SELINUS UNIVERSITY
OF SCIENCES AND LITERATURE

RENEWABLE ENERGY AND ENERGY EFFICIENCY APPLICATIONS FOR GREENHOUSE GAS EMISSION MITIGATION - A CLEAN ENERGY TECHNOLOGY DEVELOPMENT, POLICY, AND SUSTAINABILITY APPROACHES: A CASE IN PAPUA NEW GUINEA

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A DISSERTATION

Presented to the Department of
Energy Engineering
program at Selinus University

Faculty of Engineering & Technology
in fulfillment of the requirements
for the degree of Doctor of Philosophy
in Energy Engineering

2024

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ACKNOWLEDGEMENTS

First and foremost, I would like to express my profound gratitude to our Almighty God, who gave me the energy, strength, courage, and wisdom in preparing my PhD Dissertation until the completion of my research and data collection. All of these would not be possible without his divine presence, interventions, and holy will. Also, to my spiritual father, St. Padre Pio de Pietrelcina whom I kept asking for his daily intercessions and spiritual directions – instrumental for the success of my data collections, analysis of results, and organization of summing up the actionable priorities, conclusions, and recommendations. I would like also to extend my heartfelt appreciation to the following individuals who have been substantially contributed to making my PhD Dissertation a successful research outcome.

To my General Supervising Professor and Coordinator, Dr. Salvatore Fava, for his expertise in advising, guidance, and patience that contributes value added to my PhD research experience. I appreciated his vast knowledge and expertise in many areas of conducting research and his assistance in making my PhD Dissertation detailed, comprehensive, and well organized. For Dr. Irene Difalco and Ms. Elvira Di Mauro, for their academic support extended to me while preparing to complete my Dissertation.

To my late parents Vidal Saing, Florencia Saing, my siblings (Luz, Merelie, Alcher, Zenaida, Mary Jeane, Ritcho, and Liz) for support, help and guidance. To my spouse, Judith for her moral support and unconditional love. And to my children, Jhudiel, Sealtiel, and Raphael Pia, for being my source of inspirations, motivations and joy to do the best of my intellectual capacity. Lastly, I want to thank my colleagues and true friends for their unwavering encouragements that made this journey possible all throughout the process of completing my PhD dissertation.

Thank you very much and may GOD continue to bless everyone.

ABSTRACT

Papua New Guinea's energy sector heavily relies on fossil fuels, with a growing demand for energy from industrial, transport, agricultural, and residential sectors. Currently, only 13% of the population has access to grid electricity, which is a major challenge. The government aims to raise the electrification rate to 70% by 2030 and achieve carbon neutrality by 2050. To meet these goals, they have launched the National Electrification Rollout Plan (NEROP), which includes grid extensions and off-grid energy solutions. Micro-grids and stand-alone systems will play a significant role in electrifying rural communities. To achieve 70%, rural access rates need to rise from below 10% to close to 65% over the next decade. The National Energy Policy 2017-2027 has been adopted to ensure an affordable, competitive, reliable, and sustainable energy supply. It establishes the National Energy Authority to lead the development of renewable energy resources and promote energy efficiency and conservation. However, energy efficiency has received less attention compared to increasing electricity access. To successfully implement their long-term plans and promote low-carbon development, PNG needs a national-scale energy efficiency program with a strong policy and regulatory framework. This study aims to promote the development of renewable energy and energy efficiency technologies in PNG to achieve the electrification and carbon neutrality targets. It aims to demonstrate the potential for reducing emissions resulting from increasing energy demand and economic development.

The study was conducted through a combination of desk research and consultations with various stakeholders in Papua New Guinea (PNG), including the government, private sector, academia, and civil society. The aim was to assess the market and gather perspectives on renewable energy and energy efficiency for mitigating greenhouse gas emissions in the country. The Government of PNG has recently passed the National Energy Bill, establishing a new National Energy Authority responsible for implementing the National Energy Policy and promoting renewable resources and electrification. This reform reflects the government's commitment to providing affordable and reliable electricity in PNG. The government faces challenges in reducing poverty and adapting to climate change. The government in Papua New Guinea is crucial for promoting renewable energy and energy efficiency applications for greenhouse gas emission mitigation. They will support the implementation of these technologies, reducing electricity costs and developing a rural electrification master plan. This study was prepared through desk research and extensive consultations to gather data from various sectors, including the government, industry, academia, and civil society. However, due to COVID-19 travel restrictions, stakeholder consultations were conducted through remote teleconferences with local assistance from the CCDA and UNDP.

The electricity market is vertically integrated, with PNG Power Ltd. responsible for generation, transmission, distribution, and retail sale. In 2020, the GoPNG approved the National Energy Policy 2017-2027 (NEP), which aims to implement institutional reforms to the energy sector. Energy efficiency is crucial for PNG, as it reduces greenhouse gas emissions, improves energy security, lowers energy demand, and provides cost savings. The 2030 Agenda for Sustainable Development (SDGs) recognizes energy efficiency as a key component of SDG 7, promoting affordable and clean energy. To ensure compliance with MEPS and enforcement capabilities, the GoPNG needs strong coordination mechanisms, including empowering lead agencies and departments to enforce energy efficiency requirements. Enhancing energy efficiency is a crucial national objective for PNG as it increases energy security and supports economic development across sectors. Utilities can utilize energy efficiency measures to lower emissions and optimize power systems in the electricity sector

CHAPTER 1

THE PROBLEM AND ITS SCOPE

1.1 Rationale

The energy sector in Papua New Guinea (PNG) relies heavily on fossil fuels, including substantial production, consumption and export of oil and gas. Demand for energy is expected to grow considerably, especially from the industrial and transport sectors, which account for the largest share of energy consumption, followed by the agricultural and residential sectors. Electricity access remains a critical development challenge for PNG, as approximately 13% of the population has access to grid electricity.

The Government of PNG (GoPNG or "the Government") aims to increase the national electrification rate to 70% by 2030 and to make the country carbon neutral by 2050. In 2019, the Government launched a USD 1.7B (PGK 5.7B) National Electrification Rollout Plan (NEROP) to achieve its electrification targets through a combination of grid extensions and off-grid energy solutions; due to geographic barriers and small-scale household energy needs, micro-grids and stand-alone systems will play a significant role in electrifying PNG's rural communities. In order to achieve the Government's 70% electrification target, it is estimated that rural access rates will need to rise from below 10% to close to 65% over the next decade.

In 2020, the GoPNG adopted the National Energy Policy 2017-2027 (NEP), which presents a range of policies, strategies, and structural reforms that aim to ensure an affordable, competitive, reliable and sustainable supply of energy to meet national and provincial development objectives at least cost while protecting and conserving the environment. Among other measures, the NEP established a designated National Energy Authority (NEA) to lead development of the country's renewable energy (RE) resources and promote energy efficiency (EE) and conservation. The NEP includes several regulatory measures that are designed to promote competition and private sector investment in the country's energy market.

To date, energy sector investment in PNG has prioritized increasing electricity access and improving power supply; however, relatively little attention has been given to energy efficiency. Energy efficiency investments in PNG have significant potential for cost savings and environmental benefits, particularly for the country's most energy intensive sectors. In order to successfully implement its long-term development plans and promote a shift towards low-carbon and climate-resilient development, the GoPNG will need to adopt a national-scale EE program supported by a robust policy and regulatory framework.

1.2 Statement of the Problem

For many years, Papua New Guinea relies on the excessive use of fossil fuels including substantial production, consumption and export of oil and gas to supply power and energy requirements for the economic activities. This important concern becomes a major economic problem among the local and the national government and is associated with inefficient and unreliable energy/ power supply issues generally in the main urban centers and access to electricity is very limited in off-grid rural areas.

Objective of the Study

The objective of this research study is to help develop a National Energy Efficiency Roadmap in order to strengthen policy, development planning and overall national literacy in relation to energy efficiency, renewable energy, and sustainability. Further, this study is envisioned to apply the most feasible renewable energy and energy efficiency sector recommendations to the Government of Papua New Guinea for sustainable development to achieve greenhouse gas emission mitigation. This research study is divided into the following sections:

a. Introduction: This section includes the background and context of the research scope,

b. Market Assessment: This section includes analysis of existing EE market conditions in PNG, including EE opportunities by sector and key barriers to EE market development,

c. Case Studies and Linkages: This section includes a review of case studies and linkages to international and regional EE programs and initiatives, and

d. Energy Efficiency Roadmap Design and Implementation: This section presents an energy efficiency roadmap for PNG, including proposed EE policies and regulations; management approaches; financing and business models; awareness creation; capacity building; research and development; monitoring, verification and enforcement; and a framework for implementation.

1.3 Significance of the Study

The expected outcome of this research study will identify potential areas of improvement in the entire energy efficiency and renewable energy ecosystems. Below are the identified sectors that would benefit the study.

General Public

The general public's demand for energy drives investments and developments in the sector. As the population grows and modernizes, there's an increasing need for reliable and affordable energy sources for households, businesses, and industries. It is evident that energy has great potential to become a significant catalyst for welfare improvements and economic prosperity in the country. Through the expansion of reliable and affordable electricity that will help advance inclusive growth, development, and empowerment in communities throughout the country.

Local Government

The PNG government seeks to create an enabling environment to encourage greater private sector participation in the energy sector. According to the MTDP, 2011–2015, the government plans to introduce a private sector growth strategy and a Public-Private Partnership (PPP) policy. The MTDP outlines the specific players who will be responsible for achieving key deliverables. It strengthens the National Government’s ability to monitor and evaluate investments over the coming years during the life of the PNGDSP 2010-2030. The provincial governments are responsible for managing the village power systems; however, due to the lack of an operating budget and maintenance capacity constraints, most village power systems have ceased to operate. Local governments should promote energy efficiency and conservation initiatives at the community level. This includes awareness campaigns,

incentives for energy-efficient technologies, and policies to reduce energy consumption in public facilities and buildings.

To give a gist, local governments are essential partners in the Papua New Guinea energy sector, contributing to infrastructure development, community engagement, resource management, economic growth, environmental stewardship, energy efficiency, disaster resilience, and regulatory oversight at the grassroots level.

National Government

Papua New Guinea (PNG) is a vast country with a population of 7.4 million people, of which only about 12.5% are estimated to live in urban areas. It is principally the urban areas that have access to grid connected electricity, and it is estimated that less than 10% of the total population has electricity access. Electricity access in rural areas is estimated to be under 3.7%. The mining industry, which is one of the main drivers of PNG's economy, largely depends on captive power stations for their operations. Addressing environmental concerns is a key responsibility of the government. This includes promoting renewable energy sources, implementing climate change mitigation strategies, and regulating emissions from energy production. Balancing energy development with environmental protection is essential for long-term sustainability. PNG recently established a regulatory body for the electricity sector, the National Energy Authority (NEA), to oversee the improvement and implementation of energy regulations in the country. Our technical assistance will help the NEA develop and implement stakeholder-informed rules, guidelines, and standards, including for off-grid electrification. This support will create a stronger enabling environment and facilitate private sector investment.

Electrification is important in realizing the agenda of the PNG Medium-Term Development Strategy aimed at export-driven economic growth, rural development, and poverty reduction. An expanded, more efficient electricity system will be an integral element of successful economic development in PNG. The government has included the power sector as a key sector in the PNG

Development Strategic Plan, 2010–2030. The proposed development of the power sector in each province is detailed in PPL's 10-year power development plan, which (i) lists the status of current infrastructure and proposed investments over a 10-year timeframe, and (ii) provides a road map of priority hydropower developments in the provinces to reduce reliance on diesel generation and improve service delivery. The investment program will support implementation of the power development plan. The National Government's involvement is crucial for shaping the direction of Papua New Guinea's energy sector, ensuring a balance between economic development, energy security, environmental sustainability, and social equity.

1.4 Scope and Limitation

Scope

The scope of the study mainly focuses on facilitating Renewable Energy and Energy Efficiency applications for greenhouse gas emissions mitigation specifically in four (4) provinces namely: East Sepik, Eastern Highlands, Milne Bay, and Morobe in Papua New Guinea. This study committed on its nationally determined contribution that the country’s electricity will be generated fully from renewable sources.

Limitation

The researcher would like to specifically limit this study on. The main feature of this study is to mitigate the use of fossil fuels that can contribute to Greenhouse Gas Emission in Papua New Guinea. This study is only limited through diversifying the utilization of renewable energy resources and promoting energy efficiency that produces no greenhouse gas emissions in four (4) provinces mentioned above. This study limits the designing of renewable energy sources but only facilitating what are existing and potential sources of energy.

1.5 Definition of Terms

Renewable Energy comes to limitless supply of natural resources such as sun and wind. It is a clean energy that helps the environment and climate change.

Energy Efficiency refers to utilizing less energy to accomplish the same activities with the same output. This is one way to establish sustainable development in the long run.

Greenhouse Gas Emission refers to the gasses that trap the heat in the earth atmosphere that can contribute to greenhouse effect and global warming.

Mitigation refers to the action of reducing or lessen the risk of the occurrence of harmful events.

Sustainability consists of fulfilling the needs of current generations without compromising the needs of future generations, while ensuring a balance between economic growth, environmental care and social well-being.

Clean energy is energy in full development to fulfill our current desire to conserve the environment and deal with the non-renewable fuel crisis.

Technology is the application of conceptual knowledge for achieving practical goals, especially in a reproducible way.

Policy is a set of ideas or plans that is used as a basis for making decisions, especially in politics, economics or business.

Development the process in which someone or something grows or changes and becomes more advanced.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Renewable Energy

One of the significant features in the energy policy is the call for harnessing renewables using appropriate technology. For example, the NEP reiterates the important role of both grid and off-grid renewable solutions in meeting the energy sector's long-term targets (DPE, 2017). This is backed by the DSP which sets a target of meeting all electricity needs through renewable resources by 2050 (Department of National Planning and Monitoring, 2010).

The overarching PNG vision 2050 plan also envisions electricity to be completely provided by renewable energy by 2050 (National Strategic Plan Taskforce, 2010), despite the country's INDC report stating that this should be achieved by 2030 (Climate Change and Development Authority, 2015) *Intended Nationally Determined Contribution to the UNFCCC.*

With minimal support from the government, off grid technologies have been introduced by mostly development partners to many rural communities since independence. However most of these projects have been unsuccessful (Isaka et al., 2013) due to the communities' lack of knowledge and skills to maintain the systems (Robinson, 1988; Sovacool et al., 2011), and inappropriate project design and implementation. Moreover communities have little understanding of the benefits of electricity and thus do not prioritize these projects (Sovacool et al., 2011).

It is widely accepted that decentralized systems using renewable sources have an important role to play in providing cost-effective electricity access (IEA/IRENA/UNSD/WB/WHO, 2019). Certainly, in the small offgrid standalone market, pico solar-lighting has been very successful in PNG, as shown by exponential growth in the recent IFC report (Engelmeier & Gaihre, 2019). According to the NEP, there are plans to use and upgrade geothermal and biomass generation from the existing generation capacity of 7 percent and 1 percent out from the total installed capacity. It is reported that a private sector

funded biomass project is set to become a genuine catalyst for the country's drive to embrace clean energy (PNG Biomass, 2017). This would entail wood chips being harvested from eucalyptus tree plantations in the plains of Morobe Province to supply a power plant of 30-MW generation capacity which has potential to feed into the Ramu Grid system under power purchase agreement with PNG Power Limited (PPL). In addition, a new study by the International Finance Corporation (World Bank Group) found that the majority of the rural population is using off-grid solar lighting and battery powered lamps (Engelmeier and Gaihre, 2019). This adds to the investment prospect of solar energy within the renewables and off-grid sector. All in all, the deployment of these renewables will allow increased access to electricity which is critical in the effort to accomplish the Government's ambitious target of 70 percent electrification.

Energy Efficiency

Many developing countries have undertaken substantial reforms in their energy and power sector over the years. According to Zhang et al. (2008), the reforms were driven by strong intent to address poor performance of State-owned electricity operators in terms of high costs, inadequate expansion of access to electricity services and unreliable supply. It is a daunting challenge producing reliable electricity service which is accessible by the needed population in an affordable manner. It is noted that the State utility who is tasked to generate and supply power is reported to be riddled with multi-faceted problems ranging from financial constraints, aging infrastructure to poor leadership and mismanagement (Post Courier, 2019). It builds on the existing policies and development plans relevant to the sector such as the Electricity Industry Policy (EIP), 2011, and the PNG Development Strategic Plan (DSP), 2010-2030. In line with the key themes in those documents, the policy emphasizes the development of renewable energy to cut down on the use of fossil fuels. It also focuses on improving reliability and expanding access to electricity in a manner affordable to the users. The policy envisages that 70 percent of the population will have access to electricity by 2030 through the implementation of the National Electrification Rollout Plan (NEROP) (DPE, 2017).

Based on the grid-connected concept, the current electricity policies all align with the PNG

Development Strategic Plan 201-2030 (PNGDS2030) target of connecting 70% of households by 2030 (Department of National Planning Monitoring, 2010). Under the EIA2002 the role of increasing provision of electricity was left on the shoulders of PPL through their internal community service obligation. However, apart from the limited support from the Government, PPL lacks the technical and financial capacity to extend the grid (Asian Development Bank, 2017; Isaka et al., 2013; World Bank, 2019).

Greenhouse Gas Emission

In March 2008, Papua New Guinea entered into a cooperative agreement with Australia to reduce greenhouse gas emissions from deforestation and forest degradation: the 'Papua New Guinea–Australia Forest Carbon Partnership'. Nearly two-thirds of PNG's land area is forested (more than 29 million hectares). Emissions of greenhouse gasses were calculated in accordance with methods provided by the Australian Greenhouse Office (AGO, 2006) and Australian Department of Climate Change, which are generally in accordance with the World Business Council for Sustainable Development/World Resources Institute Greenhouse Gas Protocol. Government needs to embrace and support climate change plans. The National REDD+ Strategy (2017-2027) offers a strategic framework to address land use emissions. Incentives from Green Climate Funds should be accessible to encourage forest conservation. PNG's forests, vital carbon sinks, are declining due to land use activities. However, the increase of greenhouse gas emissions, particularly of carbon dioxide, nitrous oxide [commonly known as laughing gas], and methane, in the atmosphere enhances radiative forcing upsetting the earth's energy balance which becomes destructive and destabilized this equilibrium resulting in global warming (World Meteorological Organization, 2022). According to IPCC AR6 Report (2023), the global net anthropogenic greenhouse gas emissions are carbon dioxide gas (derived from fossil fuel combustions and industrial processes), methane, and nitrous oxide (from agricultural and land use and land use change activities). The National REDD+ Strategy (2017-2027) offers a strategic framework to address land use emissions. Incentives from Green Climate Funds should be accessible to encourage forest conservation.

OCCD (2014) aims to enable 'a robust and sustainable economy for Papua New Guinea through a low carbon pathway and green economic growth'. Mitigation and adaptation to climate change form the core themes of the policy. Adaptation strategies included in the policy cover quantifying and prioritizing hazards, identifying and selecting interventions, sectoral coordination and institutional strengthening. Importantly, mitigation strategies include an aspiration for PNG to be carbon neutral by 2050, a prioritization of land use and forest sector emissions abatement, focus on green economic growth, REDD+ and sustainable land use planning.

FIJI

Renewable Energy

Power generation in Fiji is dominated by renewable energy sources (67% from Hydro, Biomass and Wind) and the Government of Fiji has an ambitious target to achieve 90% of total energy generation from renewable energy sources in 2015. Taking into account high import costs for fossil fuels and the continued reduction of renewable electricity generation costs, this ought to be an economically attractive option (IRENA, 2013). FEA has in its Mission Statement published in 2011, "… aims to provide clean and affordable energy solutions to Fiji with at least 90% of the energy requirements through renewable sources by 2015". This means a target for maximum renewable energy generation using hydropower, biomass, and wind, either through FEA's generation or with assistance from the Independent Power Producers (IPPs). Considering the current situation, the further development and utilization of renewable energy, particularly exploitation of hydro and biomass energy should be accelerated in the power sector.

Energy Efficiency

The FREPP is also consistent with the priorities outlined in the National Energy Policy (NEP) that has the vision of. A sustainable energy sector for Fiji and a mission. To provide an enabling environment for a sustainable energy sector *(In 2012 the Fijian economy grew by 2.2%, up from 1.9% in 2011 and 0.1% in 2010. The economy is projected to grow by a very strong 3.6% in 2013 and forecast growth for 2014 is 3.0% (source: 2014 National Budget Announcement, Govt. of Fiji)*

Petroleum consumption in 2007 was about 844 million litres and petroleum demand is projected to be 1003 million litres in 2015 (source: Fiji National Energy Security Situation Report, 2010). As per the 2007 Census, 89% of Fiji's population has access to electricity. Further it is estimated that the overall grid electricity consumption annual average growth rate during 2007 to 2025 is about 4%. The Government of Fiji has an ambitious target to achieve 100% electricity access by 2030. The Government's Rural Electrification Programme is focused on increasing the electricity coverage to the entire population by 2016. Approximately 10% of the population is still without access to electricity and Fiji is struggling to provide remote areas and isolated islands with access to electricity in a sustainable manner. In conclusion significant measures need to be implemented to attain affordable, stable and secure source of energy for the future economic growth and prosperity of Fiji (*Source: FEA Presentation National Energy Forum April 2013).*

The first National Energy Policy10 (NEP) for Fiji was approved by the Fijian Cabinet in 2006. The main goal of the NEP is Affordable energy for all, ensuring that all Fijians have access to affordable and reliable modern energy services.

Greenhouse Gas Emission

As a Small Island Developing State (SIDS), Fiji is one of the country's most vulnerable to the impacts of climate change, while also being among those countries least responsible for contributing to the problem. Yet Fiji has in many ways demonstrated leadership in international climate action, by being the first country to ratify the Paris Agreement and serving as President of the 23rd Conference of the Parties (COP23) of the United Nations Framework Convention on Climate Change (UNFCCC). For Fiji's case, the transport sector accounts for 60% of the total petroleum consumption in the country (ECA, 2013). Fiji being an island country with around 900000 population is committed to reducing its fossil fuel consumption as noted in its Nationally Determined Contributions (NDC) to GHG reductions (GoF, 2015). A number of studies have been done globally, nationally and regionally to study how different strategic interventions are affecting fossil fuel consumption and GHG emissions. It was noted by Sadri et al. (2014) that energy-environment planning for transportation requires extensive data for

energy carriers, production, consumption and vehicle technologies.

The 5-year and 20- year National Development Plan (hereinafter National Development Plan or NDP) recognizes this in its vision of transforming Fiji, stating that "Consistent with the goal of the Paris Agreement to achieve climate neutrality and a low-emission world, [Fiji] will develop a 2050 Pathway to decarbonize the Fijian economy." *Fiji aims to reach net zero carbon emissions by 2050 across all sectors of its economy. This is consistent and aligns directly with Fiji's objective stated above to ensure that net zero emissions is achieved globally by 2050.* Fiji's 2050 LEDS vision is underpinned by similar visions contained in national development frameworks, including "a better Fiji for all," which guides A Green Growth Framework for Fiji (2014) and aims for accelerated green growth that is innovative, integrated, inclusive, inspires, and creates investment for transformational change and "transforming Fiji," the vision of the NDP (2017*).*

GUAM

Renewable Energy

In 2008, Guam's legislature enacted a renewable energy portfolio standard (RPS) goal for renewable sources to generate 8% of the island's electricity sales by the end of 2020. The renewable goal would increase to 10% of electricity sales by 2025 and to 25% by 2035. In 2019, Guam's legislature updated the voluntary standard so renewables would provide 50% of the island's electricity sales by 2035 and 100% by 2045. In 2015, Guam's first commercial solar PV facility—the 26-megawatt Dandan solar farm with more than 120,000 solar panels—began operating. The facility can generate enough electricity to serve an estimated 10,000 homes. The 60-megawatt Mangilao solar farm came online in 2022, and the planned 41-megawatt Malojloj solar farm is scheduled to be completed by December 2025. GPA plans to procure 180 megawatts of new renewable generating capacity by 2027, which in addition to solar energy could include biomass, wind, geothermal, and wave energy.

In 2008, Guam's legislature enacted a renewable energy portfolio standard (RPS) goal for renewable sources to generate 8% of the island's electricity sales by the end of 2020. *GPA offers net*

metering and pays its customers for surplus power they generate from small-scale solar, wind, and other customer-sited renewable generation installations. The surplus power is distributed on the island's grid.[66] All new net metering systems connected to the grid after June 2020 are required to have energy storage batteries to improve the reliability of electricity supplies.

Energy Efficiency

Guam's residential electricity costs, including fuel surcharges, are more than two times higher than the U.S. average, although Guam's residential electricity rates are typically the lowest among the nearby Pacific islands. Because petroleum products generate nearly all of Guam's electricity, GPA imposes a fuel surcharge that can be adjusted every six months to reflect changes in petroleum costs.

Greenhouse Gas Emission

Every day, GPA's progressive energy management brings Guam closer to a cleaner, greener energy environment. GPA is on-track to achieve 50% renewable energy by 2030 and 100% renewable energy by 2045. We applaud GPA's work toward these milestone achievements, in addition to bringing online the 24-megawatt utility-scale Energy Storage System in Hagåtña and the 16-megawatt utility-scale Energy Storage System in Talo'fo'fo.

MICRONESIA

Renewable Energy

NEP also aims to increase the share of renewable energy with the aim of reaching 30 percent of energy supply by 2020. Each of the four states has prepared its own action plan for meeting NEP goals. As part of the "Green Micronesia Initiative," FSM aims to increase energy efficiency by 50 percent, also by 2020. In September 2008, five grid-connected Solar PV Systems were installed (financed by the EU), four were roof mounted and one was post mounted. The total installed capacity is 52.3 kWp. Further projects currently underway will increase capacity to 400 kW, which will require proper power conditioning to maintain the quality of power supply. KUA operates and maintains the grid-connected solar PV systems.

Energy Efficiency

The government approved its National Energy Policy (NEP) in 2012, with the goal of becoming less dependent on imported sources of energy by having (i) an increased share of renewable energy sources, (ii) cross-sector energy conservation, and (iii) efficiency standards in place (source: *Government of the FSM, DORD. 2012. Page 10. 2012 Energy Policy: Volume I. Palikir).* To date, access to electricity varies across the country. 85% of communities in Yap, 94% of communities in Pohnpei and 98% of communities in Kosrae have access to electricity. However, the State of Chuuk has the lowest levels of access with approximately 30% of the population having access to electricity. To date, a large number of small-scale solar installations have been deployed in the Federated States of Micronesia, with a total installed capacity of almost 500 kW. To date, a large number of small-scale solar installations have been deployed in the Federated States of Micronesia, with a total installed capacity of almost 500 kW. Reflecting the geographic constraints of the nation, roughly one- of this capacity is deployed in off-grid or stand-alone applications while the remaining two-thirds is grid-tied.

Greenhouse Gas Emissions

Although Micronesia's contribution to global greenhouse gas emissions is minimal, the country is faced with some of the most devastating impacts of climate change. For this reason, the government has been a longstanding advocate for climate action, especially through short-lived climate pollutant mitigation, to quickly reverse the effects of climate change. Following the Strategic Development Plan, Micronesia developed the Climate Change Act in 2014 to address and integrate climate change action across ministries. The Climate Change and Sustainable Development Council were also established in 2017 to implement the Act.

SAMOA

Renewable Energy

In 2016, Samoa was estimated to have generated around 129.4 kilo-tons of oil equivalent. Of these, it was estimated that 27.3% was met by biomass, 69.0% by petroleum products while the

remaining 3.2% was met by hydropower, solar, wind and other minor renewables. Of the total primary energy supplied, 21% was transformed into electricity generation to give a net energy supply of 113.9 kilo tons of oil equivalent.

Energy Efficiency

Electric Power Corporation (EPC) IS THE SOLE SUPPLIER OF ELECTRICITY IN Samoa and is consistently striving towards 100% electricity generation from renewable energy sources by 2025. The electricity sub-sector is heavily dependent on imported fossil fuels and diesel generation remains the dominant supply of electricity, which is increased by 2% in 2025. The Government and EPC both work actively with stakeholders and prospective Independent Power Producers (IPP) to reduce the importation and use of fossil fuels through harnessing of locally available renewable energy resources, mainly solar, wind, and hydro resources. The 2030 Agenda for the Sustainable Development Goals (SDGs), which emphasizes a need to ensure access to affordable, reliable, sustainable and modern energy for all. This is to ensure that by 2030, there shall be universal access to affordable, reliable, and modern energy services, substantially increasing the share of renewable energy in the global energy mix, and to double the global rate of improvement in energy efficiency. *(Source: GA, U., 2015. Transforming our world: the 2030 Agenda for Sustainable Development. Division for Sustainable Development Goals: New York, NY, USA. 3 The Government of Samoa.*

Greenhouse Gas Emissions

The Government of Samoa, in its efforts to achieve its intended National Determined Contribution (NDC) under the United Nations Framework Convention on Climate Change (UNFCCC), looks to reduce Samoa's greenhouse gas (GHG) emissions from the Electricity sub sector through the adoption of a - 100% Renewable energy target for electricity generation through to the year 2025. Climate change impacts are adding to these challenges. With a small population and as a lower-middle income country, Samoa contributes very little to global CO2 emissions: less than 0.001% in 2019 (World Bank, 2023b).

Samoa currently produces 1.4 tonnes of carbon dioxide equivalent (tCO2- e) per person – well

below the global average of 4.4tCO2-e (World Bank, 2023). Its energy related emissions can primarily be attributed to the transport sector (which includes shipping between Samoa's islands, but not to and from the country), followed by emissions from electricity generation, which is almost exclusively from imported oil (IRENA, 2022). Samoa's first national climate change policy was written in 2007, alongside the NAPA. The recent iteration of 2020 provides a mandate for proactive national coordination across sectors and levels of government. Samoa's National Climate Change Policy 2020–2030 (NCCP) provides a more detailed and climate-focused framework for national adaptation and mitigation actions. It details the interventions needed by the public sector, private sector, civil society and communities to build climate resilience in line with the country's international obligations and sustainable development objectives.

TONGA

Renewable Energy

The Tonga Outer Island Renewable Energy Project (OIREP) will construct Solar Photovoltaic (PV) power plants on eight outer islands, with a total installed capacity of 1.25 MWp (GEF, 2016). Tonga is still reliant on imported fossil fuels for its overall energy needs despite the efforts to use renewable energy sources such as solar, wind, smart grid and biomass. Tonga's dependence on imported fuels is evident in the total fuel import, accounting for about 20% of the total import value in 2011 (SPC, 2012).

Energy Efficiency

Tonga is highly dependent on imported fuels to meet its overall energy requirements. In 2000, when the last energy balance table for Tonga was compiled, imported petroleum products accounted for 75% of Tonga's energy supply, with 25% coming from biomass and off-grid solar PV. All grid-supplied electricity, which accounts for over 98% of electricity used in Tonga, is generated using imported diesel fuel. Energy accounts were identified as a priority in an assessment report prepared by Statistics Divisions of Department of Resource and Development, FSM National Government with support from

the United Nations Economic and Social Commission for the Asia Pacific (UNESCAP) in 2015. The establishment of the Tonga Energy Road Map (TERM) 2010 - 2020 aimed to lay out a least cost approach and implementation plan to reduce Tonga's vulnerability to oil price shocks and achieve an increase in quality access to modern energy services in a financially and environmentally sustainable manner.

Greenhouse Gas Emission

The Tongan Government, in 2009, responded to the twin challenges of reducing the Tongan contribution to global Green House Gas (GHG) emissions and improving national energy security by approving a policy to supply 50% of electricity generation through renewable resources by 2012. The National Greenhouse Gas Inventory (NGHGI) chapter covers major greenhouse gas (carbon dioxide, nitrous oxide & methane) emissions from different sources under four sectors – Energy, Agriculture, Land use change and forestry (LULUCF) and Waste. Guided by the Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines for GHGI, Tonga's greenhouse gas emissions were calculated for the baseline year 2006 and reported a total emission of 310.41 Gg whereby 300.55Gg or 96.8% of the total emissions is carbon dioxide.

SOLOMON ISLANDS

Renewable Energy

ADB has also provided support for renewable energy by improving access to carbon finance under the Clean Development Mechanism through the establishment of the Solomon Islands Designated National Authority. All grid-connected electricity generation in Solomon Islands is currently fueled by diesel. Two grid-connected renewable energy projects are proposed for the Honiara grid: Tina River Hydropower Project (14 MW) and Savo Island Geothermal (20 MW). *SIEA manages two hydropower plants—Buala with a capacity of 185 kilowatts (kW) and Malu'u (32 kW)—but both are currently nonoperational due to landowner disputes and equipment needing replacement. Both issues are being dealt with. Both projects are to be developed by private sector financing through independent power*

producers. The Government of Australia, European Investment Bank, International Finance Corporation, and the World Bank are supporting the Tina River Hydropower Project.

A National Development Strategy, 2011–2020, prepared by the Ministry of Development Planning and Aid Coordination, highlights the long-term nature of developing renewable energy resources to provide access to affordable electricity in rural areas. The government's policy for the sector is presented in Solomon Islands National Energy Policy Framework, 2007 and the draft National Energy Policy Framework, 2013, which both prioritize development of renewable energy. Proposed investments in the sector are detailed in the draft Solomon Islands Renewable Energy Investment Plan, 2013.
Government of Solomon Islands. {2010}. National Development Strategy. Honiara 9 (i) Government of Solomon Islands. {2006}. Solomon Islands National Energy Policy Framework, 2007. Honiara. (ii) Government of Solomon Islands. {2013}. draft National Energy Policy Framework, 2013, Honiara. (iii) Government of Solomon Islands. {2013}. draft Solomon Islands Renewable Energy Investment Plan, 2013, Honiara.

Energy Efficiency

Access to electricity is extremely low in Solomon Islands. Grid-connected electricity is supplied to about 12% of the population. The overall access rate in Honiara is 64%, but access in the rest of the country averages just 6%, and five of nine provinces have access rates below 4%. Solomon Islands' electricity prices, the highest among Pacific Island developing nations (SPC 2012a), are part of the issue, as well as limited knowledge of (and limited existence of) energy efficiency and alternative energy supply policies and possibilities. The state-owned enterprise, Solomon Islands Electricity Authority (SIEA), "has the sole mandate to provide power across the country" (ADB 2014c, 2), as per compliance with the country's Electricity Act and State-Owned Enterprises Act (SIEA 2014c). According to the IRENA data, the goal was for 73% of the Solomon Islands' population to have access to electricity by 2020, with a further ambition to achieve universal electricity access for its population by 2050.

Greenhouse Gas Emission

The NDC defines actions to reduce emissions covering five-year periods starting 2020, with reference to 2025 and ending in 2030. Its commitment is to reduce its emissions by 14% by 2025 below 2015 and by 33% below 2015 by 2030. The NDC addresses the importance of international assistance to access financial and technical resources to enable its (conditional) contribution to a further 27% reduction in GHG emissions by 2025, and a further 45% reduction in GHG emissions by 2030.

TUVALU

Renewable Energy

In 2012, the Tuvalu Master Plan for Renewable Energy Electricity and Energy Efficiency was developed and endorsed by the government. This initiative is part of the Tuvalu Energy Sector Development Project and is supported by investments from the World Bank. The objective of the Master Plan is to outline the path for achieving 100% renewable energy in electricity generation by 2020 and to increase energy efficiency on Funafuti by 30% (Government of Tuvalu, 2012). The Tuvalu National Energy Policy (TNEP), formulated in 2009, and the Energy Strategic Action Plan defines and directs current and future energy developments so that Tuvalu can achieve the ambitious target of 100% RE for power generation by 2020. Tuvalu's Master Plan for Renewable Energy and Energy Efficiency (TMPREEE), 2012- 2020, outlines the way forward to generate electricity from renewable energy and to develop an energy efficiency programme. It has two stated goals: 1. To generate electricity with 100% renewable energy by 2020, and 2. To increase energy efficiency on Funafuti by 30%.

Energy Efficiency

The MPREEE outlines the way forward to generate electricity from renewable resources ("renewable electricity") and to develop an energy efficiency programme in Tuvalu. It builds on the Tuvalu National Energy Policy, 2009. In 2009, the government of Tuvalu adopted the National Energy Policy (NEP) setting out its 100% target. The National Energy Policy includes a mechanism which is analogous to a Renewable Portfolio Standard, which relies on most projects being funded by external

development assistance, on a bilateral basis with the Tuvalu Electric Company. As of 2020, the total installed generation capacity in Funafuti is 2,550 kW, of which 1,800 kW (74%) is diesel. Off-grid generators and solar PV installations make up the additional electricity capacity. Since 2012, there has been substantial donor investment in solar energy across the country. Starting in Funafuti, a 66 kWp grid-connected PV (funded by Japan) and a 9kWp solar PV standalone (funded by Australia, United Kingdom and United States) have been installed at the desalination plant.

By 2015, solar PVs had been installed at the government building (130kWp), Tuvalu Media (49 kWp) and Princess Margaret Hospital (75 kWp) in Funafuti as well as on the outer islands. Tuvalu's electric power industry is under the supervision of the Ministry of Works and Energy, and the Tuvalu Electric Corporation (TEC) is the state-owned power utility which plans, operates and maintains the generation, distribution and sales of electric power on the archipelago's inhabited islands (e8 Tuvalu Solar Power Project, 2009). Tuvalu does not provide specific targets or actions for commercial, institutional, and residential energy use. Despite this, Tuvalu has implemented some energy efficiency projects to support energy sector targets. The Development Bank of Tuvalu started a subsidy scheme for energy efficient appliances and housing retrofits in 2016. In November 2020, the bank was given financial assistance of US$38,600 to buffer the bank's existing energy efficiency program. The programme will now be enhanced and implemented as part of the FASNETT project13. The Department of Energy has also been running a quarterly education programme, broadcast on public radio, covering household energy efficiency. The project is set to be completed by the end of 2022. Tuvalu also passed the Energy Efficiency Act in 2016. The Act promotes energy efficiency and legislates control of the import, use, and sale of inefficient electrical appliances. Currently, 50% of electricity is derived from renewables, mainly solar, and this figure will rise to 75% by 2020 and 100% by 2025.

Greenhouse Gas emission

According to Tuvalu's draft Second National Communications, the Energy sector is the major contributor to CO2 emissions (100%). The Waste sector is the main contributor of CH4 emissions (74.7%) followed respectively by the Agriculture sector (24.7%). On a mass basis, emissions of CO2

are the most important. This is largely due to the importance of fossil fuel combustion as a source of CO2. Tuvalu's last comprehensive national GHG inventory was prepared in 2002. Data on electricity sector GHG emissions was updated in 2014. According to Tuvalu's Second National Communication (SNC), Tuvalu's total GHG emissions in 2014 were 18.47 Gg CO2e. Of this total, 11.16 Gg CO2e came from the energy sector (60% of total GHG emissions). Within the energy sector, electricity generation was the largest source of GHG emissions included in Tuvalu's SNC, contributing 5.43 Gg CO2e (49% of the total energy sector GHG emissions).

VANUATU

Renewable Energy

With regards, to energy access, Vanuatu has more than 60 inhabited islands and is extremely vulnerable to climate change but has only 9% electrification in off-grid areas (outside of urban concession areas). A USD 20million financing gap to achieve national energy access targets has been identified (NERM, 2016). At the same time under the sustainable energy objective, a target of 100% renewable energy in the electricity sector has been set for the year 2030 (INDC, 2015). The Government of Vanuatu (GoV) has set ambitious targets of reaching 100% renewable energy for electricity production by 2030, requiring 5% energy savings through energy efficiency measures in commercial and residential sector (source: *Vanuatu's Revised and Enhanced 1st Nationally Determined Contribution 2021–2030).*

In 2015-2016, GGGI in collaboration with the World Bank provided technical assistance to the Department of Energy for the revision of the National Energy Road Map (NERM). The revised NERM has identified five strategic areas for policy intervention in the energy sector: accessible energy, affordable energy, secure and reliable energy, sustainable energy and green growth (NERM, 2016). With funding from the Global Environment Facility (GEF) and implemented through the United Nations Development Programme (UNDP), the Department of Energy is implementing an energy project called 'Barrier Removal to Achieve National Energy Road Map Targets

for Vanuatu (BRANTV)'. BRANTV is initially supporting 40 communities with solar Photovoltaic (PV) and pico hydropower systems.

