated company in PNG and the oldest operating company in the country. With a 29-percent stake, it is the second-largest equity owner in the PNG LNG project. It also has significant equity in Papua LNG and P'nyang.

Santos Ltd. Santos Ltd is an Australian energy company with 13.5-percent stake in the PNG LNG project as well as equity in the P'nyang development proposal.

Total SA. Total SA, a French multinational company, is a relatively new participant in PNG's petroleum exploration and production industry. It will be the operator in the Papua LNG project.

[204] Kumul Petroleum Holdings Limited, "Kumul Petroleum Holdings Limited."

[205] ICCC PNG, "Home - Papua New Guinea Independent Consumer & Competition Commission."

[206] CEPA PNG, "Home - Conservation & Environment Protection Authority of Papua New Guinea."

[207] Asian Development Bank, "Energy Sector Assessment CAPE PNG."

[208] Papua New Guinea Chamber of Mines and Petroleum, "Petroleum."

Twinza Oil. Twinza is an Australian oil and gas company with projects in PNG. The company has conducted appraisal drilling of a gas condensate field offshore in the Gulf of Papua and expects to host PNG's first offshore field development with production in 2025.[209]

INDUSTRY ASSOCIATIONS: ELECTRICITY GENERATION

Dirio Power. Dirio Gas and Power is a relatively new power producer that came online in 2020. It supplies 45 MW power from gas purchased from Exxon's PNG LNG project.[210] PPL will distribute the power per a Power Purchase Agreement and will supply demand in Port Moresby. Dirio the first nationally owned independent power producer in PNG.[211]

NiuPower Limited. NiuPower is a power generation company incorporated in PNG with a focus on natural gas generation. It was founded in 2017, and KPHL and Oil Search Ltd. jointly own it.[212] NiuPower is the operator of the 58-MW Port Moresby Power Station, PNG's first dedicated grid-connected gas-fired power plant. The company has a long-term PPA with PPL to expand the Port Moresby Power Station to approximately 175 MW.

PNG Biomass. PNG Biomass is a renewable energy project that began in the Markham Valley of the Morobe Province in 2011.[213] It was acquired by Oil Search Ltd. in 2016.[214] It consists of a 30-MW biomass power plant and will oversee the construction and operation of an adjacent 11 MW solar PV farm that PPL owns. Together, these two plants will provide the Ramu grid with up to 40 MW of renewable energy.

PNG Hydro Development Ltd. PNG Hydro Development Ltd. (PNGHDL) is a Chinese company working to construct the 50-MW Edevu hydropower plant and associated Edevu-Moitaka 132-kW transmission line from the station to the Central Province.[215]

PNGFP Hydro. PNG Forest Products (PNGFP) Hydro is an IPP that owns and operates three hydropower stations with the combined installed capacity of 14.9 MW at Baiune near Bulolo.[216] In 1947, PNGFP commissioned the oldest hydropower plant of the three to supply power for the company's forest products production, but currently all three plants supply power to local businesses and residential consumers. The 9.4-MW Upper Baiune power station was commissioned in 2013 to supply power to the Ramu Grid and is currently the only hydropower station in PNG built for the sole purpose of supplying power to PPL. PNGFP Hydro is currently planning and developing two additional hydropower stations to increase electricity supply to PPL.

POSCO International. POSCO International is a Korean company that has built two heavy fuel oil (HFO) internal combustion power plants in PNG: a 25-MW plant in Port Moresby and a 34-MW plant in Lae. The plant in Port Moresby was contracted from 1999 to 2014 and served an

[209] Wilkinson, "Twinza Nearing FEED for Pasca A Development in PNG."

[210] Business Advantage PNG, "In Brief."

[211] Dirio Gas & Power, "Dirio Gas & Power Company Limited: Overview."

[212] NiuPower, "Home - NiuPower."

[213] IP3, "Independent Power Producers of Papua New Guinea Industry Group."

[214] PNG Biomass, "PNG Biomass - Powering Papua New Guinea, Empowering Communities."

[215] PNG Power Ltd, "Projects."

[216] PNG Forest Products, "Hydro Power Experts | PNGFP."

additional five years through successful rehabilitation and efficiency enhancement.[217] At the end of 2019, when the contract expired, POSCO International turned the plant over to PPL. In 2018, the plant in Lae began commercial operation.

INTERNATIONAL DONORS

This section includes descriptions of key international partners and donors. Annex 2 shows a list of active energy projects in PNG that international donors funded in part.

Asian Development Bank. In 2019, the Asian Development Bank (ADB) announced a pledge to invest over $1 billion to help countries in the Pacific increase renewable energy generation. This includes expanding transmission and distribution infrastructure in PNG to increase the national electrification rate from 12 percent to 19 percent by 2028.[218] To date, ADB has funded over 30 energy-related projects in PNG that total $248 million.[219] Other examples of projects include financing the extension of the Port Moresby Grid and constructing new and renovating existing hydropower plants.

Australia Department of Foreign Affairs and Trade. The Government of Australia, primarily through its Department of Foreign Affairs and Trade (DFAT), is PNG's largest development partner.[220] DFAT is responsible for supporting investments in PNG through programs such as the Australian Infrastructure Financing Facility for the Pacific (AIFFP). In 2019, the AIFFP became operational as a strategy for financing large-scale electricity infrastructure projects across the Pacific. It is financing the proposed large-scale Markham Valley Solar Plant in the Morobe Province, which is expected to commence construction in 2021 and will be PNG's first utility-scale solar plant.