Energy Efficiency

Access to electricity nationwide is low (33%), however drops even further in rural areas. Low access to reliable, affordable electricity has negative impact on the livelihoods of households, particularly rural households. Where electricity is available in the provinces, it is largely diesel generated. Cost of electricity is high, however, quality of supply is high which is partially due to the electricity grids being operated by the private sector. High cost and limited access to electricity is having a negative impact on economic development, particularly in the provinces. Over-reliance on imported fossil fuels (diesel) also has a negative macro-economic impact.

This Project was established following a request from the Government of Vanuatu to support its development agenda for the energy sector. At the time, the newly approved Vanuatu National Energy Road Map (NERM) 2013-2020, developed with the support of the World Bank and funded by the Australian Government, was premised on three pillars: (i) government commitment and leadership in putting in place robust polices and staying on course for reform; (ii) empowering and holding key institutions accountable; and (iii) implementing a sector wide approach to planning and investments in the sector. Vanuatu's National Energy Road Map (NERM) 2016-2030 lists targets and objectives that the Government, through the Department of Energy (DoE), considers essential for overall growth. They include sustainable energy, and green growth. Both objectives allow increased penetration of renewable energy sources into electricity generation with a target for 2030 set at 100%. Energy and development are mutually reinforcing factors, in that energy not only results from, but also actively contributes to, economic growth and development in national aggregate average terms (IEA 2010). An energy sector priority identified in the road map is mitigating climate change through renewable energy, energy efficiency and conservation. A further objective is to reduce reliance on imported diesel and petroleum products through efficiency improvements in the transport sector and investment in renewable energy in the power generation sector. In June 2016, Vanuatu's Council of Ministers endorsed an updated

National Energy Road Map (NERM) 2016-2030 (NAB, 2016), which was initially developed in 2013. The NERM is based on a 15-year vision and identifies five strategic areas for policy intervention in the energy sector: accessible energy, affordable energy, secure and reliable energy, sustainable energy (including energy efficiency) and green growth.

Greenhouse Gas Emission

Energy is a large contributor to CO_2 – the burning of fossil fuels accounts for around three-quarters of global greenhouse gas emissions. So, reducing energy consumption can inevitably help to reduce emissions. However, some energy consumption is essential to human wellbeing and rising living standards. The increase and dependency on fossil fuel consumptions, Improper Waste management opportunities and approaches, increase in Livestock, and Land use and Land use changes which is also captured on the National GHG Inventory reporting to the United Nation Framework of Convention for Climate Change Convention (UNFCCC) being the most GHG emitting sectors nationally.

The government of Vanuatu endorsed the Vanuatu National Energy Road Map 2013–2020, implemented by the Department of Energy, which commenced in March 2013. This document provides for Vanuatu's future strategic direction on energy, including climate change mitigation, through increased use of renewable and geothermal energy. The road map will play a vital role in shaping renewable energy demand, energy efficiency and carbon dioxide emissions, and meeting proposed carbon intensity targets and climate commitments in the NSDP. A National Energy Road map will outline the energy sector's implementation plans to achieve the climate change and disaster risk-reduction commitments.

Vanuatu's CO2 emissions are amongst the lowest of all nations, and yet it is one that will suffer the most devastating impacts of climate change. The Vanuatu National Energy Roadmap proposes a long-term development plan for the energy sector to reduce its reliance on imported petroleum fuels and focuses on five energy sector prioritized – Access to secure, reliable and affordable electricity for all citizens by 2030 – Reliable, secure and affordable petroleum supply throughout Vanuatu – A more

affordable and low cost of energy services in Vanuatu – An energy secure Vanuatu at all times – Mitigating climate change through renewable energy and energy efficiency.

CHAPTER 3

METHODOLOGY

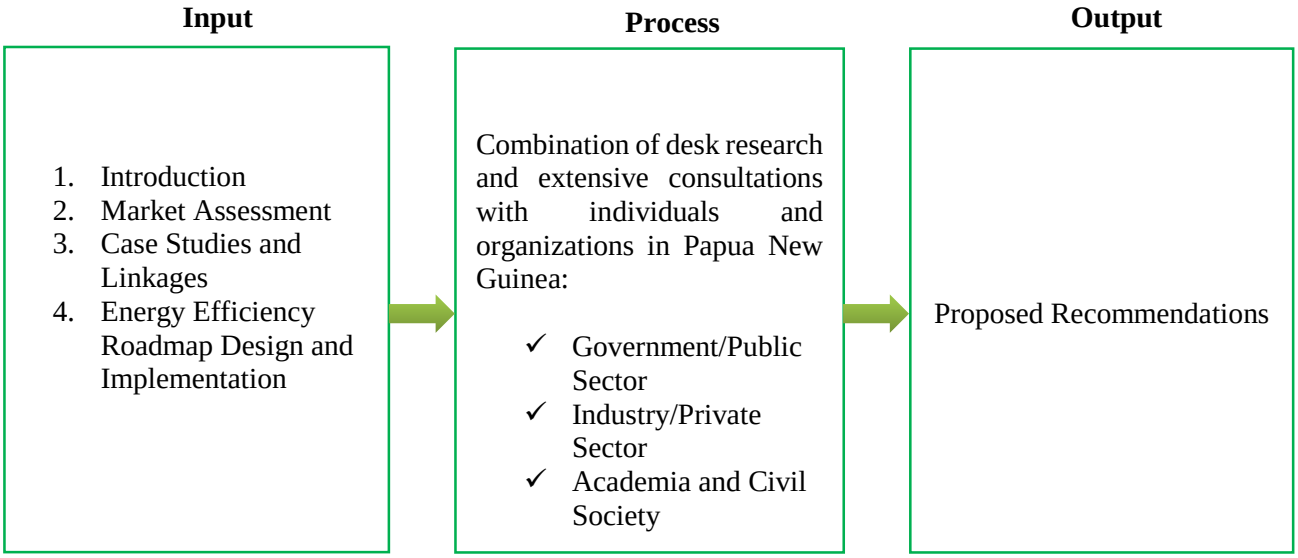
This chapter provides how the researcher gathered the information and data which are necessary for the completion of the study. It includes research design, research environment, research respondents, and research instruments.

3.1 Research Design

This study was prepared through a combination of desk research and extensive consultations with individuals and organizations in PNG's government/public sector, industry/private sector, academia and civil society. Missions to the country were initially planned in order to conduct a market assessment and better understand the perspectives of all stakeholders in facilitating renewable energy and energy efficiency applications for greenhouse gas emission mitigation wherein a case in Papua New Guinea.

These problems ensure the strategy and plans to achieve its electrification targets through a combination of grid extensions and off-grid energy solutions. Recently, the Government of PNG (GoPNG) endorsed and passed the National Energy Bill (2020) with immediate effect to set up a new National Energy Authority (Post Courier, 2021). The new entity will now take charge of all energy related matters including implementation of the National Energy Policy (2017-2027), development of renewable resources and electrification roll-out. It appears, the move is driven by an overwhelming desire to introduce needed reform in the sector in order to fulfill the government's aspiration to deliver affordable and reliable electricity in the country. The policy outlines the aspiration to produce affordable, reliable and sustainable energy through the harnessing of the energy resources, expansion of electrification, and effective sector planning and coordination. It also highlights the desire to harness the locally produced natural gas for domestic energy use (Department of Petroleum and Energy [DPE], 2017). It builds on the existing policies and development plans relevant to the sector such as the Electricity Industry Policy (EIP), 2011, and the PNG Development Strategic Plan (DSP), 2010-2030.

Figure 1: The Flow of the Study



3.2 Research Environment

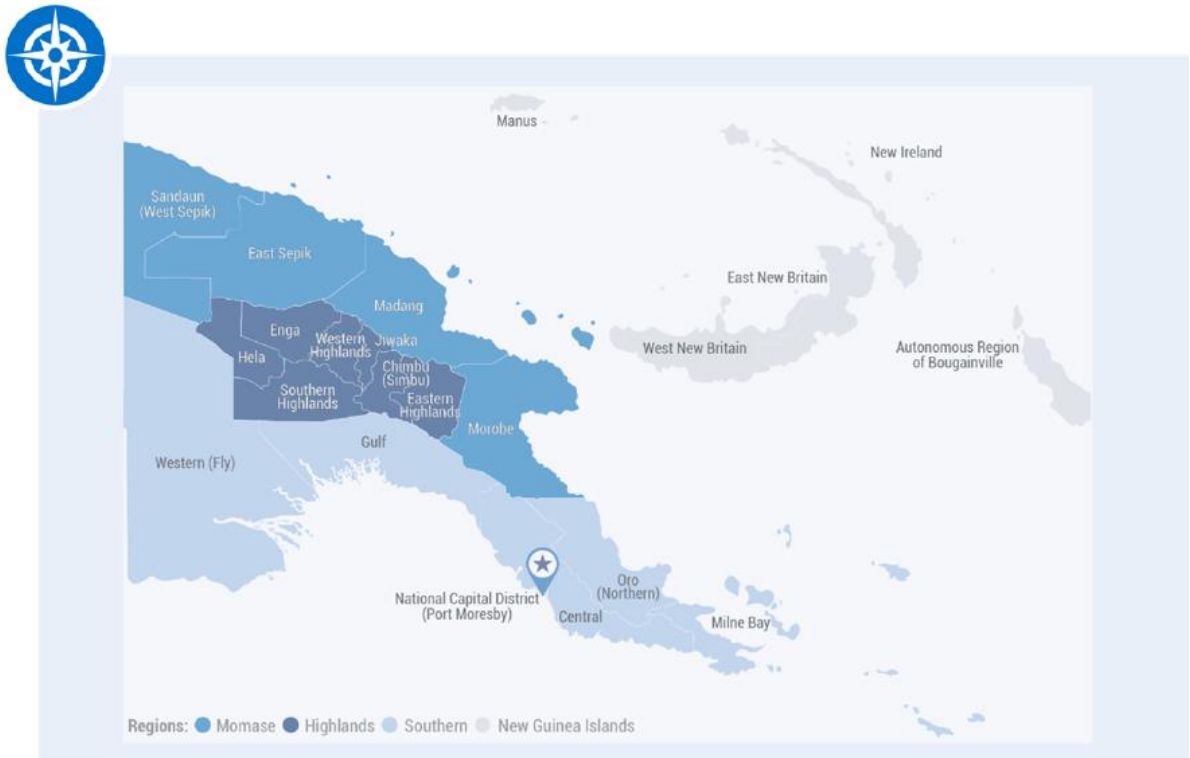
This study is conducted in Papua New Guinea in four provinces namely; East Sepik, East Sepik, Eastern Highlands, Milne Bay, and Morobe. In this procedure, through a combination of desk research and extensive consultations with individuals and organizations in PNG's government/public sector, industry/private sector, academia and civil society, appropriate data is necessary to answer the objectives of the study.

Figure 1 below shows the location of the study. This study is focused in Papua New Guinea. 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 2). The area of PNG covers more than 462,800 square kilometers, making it the third-largest island country in the world. 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. 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. Rural areas in PNG are predominantly inhabited, but their isolation is a result of the mountainous terrain, dense rainforests, and inadequate road infrastructure. PNG faces significant vulnerability to climate change impacts, such as temperature and precipitation increases, extreme weather events, rising sea levels, coastal erosion, and threats to food security, public health, and economic growth.

Despite its abundance of natural resources, PNG remains one of the least developed countries in the world, with about half of the population still living below the international poverty line. Going forward, the Government faces considerable challenges in its efforts to reduce poverty, provide opportunities for its young and rapidly growing population, and adapt to the worsening impacts of climate change.

Figure 2: Location of the Study



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

3.3 Research Respondents

The government or public sector is the key demographic as respondents and play an important role for facilitating renewable energy and energy efficiency applications for greenhouse gas emission mitigation in Papua New Guinea. The government will provide necessary support for the implementation of renewable energy and energy efficiency that will reduce the cost of electricity to the consumer by absorbing the capital cost of transmission lines and develop a rural electrification master plan while promoting off-grid renewable energy technologies.

3.4 Research Instruments

This section presents the source of information as well as the methods used in order to collect the necessary data for this study. This study was prepared through a combination of desk research and extensive consultations. In order to get the responses needed for the basis of the study the researcher used desk research and extensive consultations to those individuals and organizations in PNG's government/public sector, industry/private sector, academia and civil society. Desk research was created to gather information and insights by analyzing and synthesizing existing data and sources. In addition, it involves scouring through published reports, articles, studies, any other scientific databases, and any publicly available materials to extract valuable knowledge and make informed decisions while extensive consultations are seeking advice or opinion to professionals who are related to this study.

Data gathered is used to proceed to this study. In this procedure, may achieve consistent, precise and reliable data. Most data are taken in reliable sources, articles, desk research and extensive consultations.

3.5 Research Procedures

Data Gathering Procedures. Due to International travel restrictions associated with the COVID-19 pandemic, the missions were canceled and stakeholder's consultations were instead conducted through remote teleconferences with local assistance from the CCDA, UNDP, and local stakeholders.

CHAPTER 4

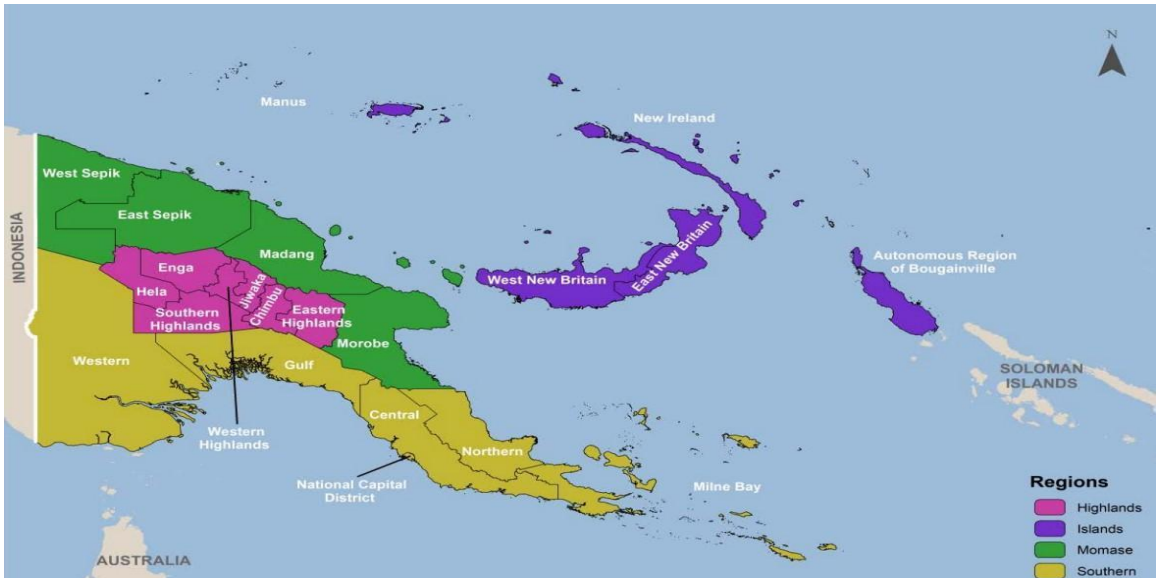
RESULTS AND DISCUSSIONS

4.1 MARKET ASSESSMENT

4.1.1 Country Overview

Papua New Guinea (PNG) is the largest Pacific Island country and the third largest island country in the world, comprised of four geographic regions and 22 provinces, which are further sub-divided into districts and local-level governments (**Figure 3**). As of 2021, the population of PNG exceeded 9 million people, most of whom live in the highlands and eastern coastal areas on the island of New Guinea. Port Moresby is the capital of PNG and its largest city, followed by the port city of Lae in Morobe Province, which is the industrial hub of the country. A large majority of the population lives in rural areas, which are typically isolated due to PNG's mountainous topography, dense tropical rainforests, and poor road infrastructure. PNG is particularly vulnerable to the impacts of climate change, including higher temperatures and precipitation levels, extreme weather events/natural disasters, rising sea levels and coastal erosion, and risks to food security, public health and economic growth.

Figure 3: Map of Papua New Guinea



Source: National Statistical Office of PNG

PNG is among the most culturally diverse countries in the world, with hundreds of indigenous ethnic groups and more than 800 spoken languages. Cultural dynamics are deeply rooted in tribal and ethnic identity, traditional social institutions, and relationships to the land. Social and political life is dominated by the *'wantok'* system ("one talk" in Tok Pisin, the national lingua franca), an informal social system where people who are related to each other by a common language, ethnicity, district or by provincial boundaries (defined as '*wantoks*') jointly participate in socio-political, economic, traditional, and cultural activities. In rural areas, the *wantok* system is typically embedded in smaller familial and clan units and is rooted in communal land holdings. While it has evolved over time, the system is a vestige of pre-state social organization, when the territory now known as PNG was home to small-scale, egalitarian, and non-stratified Melanesian societies. Economic growth has fluctuated over the last five years, impacted by volatile commodity prices, a magnitude-7.5 earthquake in 2018 that disrupted economic activity, and more recently by the COVID-19 pandemic. The formal economy in PNG is dominated by extractive industries – namely, the mining, production and export of gold, copper, silver, nickel, cobalt, timber, oil and gas – which account for the majority of export earnings and GDP. About 80% of PNG's energy exports are in the form of liquefied natural gas (LNG), which the country has been exporting since 2014 when ExxonMobil's LNG megaproject – the biggest private-sector investment in PNG's history – began production. PNG's reliance on natural resource export revenues leaves it vulnerable to commodity price fluctuations; for instance, the slowdown in global economic activity resulting from the COVID-19 pandemic has sharply reduced energy and commodity prices, which has in turn negatively affected the country's economic outlook. The World Bank estimates that real GDP growth in PNG will experience a contraction of 1.3% in 2020, after averaging an annual growth rate of 5.6% between 2010 and 2019. Employment in PNG's formal economy is relatively low, as most of the population works in the informal or subsistence economy. In rural areas, over 80% of the labor force is engaged in the agriculture, forestry and fishing sectors, while the range of occupations in urban areas tends to be more diverse. Cash crops such as coffee, cocoa, copra and palm oil, are grown both on large-scale plantations and by smallholders. Although the agricultural sector supports rural livelihoods and accounts for about 25% of GDP, agricultural exports make up a

relatively small share of total export earnings, as rural farmers are widely dispersed and have limited access to markets due to funding, logistical and transport-related constraints.

Despite its abundance of natural resources, PNG remains one of the least developed countries in the world, with about half of the population still living below the international poverty line. Going forward, the Government faces considerable challenges in its efforts to reduce poverty, provide opportunities for its young and rapidly growing population, and adapt to the worsening impacts of climate change.

4.1.2 Energy Market

4.1.2.1 Energy Sector Overview

The electricity market in PNG is vertically integrated, with state-owned utility, PNG Power Ltd. (PPL), responsible for the generation, transmission, distribution and retail sale of electricity throughout the country. The Independent Consumer and Competition Commission (ICCC) is the principal regulatory authority in PNG; in the power sector, the ICCC regulates licensing, industrial codes, tariffs and service standards and monitors competition. The National Energy Authority (NEA) is responsible for the development and administration of energy sector policies, regulations, programs and initiatives. The Climate Change and Development Authority (CCDA) is the coordinating entity for all climate change related policy and actions and is the Designated National Authority for PNG under the United Nations Framework Convention on Climate Change (UNFCCC). In 2020, the GoPNG approved the National Energy Policy 2017-2027 (NEP), which plans to implement a series of institutional reforms to the energy sector, including the unbundling of PPL, the establishment of the NEA to lead RE and EE development, and the creation of an independent Energy Regulatory Commission to take over regulation of the power sector and promote competition and private sector investment in the energy market.

The institutional and market actors that will play a role in development of the country's energy efficiency sector are summarized in **Table 1**.

Table 1: Institutional and Market Actors in the Energy Efficiency Sector

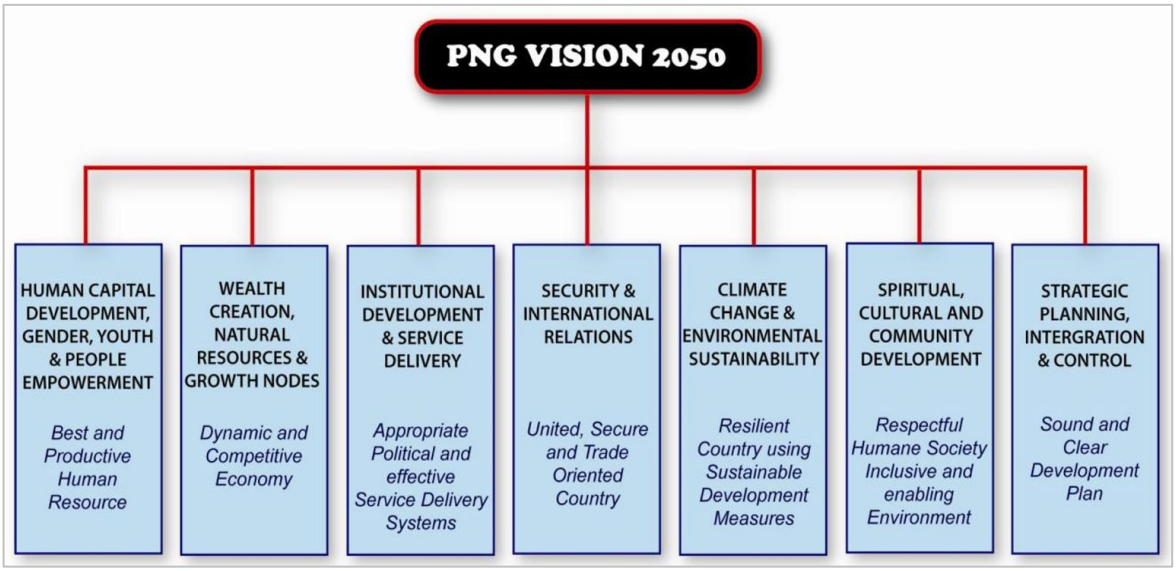
Institution / Market Actor	Role in the Energy Sector
National Energy Authority (NEA)	• Government agency responsible for overall energy sector planning, policy development and implementation, as well as management and oversight of all energy sector programs and initiatives • The Authority is responsible for management, coordination and implementation of the National Energy Policy (NEP), the National Electrification Rollout Plan (NEROP) and all other energy sector policies, plans, programs and functions • The Authority will take over some of the functions previously undertaken by the ICCC, the Energy Wing of the former Department of Petroleum and Energy and PPL, including licensing and regulation of the electricity supply industry for IPPs (i.e., generation, transmission, distribution, supply and sale of electricity)
Independent Consumer and Competition Commission (ICCC)	• Regulatory authority responsible for ensuring compliance with the laws and regulations governing the electricity sector, protecting the public interest and guaranteeing the continuity and quality of service • Responsible for issuing licenses to IPPs for electricity generation, the establishment of electricity tariffs and control of the maximum prices of some petroleum fuels
PNG Power Limited (PPL)	• Integrated, state-owned national electricity utility responsible for generation, transmission, distribution and retail sale of electricity • Works with the NEA on power sector planning
Climate Change and Development Authority (CCDA)	• Government coordinating entity for all climate change policies, programs and initiatives • Designated National Authority for PNG under the UNFCCC • Responsible for facilitating implementation of all policies and actions related to climate change mitigation under Pillar Five of Vision 2050
Conservation and Environment Protection Authority (CEPA)	• Established under the former Department of Environment and Conservation in 1985 and vested with the powers to protect the environment (air, water, soil and biodiversity) and promote sustainable use of natural resources in PNG • Responsible for policy development related to environmental management, biodiversity protection, pollution control, and management of water resources
Department of Prime Minister and National Executive Council (NEC)	• Coordinates government policy development, monitors policy actions, facilitates policy implementation and measures performance and effectiveness of policies and programs
Department of National Planning and Monitoring (DNPM)	• Leads, plans, coordinates and facilitates sustainable development planning to present a clear vision and direction for the nation's future • Monitors implementation of projects and programs undertaken in line with the nation's strategic development plans
Department of Finance (DoF)	• Prepares the national budget and provides policy advice on finance and resource management of government departments, provincial and local governments and state- owned enterprises
National Institute of Standards and Industrial Technology (NISIT)	• Government agency responsible for development and implementation of all technical standards used in PNG; coordinates with government to develop associated regulations for adopted standards • Responsible for managing accreditation and registration of products to meet specified standards
Department of Transport (DOT)	• Government agency responsible for development and implementation of policies, strategies, plans and projects across all modes of transportation in PNG (land, air, water)
Department of Works (DOW)	• Government agency within the Ministry of Transport responsible for management and implementation of infrastructure projects in PNG (buildings, roads, rural infrastructure) • Develops and regulates building codes and technical standards (e.g., materials for building construction) • Coordinates with Building Board, which provides construction permits • Conducts inspections to ensure compliance with permits/standards

Mineral Resources Authority (MRA)	• Regulates the mining industry and its management, exploration and development of PNG's mineral resources
Institution of Engineers Papua New Guinea Incorporated (IEPNG)	• Professional body that represents engineers from all engineering disciplines in PNG. • Provides services for about 1,400 members, who are classified into membership classes according to their level of education and extent of experience in engineering practice. • Provides training and professional development services through a four-year Graduate Professional Development Program.
Papua New Guinea University of Technology, Sustainable Energy Research Institute (SERI)	• Institute within the PNG University of Technology (UNITECH) that initiates and leads research activities in the areas of sustainable energy, energy technology development and transfer. • Collaborates with government, industry, the private sector and development partners to conduct research
Kumul Consolidated Holdings Limited (KCHL) *formerly known as Independent Public Business Corporation (IPBC)*	• Holding company with ownership in state-owned enterprises, including PPL (responsible for approval of PPL's projects) • Established as an independent entity to hold the majority of state-owned commercial assets and to manage those assets prudently to improve commercial performance and promote economic development
Western Power Ltd.	• Wholly owned subsidiary of PNG Sustainable Development Program Ltd. • Provides generation, distribution, and retail electricity services in the Western Province through small-scale power projects

4.1.2.2 Policy, Legal and Regulatory Framework

In 2009, the GoPNG developed PNG Vision 2050, which provided a detailed strategic framework to guide the country's development planning through 2050. The policy framework is supported by seven 'Strategic Focus Areas' or development pillars, designed to ensure that policies and sectoral plans be prepared and implemented in a coordinated, logical and effective manner with prioritized, achievable and measurable objectives and outcomes (**Figure 4**). The fifth pillar of Vision 2050 – Environmental Sustainability and Climate Change – seeks to make improvements in the areas of governance, education, awareness around the issue of climate change in order to pursue appropriate climate adaptation and mitigation measures, as well as to ensure proper environmental management, conservation and sustainable use of natural resources.

Figure 4: Seven Strategic Focus Areas of Vision 2050



Source: PNG Vision 2050

Energy efficiency will play a critical role in achieving the environmental sustainability objectives of Vision 2050, as it is a key driver of climate change mitigation and adaptation. Energy efficiency mitigates climate change by reducing energy-related CO_2 emissions and offsetting energy demand growth. There are also several ways in which EE supports adaptation to the impacts of climate change; for instance, EE measures can strengthen the resiliency of electric utility systems (e.g., through demand response and efficiency programs to counteract peak demand and address risks associated with extreme weather) and facilitate climate adaptation improvements in urban planning and building design (e.g., heating, cooling and lighting retrofits, weatherization, green roofs etc.), among others.

In order to realize the wide-ranging economic and social benefits of EE and promote a shift towards low- emission and climate-resilient development, the GoPNG will need to develop and implement a national- scale EE program supported by a robust policy and regulatory framework (the key elements of this framework are described in **Section 4.1**). As an initial policy measure, the Government has adopted the NEP, which underscores the importance of energy efficiency and conservation in PNG's long-term development planning. The NEP contains provisions to promote EE in all end-use sectors of the economy (buildings, industry, transport, agriculture residential), including through minimum

energy performance standards (MEPS) and labelling for equipment and appliances, among other measures.

Table 2 summarizes the energy and electricity sector policies, laws, regulations and roadmaps that have been adopted by the Government to date.

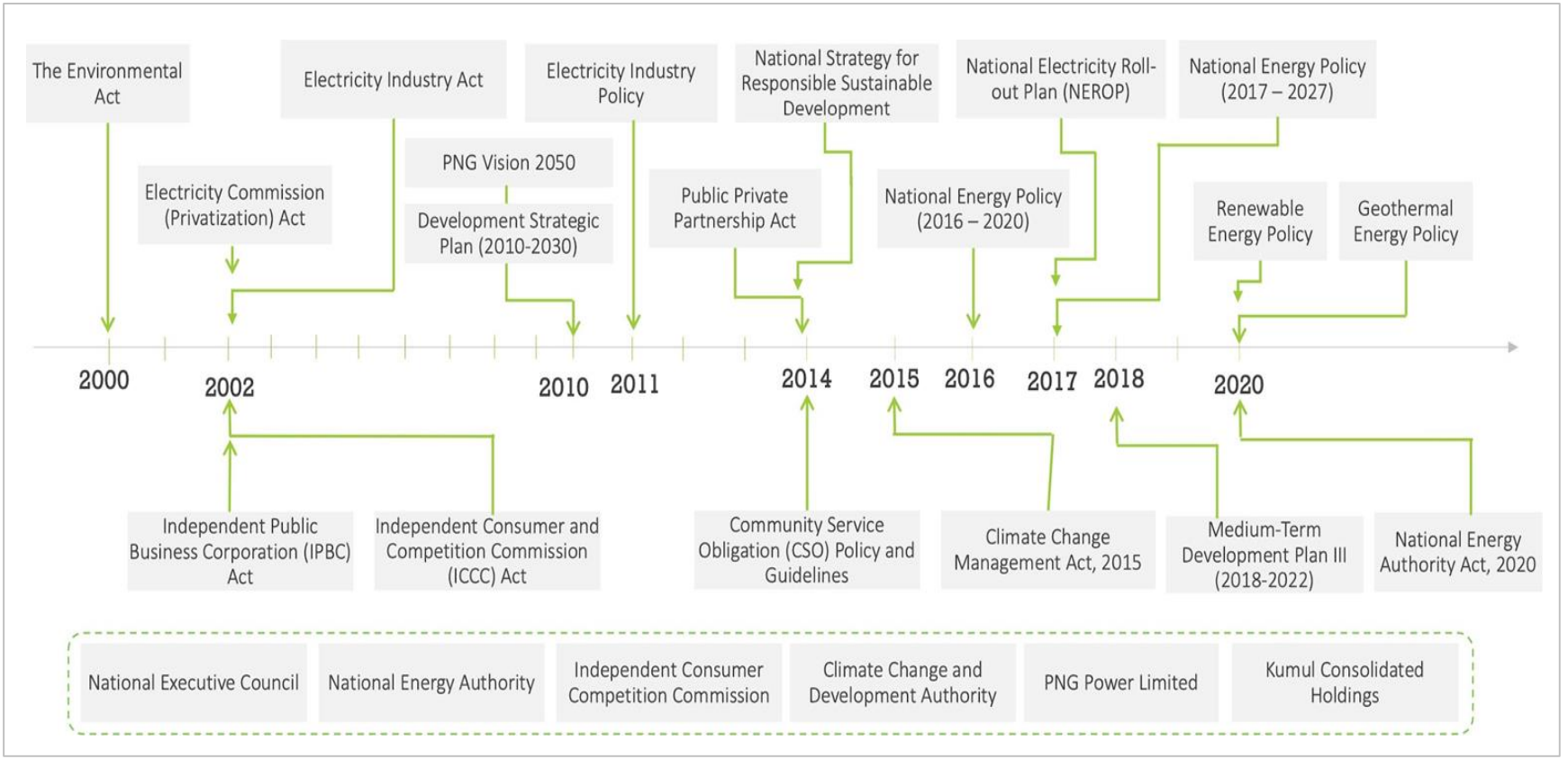
Table 2: Summary of Energy Sector Policies, Laws and Regulations

Name	Type	Description
PNG Vision 2050	Roadmap	• Comprehensive national roadmap and strategic framework to guide development planning through 2050 • Aims to achieve carbon neutrality for PNG by 2050 • Includes seven strategic focus areas, *including Climate Change and Environmental Sustainability* (see **Figure 4**).
National Energy Policy, 2017-2027 (NEP)	Policy	• Approved in 2020, the NEP plans to implement a series of institutional reforms to the energy sector, including the unbundling of PPL, the establishment of a designated National Energy Authority (NEA) to lead RE and EE development, and the creation of an independent energy regulatory commission (ENERCOM) • Includes provisions to formulate an Energy Efficiency and Conservation Policy to promote EE through the proposed NEA • Replaces the National Energy Policy, 2016-2020
National Energy Authority Act, 2020	Act	• The NEA Act was passed to regulate the energy industry through the establishment of the National Energy Authority. • The Authority is responsible for management, coordination and implementation of the National Energy Policy (NEP), the National Electrification Rollout Plan (NEROP) and all other energy sector policies, plans, programs and functions • The Authority will take over some of the functions previously undertaken by the ICCC, the Energy Wing of the former Department of Petroleum and Energy and PPL, including licensing and regulation of the electricity supply industry for IPPs (i.e., generation, transmission, distribution, supply and sale of electricity)
Renewable Energy Policy, 2020	Policy	• To be prepared with funding from the World Bank • Aims to achieve renewable energy production targets under the NEP
Geothermal Energy Policy, 2020	Policy	• Approved in 2020, establishes a framework to guide and promote the exploration, development and utilization of geothermal resources in PNG
Papua New Guinea National Development Strategic Plan (DSP), 2010-2030	Plan	• Establishes long-term electrification targets, including objective to increase electricity access to 70% of the population by 2030
National Electricity Roll-out Plan, 2017 (NEROP)	Roadmap	• Implementation plan/roadmap developed to achieve 70% electrification target by 2030 under DSP
Medium Term Development Plan III (2018-2022)	Plan	• Third development plan of its kind and the first to align with the parliamentary cycle of five years • Focuses on inclusive and sustainable economic growth

Climate Change Management Act, 2015	Act	• Provides for the legal and regulatory framework to: - Promote and manage climate compatible development through climate change mitigation and adaptation activities; - Implement any relevant obligations of the state under applicable rules of international law and international agreements related to climate change; and - Establish the CCDA as PNG's Designated National Authority for the purpose of managing all international climate agreements/treaties under the UN Framework Convention on Climate Change
National Strategy for Responsible Sustainable Development, 2014	Plan	• Development roadmap that intends to shift the country's socio-economic growth away from the unsustainable growth strategy that it is following towards a more sustainable path that will place PNG in a competitive, advantageous position into the future
Public Private Partnership Act, 2014	Act	• Defines the legal framework for undertaking PPPs • Establishes a PPP Centre, an unincorporated statutory body that will be responsible for assisting the government in developing, tendering and implementing PPPs
Community Service Obligation (CSO) Policy and Guidelines, 2014	Policy	• Defines a framework for providing CSO funding to PPL and other service providers to supply services at subsidized rates to rural or low- income populations
Electricity Industry Policy, 2011	Policy	• Defines the mandate and service areas of PPL • Designed to encourage private sector participation in the electricity sector to address three strategic objectives of the government: (i) Improved access in the provision of electricity services; (ii) Improved reliability of electricity supply; and (iii) Improved affordability of power for consumers
Independent Consumer and Competition Commission (ICCC) Act, 2002	Act	• Establishes the Independent Consumer and Competition Commission to promote competition and fair trading, the regulation of electricity and petroleum pricing, and to protect consumer interests
Independent Public Business Corporation of Papua New Guinea (IPBC) Act, 2002	Act	• Establishes KCHL (formerly the Independent Public Business Corporation), which is mandated to hold all Government-owned commercial assets in trust and to manage those assets to improve performance and underpin economic development
Electricity Commission (Privatization) Act, 2002	Act	• Establishes PPL as an electricity company responsible for the generation, transmission, distribution and retailing of electricity throughout PNG
Electricity Industry Act 2002	Act	• Stipulates the functions and responsibilities of PPL • Establishes an Electricity Commission to regulate the generation, supply and sale of electricity
The Environmental Act 2000	Act	• Regulates the environmental impact of development activities in order to promote sustainable development of the environment, provide for the management of national water resources and promote the economic and social well-being of the people

The key government stakeholders, and the policies, laws, regulations and roadmaps guiding development of the energy sector in Papua New Guinea are summarized in **Figure 5**.

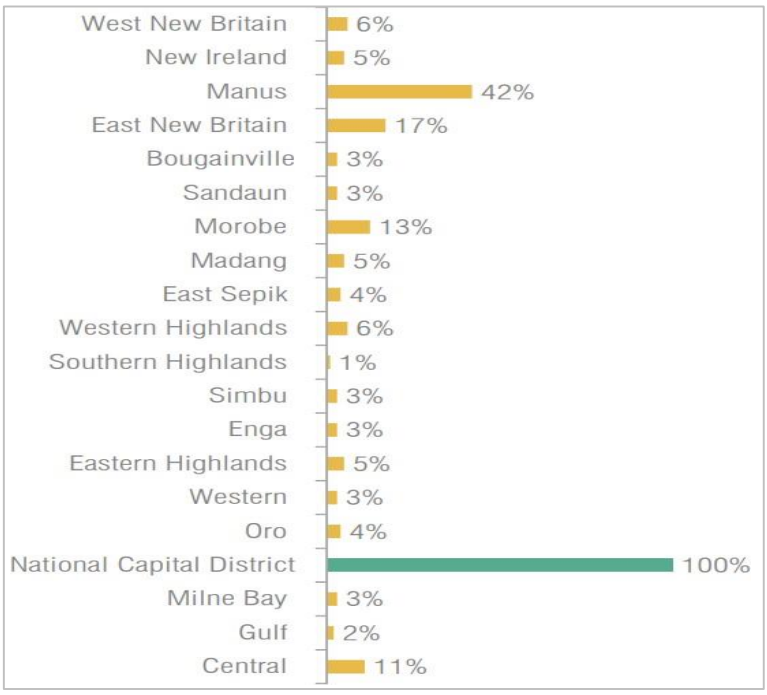
Figure 5: Key Government Stakeholders, Policies, Laws and Regulations in the Energy Sector, 2000-2020



4.1.2.3 Electricity Access

Electricity access remains a critical development challenge for PNG, as approximately 13% of the population has access to grid electricity. Where grid connections exist, the cost of service is high (about USD 0.30/kWh) and power supply is often unreliable, as PPL's network experiences frequent outages and load shedding. Overall, a significant gap exists between the infrastructure needs of the sector and the availability of resources to invest in the maintenance of grid infrastructure, as PPL is unable to fully recover the cost of supply from its customers. To date, utility investment decisions have been made on an ad-hoc basis and not based on long-term, least-cost planning.

Figure 6: Access to Grid Electricity by Province



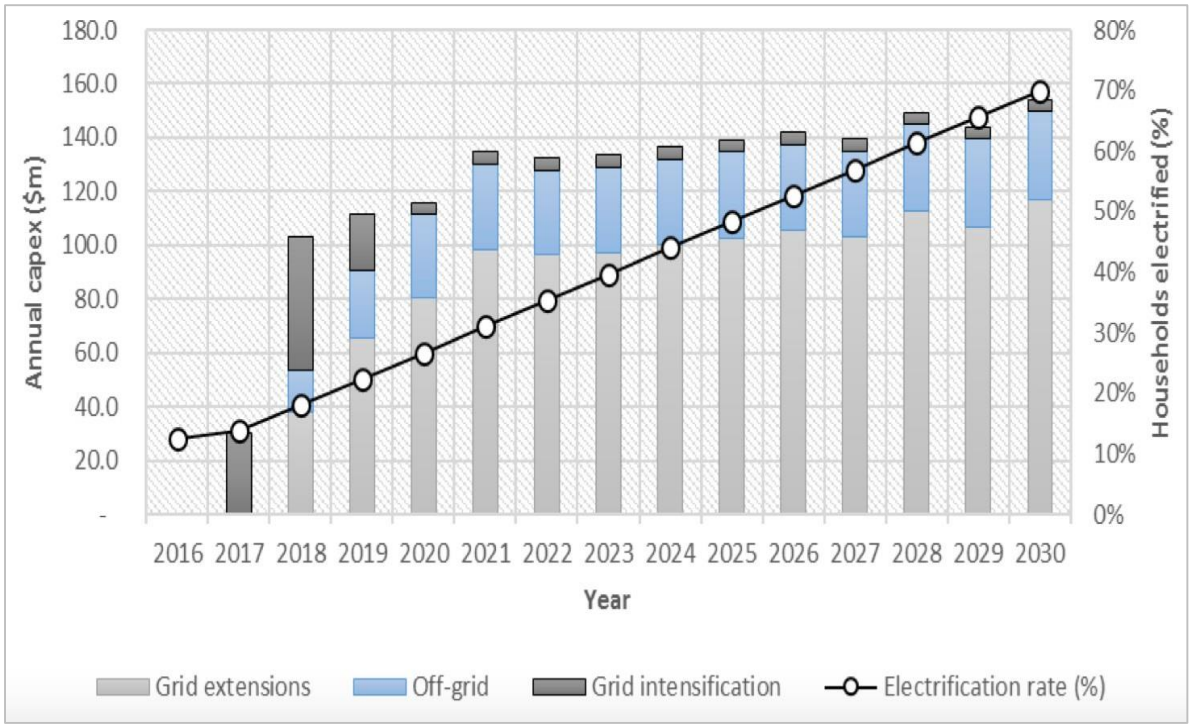
Source: National Research Institute of PNG; PPL

The Government aims to increase the national electrification rate to 70% by 2030. In order to achieve this target, it is estimated that rural access rates will need to rise from below 10% to close to 65% over the next decade, while an estimated 90,000 households will need to be connected to the grid each year.

In 2019, the GoPNG adopted the National Electrification Rollout Plan (NEROP), which includes a least-cost national electrification analysis as well as a series of proposed institutional reforms, regulatory

measures and funding mechanisms required to support implementation of NEROP and meet the 2030 electrification target. The analysis found that grid electrification is the least-cost option for approximately 75% of the nation's population that currently lacks electricity access, with mini-grids recommended for the majority of the remaining unelectrified population. The NEROP suggests that an Off-Grid Electrification Authority (OGEA) be formed as an affiliate of PPL to act as the country's procurement authority and asset manager for the off-grid sector. The study estimates that the total cost of achieving 70% electrification by 2030 is about USD 1.8 billion (**Figure 7**). During the 2018 Asia-Pacific Economic Cooperation (APEC) Summit, several countries (Australia, Japan, New Zealand and the USA) committed to support PNG's off-grid development through the PNG Electrification Partnership.

Figure 7: National Electrification Rollout Plan



Source: The Earth Institute at Columbia University and Economic Consulting Associates, 2017.

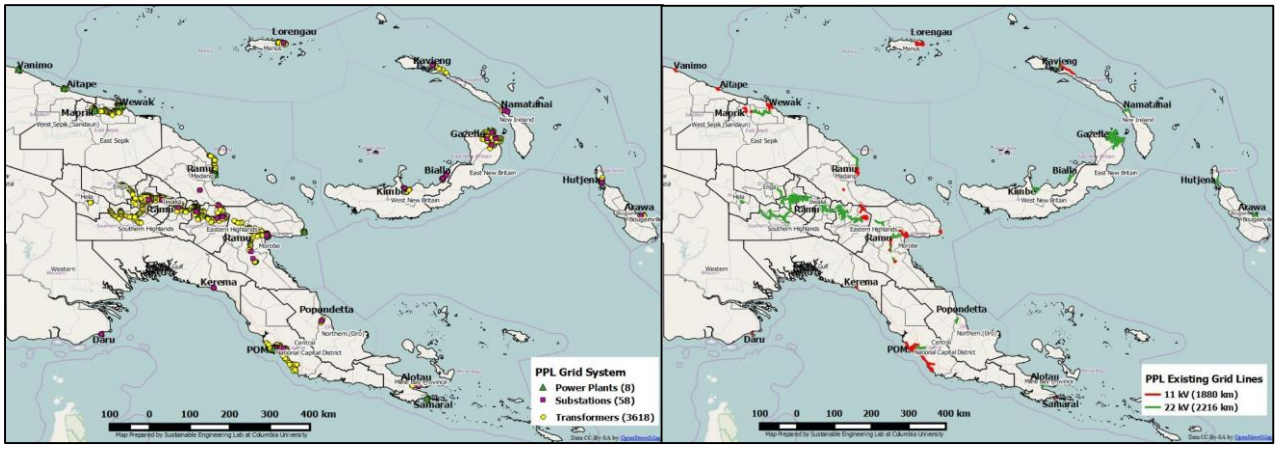
4.1.2.4 Electricity Supply

Electricity Generation Capacity

Papua New Guinea has about 580 MW of installed generation capacity, which relies mainly on a combination of hydropower, diesel and gas-fired generation; PPL manages about 300 MW of capacity, while IPPs manage about 280 MW. PPL operates three main grid networks – the Port Moresby system covering the capital; the Ramu system covering Lae and its surrounding areas in the Momase and Highlands regions; and the Gazelle system in East New Britain Province – and also manages a number of smaller isolated power systems largely serving provincial centers throughout the country (**Figure 8**).

Private generation is undertaken by mining companies, agricultural plantations and other extractive industries that rely on captive power for their own industrial or commercial operations, as well as by IPPs that sell power to PPL. Private operators utilize a variety of different technologies, including hydropower, natural gas, diesel, heavy fuel oil, biomass, solar and geothermal. As of 2020, five IPPs in PNG accounted for more than 200 MW of generation capacity either in operation or under development.

Figure 8: Map of PPL Grid Infrastructure (left) and MV Grid Network (right), 2016



Source: NEROP; The Earth Institute at Columbia University and Economic Consulting Associates, 2017.

Renewable Energy

Papua New Guinea is endowed with abundant renewable energy resources, including hydropower, solar, wind, geothermal and bioenergy; however, most of this RE potential remains untapped, as there are several barriers hindering development of large-scale renewables (see **Section 2.4**). For instance,

the presence of large hydropower generation capacity has kept PNG's electricity prices relatively low, which has in turn reduced the cost-effectiveness of grid-connected solar and wind technologies. Yet, there are substantial cost savings and emission reductions that can be achieved by fuel switching from diesel power to RE technologies. In off-grid areas, stand-alone solar systems will continue to play an important role in improving electricity access. Scaling-up the utilization of both on-grid and off-grid RE resources will be critical for PNG to achieve its long-term sustainable development objectives.

Hydropower

With its vast network of rivers, PNG has an estimated technical hydropower potential of about 15 GW, although no comprehensive hydrological studies have been completed on a national scale. Hydropower accounts for approximately 40% of Papua New Guinea's installed capacity, with hydropower plants operating in each of the country's three main power grids. The largest projects under active development include Karimui (1,800 MW), Ramu 2 (240 MW), Naoro-Brown (80 MW) and Edevu (50 MW), while the Asian Development Bank (ADB) is supporting the rehabilitation of several large hydropower projects and is leading development of run-of-river projects to increase electrification rates and supplant diesel generation in small rural centers.

PNG also has significant untapped micro- and mini-hydropower potential. A recent study that examined the potential of various renewable resources in PNG found that small hydropower ('run-of-the-river') is among the most cost-effective electrification options for rural villages in the country. Given the increasing availability of cost-effective mini-hydro technology solutions for rural areas (**Box 1**), more feasibility studies are needed to identify suitable sites for development.

Box 1: Turbulent Small Hydropower

Turbulent small hydropower (SHP) brings clean, reliable and affordable renewable energy to thousands of remote locations where hydropower was not previously viable. A key challenge for SHP technology has been to create a solution for low head water channels that is both scalable and financially accessible; Turbulent SHP systems address this specific issue. Designed for streams with very low height differences and involving minimal civil works and maintenance, Turbulent uses a vortex system to deliver stable and affordable renewable energy without damaging local ecosystems. Turbulent SHP systems generate up to 200 kW per turbine and up to multiple megawatts of energy as a network of decentralized turbines.[51] Turbulent recently developed small hydropower projects in Indonesia and the Philippines and is currently engaging in development partnerships throughout the ASEAN region.

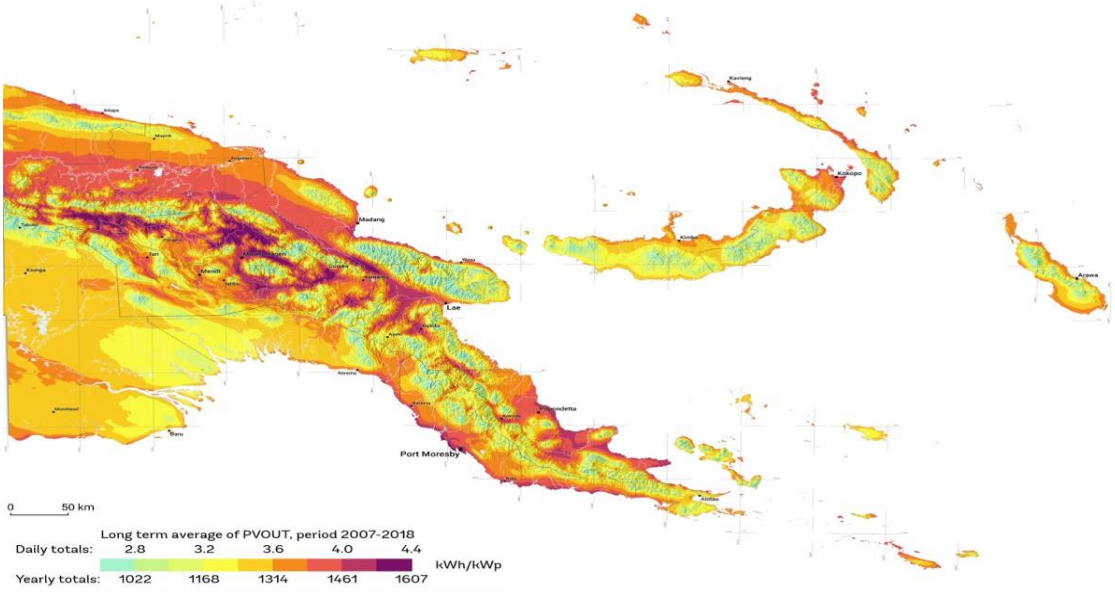
Source: Turbulent

Solar

Solar energy is among the largest potential sources of renewable energy in PNG (**Figure 9**). Although there have been few studies undertaken to confirm the resource on a national scale, the country's average solar insolation is estimated to be 400-800 W/m^2, with 4.5 to 8 sunshine hours per day. Solar radiation at a particular site is difficult to measure using satellite data due to PNG's mountainous terrain and cloud cover, which causes the amount of solar energy available at a given location to vary widely. There is significant solar potential in the capital, Port Moresby, as well as other urban areas, suggesting that solar PV can be utilized to replace existing diesel power generation and to meet shortfalls in electricity supply from existing grid networks. In 2018, PPL launched the PNG Power Pilot Rooftop Solar Program in Port Moresby, which has encouraged the participation of several local companies.

Given that such a small percentage of the population is connected to the main grid, PNG has one of the highest usage rates of off-grid solar products in the world. Existing applications of solar energy can be found in both urban and rural areas and include lighting, mobile phone charging, water heating and solar drying of agricultural products (coffee, cocoa etc.), particularly by smallholders.

Figure 9: Solar Photovoltaic Power Potential Map of Papua New Guinea



Source: World Bank, Global Solar Atlas, 2019.

Wind

Comprehensive data on wind energy potential for PNG is limited due to a lack of studies on a national scale. A preliminary World Bank resource mapping assessment identified a number of sites that might be suitable for development based on their comparatively high wind speeds. The country's average wind speed is around 4 m/s and average wind power is estimated to be 60 W/day, with good locations in coastal areas and on the islands. However, grid-connected wind faces many of the same barriers that hinder large-scale RE development in the country, including land accessibility and distribution infrastructure constraints, among others. Off-grid standalone wind turbines could be a suitable alternative to electrify remote communities, but a deficit of local skilled labor and PPL's lack of experience in the sector makes it difficult to attract the necessary private financing.

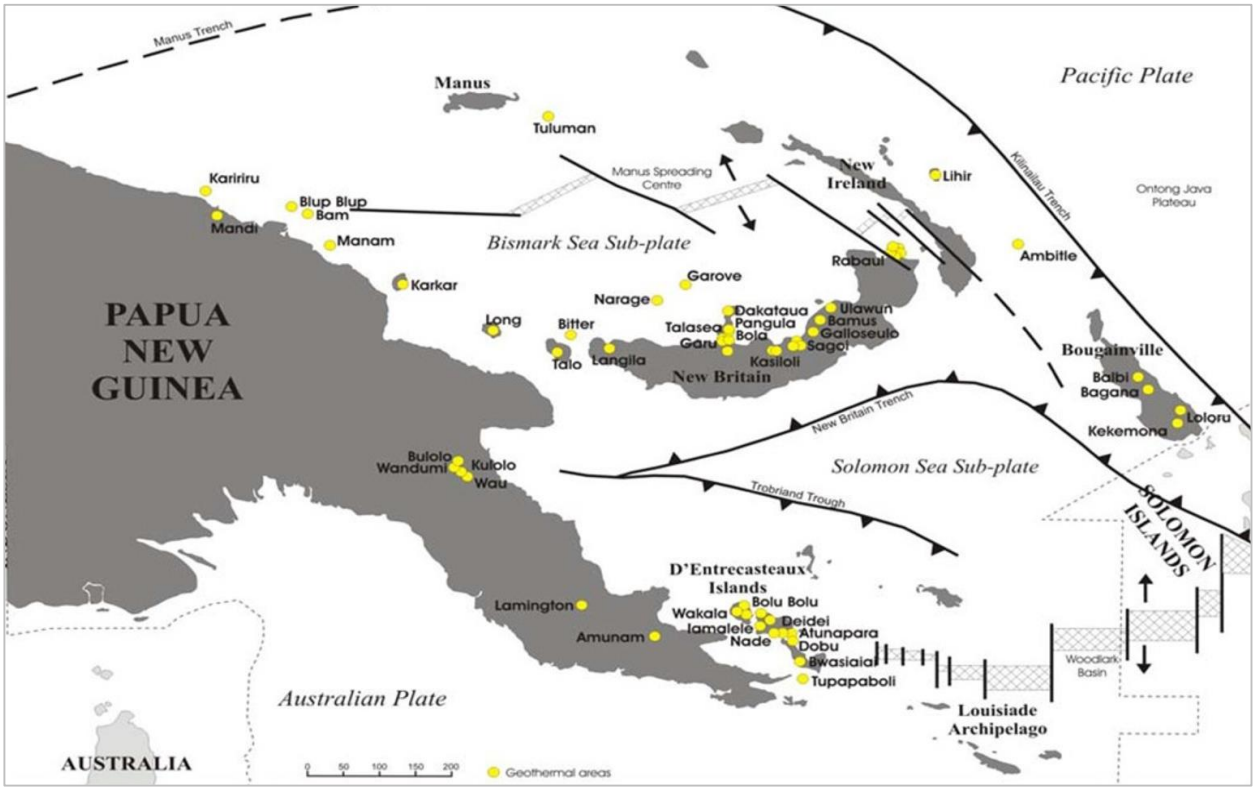
Geothermal

Situated along the Pacific 'Ring of Fire' – an area with the highest volcanic activity in the world – PNG has significant geothermal energy potential, including for electricity generation and direct use applications. According to the Mineral Resources Authority (MRA), with more than 60 active

volcanoes, the county's estimated geothermal potential exceeds 9 GW, although detailed studies are needed to assess how much of this is economically feasible for development. The MRA has identified the areas of New Britain and the D'Entrecasteaux Islands as having the greatest geothermal potential (**Figure 10**).

PNG currently has 56 MW of installed geothermal capacity on Lihir Island in New Ireland Province, which supplies electricity to the Lihir gold mine operated by Newcrest Mining Ltd. Other prospective industries in PNG that can benefit from geothermal heat and electricity include agricultural processing (e.g. drying of fruits, vegetables, grains, fish, coffee, cocoa and tea), aquaculture, greenhouses, the pulp paper and forestry industry (e.g. timber drying), and other energy-intensive industrial applications (e.g. water treatment, mineral processing). In 2020, the GoPNG endorsed a new geothermal resource policy, which provides a clear legal and regulatory framework for undertaking geothermal project development in the country.

Figure 10: Map of Geothermal Areas in Papua New Guinea



Source: Kuna and Zehner, 2015; Mineral Resource Authority

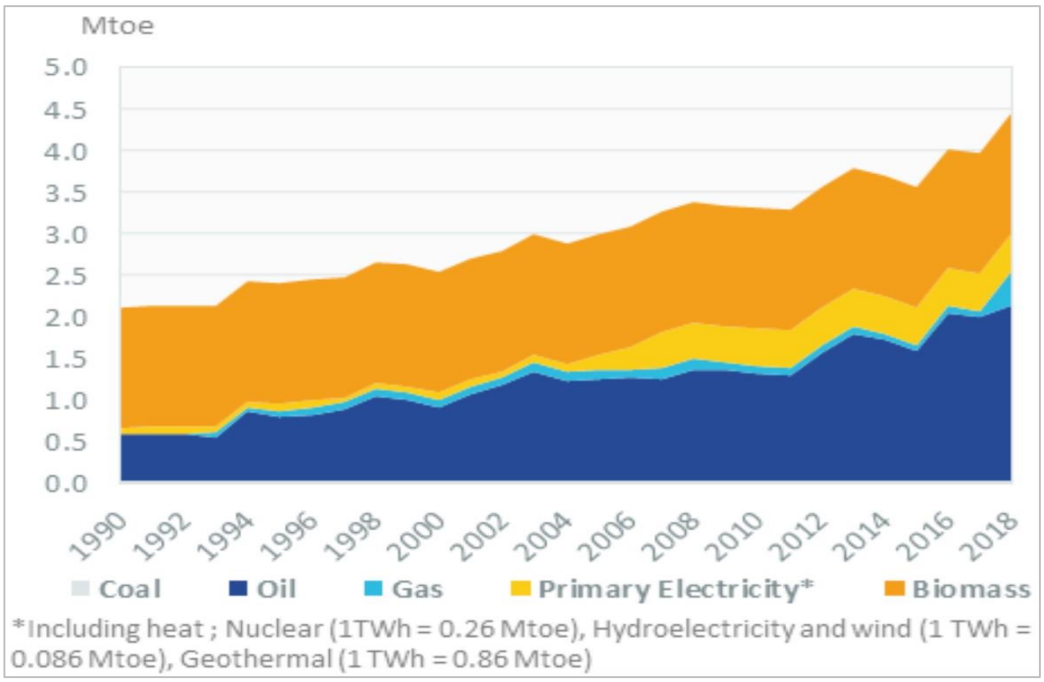
Bioenergy

Wood is still widely used in PNG for cooking fuel – a practice that is detrimental to the environment and poses significant health hazards that disproportionately and adversely affect women and young children. In the power sector, gasifiers produce electricity and process heat utilizing biomass waste in the oil palm, coffee, cocoa, sugar milling and wood processing industries. For example, New Britain Palm Oil Limited, a palm oil producer with processing facilities in five provinces of PNG, operates two biogas plants that utilize palm oil mill effluent to generate captive power. PNG Biomass, a private RE developer, is currently developing a 36 MW biomass project in Morobe Province that will offset 190,000 tons of CO2e annually. In the transportation sector, liquid biofuels (ethanol, biodiesel) can potentially replace or be blended with diesel fuel, but the practical potential of these technologies depends on the price of diesel as well their value as an export commodity.

4.1.2.5 Electricity Demand

In PNG, the extractive, industrial and transport sectors account for the largest share of energy consumption, followed by the agricultural and residential sectors. Despite the increasing penetration of off-grid solar products in the country, a majority of the population still relies heavily on petroleum products (petrol, diesel and kerosene) and biomass (fuel wood) to meet their energy needs for lighting and cooking (**Figure 11**). Domestic gas consumption has increased in recent years since the onset of megaprojects led by ExxonMobil, Total and Oil Search. Demand for electricity is driven by large, energy-intensive mining operations and industrial activities. Residential sector demand remains very low; in fact, PNG has one of the lowest per capita energy consumption rates in the world at about 420 kWh per year.

Figure 11: Consumption Trends by Energy Source (Mtoe)

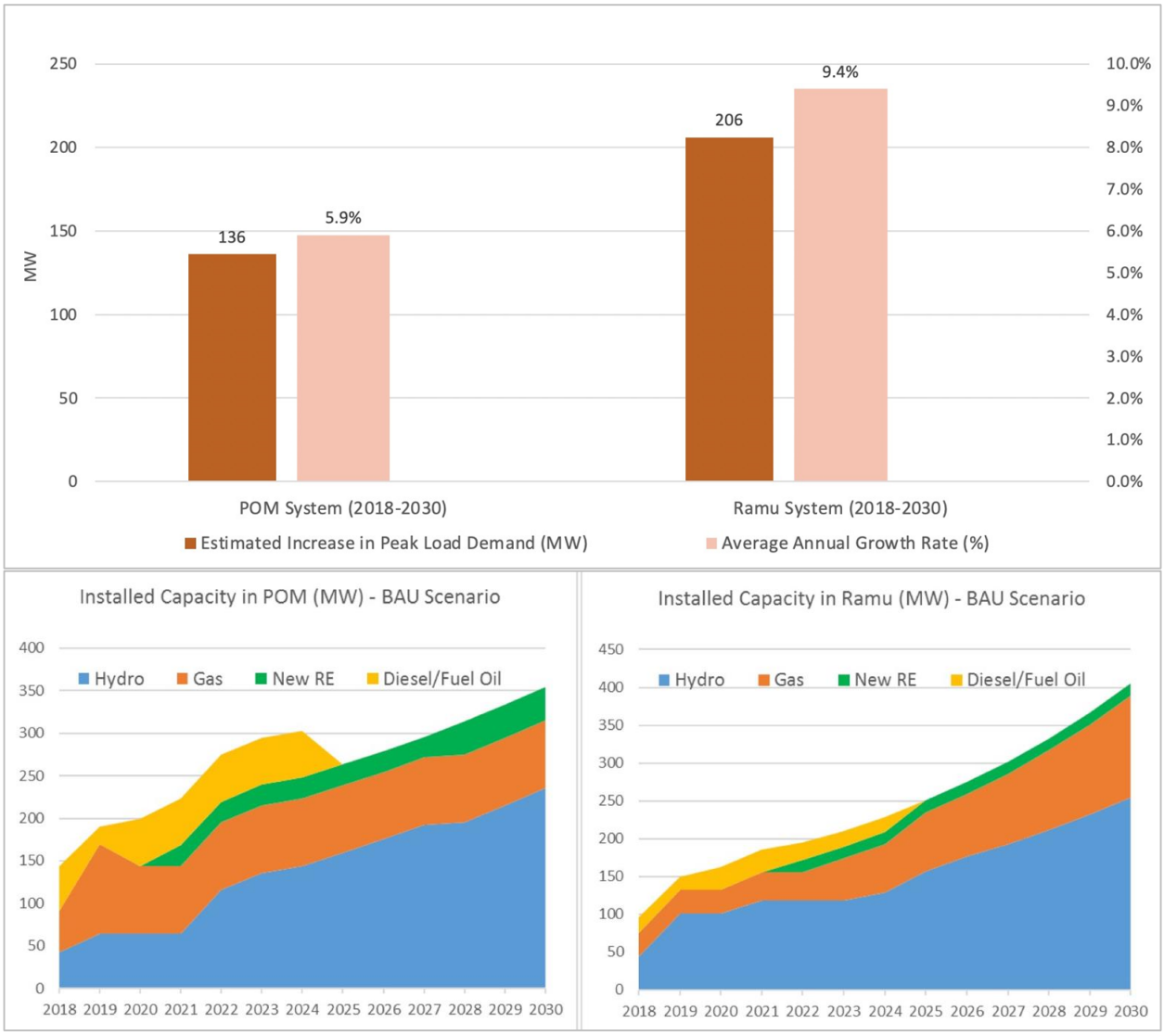


Source: Enerdata, 2019.

NOTE: Mtoe = Million tons oil equivalent
Graph includes total energy consumption for each energy product (i.e., sum of total production, balance of trade, aviation and marine bunkers, and stock variations)

Energy demand is expected to increase sharply over the next decade, driven by increased electrification planned under the NEROP, as well as growth in industry, mining and other sectors. In 2018, a World Bank estimate of electricity demand growth in the Port Moresby and Ramu grid systems found that the generation load would increase by a total of 342 MW through 2030, with an estimated generation load increase of 136 MW in the Port Moresby grid, and an estimated increase of 206 MW in the Ramu grid. Hydropower will account for the majority of the estimated installed capacity across both systems (**Figure 12**). The disparity in estimated demand between the two grid networks can largely be attributed to the mining and industrial activities that represent a significant share of demand in the Ramu system.

Figure 12: Estimated Peak Load Demand Forecast for the Port Moresby and Ramu Systems, 2018-2030



Source: World Bank, 2018.

NOTE: In the POM grid, the generation load is estimated to increase by 136 MW – from 137 MW in 2018 to 273 MW in 2030 (an average annual growth rate of 5.9%). In the Ramu grid, the generation load is expected to increase by 206 MW – from 106 MW in 2018 to 312 MW in 2030 (an average annual growth rate of 9.4%).

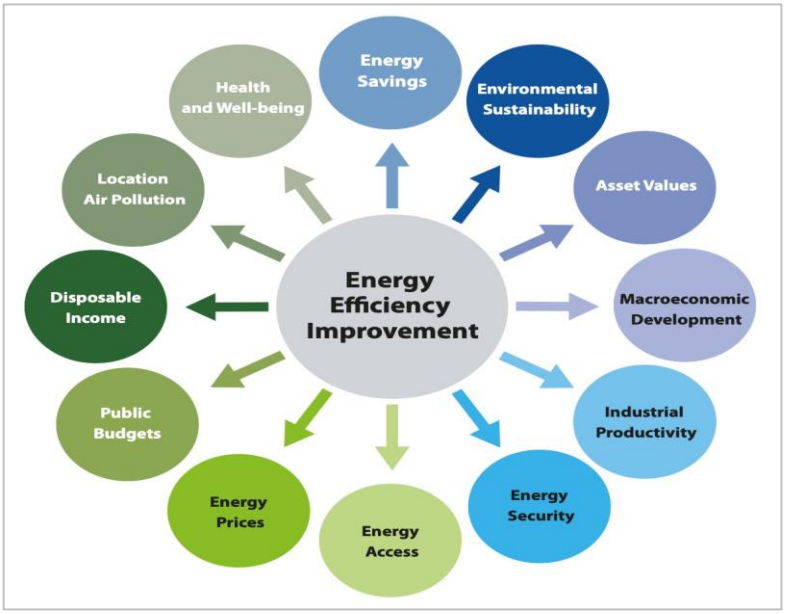
Although most of the forecasted demand growth in electricity will serve the mining sector, achieving the nation's electricity access goals may pose the greatest practical challenge, as around 80% of new residential demand must be delivered to rural areas and around half of it will be delivered through off-grid solutions. Meeting electricity demand growth at the pace and scope required to achieve 2030 targets will be challenging, particularly as capacity must be added at an unprecedented pace. Moreover, in order

to ensure that PNG also makes progress towards decarbonization, clean energy technologies will need to play a central role in electrifying PNG's rural communities.

4.1.3 Energy Efficiency Opportunities

Energy efficiency investments have wide-ranging environmental, social and economic benefits (**Figure 13**). Energy efficiency reduces greenhouse gas (GHG) emissions, improves energy security, lowers energy demand and provides cost savings for energy users across all sectors. It has numerous other co-benefits, including technology innovation and job creation in high-tech industries delivering EE solutions to the market. Improving EE is an important national objective for PNG, because achieving energy savings increases national energy security and supports the development of many sectors of the economy. In the electricity sector, utilities can apply EE to reduce emissions and optimize power systems.

Figure 13: Co-Benefits of Energy Efficiency



Source: International Energy Agency, Capturing the Multiple Benefits of Energy Efficiency, 2014.

There are many opportunities for Papua New Guinea to achieve energy savings and reduce GHG emissions through the application of energy efficiency measures. A 2020 study by the United Nations

Environment Programme's (UNEP) United for Efficiency (U4E) Program found that PNG can achieve significant energy savings through the implementation of minimum energy performance standards on lighting, refrigeration, air conditioners, transformers and electric motors. According to the assessment, between 2020 and 2030, PNG can avoid 2.3 million tons of CO_2 emissions and achieve USD 834M (PGK 2.9B) in cumulative electricity savings (**Table 3**).

Table 3: United for Efficiency – PNG Country Savings Assessment, Cumulative Savings, 2020-2030

Indicator	Unit	Cumulative Savings (2020 – 2030)
Lighting		
Energy Savings	GWh	335
CO_2 Emissions Avoided	Thousand tons	275
Energy Bill Savings	USD (million)	98
	PGK (million)	343
Refrigerator		
Energy Savings	GWh	359
CO2 Emissions Avoided	Thousand tons	295
Energy Bill Savings	USD (million)	105
	PGK (million)	368
Air Conditioner		
Energy Savings	TWh	1.86
CO2 Emissions Avoided	Million tons	1.52
Energy Bill Savings	USD (million)	543
	PGK (million)	1,900
Distribution Transformer		
Energy Savings	GWh	50.1
CO2 Emissions Avoided	Thousand tons	41.1
Energy Bill Savings	USD (million)	14.6
	PGK (million)	51
Industrial Electric Motor		
Energy Savings	GWh	255
CO2 Emissions Avoided	Thousand	20

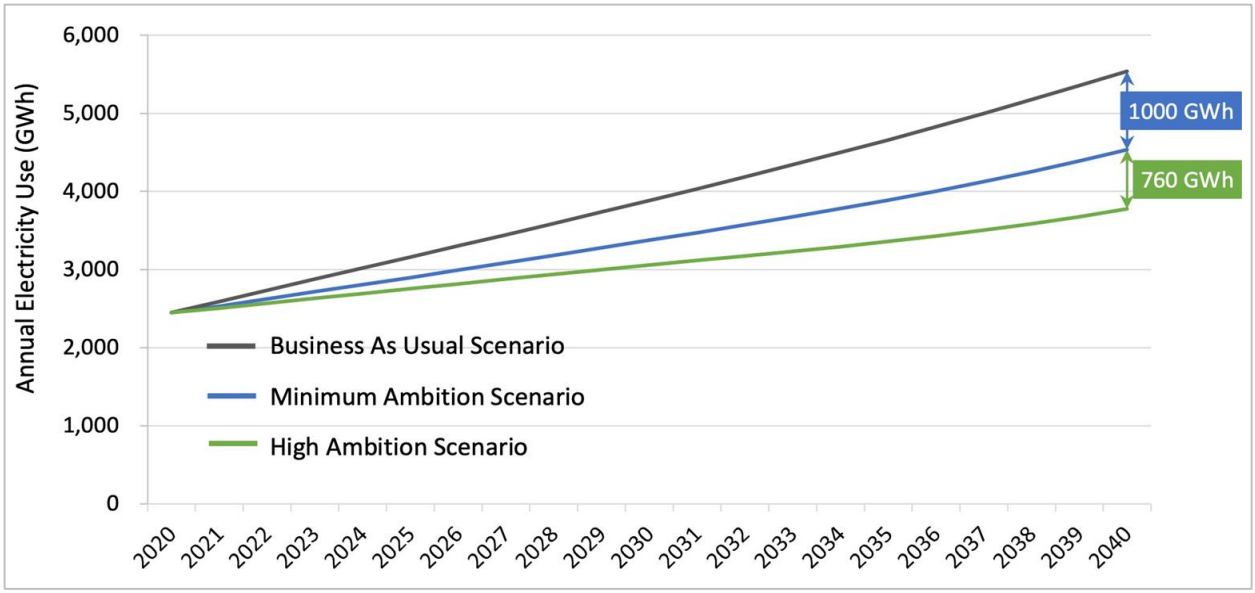
	tons	9
Energy Bill Savings	USD (million)	74.4
	PGK (million)	260
TOTAL SAVINGS		
Energy Savings	**TWh**	**2.86**
CO_2 Emissions Avoided	**Million tons**	**2.35**
Energy Bill Savings	**USD (million)**	**834**
	PGK (million)	**2,930**

Source: UNEP United for Efficiency, 2020.

NOTE: All figures from U4E minimum ambition scenario; savings potentials are calculated based on the assumption that Minimum Energy Performance Standards are implemented in 2020 at a level derived from the U4E Model Regulation Guidelines.
GWh = Gigawatt hour; TWh = Terawatt hour PGK = Papua New Guinean Kina
1 USD = 3.5 PGK

According to the U4E minimum ambition scenario, PNG can reduce annual electricity use in 2030 by 500 GWh (equivalent to about 15% of current national electricity use), achieving annual savings of electricity worth USD 150 million (PGK 525 million) and reducing over 410,000 tons of annual CO_2 emissions (equivalent to the emissions from 230,000 passenger cars). The U4E study also analyzed a high ambition scenario, which reflects more robust EE policy interventions to increase the level of energy efficiency of products sold in the country. Intuitively, the more ambitious the regulation, the more savings are possible (**Figure 14**).

Figure 14: Annual Electricity Use (GWh) in PNG under Three Scenarios, 2020-2040



Source: UNEP United for Efficiency, 2020.

The sections that follow examine both supply-side and demand-side EE opportunities in PNG. On the supply-side, there are opportunities in resource extraction and electricity generation, especially through the uptake of renewable energy. Demand-side EE includes buildings, transport, commercial and industrial (C&I) applications, the agricultural sector, and clean and efficient cooling. Each section includes a list of actionable priorities by sector for the GoPNG to consider in its future EE plans, together with relevant stakeholders that could lead EE initiatives in the sector. It is presumed that the NEA and/or CCDA would be responsible for overall management and implementation of EE policies and programs at the national level, in coordination with relevant agencies and stakeholders at the provincial level.

4.1.3.1 Supply-Side Energy Efficiency

4.1.3.1.1 Resource Extraction and Energy Supply

In PNG, much like other emerging markets, the energy intensity of GDP is relatively high due to inefficiencies in industrial-scale systems and operations. As countries develop and witness an increase in the service sector's contribution to GDP, economic growth tends to gradually decouple from resource extraction (namely fossil fuels, metals, minerals and biomass). As this process unfolds in PNG, it will

be critical for the country to strengthen its economic prospects by boosting EE and energy productivity across key supply chains. This will require the GoPNG to implement and enforce EE standards, invest in upgrading infrastructure and transportation assets, and provide incentives to the private sector in order to increase production and uptake of more efficient appliances and equipment. Increasing productivity also requires developing metrics and methods to identify and reduce waste from existing systems and operating procedures, incorporating energy consumption and performance indicators into management systems, and building capabilities for ongoing EE improvement.

Most of the primary energy supplied in PNG is used as fuel for transport and to power industrial activities largely concentrated around the urban areas of Port Moresby, Lae and Madang. As described in **Section 2.1**, the country is dominated by extractive industries – namely, the mining, production and export of gold, copper, silver, nickel, cobalt, timber, oil and gas – which account for the majority of export earnings and GDP. Natural gas production and export, particularly LNG, will continue to increase, while domestic consumption is also expected to grow over the coming decade (**Figure 12**).

The NEP estimates that 15% of the country's vast natural gas reserves will be utilized locally. The use of gas-fired cogeneration/combined heat and power technologies can replace diesel generators, increasing the efficiency of power generation. Natural gas can also be converted to support other domestic industries (e.g., methanol, fertilizer, cement, iron and steel manufacturing), the most common being liquefied petroleum gas (LPG), which can be used as an environmentally friendly household cooking fuel.

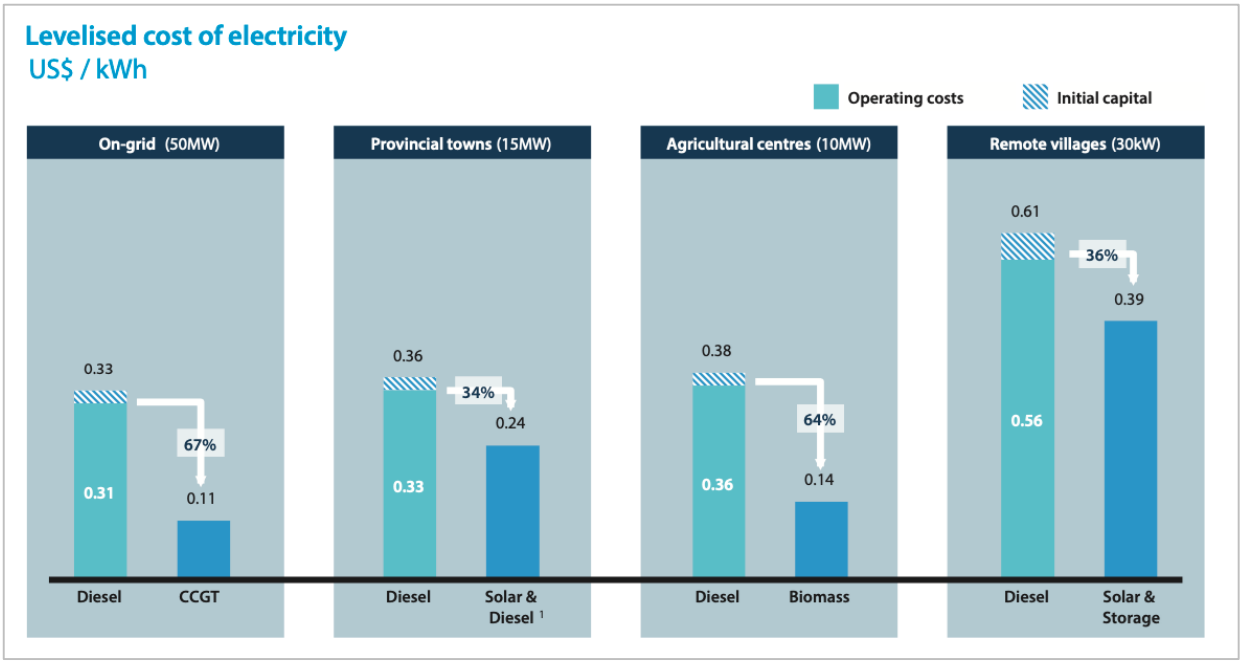
4.1.3.1.2 Electricity Generation and Demand-Side Management

PNG's electricity sector is highly dependent upon fuel imports, leading to high energy costs and exposure to fuel price volatility. The country also faces geographic and logistical constraints, which contribute to high transport costs. As described in **Section 2.2.3**, rates of electricity access remain low, particularly in rural communities, while existing electricity services are often unreliable due to underinvestment in the maintenance of power system infrastructure.

C-Centres – mini-grid systems mainly powered by diesel fuel that are currently managed by PPL and/or provincial governments – would benefit greatly from a transition to renewable energy. Powering these facilities with solar power (or through hybrid technologies, with battery or diesel backup) would drastically improve their efficiency. Diesel fuel is currently airlifted to many remote areas to allow fossil fuel power plants to run, often for only a few hours a day. This is not a sustainable approach to electrification and poses a key barrier to economic development as well as to the country's renewable energy objectives under Vision 2050. Converting PNG's C-Centres to be powered by RE supply represents a relatively low-cost improvement that would have wide-ranging benefits for the country's electricity system.