Japanese International Cooperation Agency. The Japanese International Cooperation Agency (JICA) has been involved in funding two major electric sector projects in PNG: the Ramu Transmission System Reinforcement Project (and the Project for the Formulation of Ramu System Power Development Masterplan) and the Lae Area Distribution Network Improvement Plan.[221] The former ends in 2022, while the latter ended in 2016.

New Zealand High Commission. The New Zealand High Commission supports the Rural On-Grid Extension Project (ROGEP), which is New Zealand's single largest aid activity in PNG.[222] Through the construction of 86 km of grid lines, with PPL as an implementing partner, the project has provided electricity to 5,000 households, six schools, and four health centers in the Central Province.[223] The New Zealand High Commission has

[217] Independent Power Producers of Papua New Guinea, "Home - IP3."

[218] Asian Development Bank, "Investing Over $1 Billion to Help Pacific's Renewable Energy Transition."

[219] Asian Development Bank, "Papua New Guinea."

[220] Australian Government Department of Foreign Affairs and Trade, "Australia's Development Partnership with Papua New Guinea."

[221] Japan International Cooperation Agency, "Activities in Papua New Guinea | Papua New Guinea | Countries & Regions | JICA."

[222] New Zealand Ministry of Foreign Affairs and Trade, "Evaluation of New Zealand's Country Programme in PNG." Regions | JICA."

[223] New Zealand Ministry of Foreign Affairs and Trade, "Our Development Cooperation with Papua New Guinea."

provided over $17 million in total (24.7 million New Zealand Dollars [NZD]) for this project. Other projects that the New Zealand High Commission is involved in include the Town Electrification Investment Program (TEIP) with the ADB and the Enga Hydropower Project.[224]

United Nations Development Programme. The United Nations Development Programme (UNDP) is responsible for supporting and financing several energy projects in PNG. These include the $3.39-million program Support to Rural Entrepreneurship, Investment, and Trade in Papua New Guinea (STREIT PNG), whose goal is to increase sustainable and inclusive economic development of rural areas through renewable energy technologies; the $3.14-million Facilitating Renewable Energy and Energy Efficiency Project to reduce greenhouse gas emissions from the energy production and energy end use sectors in PNG; and the $1.74-million Advancing Papua New Guinea's National Adaptation Plan effort to increase climate change adaptation efforts particularly in infrastructure development.[225]

United States Agency for International Development. The United States Agency for International Development (USAID) supports projects across PNG with a focus on humanitarian aid, disaster preparedness, and climate change adaptation and resilience. At the end of 2020, USAID launched the $57-million PNG Electrification Partnership (PEP) with the goal of providing electricity to at least 200,000 households across the country. This five-year project will contribute to the broader PNG Electricity Partnership that the Governments of PNG, the United States, Australia, Japan, and New Zealand created during the 2018 APEC Leaders' Summit.[226]

The World Bank Group. The World Bank Group has been involved in many development projects in PNG, including several in the energy sector. The most recently completed project ended in 2019 and provided $7.3 million for DPE and PPL to develop an electrification plan to increase rural connections, attract investors for the Naoro Brown hydropower project to supply to the Port Moresby electricity grid, and finance a natural gas master plan.[227] The World Bank supported GoPNG in the development of PNG's National Energy Policy and National Electrification Roll-Out Plan and subsequently its implementation strategy and investment plan. Currently, the World Bank is financing a $30-million International Bank for Reconstruction and Development (IBRD) loan for PPL's PNG Energy Utility Performance and Reliability Improvement Project (EUPRIP). The International Finance Corporation (IFC), a member of the World Bank Group, has conducted a market assessment of off-grid solar products and is in discussions with PPL about a pilot rooftop solar program in Port Moresby and the refurbishment of the existing mini-grids.[228]

[224] New Zealand Ministry of Foreign Affairs and Trade, "Evaluation of New Zealand's Country Programme in PNG."

[225] UNDP Papua New Guinea, "All Projects | UNDP in Papua New Guinea."

[226] US Agency for International Development, "U.S. Government Delivers on PNG Electrification Partnership Promise."

[227] The World Bank, "World Bank Project."

[228] PNG Power Ltd, "Home."

ANNEX 2: CURRENT ENERGY SECTOR PROJECTS

TABLE 22. CURRENT ENERGY SECTOR PROJECTS

PROJECT NAME	LOCATION	TECHNOLOGY/TYPE	RATED CAPACITY	FUNDING ENTITY/OFFTAKER
Ramu 1	Eastern Highland	Hydro Rehab	35 MW	PPL
Pauanda	Western Highland	Hydro Rehab	4 MW	PPL
Yonki Toe	Eastern Highland	Hydro Rehab	18 MW	PPL
Baime	Morobe	Hydro (expansion)	11.2 MW	PNG Forest Product
PNG Biomass	Morobe	Biomasss + Solar	30 MW+ 15 MW	Oil Search
Ramu 2	Eastern Highland	Hydro	180 MW	Shenzhen Energy Group (25 years)/ PPL
Mongi-Bulum	Morebe	Hydro	116 MW	PPL
Pilikambi Hydropower Project (PKHPP)	Enga	Hydro	13.6 MW	AG Energy (Enga) Limited (AGEEL) (60%); Enga government/ landowners (40%)
Gurokor and Timini	Morobe	Hydro	N/A	PNG Forest Product
Kaugel	Highland	Hydro	60 MW	PPL
Edevu Hydro Project	Kairuku-Hiri District, Central Province	Hydro	50 MW	Chinese Development Bank, PNG Hydro, PPL
Naoro Brown Hydropower Project	POM	Hydro	80 MW (4 x 20 MW turbines)	World Bank