As described in **Section 2.2.4**, PNG has considerable but poorly assessed and developed indigenous RE resources. A recent study that examined the potential of various renewable resources in PNG found that both solar PV and small hydropower ('run-of-the-river') resources, when combined with gas-fired generators into hybrid systems, offer the most cost-effective electrification options for rural villages in the country. For utility-scale power generation, fuel switching from diesel to RE saves money and reduces emissions. A study commissioned by ANZ in 2015 that reviewed the levelized cost of electricity (LCOE) of different electricity generation technologies found that diesel is more expensive than other clean energy alternatives (**Figure 15**). Similarly, a 2018 World Bank analysis revealed that the LCOE for diesel and fuel oil-fired plants in the Port Moresby and Ramu grid systems was more than *four times* as high as the LCOE for solar PV power plants.

Figure 15: LCOE for Diesel Fuel vs. Alternative Electricity Generation Technologies



Source: ANZ, 2015.

From the utility's perspective, energy efficiency measures will help PPL reduce the cost of electricity service delivery and the long-term investment required for electricity generation, transmission, and distribution. Efficiency upgrades to power transmission and distribution infrastructure can also provide PPL with improved capability to balance and optimize loads dynamically, which helps improve service reliability. More broadly, EE supports the national objective of increasing electricity access, including reducing electricity delivery costs, reducing peak demand, and decreasing energy costs for consumers.

Power system optimization and demand-side management (DSM) practices can be utilized to audit commercial, industrial and residential energy use in order to ensure that technical and non-technical losses in electricity transmission and distribution are reduced. In 2009, under Phase 1 of the Promoting Energy Efficiency in the Pacific program, the Asian Development Bank (ADB) funded a power factor correction program in PNG, with a pilot project implemented by PPL in Port Moresby. The program was designed to assist PPL with meeting peak demand. Peak demand is an important indicator for utilities, as it often dictates utility decision-making around DSM and impacts the capital requirements for building new generation capacity. Improving power factor also reduces voltage drops, another issue

facing PPL's network. The program led to improved PPL capacity and expanded its power factor correction among its customers.

Table 4 provides a summary of supply-side energy efficiency strategic objectives, along with recommended actionable priorities for the GoPNG and the coordinating government agencies and other relevant stakeholder involved in implementation.

Table 4: Summary of Supply-Side EE Strategic Objectives and Recommended Actionable Priorities

Sector	Strategic Objectives	Recommended Actionable Priorities	Coordinating Government Agencies and other Relevant Stakeholders
Cross-cutting / economy-wide	Become a signatory to / participate in international agreements, treaties and initiatives dedicated to improving energy efficiency	• Become a signatory of the Kigali Amendment to the Montreal Protocol • Join the Super-efficient Equipment and Appliance Deployment (SEAD) Initiative of the Clean Energy Ministerial – a voluntary collaboration among governments working to promote the manufacture, purchase, and use of EE appliances, lighting, and equipment worldwide. • Participate in international (UNEP United for Efficiency) and regional (ASEAN SHINE) programs and initiatives that support developing countries to transition their markets to EE appliances and equipment.	National Energy Authority (NEA), Climate Change and Development Authority (CCDA)
	Develop and adopt national energy efficiency policy and regulation	• Designate lead institutions for planning, implementing, and monitoring EE policies and programs. • Establish centralized national repository to collect energy data and information across all sectors in order to set appropriate EE benchmarks and targets. • Draft EE policy and regulation • Consult with relevant stakeholders and revise draft based on feedback received • Finalize EE policy and adopt/ratify associated regulation	NEA, CCDA, PNG Power Ltd. (PPL), National Institute of Standards and Industrial Technology (NISIT), Independent Consumer and Competition Commission (ICCC)
	Raise awareness of EE policy/regulation and associated programs and initiatives among industry leaders, energy managers and engineers	• Develop strategies and marketing campaigns for EE awareness raising • Train relevant personnel to carry out national awareness raising campaign • Implement awareness raising campaign • Publish EE guidelines targeting specific industries	NEA, CCDA, NISIT, Institution of Engineers Papua New Guinea (IEPNG), UPNG Centre of Renewable Energy (CORE), PNG University of Technology (UNITECH) Sustainable Energy Research Institute (SERI) and

			Appropriate Technology and Community Development Institute (ATCDI)
	Build the capacity of relevant stakeholders	• Design sector-specific EE training modules based on international best practices and conduct organized workshops and trainings for technical and managerial staff • Utilize resources available through international (UNEP U4E) and regional (ASEAN SHINE) programs and initiatives • Introduce energy auditor and energy manager certification programs • Support the development of ESCOs to provide EE services to the market	NEA, CCDA, ICCC, NISIT, Department of Works (DOW), Department of Transport (DOT), IEPNG, UPNG CORE, UNITECH SERI and ATCDI, PPL, private IPPs, off-grid enterprises, private sector ESCOs

	Provide government leadership by setting an example for other buyers and by harnessing public sector buying power to create or expand the domestic market for energy-saving products and services	• Mandate energy audits for government buildings and facilities • Incorporate EE measures into government operations and procurement processes • Establish EE units within government ministries, departments and agencies to mainstream EE best practices in government operations and for effective implementation of EE policies and programs	NEA, CCDA, NISIT, DOW, DOT, Department of National Planning and Monitoring (DNPM), National Procurement Commission
	Develop and implement EE roadmap business plan and EE fund to support the rollout of EE financing and incentive programs	• Develop business plan for EE roadmap • Design an EE fund/financing facility and other market-based instruments to leverage private sector investment in EE • Implement national incentive program(s) to stimulate demand for EE products and services • Conduct legislative review to adopt EE business plan and establish EE fund	NEA, CCDA, DNPM, Department of Finance (DoF)
	Develop and implement measurement, verification and enforcement (MV&E) modalities and protocols for the EE sector	• Design MV&E protocols for EE projects and programs based on international best practices • Designate lead institution(s) responsible for implementing MV&E protocols (e.g., NEA, Department of National Planning and Monitoring) • Train relevant personnel to carry out MV&E functions and/or retain an external consultant through a tender process for this purpose	NISIT, ICCC, NEA, CCDA, DNPM, IEPNG, UPNG CORE, UNITECH SERI and ATCDI
Resource Extraction and Energy Supply	Adopt EE measures and technologies in all extractive industries (fossil fuel and mining sectors)	• Establish energy data collection procedures; set EE benchmarks and targets • Implement a national energy audit program for enterprises • Introduce protocols to establish best practices in energy management systems • Introduce MEPS and promote EE in industrial motors and motor-driven systems • Design and implement a financial incentives program to promote EE in extractive industries	NEA, CCDA, ICCC, NISIT, IEPNG, DoF, Mineral Resources Authority (MRA), IEPNG, PPL, IPPs, oil and gas companies, mining companies, private sector

			ESCOs
Electricity Generation and Demand-Side Management	Adopt EE measures and technologies in electricity generation	• Establish energy data collection procedures; set EE benchmarks and targets • Establish utility EE obligations and other market- based instruments to promote EE in electricity generation, transmission and consumption. • Promote fuel switching from fossil fuel-powered generation to renewable energy • Introduce protocols to establish best practices in energy management systems • Introduce MEPS and promote EE in industrial motors and motor-driven systems • Design and implement a financial incentives program to promote EE measures in power generation • Work with PPL to implement demand-side management and power system optimization practices	NEA, CCDA, ICCC, NISIT, DoF, IEPNG, UPNG CORE, UNITECH SERI and ATCDI, PPL, IPPs, off-grid enterprises, private sector ESCOs

4.1.3.2 Demand-Side Energy Efficiency

4.1.3.2.1 Buildings

Public and Commercial Building Energy Efficiency

In industrialized countries, buildings consume about one-third of primary energy demand, two-thirds of electricity generated and contribute to about one-fifth of energy-related greenhouse gas emissions. This is not yet the case in PNG, where energy use is dominated by the industrial, transport and agricultural sectors, but energy demand from buildings is a fast-growing segment, driven by economic growth, urbanization, increasing use of refrigeration and air conditioning (RAC) equipment, and a lack of codes or standards to help make buildings more efficient.

Public sector buildings – including schools, health facilities and government offices as well as public infrastructure such as streetlighting and water services – represent an excellent market for EE investment. These buildings provide essential services, so their energy loads are typically consistent and predictable, making them strong candidates for EE. Moreover, public agencies tend to have greater resources available for EE financing and procurement and are thus well positioned to lead market development. The GoPNG can implement pilot EE projects and invest in EE upgrades in public facilities to introduce such tools and mechanisms to the market. It will also sensitize officials and government

workers to the importance of EE, and the same pilot models initiated by the government can then be replicated in other sectors.

Buildings require electricity for power, lighting and cooling, while as much as 80% of the energy consumed by a building is wasted; for example, lights and electronics are left on unnecessarily and gaps in building envelopes allow air to seep in and out. To achieve energy savings in the buildings sector, building energy efficiency codes and MEPS can be adopted to ensure that new building design and construction is energy efficient (e.g., International Green Construction Code). Various standards – Leadership in Energy and Environmental Design (LEED), Net Zero (International Living Future Institute) etc. – specify how to build from the start. While this is important, it is equally as important to modify/retrofit existing building stock in the public, commercial and residential sectors. Good building performance data is necessary to make EE retrofitting possible.

In addition to MEPS, building EE policy measures aim to support building owners through energy audits, energy rating and certification programs, incentive schemes to encourage investment in building envelope and energy system improvements, and the increased market penetration of high-efficiency products and equipment. Ultimately, the objective is to achieve net-zero consumption in buildings, whereby a building produces as much energy as it uses in a given period. Net-zero buildings are insulated extremely well, use electricity and water efficiently, and are designed and engineered in a way that reduces energy use and promotes conservation at every level. Lighting is reduced to favor daylighting wherever possible, while electrochromic glass changes its opacity according to heat, sun and indoor/outdoor temperatures. Green roofs and cool roofs are able to curtail a building's carbon emissions and reduce energy use for cooling.

LED (light emitting diodes) technology uses 90% less energy for the same amount of light as an incandescent bulb and lasts much longer, thus reducing building loads significantly. For street lighting, LED lights can save up to 70% of energy and significantly reduce maintenance costs. Virtually any type of bulb currently in use in residential or commercial settings can be replaced by an LED bulb. The price

of LED lights is still about twice that of alternatives, but prices are falling quickly; according to the University of California's Lawrence Berkeley National Laboratory, solar LED products pay for themselves within a year of purchase.

In PNG, the Department of Works (DOW), which is responsible for developing and regulating building codes and technical standards, is currently reviewing and updating the national building code to include EE standards. The legal framework for the buildings sector dates back to the Building Act of 1971, which was subsequently updated in 2005 when PNG adopted building codes based on those in Australia. In addition to EE building codes, Australia also maintains the Green Star Program – a voluntary environmental rating scheme supported by the Green Building Council of Australia that provides a framework for evaluating the environmental design and performance of buildings.

Residential Energy Efficiency

Energy use in households in dominated by lighting, cooking, refrigeration and cooling appliances. In rural off-grid areas, wood fuels are still widely used for cooking. Given that such a small percentage of the population is connected to the main grid, PNG has one of the highest usage rates of off-grid solar lighting products in the world. The presence of a large informal market for solar products means that a large share of these products remains inefficient and low-quality. This dynamic makes public awareness raising and consumer education on product quality critical; moreover, to ensure sustainable market growth, International Electrotechnical Commission (IEC) and/or regional Australia/New Zealand standards need to be adopted and enforced.

With the off-grid market poised to grow sharply over the next decade, it will be important for the GoPNG to adopt EE policies that specifically target this sector. For instance, a recent study by the Efficiency for Access Coalition found that appliances using permanent magnet motors use up to 42% less energy than those using conventional alternating current (AC) motors. Off-grid households that use EE motor appliances (fans, refrigerators, air conditioners, washing machines, solar water pumps, electric vehicles etc.) can achieve a net cost savings of up to 30%, as the higher price of the EE

appliances is outweighed by cost reductions at the system level. Barriers to the uptake of EE appliances in off-grid households include lack of awareness, financing options and post-sale services, as well as constraints around product affordability and higher perceived credit risk of customers. To overcome these barriers, the GoPNG can collaborate with local service providers to establish MEPS and an appliance labeling program; support consumer education and awareness raising initiatives; provide fiscal incentives, subsidies, and consumer financing; develop demand aggregation and bulk procurement models for EE appliances; and provide TA and capacity building to suppliers in order to expand post-sales services.

Energy efficiency in the household sector also needs to consider clean cooking. The GoPNG can work with development partners to launch awareness raising campaigns that promote the use of fuel-efficient cook stoves, emphasizing their environmental and health benefits compared to wood fuels

4.1.3.2.2 Commercial and Industrial

There are many opportunities to save energy and reduce emissions from commercial and industrial applications. Energy efficiency investments in commercial and industrial facilities improve enterprise competitiveness and can frequently pay for themselves through energy cost savings. In PNG, commercial and industrial economic activities account for a growing share of energy consumption. Energy demand is mainly driven by extractive industries, infrastructure development and other economic activities concentrated around the urban areas of Port Moresby, Lae and Madang. This is particularly true for the mining, oil and gas sectors, which require a huge amount of energy to power large-scale mining operations and to develop megaprojects such as the country's LNG facilities.

In the commercial sector, the GoPNG can implement a national energy audit program for SMEs and provide them with financing and incentives to adopt EE measures and purchase efficient appliances and equipment. Public-private partnerships and coalitions between government agencies, businesses, industry associations and energy service companies (ESCOs) can help implement EE programs and initiatives, raise awareness among stakeholders and mobilize investment for EE projects.

In the industrial sector, the government should require energy-intensive industries to conform to energy management protocols (e.g., ISO 50001), including adopting energy management systems (EnMS) to conduct energy audits of industrial facilities and processes, report EE improvement plans and monitor progress. International development organizations have also established frameworks for eco-industrial parks, which incorporate sustainability into the siting, planning, management and operations of industrial parks/zones (see **Box 7** in **Section 3.3.1**). Another priority for the sector is to introduce MEPS and promote EE in industrial motors and motor-driven systems (**Box 2**), particularly given the sizable energy savings and emission reductions associated with these efficiency improvements (**Table 3**).

Box 2: National Motor Replacement Program in India

In India, the industrial sector accounts for around 40% of electricity demand, while the share of consumption from motor and motor-driven systems could be as high as 69% of industrial electricity consumption. Energy efficiency therefore has immense benefits to offer in reducing energy consumption and greenhouse gas emissions from industrial motor and motor-driven systems. In 2018, the India Bureau of Energy Efficiency and Department for the Promotion of Industry and Internal Trade adopted mandatory regulatory measures and supporting policies in an effort to transition the country towards high efficiency motors and motor-driven systems. In addition, Energy Efficiency Services Limited (EESL) – a government-run Super ESCO – is leading a voluntary motors replacement program targeting large industries and motor manufacturers. The program aims to address the two main concerns which act as a deterrent for the adoption of higher efficiency motors. First, it aims to address the higher first-cost barrier by providing an approximately 20-25% reduction in price compared to market retail price for end-users through demand aggregation and bulk procurement. Second, to accelerate the scale of adoption and encourage users with lower financial capability, particularly SMEs, it includes a financing option of up to three years with repayment in periodic installments.

Source: Energy Efficiency Services Limited

4.1.3.2.3 Transportation

The transportation sector is one of the most energy intensive sectors of any economy and the main consumer of liquid fuels, contributing significantly to CO_2 emissions. This is a growing challenge for PNG, and the Department of Transport (DOT) is seeking to improve transportation efficiency and reduce the amount of liquid fuel that is consumed by the sector. Most vehicles are currently imported as used vehicles from Australia and other parts of Asia, and there are currently no fuel efficiency standards in place. The DOT can address this by mandating minimum fuel efficiency standards for all commercial and private vehicles and through initiatives that aim to gradually phase out old and

inefficient vehicles. Incentive programs can also be designed to increase the share of biofuels in the transport sector, and to promote the uptake of fuel efficient and zero-emission, hybrid and electric vehicles (electric motors offer three to four times higher efficiency than internal combustion engines, so electric vehicles can provide the same level of energy service – or activity such as passenger kilometers – using significantly less energy). In addition to fuel efficiency, investing in integrated public transit infrastructure can reduce emissions as well as traffic and congestion in cities, which is a growing issue in the capital, Port Moresby.

Transportation and logistics infrastructure in PNG is not well developed – over half of rural households live more than 5 km from a national road, while an estimated 60% of PNG's population resides on coastline and waterways, often without access to roads. Lack of adequate road transportation infrastructure has affected connectivity, disrupted access to essential public services in many parts of the country and hindered inclusive economic growth, as transporting goods and providing services is difficult and expensive. Geography is the main obstacle to transport infrastructure development in PNG, which is managed by the Department of Works (DOW). Existing road infrastructure is unevenly distributed across the country, as there are no main highways connecting Port Moresby to the Highlands Region, which is home to around 40% of the population. Therefore, aviation and maritime transport are critical to link the 22 provincial centers to the capital.

Like vehicles, planes and ships also require fuel efficiency standards. Ships are powered by low-grade bunker fuel, which contains thirty-five hundred times more sulfur than the diesel used in cars and trucks, making EE in the sector a priority. Fuel-saving ship design, onboard technologies, and operational practices can improve efficiency and reduce emissions. The International Maritime Organization is a UN agency that has established the Energy Efficiency Design Index (EEDI), which requires newly built ships to meet a minimum level of energy efficiency. The Sustainable Shipping Initiative, a leading global partnership that is working to promote sustainability in the maritime industry, established a Greenhouse Gas Emissions Rating system for commercial vessels that aims to reduce costs across the supply chain. An estimated 20% of the global trade uses the system, as do banks, insurers and port

authorities.

4.13.2.4 Agriculture

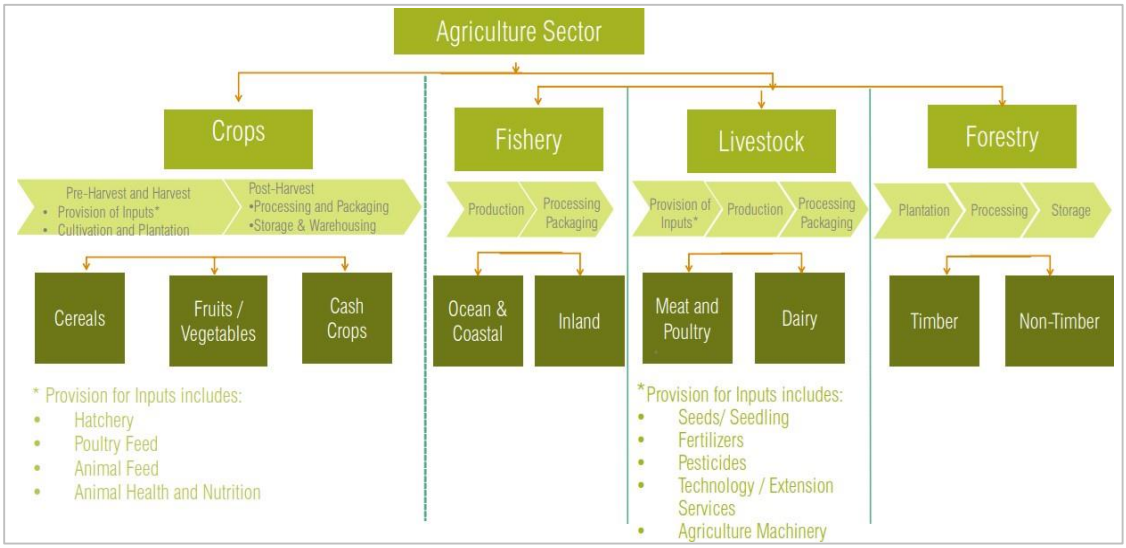
The agricultural sector is a key driver of PNG's economy, as it supports the livelihoods of over 80% of the rural population and accounts for about 25% of GDP. Cash crops such as coffee, cocoa and palm oil, are grown both on large-scale plantations and by smallholders. Agricultural exports make up a relatively small share of total export earnings, as rural farmers are widely dispersed and have limited access to markets due to funding, logistical and transport-related constraints. According to the Fresh Produce Development Agency, which is working to develop a sustainable commercial food industry in PNG, up to 50% of food produced in the country is lost in the post-harvest phase due to an inadequate transportation network and a lack of infrastructure such as warehouses and cold storage facilities. Solar powered refrigeration, cooling and processing equipment can enable rural farmers and traders to sell dairy products, while cold storage of agricultural produce can reduce losses and increase output (**Box 3**).

Box 3: Cold Chain Solutions for Indian Banana Farmers

India is the global leader in banana cultivation. In 2013, Danfoss, a Danish multinational manufacturing firm that offers energy system management services, partnered with the Indian government and the Confederation of Indian Industry to form a task force that aimed to deliver cold chain solutions to banana farmers in order to reduce post-harvest losses. With support from local industry associations, the task force conducted a feasibility study of the banana sector to assess how cold chains could be utilized to reduce losses and boost export revenue. The study's findings helped educate farmers on cold chain infrastructure and technologies, resulting in a 300% increase in farmer income and a 20% reduction in post-harvest losses. By 2018, India began exporting bananas to Europe. India's government is now exploring how cold chain solutions can be applied to support other agricultural crops/sectors.

Source: Danfoss

Figure 16: Agriculture Sector Value Chain in Papua New Guinea



Source: Intellecap, 2019; Food and Agricultural Organization of the United Nations (FAO)

Commercial and Smallholder Farming

Much like other countries in the Asia-Pacific region, PNG has experienced a shift from traditional low-energy agriculture to mechanized and fertilizer-based food production in order to increase productivity, resulting in farming practices that require more energy and have become more fossil-fuel intensive. At the smallholder level, agricultural practices remain traditional, with farmers generally lacking access to quality inputs and extension services, resulting in lower land productivity. Supply of food crops such as cereals, fruits and vegetables, and meat and poultry products for domestic consumption is largely dominated by small-holder farmers that sell their produce either in the local markets or to regional wholesalers.

Energy efficiency measures in the agricultural sector focus more on large-scale commercial farming operations, which offer greater energy saving potential. Typical EE measures include upgrading the efficiency of farm machinery, irrigation pumps, water systems, lighting, heating, cooling and ventilation systems (e.g., for animal housing). Other measures include organic farming methods that make the best use of agricultural residues and animal waste to improve soil quality, reduce dependence on chemical fertilizers, prevent environmental contamination and produce energy (biogas) through anaerobic

digestion of manure and other feedstocks. Improving the EE of agricultural processing equipment and fuel switching from diesel to RE sources such as solar will optimize production, reduce energy use and associated emissions, and lead to cost savings for the sector. Solar powered irrigation technology allows smallholder farmers to switch from expensive and polluting diesel-powered pumps to renewable power. Regular, consistent watering with an irrigation system can improve yields and allows farmers to capitalize on higher market prices that occur during dry seasons. Similarly, solar powered electric mills offer a reliable and sustainable alternative to diesel- powered mills to process important staple crops. Smallholder farmers require awareness raising, financing, technical assistance and training in order to take advantage of EE opportunities. The PNG Department of Agriculture and Livestock can support smallholders through key partnerships with rural development organizations such as the UNITECH Appropriate Technology and Community Development Institute (ATCDI), as well as organizations like the International Fund for Agricultural Development, which works with smallholder farmers to promote climate-resilient agricultural development.

Fisheries

The prevailing challenges across the fisheries value chain in PNG are similar to those of other agricultural market segments, including high post-harvest losses due to inefficient processing methods, a lack of cold storage, transport challenges and limited access to credit. The artisanal fish value chain is where losses are the highest. Access to finance, particularly for distribution and market linkages is essential. Government funding and incentive programs should provide this much-needed support to the sector, with a particular focus on development of cold chains and storage facilities. As an example, in Vanuatu, the government's recently launched National Green Energy Fund provided financing to a remote island community for the purchase of a solar-powered refrigeration system used for fish storage (**Box 4**).

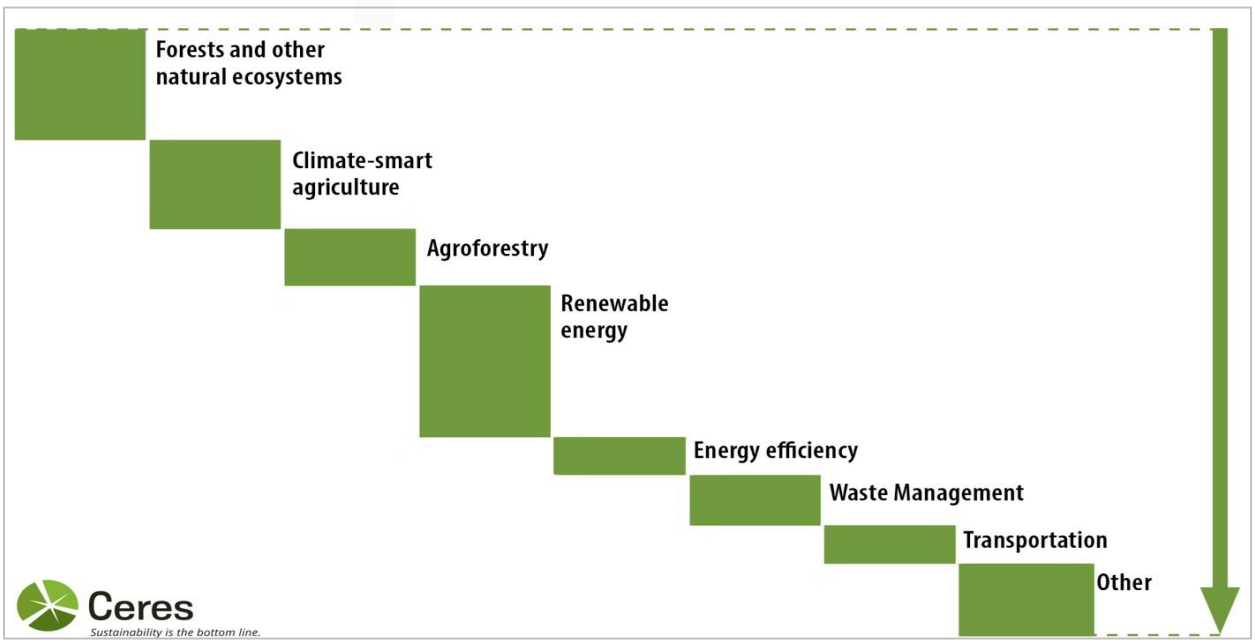
Box 4: Solar Powered Refrigeration for Fish Storage in Vanuatu

In Vanuatu, the National Green Energy Fund (NGEF) was established in 2018 as an independent public entity to source funds to help the government achieve its energy targets. In 2020, the NGEF launched its first pilot project – a VT30 million concessional loan to a fishing cooperative on the remote island of Futuna for the purchase of a solar powered refrigeration system that local fishermen will use to store their fish safely before sale. The system was installed at the Futuna fish market by an approved supplier. The Department of Energy is implementing the project with the support of the Cooperatives Department. Fishing is a main economic activity on Futuna where planes and cargo ships rarely visit. Being one of the most isolated islands in the country makes it hard to transport fish to urban markets. The new refrigeration system solves this logistical challenge, while also replacing expensive and polluting diesel-powered system with renewable solar power.

Forestry and Land Use

According to the IPCC Special Report on Climate Change and Land, 23% of global GHG emissions come from human use of land. Deforestation is one of the largest single sources of these emissions; 5 percent of global emissions come from commodity-driven deforestation in the tropics. In addition to releasing emissions, deforestation eliminates the cleared land's ability to store more carbon and can disrupt local and global precipitation patterns in ways that exacerbate drought. It is estimated that the combined effect of eliminating deforestation and reforesting previously cleared land could provide nearly three-quarters of the mitigation potential of all renewable energy technologies combined (**Figure 17**).

Figure 17: Estimated Total Mitigation Needed to Limit Global Warming to 1.5 C



Source: Ceres

There have been relatively limited advances in forestry and land use management in PNG over the last decade. In the country's Enhanced Nationally Determined Contribution 2020, the land use and forestry sector is identified as one of the biggest contributors to GHG emissions, largely due to deforestation and forest degradation. Deforestation can be mainly attributed to land-use conversion from forest to agricultural land to support both subsistence agriculture as well as commercial agriculture (especially oil palm plantation development). Commercial logging is a key driver of forest degradation, accounting for over 90% of the total degraded forest in PNG.

In response, the government is pursuing a range of policies to reduce emissions from this sector and to ensure sustainable land use, forest management, and agricultural practices. These measures include promotion of REDD+ activities such as enhancement of land use planning and monitoring; promotion of climate-friendly agriculture; strengthened enforcement of PNG Forest Authority logging permits; enhancement of timber legality standards; and promotion of reforestation and ecosystem restoration.

4.1.3.2.5 Energy Efficient and Sustainable Cooling

Global Context

Globally, cooling represents 10% of electricity consumption, and demand for cooling is increasing rapidly due to growing populations, urbanization and rising income levels in developing countries. By 2050, global energy use for cooling is projected to triple, putting pressure on energy systems and hampering efforts to address climate change, as cooling appliances typically use large amounts of energy and also leak harmful refrigerants that contribute to climate change. Without policies to reduce cooling demand, the projected growth in demand from refrigeration and air conditioning (RAC) equipment could result in energy-related climate emissions of 230–430 GtCO2e by 2050, representing about a decade of global energy-related CO2 emissions at 2018 levels.

As global temperatures continue to rise, more than 1 billion people worldwide lack access to sustainable cooling solutions, with significant implications for public health, food security, sustainable development, productivity and economic growth. The lack of cold storage in public health systems

contributes to an estimated 1.5 million vaccine-preventable deaths each year. The COVID-19 pandemic has exacerbated an already challenging situation; a dramatic expansion in cold chain equipment will be necessary to guarantee equitable distribution of coronavirus vaccines, particularly for rural poor populations who often lack access to electricity and medical cold chains. In the food system, a lack of cold storage and refrigerated transportation results in the loss or waste of nearly one-third of the total food produced for human consumption annually, with associated financial losses of almost USD 1 trillion per year.

In light of these trends, in 2016, the international community adopted the Kigali Amendment to the Montreal Protocol, which aims to phase out production and consumption of harmful refrigerant chemicals used in RAC equipment and to promote the use of low Global Warming Potential (GWP) refrigerants through new appliance standards, labeling and conversion of equipment manufacturing. The Kigali Cooling Efficiency Programme (K-CEP) was launched in 2017 to help countries develop policy frameworks, standards, programs and finance initiatives designed to increase access to clean cooling and address growing demand from the sector. K-CEP currently supports countries with preparation of National Cooling Action Plans (NCAPs), which are national policy frameworks that promote sustainable cooling solutions in line with the Kigali Amendment (see **Section 4.1.3** for more details on NCAPs).

K-CEP is currently providing a wide range of technical assistance, policy and financial support to dozens of countries around the world to support development of policies, standards, programs and frameworks designed to increase access to clean cooling and address growing demand from the sector – including technical assistance to over 25 countries with preparation of their NCAPs. The program has helped structure and fund many innovative cooling finance initiatives using a range of business models targeting distinct end-user sectors. It is also working with governments to facilitate the refrigerant transition (**Box 5**). For example, K-CEP is providing training for National Ozone Officers and energy efficiency policymakers to link EE planning and policy development with the objectives of the Montreal Protocol. In 2020, K-CEP launched the NDC Support Facility for Efficient, Climate-Friendly Cooling,

to provide funding and guidance to support governments that include cooling in their NDC updates.

Box 5: Facilitating the Refrigerant Transition in Bangladesh

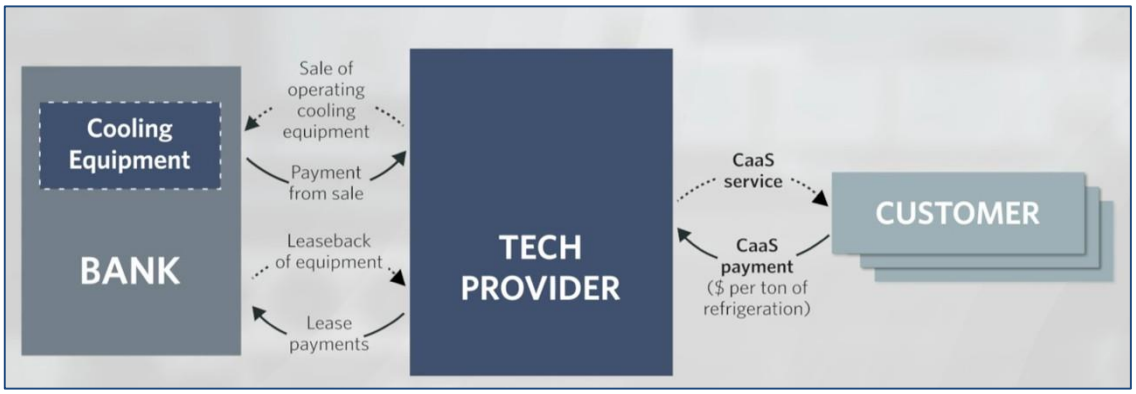
The international HFC phase-down will mean that many manufacturers must retool their production lines to produce appliances which use climate-friendly refrigerants. This transition provides an opportunity to switch to energy efficient appliance designs at the same time. In 2017, the Multilateral Fund for the Implementation of the Montreal Protocol (MLF) approved the first ever manufacturing plant conversion investment project under the Kigali Amendment in Bangladesh. This financing will allow Bangladesh to eliminate 85% of HFC-134a – a super-polluting refrigerant largely consumed by the domestic refrigerator manufacturing sector. K-CEP is co-financing with the MLF in order to maximize the EE of domestic refrigerators produced in Bangladesh as the country moves to using low-GWP refrigerants. More broadly, this initiative will shift the domestic refrigerator market to efficient, clean products, build capacity to help further develop EE standards, and raise public awareness of EE in the refrigeration sector.

Source: Kigali Cooling Efficiency Program

Cooling-as-a-Service and other Sustainable Cooling Business Models

Cooling-as-a-Service (CaaS) is a pay-per-service model for clean cooling systems that eliminates the upfront cost of clean cooling equipment for customers, who instead pay per unit of cooling they consume. The technology provider installs, maintains and operates cooling equipment, recovering costs through periodic payments made by the customer. End-users are thus incentivized to consume energy efficiently, while technology providers are incentivized to install and maintain the most efficient equipment possible. Moreover, financial service providers have the security of owning an operating asset under a CaaS contract with a customer. The CaaS business model (**Figure 16**) is cheaper for customers, more profitable for technology providers and reduces harmful refrigerant emissions; it is estimated that this approach can save customers more than 20% of cooling costs, while reducing emissions from electricity use and coolant leakage by up to 49%.

Figure 18: Cooling-as-a-Service Business Model



Source: Global Innovation Lab for Climate Finance

In addition to CaaS, other business models that can be deployed to accelerate EE market penetration include bulk procurement of high efficiency appliances, such as the Super-Efficient AC Programme deployed by Energy Efficiency Services Ltd. (EESL) in India. Policy measures can also be coupled with structuring of incentive programs and finance mechanisms targeting commercial, industrial and residential end-users. A good example of a successful EE program in the clean cooling market segment can be found in the Cook Islands, where an appliance replacement program provided rebates for consumers to swap old and inefficient refrigerators for new and efficient ones (**Box 6**).

Box 6: Cook Islands Refrigerator and Freezer Replacement Program

In 2013, under Phase 2 of the Promoting Energy Efficiency in the Pacific project, with financing from ADB, the Government of Australia and the GEF, the government of the Cook Islands implemented a Fridge and Freezer Replacement Program. The program encouraged the residential, commercial and public sector to replace old and inefficient refrigeration and freezing appliances with high efficiency models. The program also subsidized participating retailers in the country to enable them to sell new energy efficient refrigerators and freezers at more affordable rates. Under the program, retailers will offer rebates of up to$390 to customers purchasing selected highly efficient fridge/freezer models, in exchange for functional low efficient fridge/freezers of similar capacity. By using an energy efficient fridge, it is estimated that the average household in the Cook Islands would save around $150 to $235 per year on electricity.

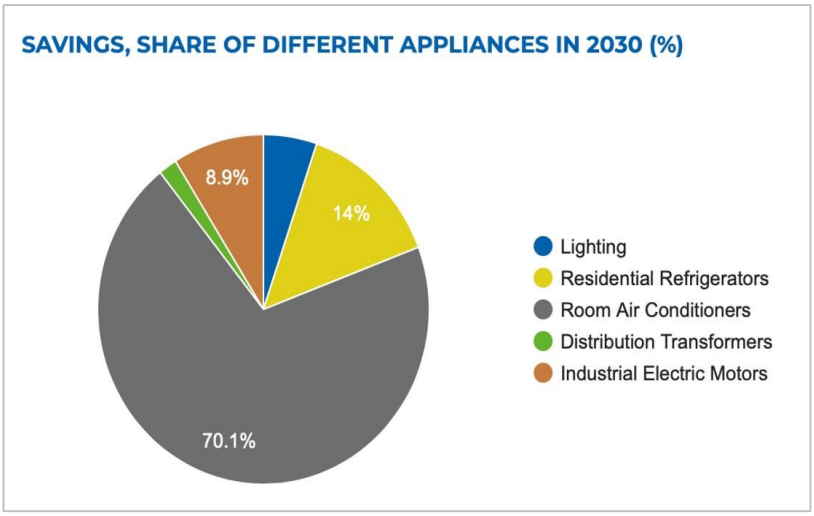
Source: ADB Promoting Energy Efficiency in the Pacific, Phase 2

Sustainable Cooling in PNG

The adoption of energy efficient and clean cooling technologies is critical to the long-term success of PNG's energy efficiency and conservation efforts. According to UNEP's United for Efficiency country

assessment (see **Table 3**), RAC equipment makes up the largest share (84.1%) of PNG's cumulative energy savings potential through 2030, with air conditioners leading all appliances at 70.1% of total savings (**Figure 19**).

Figure 19: Share of Energy Savings Among Different Appliances in 2030 (%)



Source: United for Efficiency, 2020.

Annex 4 presents a program concept for a Refrigerator and Air Conditioner Replacement Program, which resembles the ADB Promoting Energy Efficiency in the Pacific program in the Cook Islands described in **Box 6**. The program includes a bulk procurement scheme, whereby the government partners with the private sector to purchase high efficiency cooling appliances to accelerate market penetration, combined with MEPS, proposed finance and TA mechanisms, and protocols to recapture refrigerants from old/used equipment.

Table 5 provides a summary of demand-side energy efficiency strategic objectives, along with recommended actionable priorities for the GoPNG and the coordinating government agencies and other relevant stakeholder involved in implementation.