TABLE 22. CURRENT ENERGY SECTOR PROJECTS				
PROJECT NAME	LOCATION	TECHNOLOGY/TYPE	RATED CAPACITY	FUNDING ENTITY/OFFTAKER
PNG Energy Utility Performance and Reliability Improvement Project (EUPRIP) ($30M USD)	Country-wide	Multiple	N/A	World Bank
Rouna Rehab	POM	Hydro Rehab	22MW	PPL
Niu Power	POM	Gas	58 MW	Oil Search
Dirio Gas & Power	POM	Gas	45 MW	MRDC
PNG Waste to Energy IPP	POM	Waste to Energy	2 MW	Landfill Energies
Mevelo Hydropower Scheme	South of Gazelle, ENB	Run-of-river Hydro	24 MW	In consideration
Kavieng Solar	New Ireland	Solar	1 MW	JARIM PNG Limited/ New Ireland Development corporation
Alotau Solar	Milne Bay	Solar	1 MW	
Upper Warangoi	East New Britain	Hydro	10 MW	PPL
Upper Lake Hargy Hydro	West New Britain	Hydro	10 MW	ADB
Toriu	New Britain	Hydro	10 MW Phase 1, then 40 MW Phase 2	

TABLE 22. CURRENT ENERGY SECTOR PROJECTS				
PROJECT NAME	LOCATION	TECHNOLOGY/TYPE	RATED CAPACITY	FUNDING ENTITY/OFFTAKER
Frieda River Hydroelectric Project	East Sepik	Hydro	600 MW	PanAust
Yandera (off grid)	Madang Province	Mixed - renewable and coal	100 MW	Era Resources (Mine)
Hela Hydro	Hela Province	Hydro	168 MW	PPL/In consideration
Warangoi B Hydro	East New Britain	Hydro	5 MW	PPL/In consideration
Mevelo Hydro	Gazelle	Hydro	24 MW	PPL/In consideration
Purari Hydro (Upper)	Enga	Hydro	1,000 MW	PPL/In consideration
Mongi-Bulum Hydro	Morobe Province	Hydro	12 MW	PPL/In consideration
Kaugel Hydro	Southern Highlands	Hydro	30 MW	PPL/In consideration
Imbrum Hydro	Madang Province	Hydro	44 MW	PPL/In consideration
Kanudi and Moitaka Decomissioning	PM	Diesel	N/A	
Gorokor-Timini	Morobe Province	Hydro	12 MW	PNG Forest Products
Kanudi and Lae Relocation	Hides	Gas	44 MW	EFIC and OPIC
Munum HFO	Morobe Province	Gas	32 MW	Posco Daewoo / PPL
Tsak/Enga Hydro Project	Highlands/ Enga	Hydro	550 kW/3,600 homes	NZ Aid, PNG PPL, DNPM
Rural on Grid Extension – Central (24M NZD)	Papua/ Central Province	N/A	N/A	NZ Aid, PPL

TABLE 22. CURRENT ENERGY SECTOR PROJECTS				
PROJECT NAME	LOCATION	TECHNOLOGY/TYPE	RATED CAPACITY	FUNDING ENTITY/OFFTAKER
Rural Electrification Project – ADB Three Towns Project (10 million NZD)	Bougainville, West New Britain, Northern Provinces	Hydro	N/A	ADB, NZ Aid, PPL
Power Sector Development Investment Program	Country-wide	Multiple	> 10 MW	ADB
Port Moresby Power Grid Development Project	Port Moresby; Laloki River Valley	Hydro	7 MW from rehabilitated Rouna 1 and Sirinumu hydro	ADB
TEIP - Divune HPP	Oro	Hydro	3 MW run-of-the river	ADB
TEIP - Ramazon HPP	Bougainville	Hydro	3 MW run-of-the river	ADB
PNG Electrification Partnership (PEP)	Country-wide	Multiple	N/A	USAID
Karimui Hydro Project	Chimbu Province	Hydro	1800 MW	PPL, Salini-Impregilo
Konos Solar Project	New Ireland	Solar	3/10 MW	JARIM (PNG Limited/ New Ireland Development corporation
Hela / Southern IPP	Hela and Southern Provinces	Hydro	64 MW	PPL & Oil Search
Lihir Feasibility Studies	Lihir	Undetermined	N/A	KPHL
Hela - Southern Highlands	Hela	Gas	N/A	KPHL and PPL
Kavieng Biomass	New Ireland	Biomass	1.6 MW	Kavieng Biomass IPP
Mendi Hydro	Southern Highlands	Hydro	20 MW	KCH

ANNEX 3: METHODOLOGY FOR DETERMINING ON-GRID AND OFF-GRID DEVELOPMENT POTENTIAL

USAID-PEP leveraged province-level PPL billing data, differences in household demand using DHS wealth quintiles, and Facebook population data to estimate community-level electricity demand across PNG.