Table 5: Summary of Demand-Side EE Strategic Objectives and Recommended Actionable Priorities

Sector	Strategic Objectives	Recommended Actionable Priorities	Coordinating Government Agencies and other Relevant Stakeholders
Cross-cutting / economy - wide	Become a signatory to / participate in international agreements, treaties and initiatives dedicated to improving energy efficiency	• Become a signatory of the Kigali Amendment to the Montreal Protocol • Join the Super-efficient Equipment and Appliance Deployment (SEAD) Initiative of the Clean Energy Ministerial – a voluntary collaboration among governments working to promote the manufacture, purchase, and use of EE appliances, lighting, and equipment worldwide. • Participate in international (UNEP United for Efficiency) and regional (ASEAN SHINE) programs and initiatives that support developing countries to transition their markets to EE appliances and equipment.	National Energy Authority (NEA), Climate Change and Development Authority (CCDA)
	Develop and adopt national energy efficiency policy and regulation	• Designate lead institutions for planning, implementing, and monitoring EE policies and programs • Establish centralized national repository to collect energy data and information across all sectors in order to set appropriate EE benchmarks and targets • Draft EE policy and regulation • Consult with relevant stakeholders and revise draft based on feedback received • Finalize EE policy and adopt/ratify associated regulation	NEA, CCDA, PNG Power Ltd. (PPL), National Institute of Standards and Industrial Technology (NISIT), Independent Consumer and Competition Commission (ICCC)
	Raise awareness of EE policy/regulation and associated programs and initiatives among industry leaders, energy managers and engineers, households and SMEs	• Develop strategies and marketing campaigns for EE awareness raising • Train relevant personnel to carry out national awareness raising campaign • Implement awareness raising campaign • Publish EE guidelines targeting specific industries	NEA, CCDA, NISIT, Institution of Engineers Papua New Guinea (IEPNG), UPNG Centre of Renewable Energy (CORE), PNG University of Technology (UNITECH) Sustainable Energy Research Institute (SERI) and Appropriate Technology and Community Development Institute (ATCDI)

	Build the capacity of relevant stakeholders	• Design sector-specific EE training modules based on international best practices and conduct organized workshops and trainings for technical and managerial staff • Utilize resources available through international (UNEP U4E) and regional (ASEAN SHINE) programs and initiatives • Introduce energy auditor and energy manager certification programs • Support the development of ESCOs to provide EE services to the market	NEA, CCDA, ICCC, NISIT, Department of Works (DOW), Department of Transport (DOT), IEPNG, UPNG CORE, UNITECH SERI and ATCDI, PPL, private IPPs, off-grid enterprises, private sector ESCOs
	Provide government leadership by setting an example for other buyers and by harnessing public sector buying power to create or expand the domestic market for energy-saving products and services	• Mandate energy audits for government buildings and facilities • Incorporate EE measures into government operations and procurement processes • Establish EE units within government ministries, departments and agencies to mainstream EE best practices in government operations and for effective implementation of EE policies and programs	NEA, CCDA, NISIT, DOW, DOT, Department of National Planning and Monitoring (DNPM), National Procurement Commission
	Develop and implement EE roadmap business plan and EE fund to support the rollout of EE financing and incentive programs	• Develop business plan for EE roadmap • Design an EE fund/financing facility and other market- based instruments to leverage private sector investment in EE • Implement national incentive program(s) to stimulate demand for EE products and services • Conduct legislative review to adopt EE business plan and establish EE fund	NEA, CCDA, DNPM, Department of Finance (DoF)
	Develop and implement measurement, verification and enforcement (MV&E) modalities and protocols for the EE sector	• Design MV&E protocols for EE projects and programs based on international best practices • Designate lead institution(s) responsible for implementing MV&E protocols (e.g., NEA, Department of National Planning and Monitoring) • Train relevant personnel to carry out MV&E functions and/or retain an external consultant through a tender process for this purpose	NISIT, ICCC, NEA, CCDA, DNPM, IEPNG, UPNG CORE, UNITECH SERI and ATCDI

Buildings (Public, Commercial and Residential)	Adopt EE measures and technologies for new and existing public, commercial, and residential buildings	• Establish energy data collection procedures; set EE benchmarks and targets • Integrate EE into the national building code for new and existing buildings, including building EE performance standards (e.g., International Green Construction Code, LEED, Net Zero etc.) • Develop and implement a MEPS and labeling program for efficient lighting, refrigeration and air conditioning equipment in all buildings • Establish national testing and labeling program for household appliances with associated standards and regulations enacted • Design and implement a financial incentives program to promote EE in buildings • In the residential sector, promote the use of fuel efficient cook stoves, emphasizing the environmental and health benefits (vis-à-vis wood fuels and kerosene)	DOW, NEA, CCDA, ICCC, NISIT, DoF, IEPNG, UPNG CORE, UNITECH SERI and ATCDI, public, commercial and residential building owners/associations, households
Commercial and Industrial	Adopt EE measures and technologies for commercial and industrial sector	• Establish energy data collection procedures; set EE benchmarks and targets • Implement a national energy audit program for enterprises • Introduce protocols to establish best practices in energy management systems • Introduce MEPS and promote EE in industrial motors and motor-driven systems • Design and implement a financial incentives program to promote EE in the commercial and industrial sector	NEA, CCDA, ICCC, NISIT, DoF, IEPNG, UPNG CORE, UNITECH SERI and ATCDI
Transport	Adopt EE measures and technologies for land, air and sea transport	• Establish energy data collection procedures; set EE benchmarks and targets • Establish minimum fuel efficiency standards for all commercial and private vehicles • Design and implement an incentives program to promote the uptake of fuel efficient and zero-emission vehicles (e.g., hybrid, electric) • Establish minimum fuel efficiency standards for air and sea transport • Promote the use of biodiesel and bioethanol fuels • Provide funding to support road maintenance and new road infrastructure development, with particular focus on connecting the country's main cities • Promote integrated public transport systems in main cities	DOT, DOW, NEA, CCDA, ICCC, NISIT, DoF, IEPNG, UPNG CORE, UNITECH SERI and ATCDI
Agriculture	Adopt EE measures and technologies for agricultural sector	• Establish energy data collection procedures; set EE benchmarks and targets • Implement a national energy audit program for agricultural enterprises • Design and implement a financial incentives program to help commercial and smallholder farmers make EE improvements • Promote farming methods that make the best use of agricultural residues and animal waste • Provide funding and TA to support distribution and market linkages across the agricultural value chain (cash crops, fisheries etc.)	NEA, CCDA, ICCC, NISIT, DoF, Department of Agriculture and Livestock, National Fisheries Authority of PNG, PNG Forest Authority, IEPNG, UPNG CORE, UNITECH SERI and ATCDI

		• Implement policies to reduce emissions from the forestry sector and to ensure sustainable land use, forest management, and agricultural practices	

4.1.4 Key Barriers to Energy Efficiency Market Development

Most EE projects provide compelling paybacks with stable cash flows from energy and other savings and involve tested technologies with relatively low implementation risk. Despite this, many opportunities in EE remain untapped, largely because EE is not seen as a strategic priority for market actors (outside of those engaged in energy intensive activities as their core business). This dynamic often leads to inaction on behalf of decision-makers, who fail to see the value in EE investments.

In PNG, very few of the existing EE opportunities identified in **Section 2.3** have been adequately assessed and developed into projects. Some of the key barriers that inhibit EE market development in PNG are described below. A summary of the policy, technical, economic, financial, capacity and market barriers and risks in EE and corresponding potential TA interventions to address barriers and mitigate risks are presented in **Annex 1**.

Policy and Regulatory

Above all, there is an immediate need for a comprehensive policy and regulatory framework to introduce and mandate energy efficiency improvements and standards on a national scale. To date, policymakers in PNG have not included EE objectives in national and provincial development planning, instead focusing on addressing low rates of electricity access and improving power supply. Renewable energy and energy efficiency activities are largely driven by individual short-term projects, without a clear longer-term strategy for development of the sector. In the National Energy Policy 2017-2027, the Government intends to formulate an Energy Efficiency and Conservation Policy, as well as to pursue a series of policy, legal and regulatory reforms to improve energy efficiency through a proposed National Energy Authority.

Institutional

PNG's institutions currently lack the internal capacity to design, implement and successfully manage a national EE program, which will require extensive planning and coordination across various stakeholder groups. Most of the public agencies and institutions that would be responsible for managing such an effort are constrained administratively, technically and financially. Stakeholder consultations revealed that lengthy administrative, legal and institutional processes in PNG generally slow down the pace of project development. Moreover, coordination between government agencies and ministries appears to be limited. A successful national EE program will require coordination among policymakers across government agencies and ministries responsible for energy, transport, industry/commerce, buildings, standards etc. to avoid duplication of efforts and ensure the efficient allocation of scarce human and financial resources. One way to address this barrier is to establish a **National Energy Efficiency Platform** – chaired by representatives from key governments ministries that regularly plans and coordinates the implementation of EE activities across the economy. The EE Platform is described in further detail in **Section 4.2.2.**

Public Awareness

There is an overall lack of public awareness in PNG about affordable ways to reduce energy costs. Unlike RE projects where physical infrastructure is involved, EE relies heavily on data and behavioral change; inadequate awareness and information is therefore a critical barrier. Awareness raising and capacity building is needed for policymakers across all levels of government, as a national EE campaign will require close coordination among ministries and administrators at the national, provincial and district level. Awareness is also critical for consumers, who may lack information about the availability and/or benefits of investing in EE equipment and appliances, and consequently revert to purchasing low-cost, inefficient alternatives. A survey of consumer awareness and use of energy rating labels carried out in PNG in 2017 found that public understanding of energy labels was very poor, and few respondents use labels to inform energy appliance purchasing decisions.

The relatively low level of financial literacy in the country is a related barrier, as financial literacy is critical to consumer decision-making surrounding the future benefits associated with a purchase. This

is particularly true with respect to investments in RE and EE. A quality-verified solar product or an energy efficient appliance is typically more expensive than a generic solar product or inefficient appliance. Consumers who may view buying the more expensive product as a disadvantage lack an understanding of the long-term benefits and cost savings that arise from investing in RE/EE products and appliances – as well as any options that may be available for them to finance the up-front purchase. Overcoming these barriers will require a comprehensive and sustained effort by the GoPNG to raise awareness and increase access to product information (e.g., through MEPS and product labeling) so that consumers can identify energy efficient products and make informed purchasing decisions. Financial literacy issues can be accomplished in partnership with the microfinance sector, which often integrates capacity-building for customers into loan products.

Baseline Energy Data

Quality and reliable data are essential for EE sector development. Unlike RE projects, which involve building physical infrastructure, EE projects and programs often rely on data related to energy use and savings in order to change behavior or retrofit existing equipment or infrastructure. The outcome of any EE initiative is measured by its energy and monetary savings, which can only be substantiated if the saving is compared to a baseline figure (e.g., quantity of energy/money saved, emissions reduced etc.). In PNG, very little of this data is available, as it is generally not being tracked or recorded. While larger companies operating in the country keep records of energy use and expenditures (e.g., quantity of diesel for powering operators), this data is largely unavailable for smaller companies. In the public sector, no studies have been undertaken by the DOT to collect reliable data on the volume or fuel efficiency standards of imported vehicles. This dearth of research and development (R&D) materials in the EE sector makes it extremely difficult for the Government to set targets and make informed policy decisions.

Local Technical Capacity

There is a lack of adequate local technical capacity across the entire RE and EE supply chain, particularly to develop EE projects. There is a lack of capacity within government to identify, appraise,

and develop clean energy projects. Likewise, there is limited technical capacity within the private sector to provide the financial and energy management services to government, businesses or households for EE improvements. PNG's labor force is primarily low-skilled and will require extensive support to build local technical capacity; for example, the Government can partner with industry associations and academia; e.g., PNG University of Technology (UNITECH), Technical and Vocational Education and Training (TVET) programs etc. to design and implement training and technical certification programs for EE audits, monitoring and verification. Local commercial banks will also require training to develop sufficient EE lending capacity in order to appropriately appraise the clean energy sector and identify bankable project opportunities.

Standards and Quality

In PNG, no framework is in place to mandate standards and energy performance across various sectors of the economy. There are no standards for EE in building design or building renovation, no mandatory labelling or EE standards in place for electrical appliances, and no incentives in place for the public or private sector to conserve energy. Import duties and taxes do not encourage EE appliances or equipment. This has led to the presence of an informal market, where retailers provide low-cost, poor-quality energy products and appliances, which typically do not meet international standards and lack warrantees. This negatively impacts the entire market by creating a misperception about product quality and the sales and performance history of the sector, which in turn undermines consumer confidence in EE technologies.

Electricity Pricing and Utility Financial Performance

The average retail tariff for PPL customers in PNG is about USD 0.20/kWh, which does not reflect the true cost of electricity service. Energy sector prices play an important role in influencing consumer behavior with respect to EE; since EE investments are paid back in time through lower energy costs, artificially low energy prices do not encourage consumers to pursue energy efficiency. The low tariff also does not reflect the high investment costs required for power generation and transmission – especially when diesel fuel is needed for power generation. As a result, PPL does not generate enough

revenue to invest sufficiently in the maintenance of grid infrastructure, which makes the electricity network unreliable, with frequent and prolonged outages. Given PPL's poor operational and financial performance, the utility is not a creditworthy off-taker for RE project developers. This dynamic makes it challenging for IPPs to develop viable projects, leaving most IPPs dedicated to specific resource projects rather than serving a heterogeneous customer base.

Imbalanced Energy Mix

The country's power supply mix relies mainly on a combination of hydropower and thermal generation. The availability of hydropower depends heavily on climate conditions, which makes the technology increasingly susceptible to the worsening impacts of climate change (e.g., a severe drought in 2015 led to a shortage of power supply in Port Moresby). Meanwhile, thermal fuels are subject to price volatility and are environmentally unsustainable and incompatible with the country's long-term ambitions for carbon neutrality. Many RE technologies have higher efficiency than conventional sources; increasing the share of these technologies can therefore increase overall energy efficiency, and thus decrease total primary energy demand. Likewise, improved EE will also make it easier for PNG to achieve its RE targets, as less RE capacity needs to be installed to achieve the same share of a smaller overall demand.

Access to Financing

The lack of initial funding by households, businesses and institutions for the initial capital investment required for EE improvements is a critical barrier, as the cost of energy efficient equipment is generally higher than most end-users in PNG can afford. Access to financing for EE improvements can therefore hinder the uptake of EE. On the supply side, energy service companies seeking to enter the sector or expand their operations require significant working capital, which is not readily available. Project developers and other companies active in the sector are not able to access credit locally. The lack of affordable and accessible finance for EE improvements also discourages investment in the sector.

In the agricultural sector, farming is largely done on customary title land, which is not recognized by financial institutions as acceptable collateral. As a result, these businesses are often underserved by

financial institutions and have limited access to credit. The Pacific Private Sector Development Initiative (PSDI), funded by the Asian Development Bank and the governments of Australia and New Zealand, has partnered with financial services providers and businesses in PNG to structure loan products that seek to balance commercial sustainability with the practical needs of agribusinesses. These financial products are flexible enough to accept a number of moveable assets as security, including agricultural produce, confirmed contracts, and debtor books. PSDI is also conducting a scoping study on the potential introduction of warehouse financing in PNG, which would enable more smallholder famers to obtain credit using crops as security.

Public Finance and Budgetary Constraints

Public institutions at the national, provincial, district and local level face restrictions on their ability to sign multi-year contracts for RE and EE infrastructure investments. Budgetary commitments are planned on an annual basis; therefore, it is difficult for them to make commitments to pay for energy services that go beyond one year. Developers and investors face the risk of non-payment from public institutions and must often turn to third-party guarantees to backstop payments from government counterparties.

Land Access/Ownership

An estimated 80% of the land in PNG is customary land that is owned by families, making the process of acquiring land difficult. To acquire land for a project, developers must first negotiate with customary owners to secure a land lease from them. An agreement with customary owners must be signed for developers to build a project. To complete the land acquisition process, developers must also obtain approval from the Department of Lands and Physical Planning. The complexity surrounding this process may deter private sector participation in RE and EE development. Moreover, customary landholding among social clans or indigenous communities also constrains consolidation and scale in the agriculture sector, as fragmented land holding makes it difficult to achieve economies of scale.

Geography

The geography of PNG poses several challenges. The country's many islands, its mountainous terrain, and its poor road infrastructure make it difficult to reach scattered and isolated rural communities, where the majority of the population lives. These characteristics increase investment costs of power generation, transmission and distribution for PPL (and in turn, electricity prices for consumers), and logistical costs for sourcing and distributing RE and EE products and equipment.

Gender and Inclusive Participation

The inclusive participation of women will be essential for PNG to achieve its universal electrification and sustainable development objectives. Yet, significant gender disparities and inequities exist in PNG, as the country ranks 155th out of 189 countries according to the UNDP's Gender Inequality Index, which measures the inclusive participation of women will be essential for PNG to achieve its universal electrification and sustainable development objectives. Yet, significant gender disparities and inequities exist in PNG, as the country ranks 155th out of 189 countries according to the UNDP's Gender Inequality Index, which measures several indicators to assess levels of gender inequality in areas of health, access to education, economic status and empowerment. Women in PNG face several socio-economic barriers that hinder inclusive economic development, including cultural beliefs, land tenure practices, unequal control of household resources and gendered division of labor, among others. Women often encounter difficulties obtaining development assistance, including access to bank credit, education, technical knowledge and skills development. These dynamics are reflected in labor and employment trends; according to the 2011 census, women were more likely than men to engage in non-monetary (i.e., subsistence) economic activities, particularly in rural areas, where 70% of women were engaged in subsistence employment.

Improving gender outcomes in PNG will require coordinated policies to mainstream gender inclusiveness and support women's empowerment in the sustainable energy sector. There should be a gender balance in the public institutions responsible for promoting and coordinating sustainable energy and off-grid sector development in the country (i.e., the NEA, CCDA etc.). Capacity building, training, skills development and certification programs in the RE/EE sectors should also take measures to ensure

inclusive participation of women. When conducting RE and EE market studies, data should be disaggregated by sex to ensure that policymakers understand the needs and priorities of women in the context of rural electrification and sustainable development.

4.2. CASE STUDIES AND LINKAGES TO REGIONAL AND INTERNATIONAL PROGRAMS

In order to take advantage of opportunities to integrate and mainstream EE in the country, the GoPNG can seek to link its national efforts to international initiatives led by the United Nations and other development organizations as well as to regional clean energy programs in the Pacific. This section explores these important linkages and includes case studies of EE programs and initiatives in similar country contexts that can offer guidance and lessons learned to support implementation of PNG's national EE roadmap.

4.2.1 International Initiatives

4.2.1.1 UN Sustainable Development Goals

The UN has classified PNG as a Small Island Developing State (SIDS), recognizing the country's unique development challenges, particularly with respect to its vulnerabilities to the impacts of climate change and its limited resources and capacity to achieve its long-term sustainable development objectives.

In 2015, the UN adopted the 2030 Agenda for Sustainable Development, which identified 17 Sustainable Development Goals (SDGs), many of which are interrelated, with success in one goal often correlating with success in other areas under the SDG framework. Energy efficiency is a key component of SDG 7, which promotes affordable and clean energy for all. The wide-ranging economic and social benefits of EE also contribute to several other SDGs, including poverty alleviation (SDG 1), improved health and well- being (SDG 3), inclusive and sustainable economic growth (SDG 8), resilient infrastructure development (SDG 9), sustainable cities/urban development (SDG 11), responsible consumption and production (SDG 12), and climate change mitigation and adaptation (SDG 13).

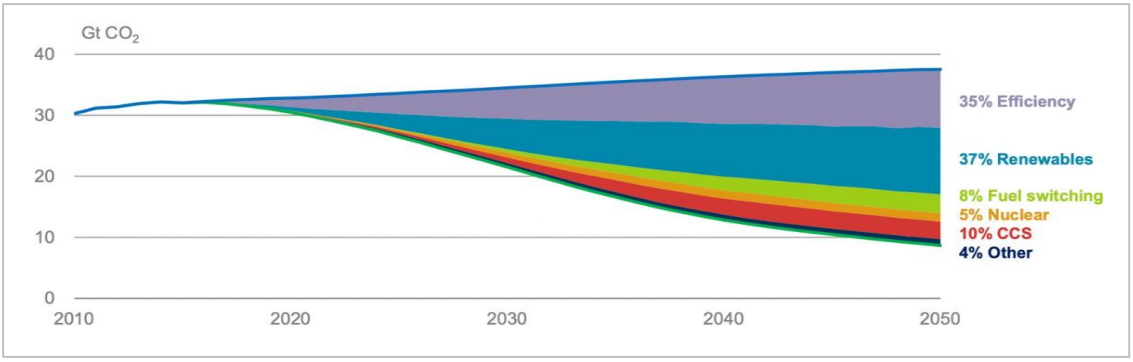
SDG 7 has established a target to double the global rate of improvement in EE by 2030. The rate of improvement in EE is measured by observing the rate of improvement of global primary energy intensity – defined as the percentage drop in global total primary energy supply per unit of GDP. In the long-term, the International Renewable Energy Agency (IRENA) estimates that in order to successfully transition to a low-carbon economy powered by clean energy, the energy intensity of global GDP will need to drop steeply in the coming decades – to about half of today's levels by 2050.

In PNG, with support from its development partners, the Government has made SDG 7 and SDG 13 key priorities in its long-term development planning, with a focus on increasing rates of energy access by 2030 and scaling up the deployment of RE and EE to ultimately achieve carbon neutrality by 2050.

4.2.1.2 UNFCCC Nationally Determined Contributions

In 1993, PNG ratified the United Nations Framework Convention on Climate Change (UNFCCC) treaty, which formally acknowledged the impacts of climate change and set to establish global standards and expectations on how signatory countries would contribute to addressing the issue. Multilateral discussions on how best to achieve global climate goals led to seminal international agreements in the Kyoto Protocol of 1997 and the Paris Agreement of 2015 – both of which were ratified by PNG. The Paris Agreement, which brought 195 nations together to combat climate change, has the central aim of limiting global temperature rise below 2 degrees Celsius above pre-industrial levels and to attempt to limit temperature increase further to 1.5 degrees Celsius. The International Energy Agency (IEA) estimates that energy efficiency will need to deliver 35% of the cumulative CO2 savings required by 2050 to achieve the goals of the Paris Agreement (**Figure 20**).

Figure 20: Global CO2 Emissions Abatement by Technology, 2010-2050



Source: International Energy Agency

The UNFCCC requires each signatory of the Paris Agreement to submit Nationally Determined Contributions (NDCs), which illustrate efforts made to reduce national emissions and adapt to the impacts of climate change. NDCs include targets, measures and policies and are the basis for national climate plans. Parties submit their NDC to the UN secretariat every five years, with the intention of enhancing the ambition of their NDC over time.

The CCDA is PNG's Designated National Authority to the UNFCCC, responsible for coordinating the country's climate change policies and actions in relation to the Paris Agreement. PNG submitted its first NDC in 2015 and its second in 2020. During this five-year period, PNG recorded an increase in its GHG emissions, which is partially attributed to "increases in emissions from the energy sector linked to economic growth and development of natural gas reserves."

In PNG's enhanced 2020 NDC, the CCDA submitted commitments to enhance climate change mitigation in the energy, transport and agriculture, forestry and other land use (AFOLU) sectors. To reduce emissions from the energy sector, the NDC intends to increase the country's share of RE in the power generation mix and to implement performance and efficiency measures. With respect to EE, the NDC proposes the adoption and implementation of Minimum Energy Performance Standards (MEPS) and appliance labeling, enhancement of public awareness of energy use and conservation, and improved collection and management of emissions related data across the energy sector and wider economy so

that PNG can establish appropriate baselines and set concrete EE targets going forward.

4.2.2 Regional Pacific Initiatives

4.2.2.1 ASEAN

Papua New Guinea has been an observer of the Association of Southeast Asian Nations (ASEAN) since 1976 and is working towards becoming the regional entity's 11th member. Although PNG's applications to be a fully-fledged member have been denied, it is nonetheless important to consider ASEAN's policies on EE. ASEAN views EE "as the most cost-effective way of enhancing energy security, addressing climate change and promoting competitiveness." During the first phase of the ASEAN Plan of Action and Energy Cooperation (APEAC), 2016-2020, the program promoted green building codes, zero energy building awards, EE financing measures, and included a training and certification program for energy managers from member countries. Member states also succeeded in endorsing:

- A Regional Policy Roadmap on Harmonization of MEPS for Air Conditioners;
- A Regional Policy Roadmap on Harmonization of MEPS for Lighting; and
- Guidelines of Integration of Energy Efficiency into ASEAN Electrical and Electronic Equipment Mutual Recognition Arrangement

In 2020, the organization published the second phase of the APEAC, 2021-2025, which sets a target to reduce regional energy intensity by 32% by 2025 (compared to a 2005 baseline), focusing especially on the transport and industry sectors. ASEAN established the Energy Efficiency and Conservation Sub-Sector Network (EE&C-SSN) to coordinate regional EE efforts during the second phase of the program. The network aims to build on what was accomplished during the first phase and to:

- Further harmonize regional EE standards;
- Extend standardization to other electrical and electronic equipment;
- Establish a database for documentation of case studies in the region; and
- Strengthen mechanisms for standardization as well as for verification and enforcement

EE&C-SN has developed individual action plans for targeted sub-sectors, as well as action plans on

how the network will harmonize regional EE policies and enhance private sector participation in furthering EE in ASEAN member countries.

Previously, in 2016, the ASEAN Centre for Energy established the ASEAN SHINE program, part of the UN Environment Programme United for Efficiency (U4E) initiative, a global effort supporting developing countries to transition their markets to energy efficient appliances and equipment. ASEAN SHINE has focused specifically on providing training, financing and technical support to member states in the areas of energy efficient lighting, air conditioning, motors and transformers.

ASEAN has taken a systematic and well-integrated approach to advance EE in the region. PNG can learn from the experiences of ASEAN member states as it develops and implements its own EE policies and action plans going forward.

4.2.2.2 Asian Development Bank

The Asian Development Bank (ADB) supports economic growth and development among its 68 member states, including PNG, which has been a member state since 1971. As countries in the region have continued to develop, with many reaching middle-income status, the ADB has expanded its mandate to support other areas, including climate change. Seven out of 10 of the world's most vulnerable countries to climate change are ADB member states, and rapid development has also made the region one of the highest contributors to GHG emissions. More investment is needed in EE across Asia-Pacific; in 2020, the region accounted for less than 14% of global public funding for energy efficiency.

The ADB's most notable ongoing energy sector investments in PNG include the Town Electrification Investment Program and the Port Moresby Power Grid Development Project – both of which focus on energy access and renewable energy integration. The ADB Town Electrification Investment Program comprises two tranches: (i) improvement of power supply in provincial urban centers by supplanting high-cost diesel generation with renewable energy sources; and (ii) extensions of the distribution network to more communities. Under the Port Moresby Power Grid Development Project, the ADB has

allocated funding to support the rehabilitation of several large hydropower projects.

In 2009, under Phase 1 of the Promoting Energy Efficiency in the Pacific program, the ADB funded a power factor correction program in PNG, with a successful pilot project implemented by PPL in Port Moresby (see **Section 2.3.1.2**).

4.2.2.3 Pacific Island Countries

PNG is a member of several regional organizations as well as a signatory to regional and joint initiatives in the Pacific and/or concerning SIDS that provide guidance on RE and EE policy and sustainability, including the Pacific Islands Forum (PIF) and the Alliance of Small Island States (AOSIS), among others. The most comprehensive joint Pacific initiatives are the SIDS Accelerated Modalities of Action (SAMOA) Pathway of 2015, and the Framework for Resilient Development in the Pacific (FRDP), which was developed in 2016. The SAMOA Pathway urges SIDS to reduce their dependence on imported fossil fuels through the development and implementation of national strategies promoting EE, RE and energy access solutions and facilitating access to clean energy financing. The FRDP targets low-carbon development through reduced carbon intensity of development processes, increased resilience of energy infrastructure and the conservation of ecosystems. In 2019, the PIF Secretariat introduced the 2050 Strategy for the Blue Pacific Continent, a long-term climate action plan with the goal of consolidating regional efforts and frameworks under a common agenda.

4.2.3 Case Studies

This section offers case studies of EE policies and programs in other countries which can serve as examples for PNG. In examining these case studies, it is important to recognize that PNG stands apart from other countries in the Asia-Pacific region. For instance, while PNG shares many similarities with other Pacific Island Countries (PICs), it is the largest and most populous of this group. Compared to many of its ASEAN neighbors, PNG is at a different stage of development with a much smaller economy, as many ASEAN states have attained middle-income status. Thus, while these countries can offer examples and case studies for PNG, it may be difficult for some of their achievements to be

replicated in PNG due to resource and capacity constraints.

4.2.3.1 Cambodia

Like PNG, Cambodia is fast-growing, lower-middle income country, albeit with a higher national electrification rate. In 2017, the Government of Cambodia adopted the National Policy, Strategy and Action Plan on Energy Efficiency, which set a target to reduce national energy demand by 20% through 2035 relative to business-as-usual projections. To meet the country's energy savings target, the government identified three key sectors as priority areas – buildings, industry and transport – and developed a strategic plan to guide EE improvements in these sectors through a combination of four main activities: (i) awareness raising; (ii) capacity building; (iii) financial incentives; and (iv) standards.

- In the **building** sector, the goal is to reduce energy use by 25% through several measures, such as the introduction of climate-responsive and energy efficient building design into building codes for new construction; the establishment of minimum efficiency standards for existing building stock; the implementation of a national labeling program for household appliances, with associated standards and regulations enacted; and the promotion of energy efficient cookstoves.
- In **industry**, the government is also targeting a 25% reduction in energy demand by implementing standards and regulations on industrial energy use that will include energy management and auditing requirements, along with a national program to certify energy managers and auditors to support development of energy services companies capable of providing these services to the market. Another focus area of government EE policy is the development of eco-industrial parks in the country's specialized economic zones, which pool together manufacturing and service businesses to take advantage of energy cost savings and other operational efficiencies (see **Box 7**).
- In the **transport** sector, the plan aims to achieve 15% energy savings through investment in integrated public transportation systems and the promotion of sustainable transport solutions, including incentives to increase the uptake of biofuels and the purchase of fuel-

efficient and zero- emission vehicles.

Box 7: Eco-Industrial Parks in Cambodia

In Cambodia, specialized economic zones (SEZ) are legal, logistical, and tax enclaves within a designated area that are structured to attract export-oriented foreign investment (mainly in the manufacturing sector). SEZs are a key driver of economic development in Cambodia and are now the focus of the country's national EE strategy. In eco-industrial parks or SEZs, manufacturing and service businesses cooperate to reduce waste and pollution and efficiently share resources such as information, materials, water, energy, infrastructure, and natural resources. Eco-industrial parks can maximize EE in the design of new (or retrofit of existing) facilities/factories, through the use of co-generation/waste heat recovery processes, and through monitoring of energy usage and impact.

Source: UNDP, 2020 and ADB, 2015

4.2.3.2 Fiji

In 2012, the Fijian government launched the Energy Conservation and Efficiency Program (ECE), which included public awareness, energy audits, and the promotion of EE appliances and equipment through a Minimum Energy Performance Standards and Labeling (MEPSL) program. Fiji's MEPSL program was a component of the Pacific Appliance Labeling and Standards (PALS) Programme, funded by the Government of Australia and implemented by the Pacific Community, and initially regulated the importation and sale of refrigerators and freezers. Fiji's Department of Energy is exploring the expansion of the MEPSL program to include air conditioners, lighting and other energy intensive electrical appliances. The Department of Energy is also undertaking a review of the National Building Code with the intended outcome of including energy efficiency measures, including the following:

- Codify current best practices, including:
- Daylighting
- Tinted windows and exterior building shading (based on shading and orientation)
- Reduced lighting loads (measured in watts/meter^2)
- Standards for natural ventilation
- Building envelope insulation and cool roofs
- Develop government building EE prototypes/pilot projects
- Adopt lease agreement standards for efficiency of all federal buildings
- Establish equipment efficiency standards for lighting ballasts and air cooling

- Establish standards for new subdivision development and land use policies to address building orientation, heat island mitigation, solar access, and solar ready construction
- Establish comprehensive 'green' building standards for all new construction
- Adopt a national incentive program to encourage the adoption of EE standards

In addition, Fiji's government has established financial incentives for EE in the form of fiscal and import duty exemptions for energy efficient lights and hybrid electric vehicles.

4.2.3.3 Rwanda

Rwanda's National Cooling Strategy (NCS) highlights opportunities for addressing the country's growing demand for cooling technologies (i.e., refrigeration and air conditioning) in a resource-conscious, climate- oriented manner. As the first phase of the Rwanda Cooling Initiative – a joint effort between the government and UN Environment's United for Efficiency (U4E) program – the NCS builds on existing policies and targets and provides recommendations for additional legislative and programmatic actions that can be undertaken to promote energy-efficient, climate-friendly cooling across multiple sectors of the economy (buildings, industry, healthcare, agriculture etc.). The NCS is part of a broader national policy framework that Rwanda is implementing to improve management of energy demand, reduce emissions and ultimately minimize the need for investment in additional power generation infrastructure.

In 2019, the Rwanda Business Development Fund and the Rwanda Green Fund (FONERWA) partnered with U4E and the Basel Agency for Sustainable Energy (BASE) to launch the 'Coolease' financial mechanism, which enables suppliers and consumers of air conditioning and refrigeration equipment to transition to upgraded, EE technology without upfront investment. The lease is provided by a financial institution to the client (typically an enterprise) through a finance leasing agreement, in which the air conditioning or refrigeration system is used as collateral. The program will help reduce Rwanda's energy intensity levels and also aligns with the Kigali Amendment to the Montreal Protocol, which requires all nations to phasedown refrigerants that are potent greenhouse gases.

4.2.3.4 Côte d'Ivoire

With technical assistance from the SEforALL Africa Hub and ECOWAS Center for Renewable Energy and Energy Efficiency (ECREEE), in 2016, Côte d'Ivoire developed a National Energy Efficiency Action Plan, which outlines the country's goals to improve energy efficiency by 2030. The Action Plan included provisions to introduce EE standards, labeling, awareness raising, data management, energy auditing requirements, and funding for training and technical capacity development. Much like other developing states, Côte d'Ivoire lacks adequate technical expertise and human resources to effectively implement its EE policies. To fill this gap, it is investing in vocational education and training institutions to develop local human resources needed to provide technical expertise in RE and EE (e.g., for the planning, installation, operation, maintenance and repair of RE systems and EE solutions).

One such initiative is currently being supported through a collaboration between the government of Côte d'Ivoire and the German Federal Ministry for Economic Cooperation and Development (BMZ), which involves the implementation of an RE and EE vocational training program. The program works with public and private vocational schools and corporate associations to design and implement RE and EE qualification measures and certification programs, as well as information-sharing platforms for businesses and training providers to support the exchange of experience and best practices.

4.2.3.5 Samoa

In 2017, Samoa passed an Energy Efficiency Act, which provides detailed regulations for energy efficient products and appliances. The regulations include MEPS and labeling for lighting products, air conditioners, refrigerators and freezers. There is a list of approved brands and models of products included in the legislation to ensure that imported products are tested, registered and approved for sale.

In addition to these appliance standards, the government of Samoa has set annual targets to reduce national energy consumption and has implemented financial incentives to promote renewable energy generation, improve electricity transmission/distribution networks, and develop demand side management strategies for major (top 10) electricity users. Additional regulations are in place for

vehicle standards and appliance energy consumption ratings. The government has also taken measures to promote energy efficiency and conservation through public awareness campaigns focused on energy audits and demonstration/pilot programs to reduce electricity usage; the use of solar water heating in commercial applications, particularly in the hotel sector; appropriate installation and maintenance of industrial and commercial heating equipment; and the use of fuel efficient cookstoves to replace wood fuels and kerosene in the residential sector.

4.3 ENERGY EFFICIENCY ROADMAP DESIGN AND IMPLEMENTATION

The development and implementation of energy efficiency measures requires a robust policy framework with clear targets, effective regulation and legislation, and strong institutional support to coordinate policy and project implementation, monitor and evaluate progress and verify results. This section provides guidance and recommendations to the GoPNG for development and implementation of an integrated national energy efficiency roadmap for the country. It includes a summary of proposed energy efficiency policies, laws and regulations (**Section 4.1**); management approaches (**4.2**); financing and business models (**4.3**); awareness creation, capacity building and training **(4.4**); research and development (**4.5**); monitoring, verification and enforcement (**4.6**); and a framework for the roadmap's implementation (**4.7**).

4.3.1 Policy, Legal and Regulatory Framework

Energy efficiency policies, laws and regulations collectively serve as the foundation for investment in EE measures on a national scale. Policy measures should be based on statistical assessments of the EE potential of various sectors of the economy. This allows for informed decision-making, as policymakers can utilize sector-specific data to establish baselines from which long-term EE targets can be determined. Legal and regulatory reform is often necessary to encourage private sector participation in the restructuring and modernization of energy intensive sectors. Well-designed technical assistance (TA) programs can provide the expertise necessary to successfully implement EE policy and regulation.

4.3.1.1 Overview of Energy Efficiency Policies, Laws and Regulation

Energy efficiency policies, laws and regulations create a set of guidelines for entire sectors or types of energy-using equipment, and thus are capable of transforming markets, even if the resulting savings and benefits accrued may take years to be fully realized. Policy and regulatory mechanisms that support EE typically include codes to improve the EE and thermal performance of buildings, minimum energy performance standards (MEPS) and labeling schemes for products and appliances (**Box 8**), and EE requirements targeting critical sectors such as power, industry and transport. Governments will also set national EE targets and implement a wide range of EE programs and initiatives, including financing mechanisms, TA, and awareness/communication strategies that aim to foster private sector participation and market-based approaches. Collectively, these measures are effective at influencing the market to adopt energy efficient technologies, building designs, and operating practices. Standards also set a baseline that can help establish a reliable market for EE products and incentivize manufacturers to adjust their production lines to produce highly efficient products and appliances.

Box 8: Minimum Energy Performance Standards and Labeling

Minimum Energy Performance Standards (MEPS) specify the minimum level of energy performance of appliances and ban the sale of appliances below this level in order to incentivize the production of more efficient appliances and equipment. MEPS are often complemented by the labeling of energy efficient equipment, which serves to raise consumer awareness about the best available products and technologies. To be effective, MEPS will increase in strength incrementally over time, with coverage expanding to other sectors.

In general, the benefits of EE policy in emerging markets such as PNG are not identical to high-income countries, but there is significant overlap. Furthermore, a standard set of EE policy tools exists with a strong track record of improving energy security, lowering energy intensity, reducing emissions, and providing energy-related cost savings for an economy. **Table 6** presents an overview of energy efficiency policies, laws and regulations.

Table 6: Summary of Energy Efficiency Policies, Laws and Regulations

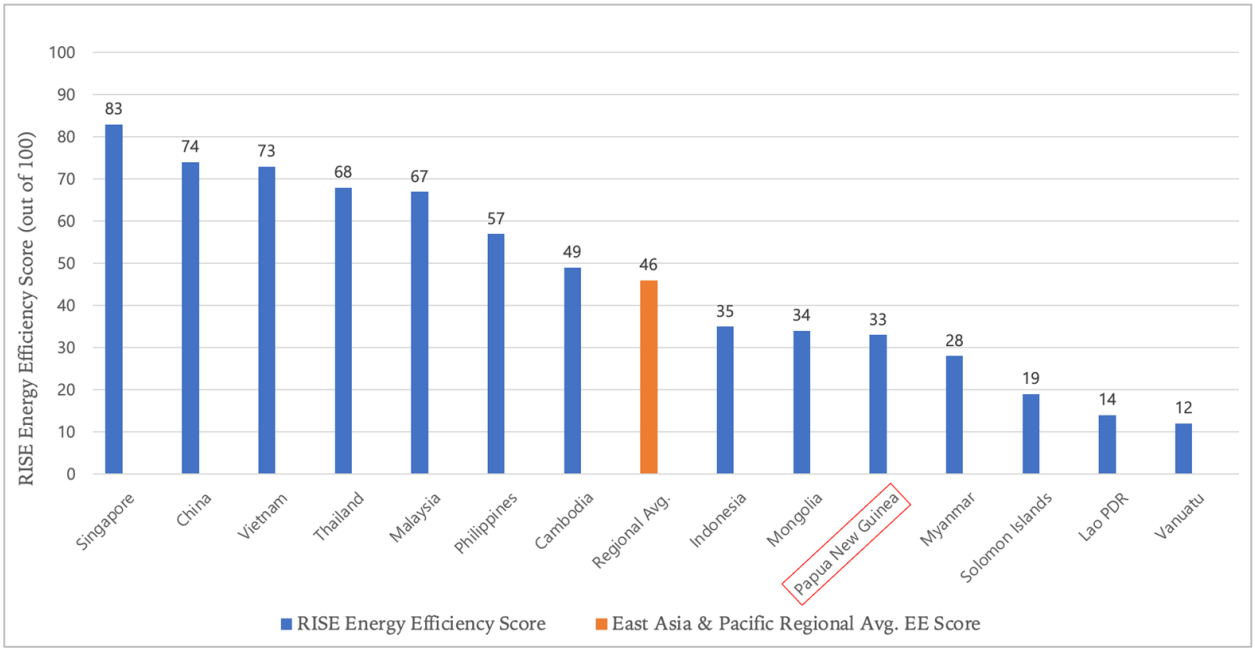
Policy/Law/Regulation	Description
Energy Efficiency Policies	• Designate lead institutions for setting EE sector objectives and leading planning, coordination, and monitoring of EE programs and initiatives • Develop and implement a systematic approach to collect and measure EE data and indicators on energy use across specific sectors to establish baseline figures and estimate CO2 abatement and energy savings (e.g., EE market research/assessments, indices and repositories of information) • Develop EE action plans or strategies establishing energy savings targets for the country as a whole and/or by sector • Design and launch EE funds/financing facilities and other market-based instruments to leverage private sector investment in energy efficiency • Provide economic and financial incentives for EE measures for households and SMEs (e.g., grants, rebates, subsidies, tax exemptions, concessional loans, financial guarantees etc.) • Launch public awareness and information campaigns on the benefits and cost savings of EE, financial incentives/mechanisms available for end-users etc. • Promote EE capacity building, training and certification programs to build local EE service industry (e.g., ESCOs, equipment manufacturers, installers, energy auditors etc.) • Implement policies and incentives to facilitate the importation of EE appliances/equipment
Energy Efficiency Laws and Regulations	• Require building energy codes and MEPS to improve building design, EE of building envelopes, systems and components (with rating systems, renovation targets, energy consumption goals etc.) • Establish mandatory MEPS and labeling for appliances, lighting and equipment (together with rating methods, testing procedures and protocols to measure performance etc.) • Adopt regulations to phase out inefficient appliances, lighting and equipment • Implement regulations to improve EE in the transportation sector (e.g., mandatory vehicle fuel efficiency standards, incentives for low-emission/hybrid electric vehicles etc.) • Implement regulations to reduce emissions from energy intensive industrial activities (e.g., mandatory EE standards for industrial equipment and systems) • Adopt regulations to mandate EE in power generation • Establish requirements for metering and consumption-based billing • Establish energy auditing requirements and supervision and certification of auditors • Develop regulatory procedures for residential EE (e.g., rebate schemes/financing mechanisms to incentivize purchases of EE equipment, such as credit lines through banks to households/SMEs) • Develop requirements, procedures and funding mechanisms for public sector EE in planning and operations (e.g., national and provincial government buildings, universities, schools, hospitals) • Establish legal authority for municipalities to borrow and use municipal assets

	as collateral • Establish legal authority for energy service companies (ESCOs) to implement projects using energy performance contracting or other EE business models • Develop and implement regulatory framework for EE monitoring, verification and enforcement mechanisms; establish legal sanctions for wasteful energy practices

The World Bank's Regulatory Indicators for Sustainable Energy (RISE) is a suite of quantitative and qualitative indicators that assess the legal and regulatory environment for investment in sustainable energy to help identify priority areas for change based on best practices across nations and to foster an enabling environment for sustainable development. In the EE sector, the RISE index covers national EE planning, MEPS, building codes, incentives and mandates, EE financing mechanisms, industrial and commercial end-use, public sector EE and the transport sector, among other indicators.

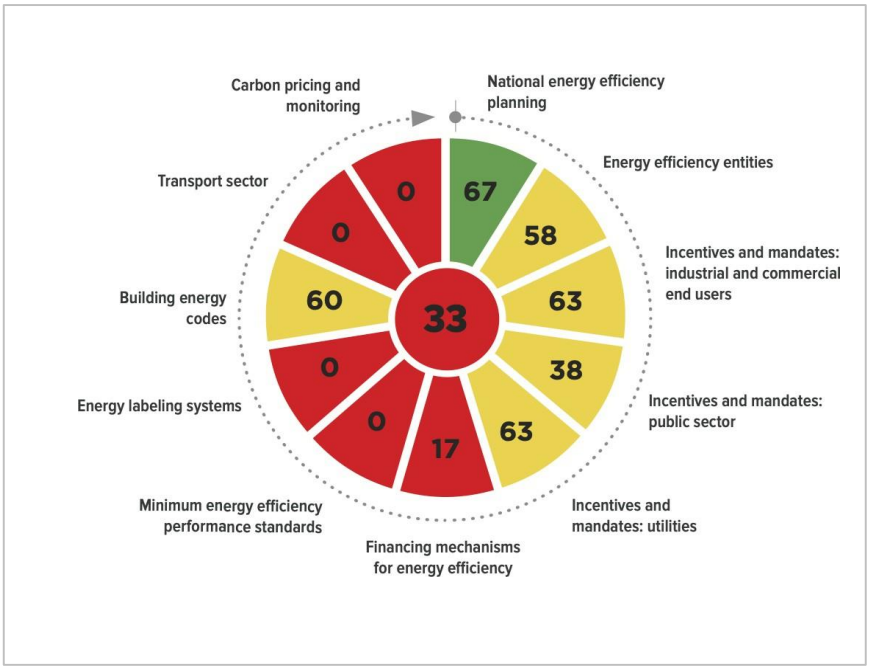
As illustrated in **Figure 21**, PNG currently ranks in the bottom half of countries in the East Asia and Pacific region – 13 points below the regional average EE score. **Figure 22** provides a scoring breakdown for each of the country's energy efficiency RISE indicators, while **Table 7** compares PNG's EE indicator scores to the East Asia and Pacific regional average.

Figure 21: RISE Energy Efficiency Scores for East Asia and Pacific Region, 2019



Source: World Bank Regulatory Indicators for Sustainable Energy (RISE) index, 2020.

Figure 22: RISE Energy Efficiency Score by Indicator for PNG, 2019



Source: World Bank Regulatory Indicators for Sustainable Energy (RISE) index, 2020.

Table 7: RISE Energy Efficiency Score by Indicator for PNG and East Asia and Pacific Region, 2019

EE Indicators	PNG EE Indicator Score	Avg. EE Indicator Score for East Asia-Pacific Region
National Energy Efficiency Planning	67	67
Energy Efficiency Entities	58	66
Incentives & Mandates: Industrial and Commercial End-Users	63	56
Incentives & Mandates: Public Sector	38	49
Incentives & Mandates: Utilities	63	50
Financing Mechanisms for Energy Efficiency	17	40
Minimum Energy Efficiency Performance Standards	0	38
Energy Labeling Systems	0	41
Building Energy Codes	60	33
Transport Sector	0	36
Carbon Pricing and Monitoring	0	11

Source: World Bank Regulatory Indicators for Sustainable Energy (RISE) index, 2020.

4.3.1.2 National Energy Efficiency Action Plan

In the recently adopted National Energy Policy 2017-2027 (NEP), the Government intends to formulate an Energy Efficiency and Conservation Policy, as well as to pursue a series of policy, legal and regulatory reforms to improve EE through a proposed National Energy Authority (NEA). One way that PNG can prepare an appropriate national EE policy is to follow the approach taken by many states that have developed National Energy Efficiency Action Plans (NEEAP). A NEEAP provides a national policy framework and a clear roadmap for EE sector development with ambitious long-term targets, integrated guidelines and standards, and supportive energy pricing schemes and market reforms.

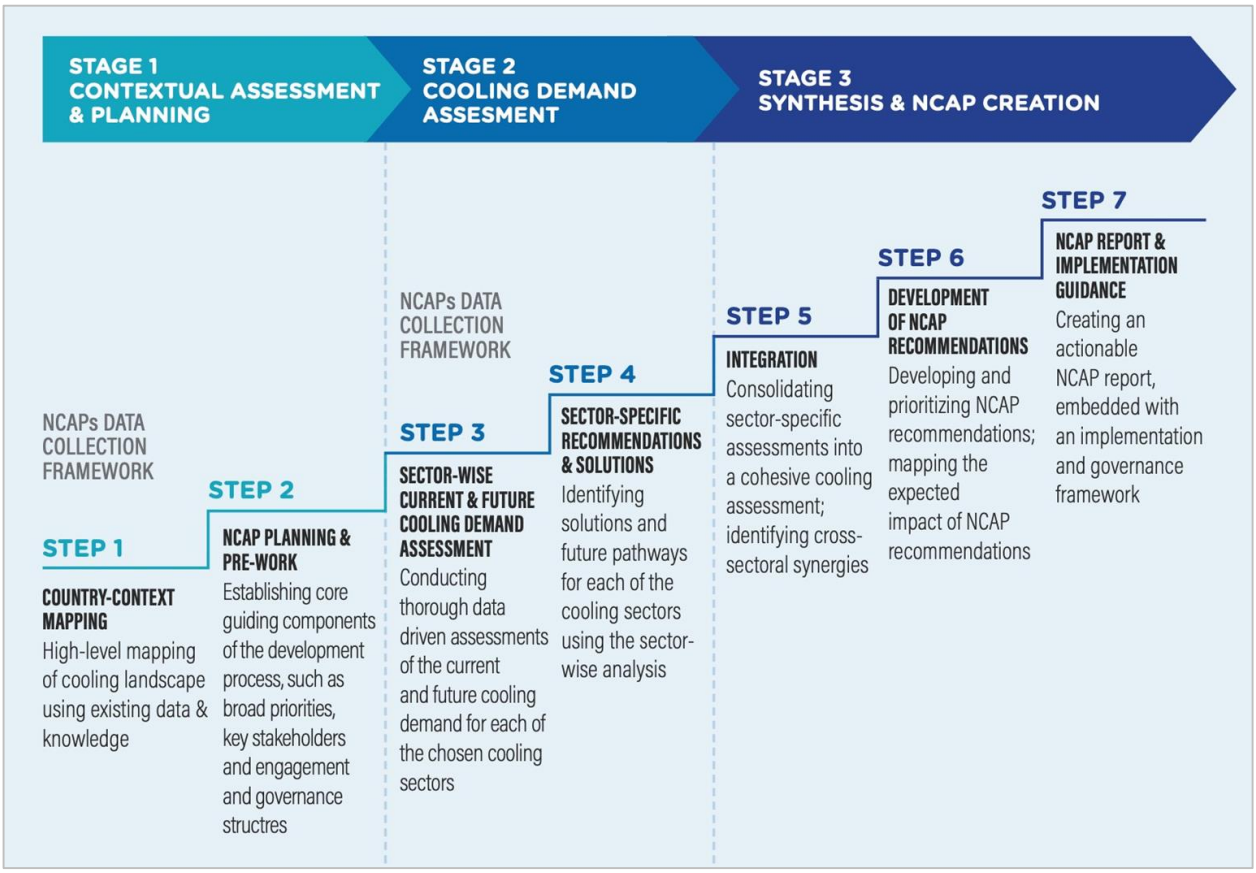
By offering clarity and predictability to market actors – notably for investors and companies who need to consider multi-year plans involving significant capital expenditure or borrowing – a NEEAP fosters private sector participation by de-risking and mobilizing financing and stimulating both demand and supply for EE investments and projects. NEEAPs typically include EE policies, programs, regulations and measures targeting specific sectors across an entire economy, including building energy codes and performance standards for appliances and equipment (as summarized in **Table 6**). In PNG, such an action plan can be developed and implemented by one or several governing bodies (e.g. NEA, CCDA) and facilitated with funding and TA provided by donor agencies and development partners. **Section 4.2** provides an overview of proposed EE management and coordination approaches to roll out a national EE plan.

4.3.1.3 National Cooling Action Plan

Much like a NEEAP, National Cooling Action Plans (NCAPs) are highly effective tools for countries to address growing cooling demand and promote sustainable development. Among other benefits, NCAPs can (i) deliver cost savings through enhanced energy efficiency for businesses and consumers; (ii) reduce emissions and support development of a stronger, more sustainable energy system; and (iii) reduce food waste, improving health, and increasing productivity through improved access to cooling. A NCAP is an important first step for countries to take, as it provides clarity and predictability for market actors and facilitates an enabling policy and regulatory environment that will foster private

sector participation, de- risk and mobilize financing, and stimulate both demand and supply for clean cooling investments and projects. **Figure 23** provides an overview of the main elements of a NCAPs policy framework.

Figure 23: National Cooling Action Plan Methodology



Source: SEforALL, 2021.

4.3.1.4 MEPS and Appliance Labeling

Minimum energy performance standards (MEPS) specify the minimum level of efficiency products must meet before they can be legally sold in a country; products must be tested to prove whether their energy performance meets the minimum energy performance standard. A MEPS program is often accompanied by a labeling scheme, whereby products that are in compliance with minimum requirements are labeled accordingly to provide accurate and comparable information on the efficiency of appliances to inform consumer decision-making. As described in **Box 8**, MEPS and appliance

labeling are effective policy tools to incentivize the production and consumption of more efficient appliances and equipment.

On a larger scale, an energy balance is an accounting system that describes the flow of energy through an economy (national, by province, by island etc.) during a given period, usually a calendar year. This combination of information is constructed from the most complete available sources of official energy statistics on imported fuels, electricity production, conversion, consumption and export. The main objective of this is to provide information for the planning of investments in different sectors of the energy system, as well as indications of where to direct investments in research and development for more efficient energy use.

A MEPS and labeling scheme requires policymakers to first establish clear benchmarks for a given sector and to introduce energy savings goals based on these benchmarks. In PNG, however, little to no detailed information exists on energy use characteristics of buildings, products and appliances. Moreover, no government entity has developed a repository of accurate and up-to-date data on the country's energy balance, energy consumption by sector, subsector and appliance type. This poses a major barrier to EE market development. Without data on energy consumption and demand profiles of certain sectors, it is not possible to define appropriate targets and objectives or to design a national EE program.

Detailed energy audits of key sectors of PNG's economy are needed to collect and analyze market data on building energy usage and materials; public, commercial, industrial and residential energy systems and applications; and a wide range of electrical appliances and equipment, such as refrigeration and air conditioning equipment, freezers, washing machines, water heaters, pumps, lighting equipment etc. These energy assessments will provide information on potential energy and cost savings (per kWh) and GHG emissions reductions (per ton of CO2e) that can be achieved from an EE upgrade or retrofit. An energy department can be established within the National Institute of Standards and Industrial Technology (NISIT) for this purpose; alternatively, a statistics department can be established within

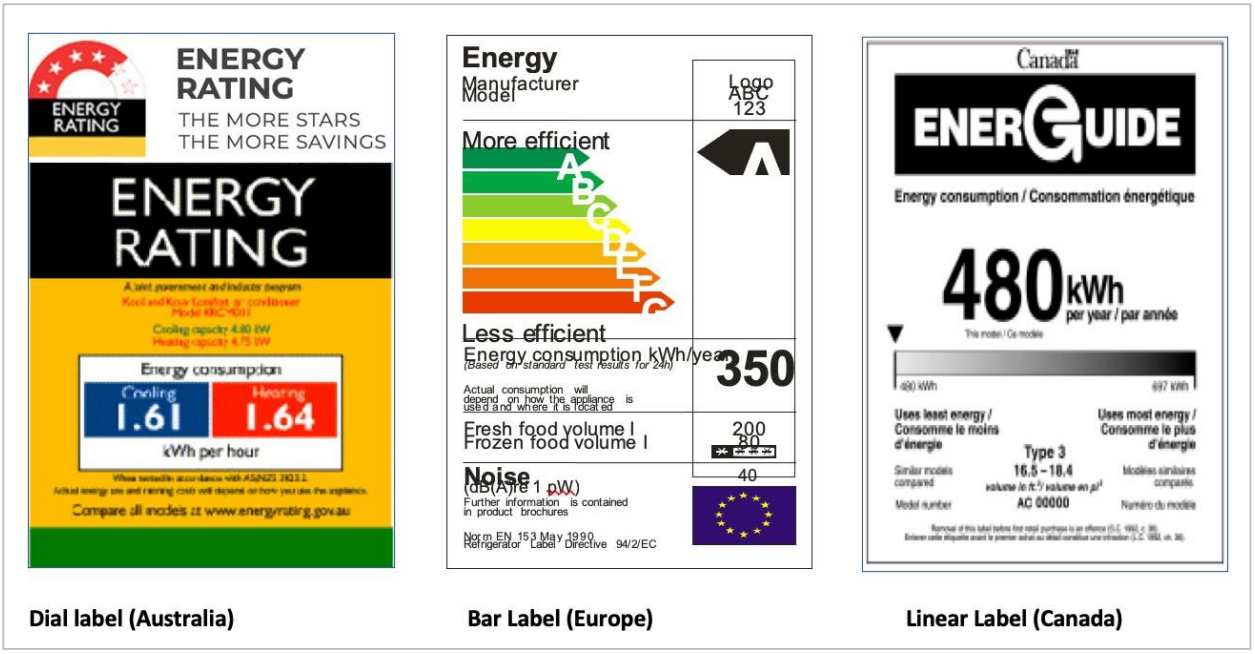
another relevant government energy agency (e.g., NEA, CCDA).

Once this market information is available, EE standards can be implemented together with an appliance labeling program so that all regulated imported appliances are tested on their energy performance according to the requirements of the program. Energy labels can then be attached to energy efficient appliances and equipment to demonstrate accurate energy consumption information, the level of efficiency and other relevant information about the products. Two categories of labels are widely used – endorsement labels and comparative labels.

- **Endorsement labels** point out to consumers that a given product meets a predetermined energy standard or eligibility criteria. This type of label merely informs consumers that the product meets a certain required standard or level of energy efficiency.
- As the name implies, **comparative labels** provide information to consumers that allow them to make a comparison among the same type of products to choose those that are more efficient. Comparative labels typically categorize and rank products on a scale in terms of their energy consumption and efficiency, thus allowing consumers to easily assess the efficiency of a product in relation to a scale, by means of a simple numerical or ranking system. There are different types of comparative labels, as illustrated in **Figure 22**.

In PNG, NISIT, in collaboration with other relevant public institutions (NEA, CCDA), can design and implement a national energy appliance labeling scheme that is integrated with a national MEPS program. Effective labeling will require market research to solicit input from consumers of energy products and appliances in order to adequately assess their needs and perceptions during program design. Typically, MEPS and appliance labeling schemes first target large-scale industrial or commercial applications or the transport sector – i.e., sectors that contribute a comparatively larger share of GHG emissions – before focusing on other areas of the economy (e.g., public and residential).

Figure 24: Different Types of Comparative Product Labels



Source: Lebot, 2009. Energy Efficiency and Market Transformation: A Short Overview of Best Practices

4.3.1.5 Incentive Schemes

In a nascent market such as PNG, it is critical that regulations are tied to incentives for the private sector, so that energy service providers view regulation as a supportive framework for development of the market. Energy sector prices play an important role in influencing consumer behavior with respect to EE, as the business case for EE is often hampered by the existence of below market rate electricity prices or market distorting cross-subsidies between sectors. Since EE investments are paid back in time through lower energy costs, artificially low energy prices do not encourage consumers to pursue energy efficiency.

In addition to setting efficiency standards for buildings and appliances, governments can also fund EE measures through direct investments in the energy services industry, public-private partnerships and incentive programs to stimulate demand for energy efficiency. Incentives in the form of subsidies or rebates can encourage the purchase of energy efficient products or the purchase of a service to promote efficiency, such as a building audit. Incentives are particularly effective when promoting new or

unfamiliar EE technologies and related services. Energy efficient products often enter the market with a higher initial cost even though they offer greater cost savings over time. Incentive schemes can influence skeptical customers to try out products and services, and then be phased out as those technologies and strategies become more accepted and consumers have a greater understanding of their value.

By providing incentives to end-users (e.g., subsidies, rebates, low-interest loans, tax reductions), government can stimulate EE demand by reducing the up-front costs associated with the purchase of new products that use less energy or are more energy efficient. Incentives can therefore help move consumers to purchase EE equipment when they otherwise may not have. In turn, this increases the market penetration of EE products at an early stage of development, which helps reduce the cost of production for manufacturers.

The key elements of an incentive program design are presented in **Table 8**. In addition to targeting consumers, incentive programs can also be designed to support manufacturers, distributors and retailers along the supply chain through various interventions (**Figure 25**). Together with standards and labeling programs and other EE policy and regulatory measures, these interventions can expedite the diffusion of high efficiency products and equipment in the market (**Figure 26**).

Table 8: Key Elements of Energy Efficiency Incentive Program Design

Indicator	Description
Efficiency criteria	• What is the efficiency level targeted by the incentive program?
Incentive amount	• What is the amount of incentive offered?
Incentive recipient	• Who is the program's target participant?
Form of incentive	• What form of incentive is offered (e.g., a tax credit, cash rebate, low-interest loan etc.)?
Eligibility requirements	• Are there any eligibility criteria to participate in the program?
Recycling component	• Does the program include a recycling component (e.g., to replace inefficient equipment)?

Source: S. de la Rue du Can et al., 2014

Figure 25: EE Incentive Program Design along the Supply Chain

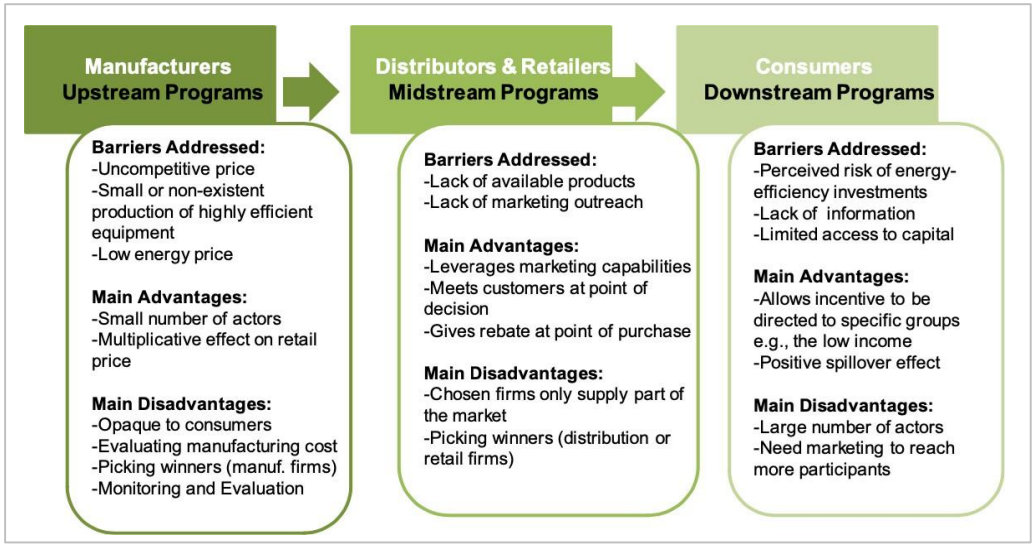
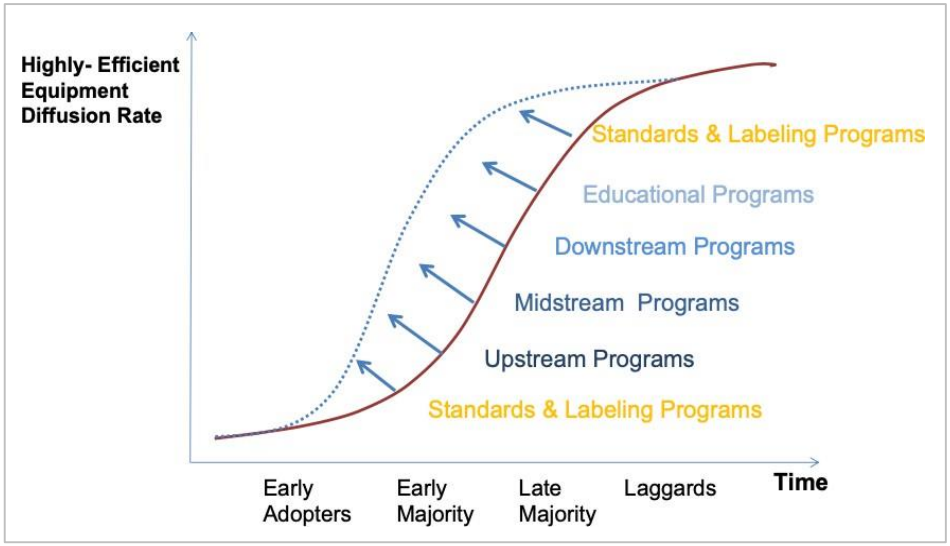


Figure 26: Impact of Market Interventions on EE Technology Diffusion Rate



Source: S. de la Rue du Can et al., 2014.

Incentive-based regulations already exist in PNG, so there is a legal precedent that EE initiatives can build upon to promote the uptake of energy efficient appliances and equipment in the market. In addition, the ICCC is working to develop frameworks to provide incentives to encourage compliance with existing codes, which would make the ICCC well equipped to champion an EE incentives program. Such an effort should be implemented in coordination with other relevant public agencies (NEA, CCDA, NISIT, DOT, DOW, PPL etc.) depending on the sector and/or equipment covered by the incentive scheme.

4.3.2 Management and Coordination

A well-designed energy efficiency action plan can help the GoPNG achieve its energy security and energy access goals in a way that effectively leverages best practices to reduce costs and improve livelihoods. A strategic EE management action plan that incorporates an understanding of both supply-side and demand-side EE measures, budgetary parameters and payback thresholds, and appropriate technology solutions, will help foster a mindset of ongoing energy planning, accountability, management and coordination. The role of the public sector in this process is critical, particularly in a nascent market such as PNG. The government can encourage efficiency and manage demand by creating new rules, offering access to affordable financing and building local capacity – all of which fuel new business opportunities. Above all, the public sector can lead the rest of the market by setting an example for other buyers and by harnessing public sector buying power to create or expand the domestic market for energy-saving products and services.

It is the job of high-level officials and policymakers to articulate a clear direction for utilities and energy users by establishing benchmarks and introducing energy savings goals, developing a plan with specific initiatives to achieve these goals, providing appropriate incentives to leverage private sector investment and support, and including a framework to monitor and evaluate progress. Forming key partnerships with international and regional development partners (see **Section III: Case Studies and Linkages**) is essential to developing the local technical expertise necessary to implement EE projects and secure the

funding necessary to develop EE projects and programs that can be financed and scaled up on a national level.

Coordination is particularly important given the long-lasting nature of utility and customer capital investments, the time and effort it takes to change customer behavior and expectations, and the rapid pace of technological change. Program sponsors and customers alike need guidance regarding the best ways to commit their resources to achieve effective energy management and coordination on both the supply-side and among end-users (see **Annex 2-A**). This section covers best practices for management and coordination of EE initiatives, including sustainable management approaches and protocols for coordination among the various political bodies and administrative agencies in PNG.

4.3.2.1 Management Approaches

A top-down management approach relies on higher level authority to determine broader goals that will filter down to lower level authority at early stages of market development. In general, a top-down approach (i) creates clear lines of authority; (ii) standardizes products and services; (iii) facilitates quality control; and (iv) streamlines tasks to achieve goals quickly. In contrast, a bottom-up approach features decision-making processes from all levels of authority that aim to achieve their respective goals in a competitive environment at more mature stages of market development.

Several measures can be taken under a top-down approach to implement a national EE policy framework that establishes a supportive enabling market environment for energy-efficient and climate friendly initiatives, including the following (see **Annex 2-B** for more details):

- National EE action plan developed by government with input from businesses, consumer groups, and other key industry stakeholders (see **Section 4.1.2**);
- EE market assessment(s) to gather data and inform policies and programs;
- Minimum performance standards for energy-efficient products and appliances, complemented by supply- and demand-driven incentive schemes

- Awareness raising campaign(s) to (i) educate the public about EE benefits, solutions, and incentive programs; and (ii) simultaneously engage with private sector EE service providers, manufacturers, distributors and retailers through interventions designed to incentivize economy- wide EE improvements and help service providers expand operations into underserved areas;
- Mechanisms for proper disposal/recycling of old/used inefficient products; and
- EE finance strategies to support the financing and development of EE projects.

Bottom-Up

Studies to estimate EE potential are a common tool for informing the development of EE program plans and budgets, as well as supporting the development of electricity savings targets. In conducting these studies, states and utilities have developed a methodology that is often described as a "bottom up" engineering-based approach. Energy efficiency potential studies are conducted at various geographic levels (e.g., national, regional, provincial and utility service territory level) and at different degrees of aggregation (e.g., economy-wide, sector-specific, programmatic), and can be broadly grouped into technical, economic, market, and program-specific as described in **Annex 2-C**.

The industry standard for assessment of EE opportunities is typically driven by a bottom-up, engineering evaluation of the EE potential of individual end-use technologies and measures. Bottom-up analyses employ a similar methodology but can vary significantly based on key assumptions (e.g., breadth of sectors and end-uses considered, aggregation level, study period, discount rate, pattern of technology penetration, whether economically justified early replacement of technologies is allowed for, and whether continued improvement in efficiency of technology is provided for). As a result, estimated efficiency potential can vary significantly among studies. While a bottom-up approach is used in many contexts, a top-down approach is better suited for a nascent market like PNG.

Top-Down

Top-down management approaches have been used by many developed and developing countries. The

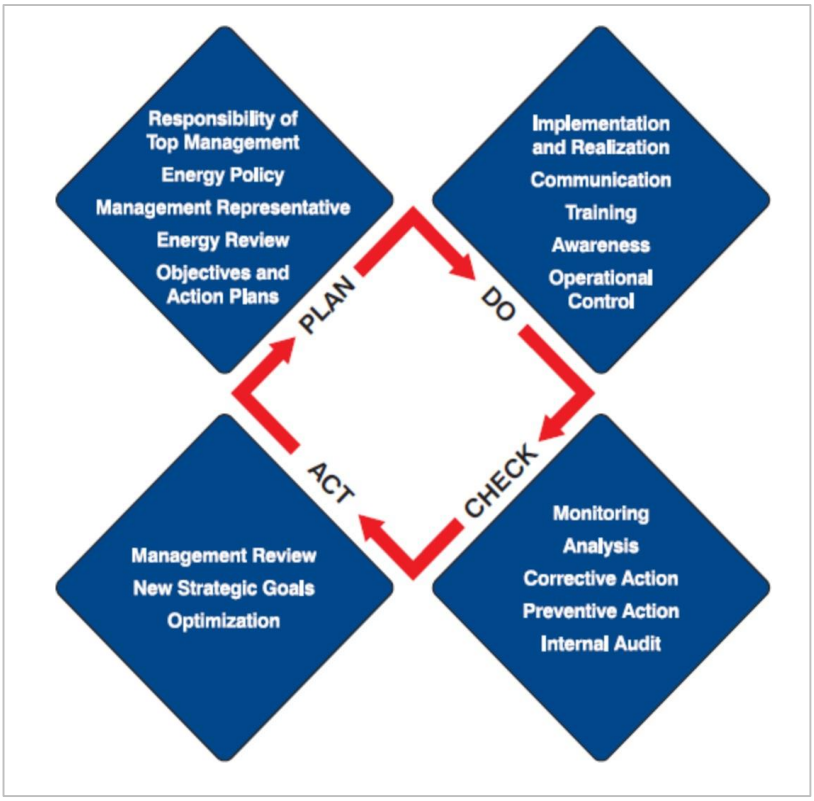
success of a top-down approach depends heavily on people as much as or even more than the EE technology. Under this approach, to maximize the energy savings potential of buildings, industry and other energy consuming sectors, a comprehensive awareness raising campaign is critical. The campaign should focus on raising the awareness of both supply- and demand-side market actors (i.e., private sector managers, executives, staff, building tenants, EE product manufactures and service providers etc.). In PNG, this will need to involve careful coordination with provincial and local-level governments.

The adoption of EE technologies helps deliver energy and cost savings. But technology alone cannot achieve optimal savings. Benefits are maximized when a combination of technological, behavioral, and organizational changes are implemented simultaneously under the guidance and leadership of management. To achieve this, EE practices need to become integrated, established procedures that ensure greater energy and process efficiency while encouraging behavior that saves energy and minimizes costs (see **Annex 2-D** for more details).

Sustainable Energy Efficiency Management Framework

The Plan-Do-Check-Act (PDCA) mechanism (**Figure 25**) provides a simple and effective approach for managing change within an institution or business. It consists of four components – Plan, Do, Check and Act – which are very effective for continuous process improvements as described in **Table 9**. The PDCA cycle has been effectively adopted and widely utilized for implementing EE planning and improvement processes, both for SMEs and large industries in developed and developing countries. At present, the PDCA cycle has been applied as an effective tool for Energy Management Systems (EnMS) ISO 50001 of countries in their ongoing efforts to save energy, reduce emissions and meet certification requirements. Similarly, the PDCA cycle has been recently introduced in some ASEAN member countries through the United Nations Industrial Development Organization (UNIDO) program on Energy Management Systems as discussed in **Annex 2-E**.

Figure 27: Plan-Do-Check-Act Energy Management Framework



Source: Emerson, Sustainable Energy Efficiency User Guide

Table 9: Plan-Do-Check-Act Energy Management Framework

PDCA Framework	Description
Plan	An energy plan is first necessary to establish an initial energy baseline, energy performance indicators, strategic objectives, timelines and corresponding action plans. At the individual building, household, or business level, this planning activity typically beings with an energy audit to assess energy consumption. Indicators and objectives for energy performance and EE improvements are defined on the basis of the results of the energy audit/assessment.
Do	During this phase, the action plan prepared during the planning phase is implemented and improvements and upgrades are made. During implementation, action plans should be monitored to ensure that the objectives for the improvement of energy performance are achieved.
Check	To ensure that plans are achieving their desired results, it is necessary to check and measure the effectiveness of energy-related performance improvements. The results are compared to the previously- established objectives. Ongoing monitoring, measuring and verification of results is typically provided in regular reporting.
Act	The reporting requirements form the basis for further studies, which can then be used to further improve energy-related performance and energy management systems.

Source: United Nations International Development Organization on ISO - 50001 Standard

4.3.2.2 Planning and Coordination

There are two main types of coordination mechanisms, vertical coordination and horizontal coordination. Vertical coordination concerns the effective communication and administration among different governmental levels – namely national, regional, local and township levels – to design and implement EE policies and programs. For instance, a vertical coordination mechanism could be a formal or informal forum through which governments on different levels either formulate common energy policies or coordinate their different approaches. During implementation, a vertical coordination mechanism could define the flow of information on implemented EE measures among the different levels of governmental in order to define steering structures for a certain program or to measure/review its effectiveness.

Horizontal coordination refers to administration and communication between measures, schemes of programs at the same level. An example could be coordination among energy saving initiatives in different departments at a local level (e.g., energy, environment, transport, commercial etc.). Horizontal coordination can also be used as a tool to facilitate financing and associated TA across different levels of government to implement energy efficiency measures.

4.3.2.2.1 National Energy Efficiency Platform

The PNG National EE Roadmap will require mobilization of the NEA, CCDA, and relevant provincial focal agencies to manage and coordinate national efforts to promote EE policies, programs and measures effectively, as well as to monitor and measure progress towards long-term EE policy objectives. A proposed method to support national EE coordination and implementation activities is through the establishment of a **National Energy Efficiency Platform** – chaired by the NEA, with representatives from the CCDA, ICCC, NISIT, DOW, DOT, PPL, DoF and DNPM as members, and supported by an **EE Platform Coordinator** – that regularly plans and coordinates the implementation of EE activities across the economy. The EE Platform Coordinator can either be staffed internally through one of the coordinating government agencies, or an individual or firm can be solicited through a tender process.

The Coordinator will serve as Secretary to the Platform group and will work in direct partnership with GoPNG officials to support management and coordination of all EE-related trainings, awareness-raising and financing campaigns, and monitoring and evaluation functions.

One possible option is to establish the EE Platform as a working group within the National Energy Authority. This working group would be composed of designated staff from the aforementioned public sector institutions and would initially operate under the guidance of an external consultant as the **EE Platform Coordinator**. In this role, the consultant would be embedded within the GoPNG and would have the following main responsibilities:

(i) assist the GoPNG with formal establishment of the National EE Platform, including relevant institutional arrangements, operating guidelines and procedures;

(ii) provide training and capacity building to the EE Platform/NEA; and

(iii) support management and coordination of the multiple EE Platform activities and work streams associated with implementation of the Roadmap.

While the work of the Platform would be continuous, it would hold quarterly meetings with stakeholders across the donor community and the private sector. A preliminary list includes (but is not necessarily limited to) representatives from the following:

- ADB
- UNDP
- World Bank/IFC
- University of Papua New Guinea (UPNG)
- PNG University of Technology (UNITECH)
- Institution of Engineers PNG (IEPNG)
- Technology providers
- Industry organizations
- Energy service companies

It is envisioned that the EE Platform will have a wide range of EE policy development and program planning and coordination responsibilities, including (but not limited to) the following:

- **EE Market Planning and Coordination:** With assistance from development partners, the Platform should lead economy-wide and sector-specific market assessments to collect reliable information on potential energy savings, cost savings and emissions reductions in order to inform EE policy and program design. The primary role of the Platform is to ensure that the different energy sector activities being implemented by various sector actors complement each other and do not compete or duplicate one another.
- **EE Policy and Incentive Program Design:** Design and implement a comprehensive national policy framework for energy efficiency that targets both supply-side and demand-side interventions (MEPS for products and equipment, consumer incentive schemes, EE requirements for energy intensive industries etc.) and is routinely monitored to assess the impacts of specific policies, programs and initiatives relative to their anticipated outcomes and in relation to national priorities (such as Vision 2050) and development objectives at the provincial level (integrated provincial development plans).
- **Information sharing**: The Platform should be a repository for all information relative to Papua New Guinea's energy efficiency sector, where both in-country and external actors interested in the sector can access data and project/program details. The Platform can establish a national database of EE market information a government website (e.g., NEA) to support the collection and regular updating of EE market information across all sectors of the economy. The purpose of this database will be to share EE market knowledge with the public and private sector (e.g., around EE products and appliances, labels etc.) and to share lessons learned etc.
- **Awareness raising**: The Platform will direct a national EE awareness raising campaign to educate the public on the wide-ranging applications and benefits of energy efficiency technology. An important aspect of this awareness campaign is educating the public on how

to select and purchase EE-verified products and appliances and to understand what policies regulations and especially incentive schemes (e.g., rebate programs, EE auditing services) are in place to support EE upgrades.

- **Capacity Building and Technical Assistance**: The Platform can provide technical assistance to both public and private sector EE market stakeholder, including policymakers, regulators, EE companies, financial institutions etc. For public officials, training can focus on building the capacity of designated staff to monitor performance and impacts and report on results. For the private sector, the TA can support EE service providers with EE audit training/certifications, business planning, marketing, financial/business model development, etc.
- **Access to finance**: The Platform should be staffed with at least one individual with a background in EE finance in order to assist the GoPNG and private sector to assess their financing needs, source and apply for funding from different financiers operating in and outside of PNG.