Data Sources

To estimate the average household demand for off-grid communities in PNG, primary data inputs were:

1. Customer billing data from PNG Power Limited (PPL):[229] PPL billing data spans from 2014 and were included in the 2016 NEROP Final Report.
2. Household-level sociodemographic data from the 2016–2018 PNG Demographic and Health Survey (DHS): The 2016–2018 DHS includes questions on household asset ownership, access to services, and other sociodemographic data that USAID-PEP used to estimate overall household wealth and average household demand for energy.
3. High-resolution population density maps from Facebook: These population density maps are based on publicly available census data and other population statistics, and provide population estimates at 30-meter resolution across PNG.

In addition to these datasets, which provide information on population characteristics across PNG, USAID-PEP leveraged several geospatial datasets to identify potential institutional demand and map community access. These include Open Street Maps (OSM) and resources through the United Nations Office for the Coordination of Humanitarian Affairs (OCHA), which allowed USAID-PEP to map the locations of schools, medical centers, and roads; the U.S. Geological Survey (USGS), which allowed USAID-PEP to map the locations of mining sites; and OpenCelliD, which allowed USAID-PEP to map the locations of cell towers.

Steps for estimating off-grid community demand

The first step in estimating energy demand for off-grid communities is to identify potential communities for off-grid energy services. Using Facebook's high-resolution population density map of PNG from 2018, USAID-PEP first adjusted this population data to that align with World Bank estimates for 2021, which put the national population at 9.1 million.

Next, USAID-PEP aggregated Facebook population maps from 30-meter-by-30-meter grids to two-km-by-two-km grids to align with the average reach of mini-grids in PNG.

This produced a gridded population map across PNG with 30,032 communities. The average community population is 300 individuals, or about 60 households per grid. Communities range in size from sparsely populated rural areas in the Islands Region with about six people per community, to very densely populated urban areas in the Highlands Region with more than 15,000 people per community grid.

[229] The 2016 NEROP Final Report was shared with USAID-PEP for this analysis.

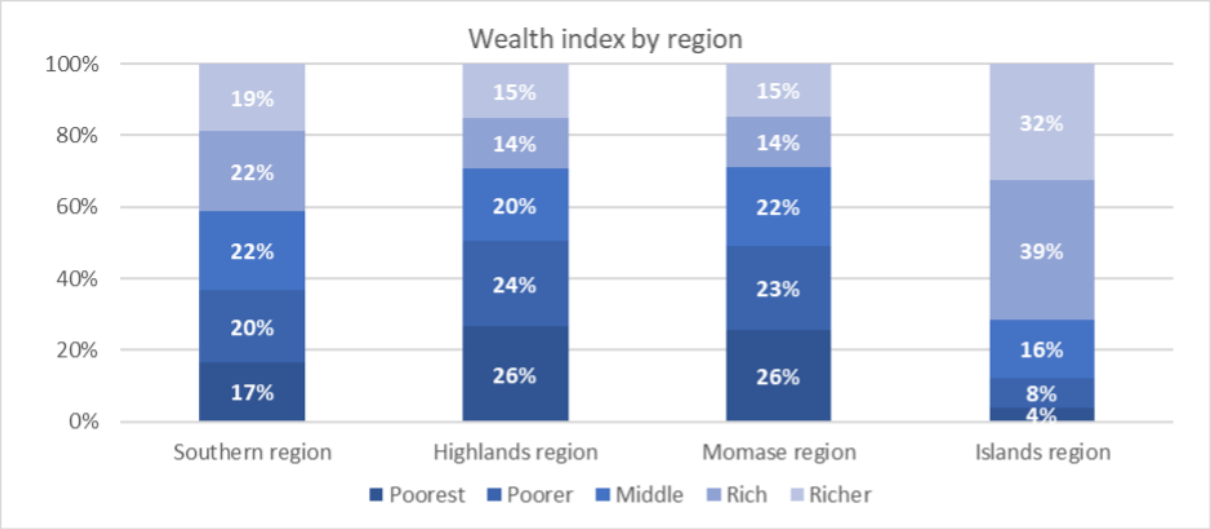
The next step was to estimate the total community demand for electricity by combining community-level population counts with customer data from PPL billing centers and DHS data on household sociodemographic characteristics.

First, using PPL billing data from the 2016 NEROP, USAID-PEP calculated the average annual electricity consumption (kWh) for current PPL customers for each province with available data. Reliability of service was not considered as an input as this data was not available which could lead to underestimating demand. However, it could be that many residential customers are spending close to their limit on electricity and may purchase the same amount of energy regardless of increased reliability (especially since most households use pre-paid service which could lead to these customers adding credit at set intervals).

As the NEROP did not include electricity consumption data for the National Capital District, Southern Highlands Province, and Hela Province, USAID-PEP assigned regional-level averages for these locations.