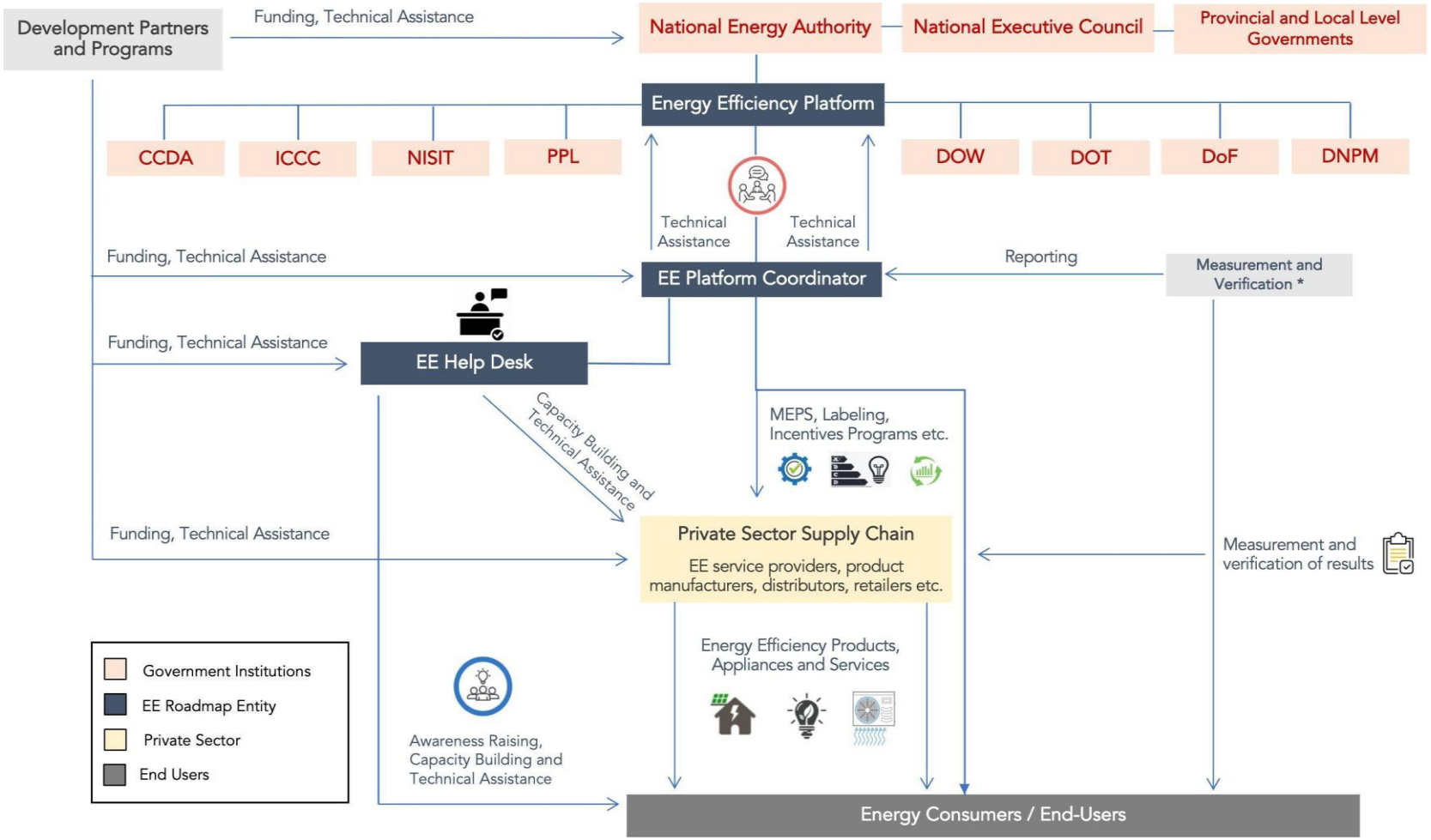
Donor agencies and development partners can provide funding and TA to support the EE Platform Group in various capacities. The EE Platform can also establish a technical sub-committee that liaises with representatives from the private sector, industry associations (IEPNG) and academia (UNITECH, UPNG) to review proposed EE policies and program designs to solicit feedback and input from these stakeholder groups.

The EE Platform would seek to integrate both the vertical and horizontal coordination methods and would be driven mainly by a top-down management approach, led by the EE Platform Coordinator. The Platform would establish protocols for information sharing and collaboration between various national government ministries and departments, as well as provincial authorities and local level governments (LLG). This function will ensure a coordinated approach between the NEA, CCDA and provincial authorities, as well as other stakeholders that have key roles in the Roadmap's implementation and enforcement to avoid conflicts and duplication of efforts. It will also help ensure maximum impact and

optimal utilization of limited available technical and financial resources.

Figure 28 presents an overview of the energy efficiency sector in PNG under the EE Roadmap's institutional framework, including the roles and responsibilities of GoPNG agencies, development partners and private sector EE market actors.

Figure 28: Overview of the Roles and Responsibilities of Energy Efficiency Market Actors



** Measurement and verification activities are necessary for the purpose of verifying and reporting energy savings for individual EE projects as well as for utility or government programs. Monitoring the progress of the National EE Roadmap can either be designated to internal staff within the government (NEA) or to an external consultant retained through a tender process with funding and assistance from development partners.*

PPL: PNG Power Ltd.; ICCC: Independent Consumer and Competition Commission; CCDA: Climate Change and Development Authority; NISIT: National Institute of Standards and Industrial Technology; DOW: Department of Works; DOT: Department of Transport; DoF: Department of Finance; DNPM: Department of National Planning and Monitoring

4.3.2.2.2 Financial Resource Needs

Both financial and technical resources will be needed to cover the various components of the Roadmap's implementation. In order to achieve the objectives of the Roadmap in the near term (i.e., 2022-2025), the GoPNG will need to collaborate with its development partners to finance several proposed activities, including awareness raising, capacity building, establishment of the National EE Platform, and design and launch of a pilot EE program. It is estimated that approximately **USD 2.8M (PGK 9.8M)** in funding will be needed to finance these initial components of the Roadmap through 2025.

Table 10: Estimated Funding Needs for Roadmap Implementation Activities through 2025

Description	Estimated Funding Needs (USD 000s)
Awareness Raising	800
Capacity Building and TA	800
EE Platform Coordinator	600
Pilot EE Program	600
Total	**2,800**

- **Awareness Raising:** The Roadmap will sponsor awareness raising activities and marketing events at the provincial level. Securing venues, transportation to and from the events, and advertisement of the events will require resources. The Roadmap will support a media campaign (TV, radio, brochures, fliers, etc.) to raise public awareness of the advantages of RE and EE technologies. This may include information dissemination about MEPS and labeling schemes (i.e., to inform consumers how to properly identify energy efficient, quality-verified products).
- **Capacity Building and Technical Assistance**: The Roadmap will provide technical and financial resources to support capacity building, training and coaching activities for RE/EE companies and service providers (energy auditors, engineers and technicians). Funding will be necessary to secure partners and skilled trainers to design and implement relevant training materials and certification programs (this can be managed in partnership with UNITECH, UPNG and IEPNG, among others). Training and capacity building will also need to be

provided to policymakers, regulators and financiers (e.g., model Energy Performance Contracts and tender documentation can be developed to facilitate the government's engagement with private sector EE service providers).

- **EE Platform Coordinator**: The EE Platform – which may function as a working group within the NEA, composed of representatives from the CCDA, ICCC, NISIT, DOW, DOT, PPL, DoF and DNPM – would initially operate under the guidance of an external consultant as the Platform Coordinator. The consultant would mainly be responsible for assisting with management and coordination of the multiple Platform activities and work streams associated with implementation of the Roadmap (see **Section 4.2.2.1** for more details). It is estimated that the fees for an external Platform Coordinator would be approximately USD 150k per year (USD 600k in total for the four-year implementation period between 2022-2025).
- **Pilot EE Program**: The GoPNG can implement a pilot EE program/project as a way of introducing energy efficiency tools and mechanisms to the market. The pilot program can take on many forms – it can be a MEPS and appliance labeling scheme; it can offer financial incentives such as rebates, subsidies, or tax incentives to reduce the cost of purchasing EE technologies or services; or it can target a specific market segment, such as the proposed Refrigerator and Air Conditioner Replacement Program Concept in **Annex 4**, which focuses on sustainable cooling.

It is important to emphasize that these funding needs are not exhaustive. Significant additional funding will be required to develop and finance a wide range of public and private sector EE investments and projects as the market matures.

4.3.3 Energy Efficiency Financing and Business Models

A value proposition exists for both energy users and the companies providing and delivering EE equipment and services. Many EE investments are cost-effective on their own merits and, if properly financed, can pay for themselves from savings. Moreover, several financing mechanisms and business

models have evolved to engage the private sector and promote investment in market-based EE solutions.

4.3.3.1 Energy Efficiency Finance

Energy efficiency financing options vary based on the consumer, the country, and the scale of investment. Governments can offer financial incentives such as rebates, subsidies, or tax incentives to reduce the cost of purchasing EE technologies or services. In other cases, public and private sector lending programs provide performance-based loans to companies based on measurable indicators that track energy efficiency. With some performance-based contracts, an energy service company (ESCO) guarantees the energy savings while the customer remains liable for the loan. With others, the ESCO assumes the financing and technical risk, sharing any savings with the customer. Performance-based contracts rely on detailed measurement to verify that the claimed energy savings are real and the result of the efficiency measures that were implemented.

Another approach – on-bill financing – enables utilities to invoice EE separately on monthly electricity bills, which are paid for from the savings accumulated through the EE upgrades and/or retrofits. Despite their complexity, these financing arrangements are able to increase the demand for EE services by preserving the investment and debt capacity of a customer, while generating attractive returns in the form of energy savings, often with a relatively short payback period. Other options include government or donor-funded revolving fund programs, where financial incentives are paid back with accrued energy savings. Another alternative is to tax less efficient energy-consuming appliances and equipment that do not meet minimum energy performance standards and to use the revenues from this tax to subsidize the purchase of more efficient products.

Deploying energy efficiency measures is capital intensive, as it requires up-front investments in the form of savings from households, equity from businesses, and/or debt financing from lending institutions. However, with the right programs and financial instruments in place, this capital burden can be greatly reduced. Different financial instruments can be deployed to complement EE policy interventions in different country contexts. Countries with robust policy and regulatory frameworks, dependable data

collection practices, and more experience in RE and EE integration tend to have the capacity to deploy more complex schemes, such as those that utilize forms of blended finance. Given the nascent stage of EE market development in PNG, policymakers – with support from the EE Platform Coordinator (see **Section 4.2.2**) – can consider different options and determine which policies, incentive programs, financing approaches and business models are best suited to the local context and how to engage with the private sector to facilitate EE adoption on a national scale.

A substantial body of experience exists with EE finance programs funded by donor agencies and international development finance institutions (DFIs) and implemented in partnership with commercial financial institutions (CFIs) and often national development banks. Successful programs are able to mobilize and leverage public and private financial resources and promote sustainable market growth by:

- Engaging with all parties to EE finance transactions – CFIs, EE equipment and contracting companies and energy users – to address and harness their business interests;
- Providing access to finance with attractive terms and using financial products structured and adapted to the needs of each specific target market segment;
- Supporting outreach, marketing and project development TA programs that generate a pipeline of investment ready projects (insufficient project pipeline development has been a major weakness of many EE finance programs); and
- Building capacities of market actors to expand their business on a commercial basis.

The best programs also plan for and deploy market aggregation strategies, working with partners such as utilities, local governments, manufacturers, industry associations and others who have existing networks and relationships.

In this context, GoPNG funding can be structured and deployed according to these best practices in order to mobilize and leverage commercial finance and drive EE market growth. This can be achieved through a combination of co-financing and TA with the intent of systematically addressing market barriers

(including limited access to affordable financing, a lack of long-term funds, credit risks, energy system performance risks, and the need for awareness raising/outreach and information campaigns on the benefits of EE solutions, among others), developing scalable business models, structuring and originating initial transactions and building the capacities of market actors.

4.3.3.2 Energy Efficiency Business Models

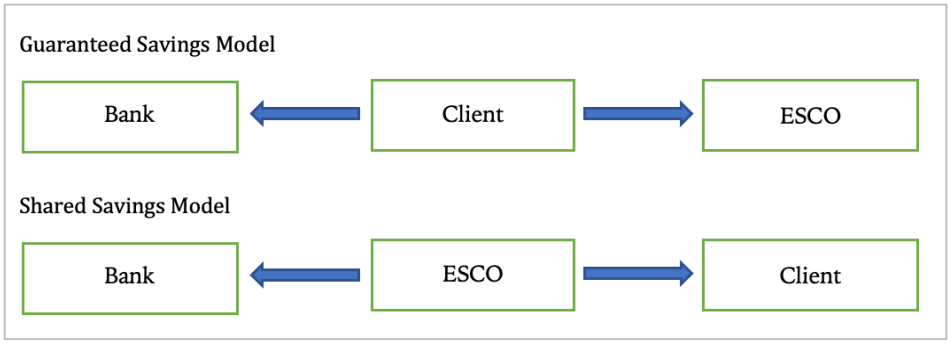
An ESCO is a company that provides a variety of energy services, ranging from design to development, that help consumers save energy and reduce costs. They provide multidisciplinary support and can arrange upfront EE financing, recouping the investment by claiming a share of future energy savings. Thus, for ESCOs remuneration is based on demonstrated performance, while for consumers, working with ESCOs is a way of outsourcing services that may be more costly to integrate independently.

Energy Performance Contracts (EnPCs), also called Energy Savings Performance Contracts, are the most common type of contracts used by ESCOs. Some models are better suited to developed countries, while others are more suitable for developing countries depending on EE market maturity. There are different ESCO business models – ranging from two-year to 20-year contracts – but they typically all implement turnkey EE projects. For ESCOs to operate in PNG, the government needs to implement policies that can create the right enabling environment. Many governments contract with ESCOs as well, and the GoPNG can replicate these practices as a way of introducing ESCO businesses in the country.

Figure 27 presents two of the most common EnPC contracts:

- **Guaranteed Savings Model**: A private ESCO implements a model that guarantees savings. The client finances the project through loans or equity and is responsible for managing recurring payments to debtors and the ESCO. In this model, the client has direct relationships with both the ESCO and its lender (if any).
- **Shared Savings Model**: A private ESCO is responsible for both the technical and financial aspects of the project and is expected to pay back loans to lenders. In this model, the client does not have a direct relationship with the lender.

Figure 29: Energy Performance Contracts – Guaranteed Savings and Shared Savings Business Models



Source: International Energy Agency

Other EE business models include:

- **Super ESCO model**: A public state-owned ESCO that helps build capacity for private ESCOs and provides financing, technical and procurement solutions. In countries where third-party EE lending is difficult to come by, the government can provide low-risk lending facilities. Governments can also work with development partners to co-finance Super ESCOs.

- **Build-Own-Operate-Transfer model**: An ESCO builds, owns, and operates a project for a fixed duration (until it has recouped its investment), after which it transfers ownership to the client.

- **"Chauffage" Model**: An ESCO assumes full responsibility for managing all aspects of the energy services outlined in the contract. This model incentivizes a high level of efficiency as the responsibility largely falls on the service provider – the more efficient the system, the higher the remuneration the ESCO receives.

- **Leasing/Energy-as-a-Service (EaaS) model**: ESCOs work with manufacturers and suppliers to lease equipment to clients or enable customers to pay to use better technology through a subscription style approach. These differ from other models as they do not require the outright purchase of equipment for a project to be developed and implemented. These

models are more cost-effective alternatives and can be used to incentivize consumers who do not prioritize EE in their budgeting due to high initial implementation costs.

- **Energy Savings Insurance (ESI) model**: While most EE transactions are based on technology supply and installation, the ESI model has emerged as an innovative market solution to provide insurance to ESCOs and borrowers to reduce investment risks. This approach is mainly used to support EE for SMEs (but also includes some larger industrial energy users). There are three main components to the ESI model:

  ✓ **Performance Contract** between service providers and end-user clients designed to share risks between parties; end-users (borrowers) take on risk to meet credit obligations; service providers have part of their payment retained by end-users, which is not repaid until energy savings occur

  ✓ **Validation Entity** to act as an impartial party between the service provider and end-user client; these entities are established institutions that verify the quality of the EE service/project (i.e., whether a project can achieve desired energy savings goals)

  ✓ **Insurance Companies** provide a minimum savings guarantee to ensure that the service provider meets guaranteed energy savings benchmarks; if it does not, it is the responsibility of the service provider to compensate end-users for the gap (with insurance company covering this obligation if the company is unable to)

As the models above indicate, ESCOs are beneficial for many reasons. They help reduce implementation costs, promote innovative approaches, develop and provide expertise, and mobilize financing for EE.

4.3.4 Awareness Creation, Capacity Building and Training

Awareness raising, capacity building and training are critical to the success of energy efficiency polices, programs, and initiatives, particularly in a nascent market like PNG. A well-orchestrated national awareness raising campaign should focus on communicating the benefits of EE to the public, while

training programs should be set up to certify energy auditors and engineers. The GoPNG will need to collaborate with development partners to design and implement capacity building programs to provide necessary TA to relevant authorities and market actors.

4.3.4.1 Marketing, Communications and Outreach

Raising public awareness through marketing, communications and outreach is critical to the success of EE programs, as it educates and mobilizes the public to embrace social or behavioral changes. Importantly, awareness raising takes something that is hidden or difficult to see – i.e., EE savings – and makes these savings visible to consumers. It is also important for consumers to be aware of the wide-ranging benefits of EE that extend beyond cost and environmental savings (**Figure 13**).

The NEA and/or CCDA are national government agencies capable of leading such a campaign, with implementation support from the EE Platform Coordinator (see **Section 4.2.2**). Awareness raising should be carried out with the aim of achieving the following key outcomes:

- Increase public awareness of the environmental, social, and economic benefits of EE;
- Educate consumers about the information displayed on energy labels indicating the level of energy efficiency of appliances and equipment in order to increase demand for these products;
- Educate the public about government incentive programs (subsidies, rebates, low-interest loans, tax reductions etc.) to encourage the purchase of energy efficient products or services, such as a building audit; and
- Engage with private sector EE service providers, manufacturers, distributors and retailers through interventions designed to incentivize economy-wide EE improvements and help service providers expand their operations into underserved rural markets.

A national awareness raising campaign can include a provincial ‘roadshow’ to support communication and outreach, raise awareness and build capacity at the local level. The roadshow can be well advertised in advance to maximize public attendance and encourage the participation of private energy sector

service providers. In addition to raising awareness among consumers, another important objective of these roadshows is to help local companies enter rural and deep rural areas and display their product and service offerings, thus expanding their reach geographically while improving the accessibility of EE products and services nationally.

A national awareness raising campaign should take into consideration the country's unique social and cultural background. As described in **Section 2.1**, the *wantok* system plays an important role in society and can thus be a particularly useful method of information dissemination. Methods of communication and marketing of EE concepts, policies, programs and initiatives by public institutions are summarized in **Table 11**.

Table 11: National Energy Efficiency Awareness Raising Campaign

Method	Description
Government-led initiatives	The public sector can lead market development by mainstreaming EE into government procurement processes and ensuring that only EE appliances and equipment are procured for government facilities. Furthermore, government can conduct energy audits of large public facilities and implement energy saving measures and management practices. This will help create a local market for EE technologies and services, and in turn will encourage the private sector to follow the government's example.
National public awareness raising and media campaign	A mass public education and media campaign is also recommended to target consumers and energy end- users across all sectors in order to raise awareness of the benefits of EE and provide details on how they can take advantage of EE programs and initiatives. Various media platforms (e.g., internet, radio) can also be used to reach a wide audience within a short period of time.
Pre-approved technologies and equipment	A list of pre-approved technologies is a powerful marketing and operational tool for scaling up EE investments. This is a market-specific technology database that introduces technologies identified as having high performance at a reasonable cost to achieve energy efficiency.
Energy labels	Energy labeling is used to communicate to consumers the technical specifications of a given energy appliance and whether/how it conforms to an existing EE standard or regulation. The two most common types of labels are (i) endorsement labels, which point out to consumers that a given product meets a predetermined energy standard; and (ii) comparative labels, which provide information to consumers that allow them to make a comparison among the same type of products to choose those that are more efficient.
Workshops, conferences and demonstration projects	This method should be used to target specific stakeholders such as product manufacturers, distributors, importers, industry associations etc. to disseminate specific information. For example, when MEPS are approved by relevant authorities, the contents of the MEPS need to be communicated to key supply chain stakeholders to enable them to align their products with the approved standards. Pilot projects are another useful tool, as consumers benefit greatly from seeing demonstrations and experiencing the products themselves, which helps to build trust and create interest in new technologies.

4.3.4.2 Capacity Building

For a national EE program to be effective and achieve sustainable results, it must be reinforced with capacity building and training of key public and private sector stakeholders. The technical capacity of local policymakers and regulators, financiers, energy service providers, industry associations, academia and NGOs, among others, should be properly developed. Training and certification programs need to be developed for RE/EE service providers (including energy auditors, engineers and technicians) for RE/EE system design, installation, O&M and repair.

Local companies in PNG will play a pivotal role in developing a sustainable RE/EE market. However, in order to compete with the international companies currently dominating the market, they will need technical assistance and training in several areas, including (but not limited to) the following:

- Business planning
- Business model development
- Costing and pricing
- Sales and marketing
- Accounting and cash flow management
- Financial modeling
- Human resource management

In collaboration with development partners, the GoPNG can establish a **National Energy Efficiency Help Desk** to provide a wide range of technical assistance to public and private sector EE market actors at the national, provincial and local level covering *inter alia* EE opportunities and projects, government incentive programs, available financing, and other training or certifications to support the roll out of the National EE Roadmap. The Help Desk can be a designated unit within the EE Platform that is staffed internally and supported directly by the EE Platform Coordinator.

Given the novelty of EE policies, regulations and associated funding schemes, capacity building and

training should be designed specifically for government officials. Capacity building also needs to be provided to local financial institutions to increase their understanding and reduce risk perceptions of RE and EE project financing and due diligence procedures. Capacity development efforts should be coordinated by the NEA or CCDA in partnership with other government agencies, academia/universities, development partners and the private sector.

4.3.4.3 Training and Certification Programs

Knowledge sharing and accreditation programs can be implemented though partnerships with academic institutions such as PNG University of Technology (UNITECH) Sustainable Energy Research Institute (SERI) and Appropriate Technology and Community Development Institute (ATCDI), University of Papua New Guinea (UPNG) Centre of Renewable Energy (CORE), and industry associations such as the Institution of Engineers PNG (IEPNG). Capacity building programs should seek to align training curricula with best international practices and take advantage of resources available through international and regional partnerships (e.g., UNEP U4E, ASEAN SHINE).

Academic Research and Training: UPNG CORE and UNITECH SERI are already involved in RE and EE research and development, while UNITECH ATCDI provides technical assistance and information about technologies to rural communities. The capacity of these institutions and programs can strengthened around RE and EE research, training and certification. As tertiary institutions, UPNG and UNITECH can help promote and mainstream the use of RE technologies and EE appliances and equipment by structuring their curricula around these topics so that everyone obtaining degrees from these institutions will be properly equipped with the basic knowledge and benefits of RE and EE practices.

Vocational Training and Certification: Technicians should be professionally trained and certified to render services that will ensure the appropriate installation, maintenance and efficient performance of products, systems, appliances and equipment. As technologies change, technicians need to update their skills and learn how to safely and properly install and maintain new equipment. Technicians are often trained with a focus on servicing and repairing malfunctioning equipment – rather than, for example, optimizing equipment for efficiency purposes. In the sustainable cooling sector, capacity building and training for technicians should ensure adequate coverage of new technologies, MEPS and protocols for refrigerants. In addition to providing RE/EE vocational training to technicians and engineers, the IEPNG – with support from the NEA, CCDA and the universities – can be equipped to become an accredited center for certifying energy auditors.

Regional and International Collaboration and Exchange Programs: The capacity of national institutions can be enhanced through collaboration with regional and international organizations that provide training in EE (e.g., UNEP U4E, ASEAN SHINE). UNITECH and UPNG can collaborate with universities in Australia/New Zealand or elsewhere in the South Pacific region to facilitate exchange programs to develop local capacity.

National Program to Implement Energy Management Standard – ISO 50001: Energy Management Standard (EnMS) according to ISO 50001 can be mandated by NISIT and operationalized by IEPNG to ensure that industries comply to the standard (and are supported with TA to ensure compliance). See **Annex 2-E** for more details on EnMS.

4.3.4.4 Engagement with the Financial Sector

A key component of any national RE and EE policy is to foster engagement with local financial institutions (FIs). Financial institutions are in the unique position of having access to key decision-makers in companies and are key influencers on questions related to a company's investment planning. By identifying bankable projects, highlighting their strategic importance, and providing financing for those projects, FIs serve as important catalysts of sustainable energy investments

Local FIs in a nascent sustainable energy market like PNG, however, remain cautious of entering the market due to high perceived risk. These institutions will therefore require training to develop their internal staffing capabilities in order to appropriately appraise the EE sector and identify bankable project opportunities. Capacity building and TA should cover several key focus areas to improve local FI understanding of the EE sector, its structures, technologies, supply chains, and accompanying financial products.

One particularly useful resource for FIs is a list of pre-approved technologies and equipment, which can serve as a powerful marketing and operational tool for scaling up EE investments. As an example, the European Bank for Reconstruction and Development (EBRD) has developed a pre-approved technologies database, the Green Technology Selector, which is an online tool that identifies high-performing products that achieve energy efficiency, renewable energy and climate resilience at reasonable cost. It contains country-specific climate technology categories and performance criteria, equipment types and models, available materials, and lists of manufacturers, suppliers and installers, among other information. The platform identifies products that are eligible for funding from EBRD's Green Economy Financing Facility via local financial institutions. This streamlined process helps reduce transaction costs and processing time, particularly for small-scale investments commonly implemented by households and SMEs. Local technology vendors are encouraged to register their technologies with this tool to increase the visibility of their products to prospective clients. If an eligible technology has no registered vendors in a given country, local FIs can encourage imports via the EBRD's Green Trade Facilitation Programme. Performance requirements for technologies and vendors are reviewed on a regular basis, in consultation with the EBRD, and adjusted to reflect market developments.

4.3.5 Energy Efficiency Research and Development

The absence of coordinated and organized data to support the development of policy and other regulatory instruments is a key barrier to the uptake of EE in PNG. The dearth of EE sector data makes it difficult for the government to set targets and make informed policy decisions, as research and development (R&D) materials are critical to sustain any market transformation initiative. For example, for energy efficient products to be purchased, they must be easily identifiable, deliver consistent quality, and not be cost prohibitive. Several measures need to be adopted for this to happen.

The necessary standards to ensure product quality need to be enforced; policy and regulatory frameworks for importing, testing, and labeling quality products needs to be in place; and consumers need to be educated around RE and EE product quality and how to read energy labels to identify energy efficient products and appliances.

In PNG, academic institutions (UPNG CORE, UNITECH SERI and ATCDI) and industry associations (IEPNG) can champion R&D in the clean energy sector. However, these entities will require financial resources and TA from the NEA, CCDA, NISIT, and PNG's development partner to do so effectively. UNITECH may also well-positioned to support NISIT and ICCC with third party testing and verification of EE appliances entering the market.

4.3.5.1 Data Collection and Management Approach

The successful implementation of EE policies and regulations and development of projects relies heavily on the ability to collect accurate and reliable market data. Unlike renewable energy projects, which involve building physical infrastructure, EE projects and programs rely on data related to energy use and savings. The outcome of any EE initiative is measured by its energy and monetary savings, which can only be substantiated if the indicator is compared to a baseline figure (e.g., quantity of energy/money saved, emissions reduced etc.).

The availability of this data in PNG is extremely limited, as it is generally not being tracked or recorded. While larger companies operating in the country keep records of energy use and expenditures (e.g.,

quantity of diesel for powering operations), this data is largely unavailable for SMEs – which comprise the largest share of the commercial market. Sector-specific energy assessments need to be undertaken to collect reliable information on potential energy and cost savings (per kWh) and GHG emissions reductions (per ton of CO2e) that can be achieved from EE measures.

4.3.5.2 Market Research and Repositories of Information

To date, energy sector research in PNG has largely prioritized electricity access and improving power supply, while relatively little attention has been given to energy efficiency. In order to track EE market data and set appropriate benchmarks and targets, a national database should be established to aggregate energy data across all sectors of the economy and serve as a repository of information for all market actors. Market research and sector-specific reporting can be used by policymakers to direct EE programs and initiatives to focus on the sectors with the largest potential impact. **Table 12** highlights several areas of EE market research that should be given priority to enable the GoPNG to make informed EE policy decisions. The systematic collection of this information on a national level can be managed by the EE Platform Coordinator (see **Section 4.2.2.**), with support from NISIT and/or another relevant government agencies (NEA, CCDA), while research studies can carried out regularly by UPNG, UNITECH and/or by external consultants.

Table 12: Recommended Areas of EE Market Research

Recommended Area of Research	Description
Appliance / equipment end-use research	The key objective of appliance end-use studies is to monitor the actual level of total electricity consumption and energy demand for electrical appliances (lighting, phone charging, fans, TVs, refrigerators, air conditioners, etc.). The outcome of this study can be used by RE/EE suppliers to inform their product/service offerings to end-users and/or by policymakers to quantify energy demand and consumption, identify energy savings opportunities and develop MEPS for appliances. This research will also allow organizations that model and forecast demand/electrical consumption to base their works on reliable data.

Market research to design and implement energy labeling scheme for RE/EE appliances and equipment	Energy efficiency labels typically complement the implementation of energy standards. They are placed on products to describe the product's energy performance in terms of energy use and efficiency. Since consumers are final users of appliances, their insights and perceptions are crucial inputs in designing an effective and comprehensive energy labeling program and any associated awareness raising or consumer education campaigns to increase the uptake of EE and phase out inefficient appliances, lighting and equipment.
Appliance / equipment compliance research	This study should be designed to collect baseline data that will form the basis for monitoring and measuring progress when the appliance market is fully regulated using MEPS. It will help to identify appliances in the market that do not meet the approved standards and make the information available to the relevant agencies (e.g., NISIT).

4.3.6 Measurement, Verification and Enforcement

Measurement, Verification and Enforcement (MV&E) is a vital component of EE policy and regulation to enforce compliance and ensure that expected EE gains are realized in order to maximize benefits and savings from a given program or practice. The goal of MV&E activities is to ensure the integrity and enhance the operation of a given EE program by minimizing non-compliance cost. Verification measures provide benefits for consumers (who receive the expected product when making a purchasing decision), participant businesses (who are provided a level playing field and do not lose competitiveness by complying) and policymakers (who can assess the effectiveness of their programs and evaluate where improvements can be made).

Best practices with regards to MV&E in national EE programs include four (4) main stages of implementation:

(i) **Plan**: Plan to integrate robust MV&E activities from the outset, which will prevent delays, waste and additional costs further down the line. MV&E should involve experts from all stakeholder groups during the planning stage;

(ii) **Implement**: Focus on informing and educating stakeholders about the change in the

marketplace and their responsibilities. Compliance will increase when MV&E leads to widespread understanding of the purpose and benefits of EE projects;

(iii) **Monitor**: Support MV&E activities that enhance enforcement capabilities by expanding MV&E from general information collection to assessing how well most at risk suppliers are meeting their responsibilities; and

(iv) **Evaluate**: Continually evaluate the goals and objectives on EE programs and make changes to MV&E protocols as necessary.

The International Performance Measurement and Verification Protocol (IPMVP) provides a framework to help increase investment in EE, demand management and RE projects around the world. Further, IPMVP is a consensus document for measuring and verifying energy savings from energy efficiency projects. The application of IPMVP approaches is discussed in **Annex 3-A**.

4.3.6.1 Measurement and Verification

A key element of the IPMVP is the definition of two measurement and verification components: (i) verifying proper installation and the equipment/systems potential to generate savings; and (ii) measuring or estimating actual savings. The first component assesses whether the baseline conditions were accurately defined; whether the proper equipment/systems were installed; whether the equipment is performing to specification; and whether it has the potential to generate the predicted savings. The general approach to verifying baseline and post-installation conditions involves inspections, spot measurement tests, or commissioning activities. Industry best practices on data analysis for monitoring and evaluation of EE projects are discussed in **Annex 3-B**.

Measurement involves assessing efficiency claims against established standards and key performance indicators (KPIs) in a consistent manner, using accurate instrumentation applied by certified professionals in controlled conditions. Similarly, verification is the measurement process where independent third parties confirm the efficiencies claimed by suppliers (or manufacturers, retailers etc.). Appropriate measurement and verification guidelines are critical to the success of any EE program and

include the following key elements:

- Quantifiable and objectively verifiable KPIs and EE targets that are both economy-wide and sector-specific
- Protocols to ensure compliance with MEPS (e.g., through appliance labeling)
- Clear performance baselines (MEPS) for product quality and bans on products that do not meet acceptable thresholds through MV&E (using incentives and penalties for non-compliance)
- Monitoring and verification mechanisms to assess emissions (e.g., from vehicles, factories etc.) with penalties for emissions above a specified level
- Capacity building across government, private sector and among implementing stakeholders the establishment of MV&E guidelines for PNG will involve the following activities:
- Develop a measurement framework with specific criteria to evaluate EE programs and verify results (i.e., energy savings, emission reductions etc.)
- Develop data collection strategies and systems to track KPIs, monitor results and measure progress towards targets
- Conduct economy-wide and sector-specific analyses to collect baseline market information that is missing/needed in order to set appropriate EE targets
- Establish systematic reporting procedures and present results annually to EE Platform Group and other EE market stakeholders
- Introduce improvements and take actions as required to improve future programs and projects

In order to systematically assess, report on and verify the performance of EE activities across relevant sectors of the economy, monitoring and verification functions can either be designated to internal staff within government (NEA) or to an external consultant retained through a tender process with funding and assistance from development partners.

Figure 28 presents the process through which information can be collected and analyzed to measure and report on the Roadmap's performance indicators and to verify results. It is anticipated that these activities will be performed on an annual basis to ensure that the country is on track to achieve the Vision 2050 carbon neutrality target.

Figure 30: Energy Efficiency Measurement and Verification Reporting Framework

4.3.6.2 Enforcement

The GoPNG needs strong and strategic coordination mechanisms to ensure compliance with MEPS and to establish enforcement capabilities in implementing MV&E protocols. Empowering the lead agencies (e.g., NEA, CCDA, NISIT) and other departments (e.g., customs authorities) will help (i) increase enforcement and verification efforts to ensure manufacturers meet EE standards; (ii) expand enforcement initiatives to go beyond compliance with EE standards to protect consumers through robust verification activities; and (iii) support enforcement to ensure that manufacturers and importers offer EE technologies as advertised and labeled.

Energy efficiency requirements can be enforced by using both incentives and penalties. One method of enforcement is to impose taxes on less efficient energy-consuming appliances and equipment that do not meet minimum energy performance standards. The revenues from this tax can in turn be used to subsidize the purchase of more efficient products.

4.3.7 Roadmap Implementation Framework

4.3.7.1 Management Approach

The establishment of an EE Platform (see **Section 4.2.2**) will provide necessary political direction and

oversight functions to ensure smooth implementation of EE programs and initiatives in PNG. The Platform, which includes representatives from the NEA, CCDA, ICCC, NISIT, DOW, DOT, PPL, DoF and DNPM, will meet regularly to ensure that adequate planning and budgetary provisions are made to support EE program implementation.

The EE Platform can establish a technical sub-committee that liaises with representatives from the private sector, industry associations (IEPNG) and academia (UNITECH, UPNG) to review proposed EE policies and program designs and solicit feedback and input from these stakeholder groups. The sub-committee will in turn be responsible for advising the EE Platform Group on key decision-making during the course of EE program design and implementation.

4.3.7.2 Implementation Timeline

Table 13 summarizes the strategic objectives of the National EE Roadmap and the corresponding actionable priorities for the GoPNG and other relevant EE market stakeholders to implement the Roadmap. The recommended actionable priorities are based on the identified potential supply-side and demand-side EE opportunities across various sectors of PNG's economy (see **Section 2.3** for more details). The table also includes proposed implementation timelines, including proposed actions/priorities designated as either short-medium term, to be implemented within the next four years (2022-2025), and long-term, to be completed over the next decade (through 2030).

Table 13: PNG Energy Efficiency Roadmap Implementation Timeline

Sector	Strategic Objectives	Recommended Actionable Priorities	Coordinating Government Agencies and other Relevant Stakeholders	Time-Frame for Implementation
Cross-cutting, economy-wide	Become a signatory to / participate in international agreements, treaties and initiatives dedicated to improving energy efficiency	• Become a signatory of the Kigali Amendment to the Montreal Protocol • Join the Super-efficient Equipment and Appliance Deployment (SEAD) Initiative of the Clean Energy Ministerial – a voluntary collaboration among governments working to promote the manufacture, purchase, and use of EE appliances, lighting, and equipment worldwide. • Participate in international (UNEP United for Efficiency) and regional (ASEAN SHINE) programs and initiatives that support developing countries to transition their markets to EE appliances and equipment.	National Energy Authority (NEA), Climate Change and Development Authority (CCDA)	Short-medium term
	Develop and adopt national energy efficiency policy and regulation	• Designate lead institutions for planning, implementing, and monitoring EE policies and programs • Establish centralized national repository to collect energy data and information across all sectors in order to set appropriate EE benchmarks and targets • Draft EE policy and regulation • Consult with relevant stakeholders and revise draft based on feedback received • Finalize EE policy and adopt/ratify associated regulation	National Energy Authority (NEA), Climate Change and Development Authority (CCDA), National Institute of Standards and Industrial Technology (NISIT), Independent Consumer and Competition Commission (ICCC)	Short-medium term

	Raise awareness of EE policy, regulation and associated programs and initiatives among industry leaders, energy managers and engineers	• Develop strategies and marketing campaigns for EE awareness raising • Train relevant personnel to carry out national awareness raising campaign • Implement awareness raising campaign • Publish EE guidelines targeting specific industries	NEA, CCDA, NISIT, Institution of Engineers Papua New Guinea (IEPNG), UPNG Centre of Renewable Energy (CORE), PNG University of Technology (UNITECH) Sustainable Energy Research Institute (SERI) and Appropriate Technology and Community Development Institute (ATCDI)	Short-medium term
	Build the capacity of relevant stakeholders	• Design sector-specific EE training modules based on international best practices and conduct organized workshops and trainings for technical and managerial staff • Utilize resources available through international (UNEP U4E) and regional (ASEAN SHINE) programs and initiatives • Introduce energy auditor and energy manager certification programs • Support the development of ESCOs to provide EE services to the market	NEA, CCDA, NISIT, ICCC, Department of Works (DOW), Department of Transport (DOT), IEPNG, UPNG CORE, UNITECH SERI and ATCDI, PNG Power Ltd. (PPL), private IPPs, off-grid enterprises, private sector ESCOs	Long-term

	Provide government leadership by setting an example for other buyers and by harnessing public sector buying power to create or expand the domestic market for energy- saving products and services	• Mandate energy audits for government buildings and facilities • Incorporate EE measures into government operations and procurement processes • Establish EE units within government ministries, departments and agencies to mainstream EE best practices in government operations and for effective implementation of EE policies and programs	NEA, CCDA, NISIT, DOW, DOT, Department of National Planning and Monitoring (DNPM), National Procurement Commission	Long-term
	Develop and implement EE roadmap business plan and EE fund to support the rollout of EE financing and incentive programs	• Develop business plan for EE roadmap • Design an EE fund/financing facility and other market-based instruments to leverage private sector investment in EE • Implement national incentive program(s) to stimulate demand for EE products and services • Conduct legislative review to adopt EE business plan and establish EE fund	NEA, CCDA, DNPM, Department of Finance (DoF)	Short-medium term
	Develop and implement measurement , verification and enforcement (MV&E) modalities and protocols for the EE sector	• Design MV&E protocols for EE projects and programs based on international best practices • Designate lead institution(s) responsible for implementing MV&E protocols • Train relevant personnel to carry out MV&E functions or retain an external consultant through a tender process for this purpose	NISIT, ICCC, NEA, CCDA, DNPM, IEPNG, UPNG CORE, UNITECH SERI and ATCDI	Short-medium term
Supply-Side Energy Efficiency				
Resource Extraction and Energy Supply	Adopt EE measures and technologies in all extractive industries (fossil fuel and mining sectors)	• Establish energy data collection procedures; set EE benchmarks and targets • Implement a national energy audit program for enterprises • Introduce protocols to establish best practices in energy management systems • Introduce MEPS and promote EE in industrial motors and motor-driven systems • Design and implement a financial incentives program to promote EE in extractive industries	NEA, CCDA, ICCC, NISIT, IEPNG, DoF, Mineral Resources Authority (MRA), IEPNG, PPL, IPPs, oil and gas companies, mining companies, private sector ESCOs	Short-medium term

Electricity Generation and Demand-Side Management	Adopt EE measures and technologies in electricity generation	• Establish energy data collection procedures; set EE benchmarks and targets • Establish utility EE obligations and other market-based instruments to promote EE in electricity generation, transmission and consumption. • Promote fuel switching from fossil fuel- powered generation to renewable energy • Introduce protocols to establish best practices in energy management systems • Introduce MEPS and promote EE in industrial motors and motor-driven systems • Design and implement a financial incentives program to promote EE measures in power generation • Work with PPL to implement demand-side management (DSM) and power system optimization practices	NEA, CCDA, ICCC, NISIT, DoF, IEPNG, UPNG CORE, UNITECH SERI and ATCDI, PPL, IPPs, off-grid enterprises, private sector ESCOs	Long-term

Demand-Side Energy Efficiency				
Buildings (Public, Commercial and Residential)	Adopt EE measures and technologies for new and existing public, commercial, and residential buildings	• Establish energy data collection procedures; set EE benchmarks and targets • Integrate EE into the national building code for new and existing buildings, including building EE performance standards (e.g., International Green Construction Code, LEED, Net Zero etc.) • Develop and implement a MEPS and labeling program for efficient lighting, refrigeration and air conditioning equipment in all buildings • Establish national testing and labeling program for household appliances with associated standards and regulations enacted • Design and implement a financial incentives program to promote EE in buildings In the residential sector, promote the use of fuel-efficient cook stoves, emphasizing the environmental and health benefits (vis-à-vis wood fuels and kerosene)	DOW, NEA, CCDA, ICCC, NISIT, DoF, IEPNG, UPNG CORE, UNITECH SERI and ATCDI, public, commercial and residential building owners/associations, households	Short-medium term
Commercial and Industrial	Adopt EE measures and technologies for commercial and industrial sector	• Establish energy data collection procedures; set EE benchmarks and targets • Implement a national energy audit program for enterprises • Introduce protocols to establish best practices in energy management systems • Introduce MEPS and promote EE in industrial motors and motor-driven systems Design and implement a financial incentives program to promote EE in the commercial and industrial sector	NEA, CCDA, ICCC, NISIT, DoF, IEPNG, UPNG CORE, UNITECH SERI and ATCDI	Short-medium term
Transport	Adopt EE measures and technologies for land, air and sea transport	• Establish energy data collection procedures; set EE benchmarks and targets • Establish minimum fuel efficiency standards for all commercial and private vehicles • Design and implement an incentives program to promote the uptake of fuel efficient and zero-emission vehicles (e.g., hybrid, electric) • Establish minimum fuel efficiency standards for air and sea transport • Promote the use of biodiesel and bioethanol fuels • Provide funding to support road maintenance and new road infrastructure development, with particular focus on connecting the country's main cities Promote integrated public transport systems in main cities	DOT, DOW, NEA, CCDA, ICCC, NISIT, DoF, IEPNG, UPNG CORE, UNITECH SERI and ATCDI	Long-term

Agriculture	Adopt EE measures and technologies for agricultural sector	• Establish energy data collection procedures; set EE benchmarks and targets • Implement a national energy audit program for agricultural enterprises • Design and implement a financial incentives program to help commercial and smallholder farmers make EE improvements • Promote farming methods that make the best use of agricultural residues and animal waste • Provide funding and TA to support distribution and market linkages across the agricultural value chain (cash crops, fisheries etc.) Implement policies to reduce emissions from the forestry sector and to ensure sustainable land use, forest management, and agricultural practices	NEA, CCDA, ICCC, NISIT, DoF, Department of Agriculture and Livestock, National Fisheries Authority of PNG, PNG Forest Authority, IEPNG, UPNG CORE, UNITECH SERI and ATCDI	Short-medium term
Sustainable cooling	Adopt measures to promote clean and efficient cooling technologies	• Develop a National Cooling Action Plan (NCAP); establish appropriate data collection procedures; set economy-wide and sector- specific EE benchmarks and targets in the sustainable cooling sector • Establish MEPS to ensure that refrigeration and air conditioning equipment is highly efficient and uses low GWP refrigerants • Set up an exchange program to recycle used equipment • Organize bulk procurement of high efficiency appliances to accelerate market penetration Design and implement an EE financial incentives program targeting commercial, industrial and residential end-users	NEA, CCDA, ICCC, NISIT, DoF, IEPNG, UPNG CORE, UNITECH SERI and ATCDI	Short-medium term

CHAPTER 5

SUMMARY, CONCLUSION, AND RECOMMENDATION

5.1 Summary

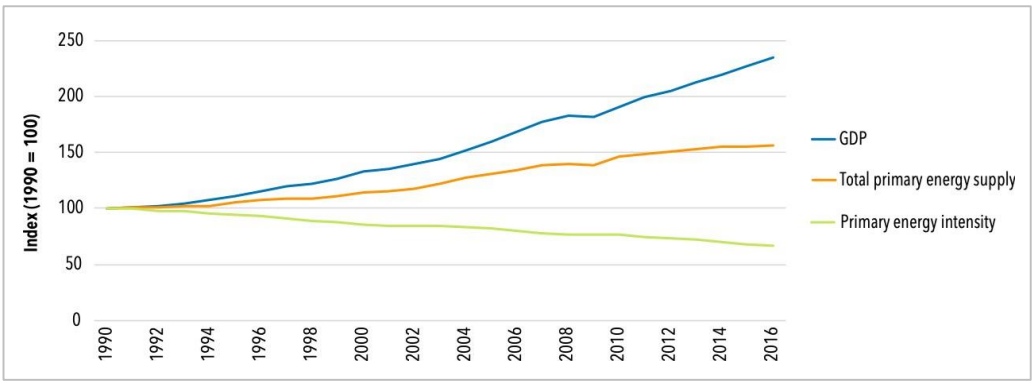
Global Context

Energy efficiency (EE) measures are broadly considered in relation to energy supply (resource extraction, power generation, fuel conversion, energy storage) and end-use sectors (buildings, industry, transport), but can also involve 'demand-side' actions, including switching to more efficient technologies and employing behavioral and operational changes that make smarter use of existing technologies. Energy efficiency investments have wide-ranging environmental, social and economic benefits and enable states to pursue low-emission, climate-resilient development. Energy efficiency reduces energy demand and associated greenhouse gas (GHG) emissions; improves energy security and trade balances by reducing reliance on fossil fuels; provides energy-related cost savings for an economy; boosts the disposable income of consumers through lower energy bills; improves industrial productivity; reduces power sector costs by limiting the infrastructure required to produce, transmit and distribute electricity; and contributes to significant innovation and job creation in high-tech industries delivering EE solutions to the market.