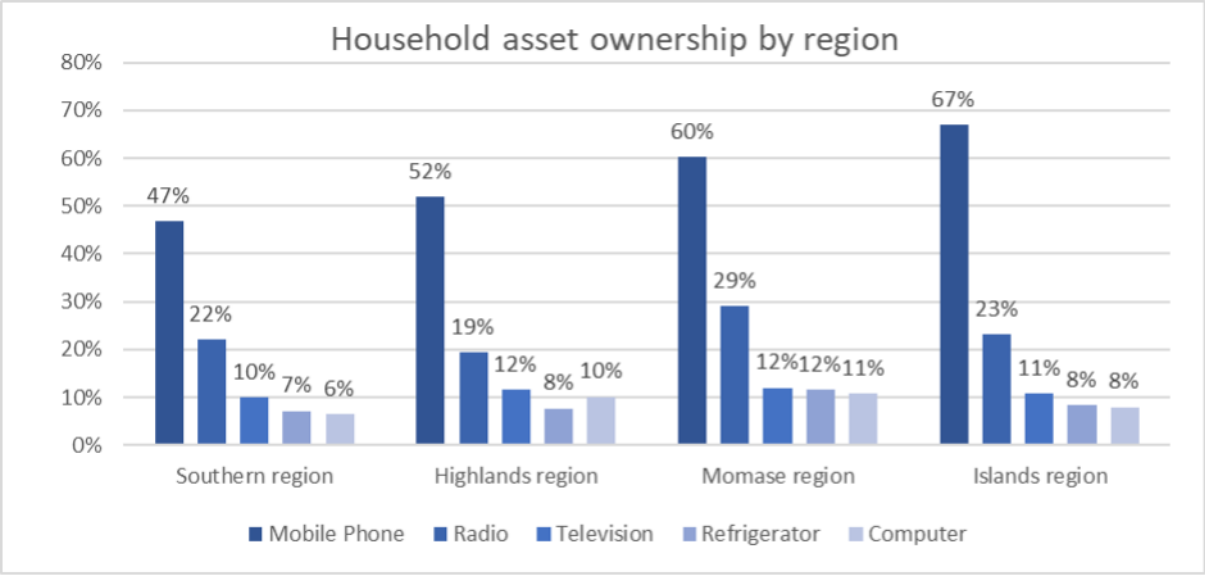
The next step was to estimate the average electricity demand for households, which are not currently connected to the electrical grid.

To do this, USAID-PEP leveraged the DHS wealth index and household-level data on electrified asset ownership. From these inputs, USAID-PEP estimated the proportion of households, per region, that are in each DHS wealth quintile.[230]



USAID-PEP calculated the regional proportion of households that own each of the electrified assets that the DHS requested. USAID-PEP did this per wealth quintile per region, and further disaggregated the data by urban–rural status.

[230] The wealth index is a composite measure of a household's cumulative living standard. The wealth index is calculated using easy-to-collect data on a household's ownership of selected assets, such as televisions and bicycles; materials used for housing construction; and types of water access, and sanitation facilities.

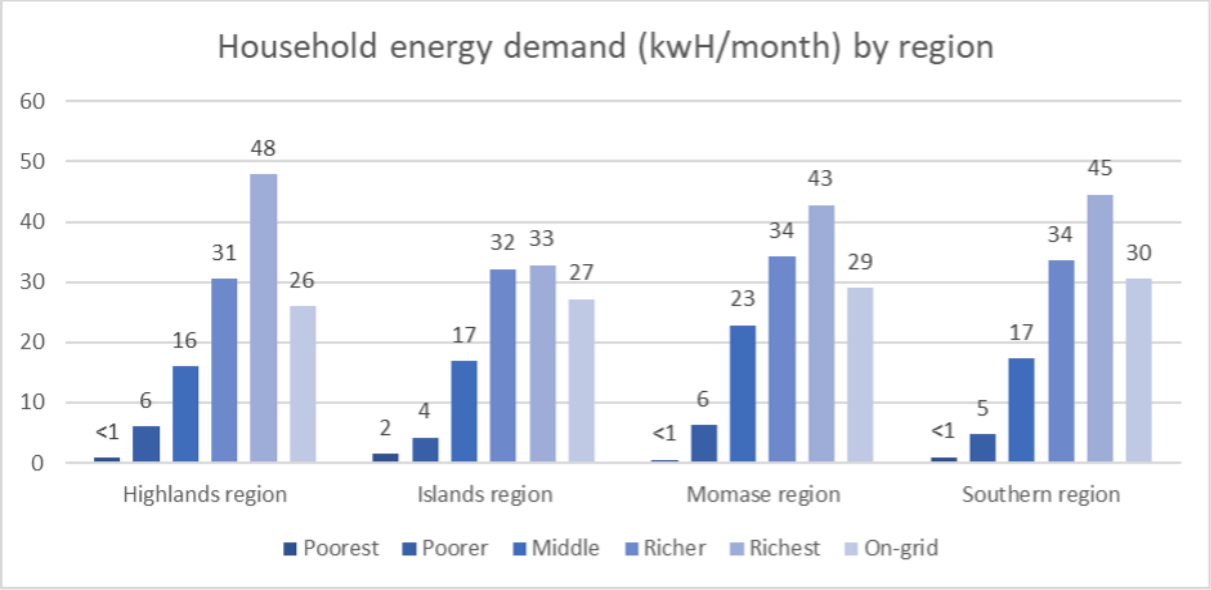


Next, using DHS data on electrified asset ownership, USAID-PEP estimated the total household energy needs per household per electrified asset, based on the average daily use and watt hours per appliance per day. Energy demands per asset came from the PNG NEROP. When these figures were not available, USAID-PEP used estimates from multi-tier framework surveys conducted in Ethiopia and Zambia.

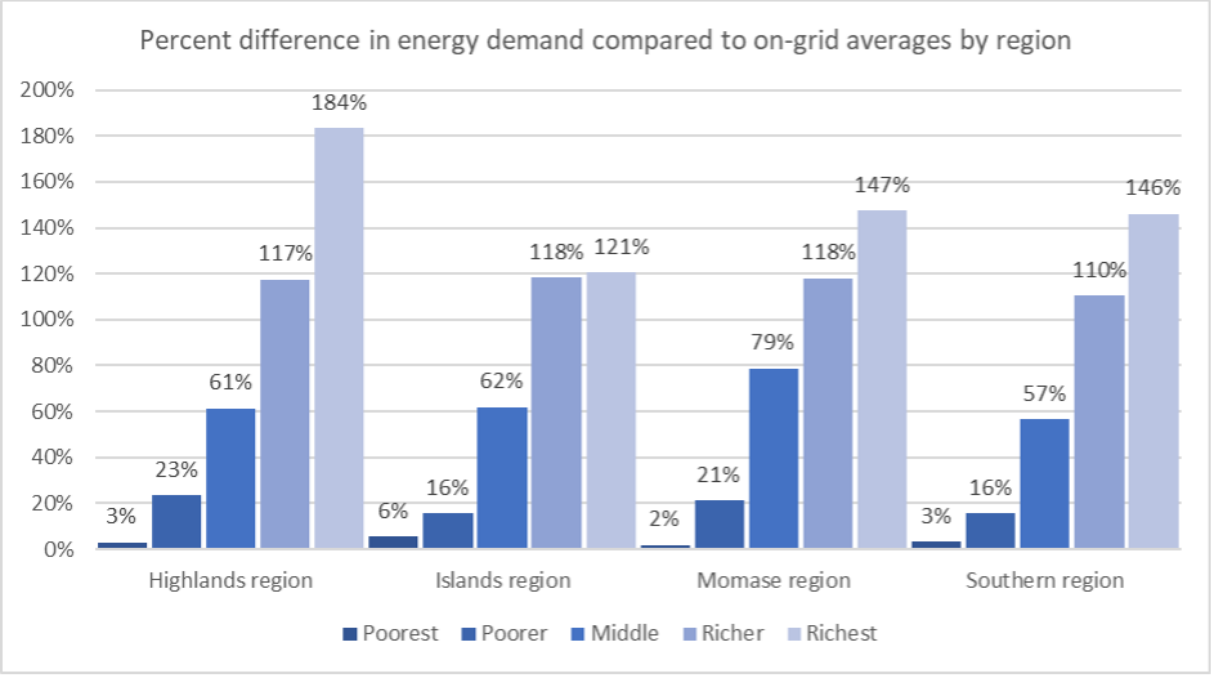
ASSET	ESTIMATED HOURS USED/DAY	WATT HOURS/DAY
Computer	2	25
Refrigerator	6.25	200
Mobile Phone (charging)	4	10
Radio	5.7	10
Television	5.6	150

Because the DHS does not collect data on the number of electrified assets that a household owns, and because the list of assets for which the DHS collects data is not exhaustive (for example, the DHS does not ask about the ownership of electric rice cookers, which is a common appliance in many households in PNG), USAID-PEP used these values as the main input in adjusting PPL customer data.

To do this, USAID-PEP calculated the average electricity needs to power these assets, per wealth quintile per region, as well as the average annual electricity needs per region for on-grid households only (to approximate PPL customers). For example, the poorest households in the Highlands Region have energy demand of less than one kWh/month due to very low ownership rates of electrified assets, compared to on-grid households, which have energy demands of about 26 kWh/month.



USAID-PEP then calculated the percent difference in energy demand of households in each wealth quintile compared to on-grid households in the same region. For example, the richest households in the Highlands Region have nearly double the energy demand (184 percent) when compared to the average on-grid household in the same region, while the poorest households have only three percent of the energy demand.



These differences, which consider regional variation in energy demand based on wealth, access to electricity, and urban–rural status as the DHS defines, USAID-PEP then combined with PPL customer billing data at the province level. The product of these inputs produced average household demand, per wealth quintile per province, for all households across PNG.

As electricity access is low in PNG, even within communities that are on the grid, the next step was to calculate the proportion of the population that would be most likely to connect to the grid if service were available.

To do this, USAID-PEP created a proxy variable for communities with electricity, defined as any DHS enumeration cluster in which at least one household reported using electricity. From this subset of communities, USAID-PEP then calculated the percentage of households that reported having electricity per wealth quintile per region, which ranged from ten percent to 50 percent.

To account for differences in electricity demand and access rates across urban and rural levels, USAID-PEP calculated all regional proportions, as described above, at both urban and rural levels, and then classified each two-by-two-km grid across PNG as urban if the population density of that grid was greater than 5,000 people. USAID-PEP calculated this threshold to align with the DHS estimates of a population that is about 89-percent rural.

Next, USAID-PEP distributed each of the proportions, as described above, across the entire population of PNG. To do this, USAID-PEP multiplied regional proportions from the DHS with the Facebook high-resolution population density maps aggregated to two-by-two-km grids. This process assumes that average population values are equally distributed across a given region at urban and rural levels.

For example, USAID-PEP assumes that all rural communities in the Highlands Region have the same average household size, the same proportion of households in each wealth quintile, the same average household energy demand, and the same proportion of households that are most likely to connect to the electrical grid. Similarly, USAID-PEP assumes that all urban communities within the same region have the same average values, though urban and rural proportions within the same region differ, and population density per community, the main input in final rubrics, varies within and across regions.

The resulting output of these calculations were total population and total households per community, and community-level values for: households per wealth quintile, average electricity demand per wealth quintile, and estimated electricity access rate per wealth quintile, per two-by-two-km community across PNG.

To estimate the total community energy demand, assuming all households connect to the grid, USAID-PEP combined the total number of households per wealth quintile with an average energy demand per wealth quintile and then summed it to the community level. Results from this at the national level are in Table 23 and in Figure 13 of the Overview of the Off-Grid Market subsection of this document.

TABLE 23. RESULTS OF HOUSEHOLD ANALYSIS						
	INDICATOR	SHS	VIABLE MINI-GRID	HIGH POTENTIAL MINI-GRID	OFF-GRID – SHS GRID EXTENSION (1-10KM FROM GRID)	ON-GRID/ GRID INTEN-SIFICATION (LESS THAN 1KM FROM GRID)
Household Count	All House-holds	436,937	285,052	134,346	297,115	663,589
Community Rubric Result	Poorest Households (Bottom 20% by Wealth Index)	87,532	67,546	43,657	79,315	199,846
	Poor Households	92,518	66,757	37,048	73,761	194,018
	Middle Households	101,996	65,485	26,614	66,452	124,116
	Rich Households	103,397	57,227	17,938	52,329	97,701
	Richest Households (Top 20% by Wealth Index)	51,494	28,037	9,088	25,257	47,908

TABLE 23. RESULTS OF HOUSEHOLD ANALYSIS						
	INDICATOR	SHS	VIABLE MINI-GRID	HIGH POTENTIAL MINI-GRID	OFF-GRID – SHS GRID EXTENSION (1-10KM FROM GRID)	ON-GRID/ GRID INTEN-SIFICATION (LESS THAN 1KM FROM GRID)
Estimated Number of Households to Connect to Electrical Grid	All Households	71,683	48,177	34,615	53,704	188,429
	Poorest Households (Bottom 20% by Wealth Index)	5,954	5,779	9,436	8,609	47,499
	Poor Households	8,105	7,492	9,054	10,361	59,257
	Middle Households	10,328	8,152	5,999	10,166	31,687
	Rich Households	17,379	10,354	4,533	10,277	23,066
	Richest Households (Top 20% by Wealth Index)	29,917	16,400	5,593	14,292	26,920

TABLE 23. RESULTS OF HOUSEHOLD ANALYSIS						
	INDICATOR	SHS	VIABLE MINI-GRID	HIGH POTENTIAL MINI-GRID	OFF-GRID – SHS GRID EXTENSION (1-10KM FROM GRID)	ON-GRID/ GRID INTEN-SIFICATION (LESS THAN 1KM FROM GRID)
Total Monthly Household Energy Demand (out of households likely to connect to electrical grid)	All Households	2,174,352	1,327,441	1,879,273	1,188,458	6,281,882
	Poorest Households (Bottom 20% by Wealth Index)	3,589	8,715	60,445	10,964	176,790
	Poor Households	21,077	34,598	269,589	53,018	1,334,327
	Middle Households	56,193	73,029	435,324	97,488	1,682,895
	Rich Households	222,798	154,295	424,692	171,771	1,265,562
	Richest Households (Top 20% by Wealth Index)	1,870,695	1,056,805	689,223	855,217	1,822,309

To estimate total community demand based on regional access rates, USAID-PEP combined the total number of households per wealth quintile with regional-level electricity rates, combined this with energy demand per wealth quintile, and then summed these values to the community level.

We then mapped all institutional demand points that are both publicly available and categorizable. This includes the following types of institutional demand: education centers, airports, mining sites, palm oil mills, hotels, cell towers, health centers, and NGO presence. USAID-PEP assigned each community in PNG a number for each institutional demand point within its grid.

Additionally, USAID-PEP mapped all available high- and medium-voltage gridlines, and all publicly available primary, secondary, and tertiary roads, and calculated the distance of each community to each of these features. While the gridline maps are incomplete, and USAID-PEP will update them when exhaustive maps are available, USAID-PEP used them in preliminary community rubric results, which categorize communities by potential for different types of off-grid electrification.

Preliminary community rubric results classify all communities into one of five categories, based on the number of households per community and the distance to mapped electrical gridlines.

Communities that are farther than ten km from the grid fall into the following categories:

1. **Solar home system communities:** those with fewer than 100 households.
2. **Viable mini-grid communities:** those with 100–320 households.
3. **High-potential mini-grid communities:** those with more than 320 households.

Communities that are within ten kilometers from the grid fall into the following categories:

4. **Grid extension communities:** communities between one and ten km from the grid. May be best served with SHS while the grid is being extended, which may take several years for less densely populated communities that are at the farthest reaches of this range.
5. **On-grid communities:** those within one km from the grid, which are most likely to already have households connected to the grid, or where grid intensification is likely to take place in the next several years.

ANNEX 4: DONOR PROGRAMS RELEVANT TO THE OFF-GRID ENERGY SECTOR

PPL is involved in most donor projects in PNG that involve the electricity sector. These programs primarily focus on grid extension, grid modernization, and technical capacity building. Donors continue to find it challenging to develop and deploy off-grid initiatives because limited frameworks exist to sustain a viable program. Furthermore, there is no coordinating office that exists in GoPNG to assist donors in focusing their off-grid development activities. As PNG's off-grid market grows, the central management of off-grid development programs under one government agency or organization will be pivotal for the success of all initiatives. Developing a viable market for PUE products hinges on this provision, which will help provide structure and coordinate efforts across different bilateral and multilateral agreements.

Though NEA is still establishing its role, sectoral progress depends on NEA fully operationalizing, managing guidelines, managing donor and grant funding, and focusing on community-based development across the country. Several multilateral agencies, bilateral agencies, nonprofit organizations, and foundations have participated in economic development activities in PNG. Prominent programs include:

PNG Electrification Partnership (PEP). Australia, Japan, New Zealand, and the United States of America created the PNG Electrification Partnership during the 2018 APEC Leaders' Summit in Port Moresby. The goal of this program is to help PNG achieve its goal of connecting 70 percent of the population to electricity by 2030 through a pledge of $1.7 billion. Under this partnership, USAID launched its five-year project USAID-PEP to provide electricity to at least 200,000 households in PNG.[231] The goal of this five-year project is not only to strengthen PPL's capacity to expand connections and reduce system losses but also to develop viable off-grid electrification models in remote communities.

***Pawarim Komuniti*.** The Government of Australia runs *Pawarim Komuniti* (part of its Economic and Social Infrastructure or ESIP program) to help provide rural households and businesses in PNG with reliable and affordable electricity. The program funds a wide range of projects, including solar and hydro mini-grids as well as QV SHS. The program also aims to help the GoPNG, the private sector, and other partners work collaboratively to develop sustainable off-grid electrification models. This program is part of the Government of Australia's commitment under the PNG Electrification Partnership to help PNG meet the target of connecting 70 percent of the country to electricity by 2030.[232]

Facilitating Renewably Energy and Energy Efficiency Applications for Greenhouse Gas Emission Reduction (FREAGER). The United Nations Development Programme leads the FREAGER project to enable the application of feasible renewable energy and energy efficiency technologies through energy policy, planning, and institutional development; renewable

[231] US Agency for International Development, "U.S. Government Delivers on PNG Electrification Partnership Promise."

[232] "Pawarim Komuniti: Papua New Guinea Off-Grid Electrification Program."

energy and energy efficiency technology applications; financing renewable energy and energy efficiency projects; and promoting energy development and awareness.[233] This project was developed in cooperation with PNG Power Limited and the provincial governments of Eastern Highlands Province, Milne Bay Province, Morobe Province, and East Sepik Province.

USAID *Lukautim Graun* Program. The USAID *Lukautim Graun* Program (LGP) has completed a program to identify MSMEs and livelihood development in PNG's industries, such as nature and wildlife conservancies. The program has effectively identified and is engaging with these MSMEs to help them develop their businesses. This presents an opportunity for USAID-PEP to identify their energy needs to help them expand.

Australia Department of Foreign Affairs and Trade. DFAT has a long history in the country and the Pacific, having managed and implemented several energy-related initiatives. DFAT's *Pawaraim Komuniti* initiative is an off-grid electrification program that helps communities in rural and isolated locations gain access to clean electricity, with Phase 2 of the program focusing on connecting health centers, aid posts, and clinics.

New Zealand Ministry of Foreign Affairs and Trade. MFAT's work in PNG focuses on increasing on- and off-grid electrification rates in villages and households. Through this, MFAT seeks to improve social services such as schools and health facilities to improve local livelihoods. As an example, MFAT worked with DFAT on a grid extension project to provide 5,000 households, six schools, and four health centers with electricity in the Central Province. MFAT continues to collaborate with other donors like DFAT and the United Nations on electrification efforts that directly benefit public works.

The World Bank and International Finance Corporation. The World Bank Group continues to support numerous development programs in PNG. The World Bank has supported the Government to prepare the NEROP and its implementation strategy and investment plan, and has reserved $100 million for off-grid and on-grid solutions in the country to support its implementation. Through its Lighting Global program, IFC has effectively pushed for durable and long-lasting QV solar off-grid products across the country, contributing to the growth of PNG and its energy sector. As a result, several Lighting Global partners have become interested in exploring activities in the country, increasing product competitiveness and supply.

Asian Development Bank. ADB has supported PNG's strategic objectives through a variety of technical and financial assistance. ADB has made significant contributions to the development of new grid infrastructure in PNG, which will connect remote communities that currently lack access to electricity. Once completed, ADB's activities will constitute a major contribution to the country's overall electrification rate.

[233] United Nations Development Programme, "Project Brief: UNDP/GEF Project on Facilitating Renewable Energy & Energy Efficiency Applications for Greenhouse Gas Emission Reduction (FREAGER)."

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