On a global scale, energy efficiency addresses critical issues in the production, delivery and consumption of energy across all sectors and is an essential tool for mitigating climate change, as it reduces energy-related CO_2 emissions and offsets energy demand growth. Energy efficiency is a key indicator in the UN Sustainable Development Goals (SDGs) framework; SDG 7 has established a target to double the global rate of improvement in EE by 2030. The rate of improvement in EE is measured by observing the rate of improvement of primary energy intensity – defined as the percentage drop in total primary energy supply per unit of GDP. Since 1990, global GDP has more than doubled, while total primary energy supply at a global level increased by just over 50%; the difference in these growth rates is the result of consistent improvements in global primary energy intensity, which fell by over 30% between 1990 and

2016 (**Figure ES-1**). It is estimated that improvements in global primary energy intensity during this period offset nearly half of the impact of GDP growth on emissions.

Figure ES-1: Trends in Global Primary Energy Intensity, 1990-2016

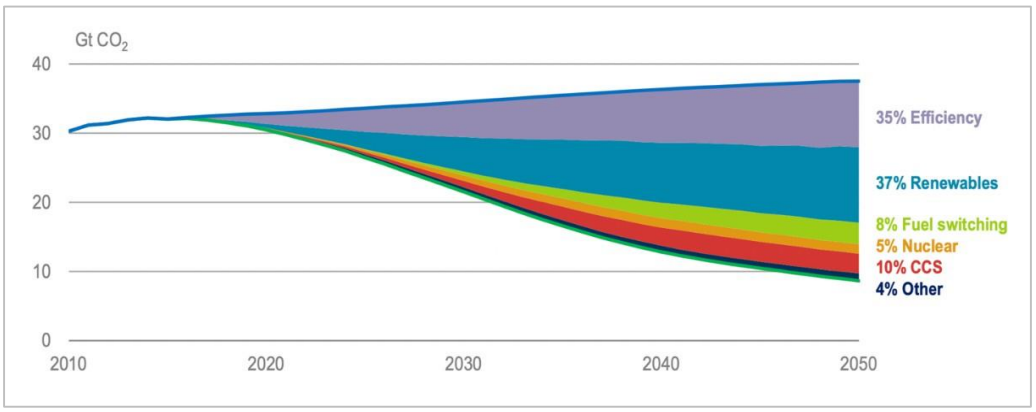


Source: International Energy Agency, United Nations Statistics Division and World Bank

Despite this promising trend, the global rate of improvement in primary energy intensity still lags behind the 2030 SDG target. Given current and planned policies, energy intensity improvements are projected to average 2.4% per year between 2017 and 2030 vis-à-vis an annual improvement of 3.6% in a scenario where cost-effective EE potential is maximized during this period. Moreover, the International Energy Agency (IEA) estimates that improvements in primary energy intensity have slowed; in 2018, the rate of improvement was just 1.3%, the slowest rate since 2010.

In the long-term, the International Renewable Energy Agency estimates that in order to successfully transition to a low-carbon economy powered by clean energy, the energy intensity of global GDP will need to drop steeply in the coming decades – to about half of today's levels by 2050. According to an IEA report on the role of EE in the global energy transition, EE will need to deliver 35% of the cumulative CO2 savings required by 2050 to achieve the goals of the Paris Agreement (**Figure ES-2**).

Figure ES-2: Global CO2 Emissions Abatement by Technology, 2010-2050



Source: International Energy Agency, 2018.

Energy efficiency factors heavily into government climate policies and strategies that aim to reduce emissions according to Nationally Determined Contributions (NDCs) pledged under the Paris Agreement. Yet, progress in adopting new EE policies or strengthening existing policies has been slow, limiting the ability of EE gains to offset the impact of economic growth on energy demand. There is thus an urgent need for countries to pursue more robust policy efforts to take advantage of EE opportunities and reduce emissions in line with global sustainable development goals.

5.2 Conclusion

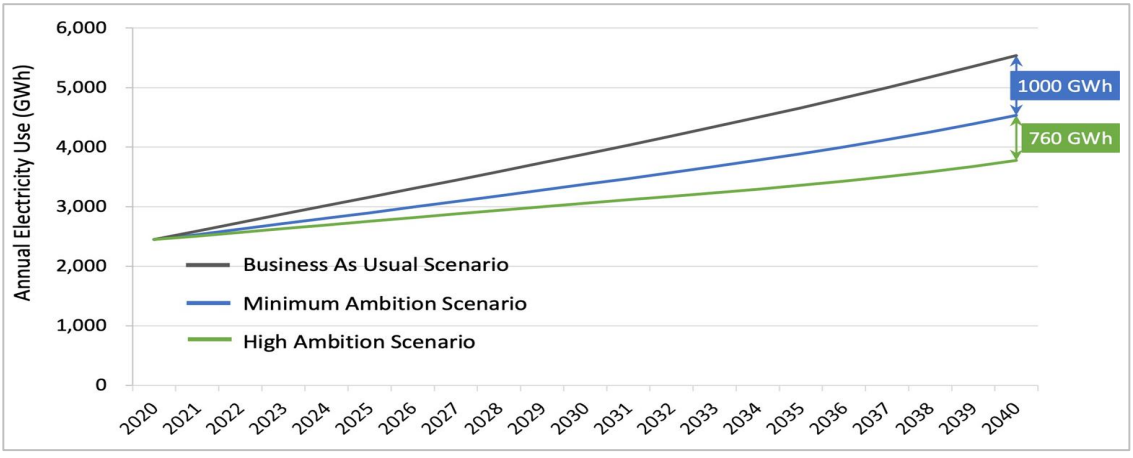
Energy Efficiency Opportunities in Papua New Guinea

The energy sector in Papua New Guinea (PNG) relies heavily on fossil fuels, including substantial production, consumption and export of oil and gas. Demand for energy is expected to grow considerably, especially from the industrial and transport sectors, which account for the largest share of energy consumption, followed by the agricultural and residential sectors. To date, energy sector investment in PNG has prioritized increasing electricity access and improving power supply; however, relatively little attention has been given to energy efficiency. Energy efficiency reduces greenhouse gas emissions, improves national energy security, and provides cost savings for energy users across all sectors. Above all, energy efficiency plays a central role in reducing energy demand to allow for an affordable and manageable transition to an energy system based on clean energy.

In its long-term national strategic development plan – PNG Vision 2050 – the Government of PNG (GoPNG or "the Government") set a target to achieve carbon neutrality for PNG by 2050. Energy efficiency will play a critical role in achieving this target, as it is a key driver of climate change mitigation and adaptation. There are many opportunities for PNG to achieve energy savings and to reduce GHG emissions through the application of EE measures (both supply-side and demand-side EE opportunities are covered in detail in **Section 2.3**).

A study undertaken in 2020 – the United Nations Environment Programme's (UNEP) United for Efficiency (U4E) Country Savings Assessment – estimates the cumulative financial, energy, and environmental benefits of energy efficient lighting, appliances and equipment on a national scale. According to the U4E minimum ambition scenario, compared to business-as-usual, through 2030 PNG can reduce annual electricity use by over 500 GWh (equivalent to about 15% of current national electricity use), achieve annual savings of electricity worth USD 150M (PGK 525M) and reduce over 410,000 tons of annual CO_2 emissions (equivalent to the emissions from 230,000 passenger cars). In addition to a minimum ambition scenario, U4E also analyzed a high ambition scenario, which reflects more robust EE policy interventions to increase the level of energy efficiency of products sold on the market. Intuitively, the more ambitious the regulation, the more savings are possible (**Figure ES-3**).

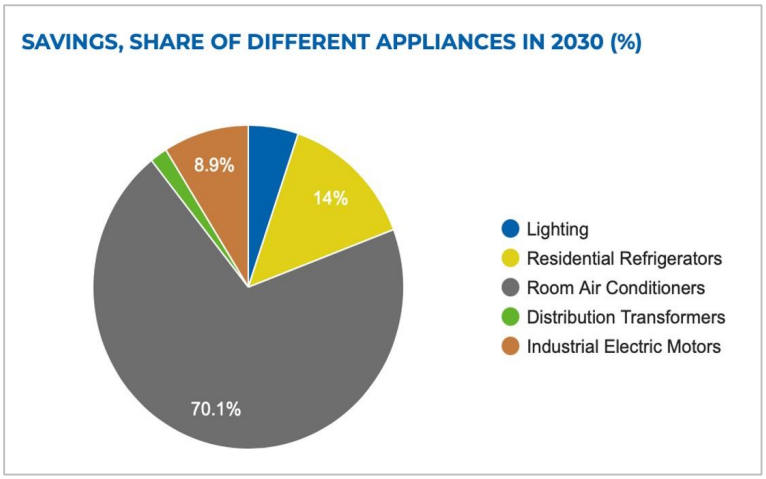
Figure ES-3: Annual Electricity Use (GWh) in PNG under Three Scenarios, 2020-2040



Source: UNEP United for Efficiency, 2020.

The adoption of sustainable and efficient cooling technologies is critical to the long-term success of PNG's energy efficiency and conservation efforts. According to the abovementioned U4E study, refrigeration and air conditioning equipment will make up the largest share (84.1%) of PNG's estimated cumulative energy savings potential through 2030, with air conditioners leading all appliances at 70.1% of total savings (**Figure ES-4**).

Figure ES-4: Share of Energy Savings among Different Appliances in PNG, 2030 (%)



Source: UNEP United for Efficiency, 2020.

National Energy Efficiency Roadmap

In order to realize the wide-ranging economic and social benefits of EE and promote a shift towards low- emission and climate-resilient development, the GoPNG will need to develop and implement a national- scale EE program supported by a robust policy and regulatory framework. As an initial measure, in 2020, the Government adopted the National Energy Policy 2017-2027 (NEP), which underscores the importance of EE and conservation in PNG's long-term development planning. The NEP contains provisions to promote EE in all end-use sectors of the economy (buildings, industry, transport, agriculture residential), including through minimum energy performance standards (MEPS) and labelling for equipment and appliances, among other measures.

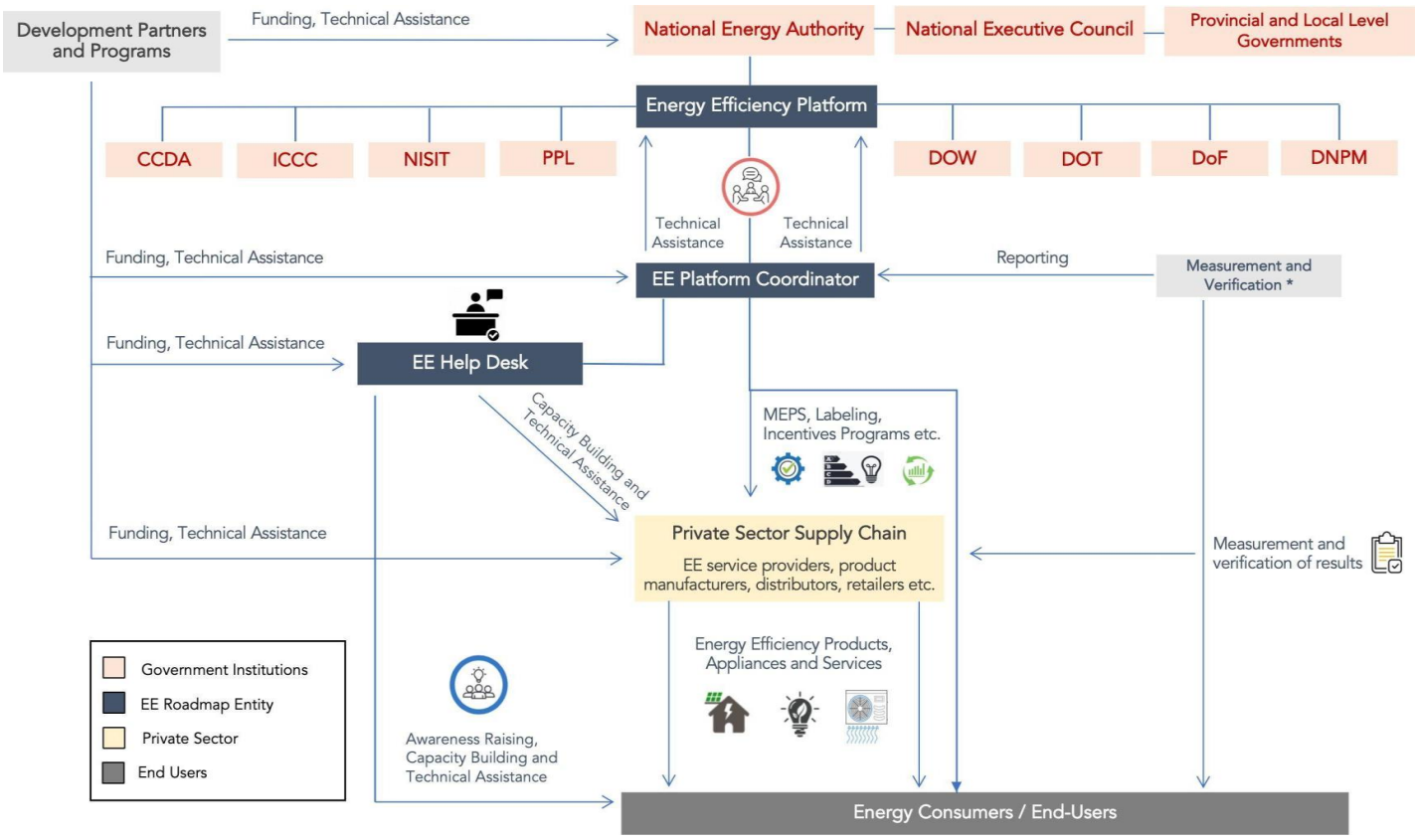
This National Energy Efficiency Roadmap has been developed under the leadership of the Government of Papua New Guinea with support from the United Nations Development Programme (UNDP) as a practical and actionable tool that provides a framework for the country to successfully implement EE polices, programs and initiatives in order to achieve its long-term sustainable development objectives. Figure ES-5 summarizes the key components of the EE Roadmap.

Figure ES-5: Key Components of the National Energy Efficiency Roadmap

	The establishment of a **National Energy Efficiency Platform** – chaired by the NEA, with representatives from the NEA, CCDA, ICCC, PPL, NISIT, DOW, DOT, DoF and DNPM as members, and supported by an Energy Efficiency Platform Coordinator[9] – that regularly plans and coordinates the implementation of EE activities across the economy.
	In collaboration with development partners, the implementation of a **National Energy Efficiency Awareness Campaign** complimented by a provincial roadshow campaign, educating the public about EE benefits and solutions, minimum energy performance standards, product labeling, and other government incentive programs (subsidies, rebates, low-interest loans, tax reductions etc.) to encourage the purchase of energy efficient products or services (such as a building audit). The campaign should simultaneously engage with private sector EE service providers, manufacturers, distributors and retailers through interventions designed to incentivize economy-wide EE improvements and to help service providers expand their operations into underserved rural markets.
	In collaboration with development partners, the establishment of an **Energy Efficiency Help Desk** to provide a wide range of technical assistance to public and private sector EE market actors at the national, provincial and local level covering *inter alia* EE opportunities and projects, government incentive programs, available financing, and other training or capacity building to support the roll out of the National EE Roadmap.

Figure ES-6 presents an overview of the energy efficiency sector in PNG under the Roadmap's institutional framework, including the roles and responsibilities of GoPNG agencies, development partners and EE market actors.

Figure ES-6: Overview of the Roles and Responsibilities of Energy Efficiency Market Actors



** Measurement and verification activities are necessary for the purpose of verifying and reporting energy savings for individual EE projects as well as for utility or government programs. Monitoring the progress of the National EE Roadmap can either be designated to internal staff within the government (NEA) or to an external consultant retained through a tender process with funding and assistance from development partners.*

CCDA: Climate Change and Development Authority DNPM: Department of National Planning and Monitoring
DoF: Department of Finance
DOT: Department of Transport DOW: Department of Works
ICCC: Independent Consumer and Competition Commission NISIT: National Institute of Standards and Industrial Technology PPL: PNG Power Ltd.

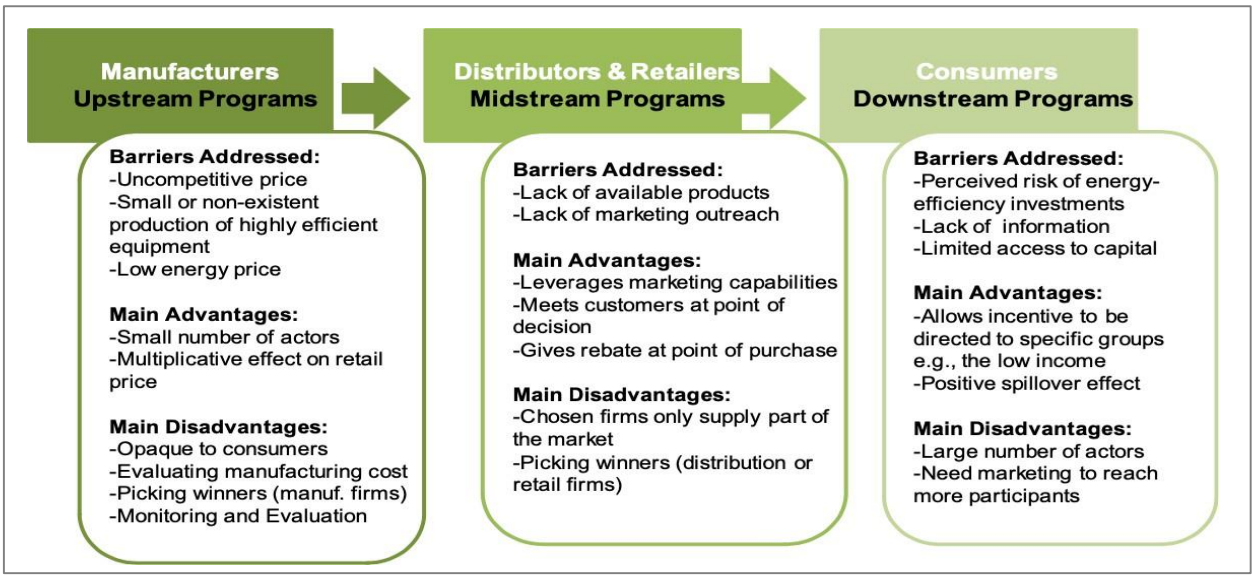
Energy Efficiency Policy and Regulatory Framework

Energy efficiency policies, laws and regulations collectively serve as the foundation for investment in EE measures on a national scale. Policy measures should be based on statistical assessments of the EE potential of various sectors of the economy. This allows for informed decision-making, as policymakers can utilize sector-specific data to establish baselines from which long-term EE targets can be determined. Legal and regulatory reform is often necessary to encourage private sector participation in

the restructuring and modernization of energy intensive sectors. Well-designed technical assistance (TA) programs can provide the expertise necessary to successfully implement EE policy and regulation.

Policy and regulatory mechanisms that support EE typically include codes to improve the EE and thermal performance of buildings, minimum performance standards and labeling schemes for products and appliances, and EE requirements targeting critical sectors such as power, industry and transport (these measures are covered in detail in **Section 4.1**). Given the nascent stage of the EE market in PNG, energy efficiency program designs should include both demand-side and supply-side interventions in order to overcome market barriers along the supply chain, foster private sector participation and stimulate consumer demand for energy efficient products and services (**Figure ES-7**).

Figure ES-7: Energy Efficiency Incentive Program Design along the Supply Chain

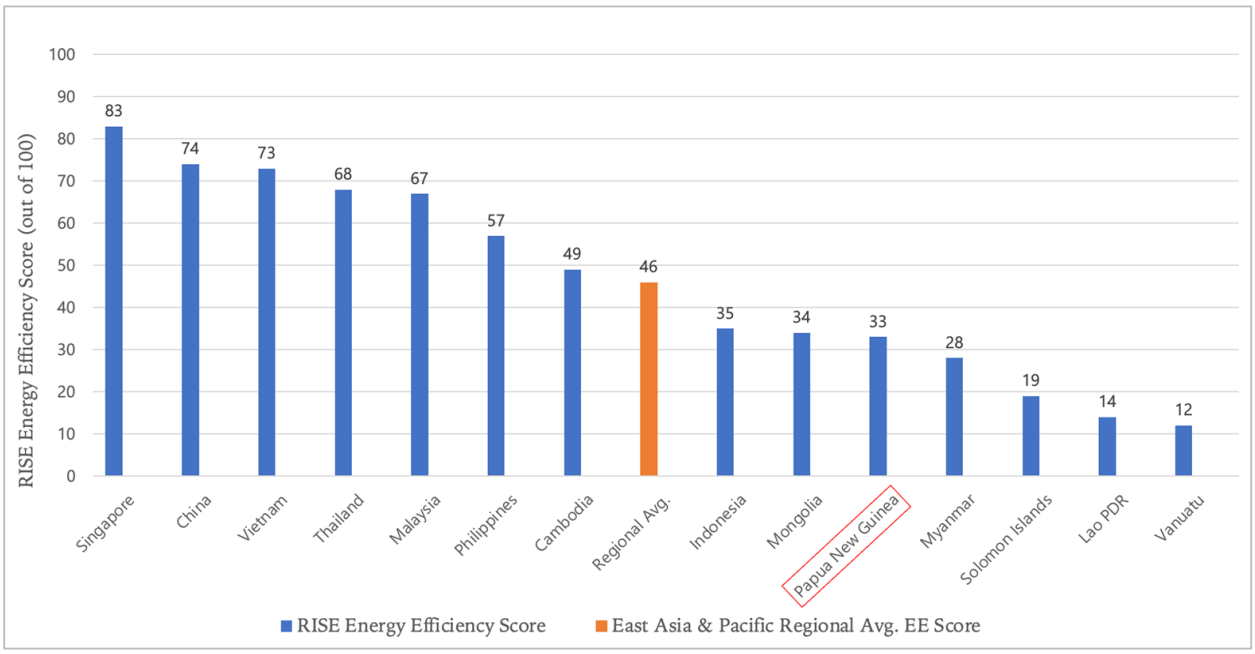


Source: S. de la Rue du Can et al., 2014.

The World Bank's Regulatory Indicators for Sustainable Energy (RISE) index has identified several areas where PNG can improve its policy and regulatory framework to create a supportive enabling environment for energy efficiency. In the EE sector, RISE covers national EE planning, MEPS, building codes, incentives and mandates, EE financing mechanisms, industrial and commercial end-use, public

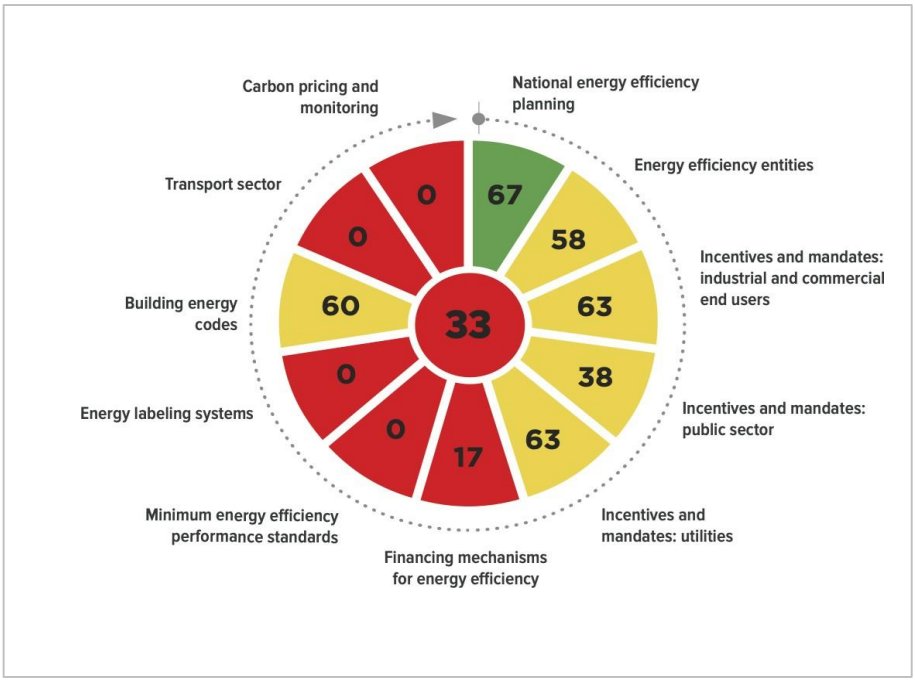
sector EE and the transport sector, among other indicators. As illustrated in **Figure ES-8**, PNG currently ranks in the bottom half of countries in the East Asia-Pacific region – 13 points below the regional average EE score. **Figure ES-9** provides a scoring breakdown for each of the country's EE RISE indicators, while **Table ES-1** compares PNG's EE indicator scores to the regional average.

Figure ES-8: RISE Energy Efficiency Scores for East Asia and Pacific Region, 2019



Source: World Bank Regulatory Indicators for Sustainable Energy (RISE) index, 2020.

Figure ES-9: RISE Energy Efficiency Score by Indicator for PNG, 2019



Source: World Bank Regulatory Indicators for Sustainable Energy (RISE) index, 2020.

Table ES-1: PNG and East Asia and Pacific Region, 2020

EE Indicators	PNG EE Indicator Score	Avg. EE Indicator Score for East Asia-Pacific Region
National Energy Efficiency Planning	67	67
Energy Efficiency Entities	58	66
Incentives & Mandates: Industrial and Commercial End-Users	63	56
Incentives & Mandates: Public Sector	38	49
Incentives & Mandates: Utilities	63	50
Financing Mechanisms for Energy Efficiency	17	40
Minimum Energy Efficiency Performance Standards	0	38
Energy Labeling Systems	0	41
Building Energy Codes	60	33
Transport Sector	0	36
Carbon Pricing and Monitoring	0	11

Source: Adapted from World Bank Regulatory Indicators for Sustainable Energy (RISE) Index, 2020.

4.3.6 Measurement, Verification and Enforcement

Measurement, Verification and Enforcement (MV&E) is a vital component of EE policy and regulation to enforce compliance and ensure that expected EE gains are realized in order to maximize benefits and savings from a given program or practice. The goal of MV&E activities is to ensure the integrity and enhance the operation of a given EE program by minimizing non-compliance cost. Verification measures provide benefits for consumers (who receive the expected product when making a purchasing decision), participant businesses (who are provided a level playing field and do not lose competitiveness by complying) and policymakers (who can assess the effectiveness of their programs and evaluate where improvements can be made).

In order to systematically assess, report on and verify the performance of EE activities across relevant sectors of the economy, monitoring and verification functions can either be designated to internal staff within government (NEA) or to an external consultant retained through a tender process with funding and assistance from development partners. **Figure ES-10** presents the process through which information can be collected and analyzed to measure and report on the Roadmap's performance indicators and to verify results. It is anticipated that these activities will be performed on an annual basis to ensure that the country is on track to achieve the Vision 2050 carbon neutrality target.

Figure ES-10: Energy Efficiency Measurement and Verification Reporting Framework

5.3. Recommendations

Strategic Objectives and Recommended Actionable Priorities

Table ES-2 summarizes the strategic objectives of the National EE Roadmap and the corresponding actionable priorities for the GoPNG and other relevant EE market stakeholders to implement the Roadmap. The recommended actionable priorities are based on the identified potential supply- side and demand-side EE opportunities across various sectors of PNG's economy (see **Section 2.3** for more details).

Table ES-2: National Energy Efficiency Roadmap Strategic Objectives and Recommended Actionable Priorities

Sector	Strategic Objectives	Recommended Actionable Priorities	Coordinating Government Agencies and other Relevant Stakeholders
Cross-cutting / economy-wide	Become a signatory to / participate in international agreements, treaties and initiatives dedicated to improving energy efficiency	• Become a signatory of the Kigali Amendment to the Montreal Protocol • Join the Super-efficient Equipment and Appliance Deployment (SEAD) Initiative of the Clean Energy Ministerial – a voluntary collaboration among governments working to promote the manufacture, purchase, and use of EE appliances, lighting, and equipment worldwide. • Participate in international (UNEP United for Efficiency) and regional (ASEAN SHINE) programs and initiatives that support developing countries to transition their markets to EE appliances and equipment.	National Energy Authority (NEA), Climate Change and Development Authority (CCDA)
	Develop and adopt national energy efficiency policy and regulation	• Designate lead institutions for planning, implementing, and monitoring EE policies and programs • Establish centralized national repository to collect energy data and information across all sectors in order to set appropriate EE benchmarks and targets • Draft EE policy and regulation • Consult with relevant stakeholders and revise draft based on feedback received • Finalize EE policy and adopt/ratify associated regulation	NEA, CCDA, National Institute of Standards and Industrial Technology (NISIT), Independent Consumer and Competition Commission (ICCC), EE Platform Coordinator, Development Partners
	Raise awareness of EE policy/regulation and associated programs and initiatives among industry leaders, energy managers and engineers	• Develop strategies and marketing campaigns for EE awareness raising • Train relevant personnel to carry out national awareness raising campaign • Implement national awareness raising campaign • Publish EE guidelines targeting specific industries	NEA, CCDA, NISIT, Institution of Engineers Papua New Guinea (IEPNG), UPNG Centre of Renewable Energy (CORE), PNG University of Technology (UNITECH) Sustainable Energy Research Institute (SERI) and Appropriate Technology and Community Development Institute (ATCDI), EE Platform Coordinator, EE Help Desk

	Build the capacity of relevant stakeholders	• Design sector-specific EE training modules based on international best practices and conduct organized workshops and trainings for technical and managerial staff • Utilize resources available through international (UNEP U4E) and regional (ASEAN SHINE) programs and initiatives • Introduce energy auditor and energy manager certification programs • Support the development of ESCOs to provide EE services to the market	NEA, CCDA, NISIT, ICCC, Department of Works (DOW), Department of Transport (DOT), IEPNG, UPNG CORE, UNITECH SERI and ATCDI, PNG Power Ltd. (PPL), private IPPs, off-grid enterprises, EE Platform Coordinator, EE Help Desk, Development Partners
	Provide government leadership by setting an example for other buyers and by harnessing public sector buying power to create or expand the domestic market for energy-saving products and services	• Mandate energy audits for government buildings and facilities • Incorporate EE measures into government operations and procurement processes • Establish EE units within government ministries, departments and agencies to mainstream EE best practices in government operations and for effective implementation of EE policies and programs	NEA, CCDA, NISIT, DOW, DOT, PPL, Department of National Planning and Monitoring (DNPM), National Procurement Commission, EE Platform Coordinator, EE Platform Coordinator, EE Help Desk, Development Partners
	Develop and implement EE roadmap business plan and EE fund to support the rollout of EE financing and incentive programs	• Develop a business plan for the National EE Roadmap • Design an EE fund/financing facility and other market-based instruments to leverage private sector investment in EE projects • Implement national incentive program(s) to stimulate demand for EE products and services • Conduct legislative review to adopt EE business plan and establish EE fund	NEA, CCDA, DNPM, Department of Finance (DoF), EE Platform Coordinator, EE Help Desk, Development Partners
	Develop and implement measurement, verification and enforcement (MV&E) modalities and protocols for the EE sector	• Design MV&E protocols for EE projects and programs based on international best practices • Designate lead institution(s) responsible for implementing MV&E protocols • Train relevant personnel to carry out MV&E functions and/or retain an external consultant through a tender process for this purpose	NEA, CCDA, NISIT, ICCC, DNPM, IEPNG, UPNG CORE, UNITECH SERI and ATCDI, EE Platform Coordinator, EE Help Desk, Development Partners
Supply-Side Energy Efficiency			
Resource Extraction and Energy Supply	Adopt EE measures and technologies in all extractive industries (fossil fuel and mining sectors)	• Establish energy data collection procedures; set EE benchmarks and targets • Implement a national energy audit program for enterprises • Introduce protocols to establish best practices in energy management systems • Introduce MEPS and promote EE in industrial motors and motor-driven systems • Design and implement a financial incentives program to promote EE in extractive industries	NEA, CCDA, ICCC, NISIT, IEPNG, Mineral Resources Authority (MRA), DoF, IEPNG, PPL, IPPs, oil and gas companies, mining companies, private sector ESCOs
Electricity Generation and Demand-Side Management	Adopt EE measures and technologies in electricity generation	• Establish energy data collection procedures; set EE benchmarks and targets • Establish utility EE obligations and other market-based instruments to promote EE in electricity generation, transmission and consumption. • Promote fuel switching from fossil fuel-powered generation to renewable energy • Introduce protocols to establish best practices in energy management systems • Introduce MEPS and promote EE in industrial motors and motor-driven systems • Design and implement a financial incentives program to promote EE measures in power generation • Work with PPL to implement demand-side management (DSM) and power system optimization practices	NEA, CCDA, ICCC, NISIT, DoF, IEPNG, UPNG CORE, UNITECH SERI and ATCDI, PPL, IPPs, off-grid enterprises, private sector ESCOs

Demand-Side Energy Efficiency			
Buildings (Public, Commercial and Residential)	Adopt EE measures and technologies for new and existing public, commercial, and residential buildings	• Establish energy data collection procedures; set EE benchmarks and targets • Integrate EE into the national building code for new and existing buildings, including building EE performance standards (e.g., International Green Construction Code, LEED, Net Zero etc.) • Develop and implement a MEPS and labeling program for efficient lighting, refrigeration and air conditioning equipment in all buildings	DOW, NEA, CCDA, ICCC, NISIT, DoF, IEPNG, UPNG CORE, UNITECH SERI and ATCDI, public, commercial and residential building owners/associations, households
		• Establish national testing and labeling program for household appliances with associated standards and regulations enacted • Design and implement a financial incentives program to promote EE in buildings • In the residential sector, promote the use of fuel efficient cook stoves, emphasizing the environmental and health benefits (vis-à-vis wood fuels and kerosene)	
Commercial and Industrial	Adopt EE measures and technologies for commercial and industrial sector	• Establish energy data collection procedures; set EE benchmarks and targets • Implement a national energy audit program for enterprises • Introduce protocols to establish best practices in energy management systems • Introduce MEPS and promote EE in industrial motors and motor-driven systems • Design and implement a financial incentives program to promote EE in the commercial and industrial sector	NEA, CCDA, ICCC, NISIT, DoF, IEPNG, UPNG CORE, UNITECH SERI and ATCDI
Transport	Adopt EE measures and technologies for land, air and sea transport	• Establish energy data collection procedures; set EE benchmarks and targets • Establish minimum fuel efficiency standards for all commercial and private vehicles • Design and implement an incentives program to promote the uptake of fuel efficient and zero-emission vehicles (e.g., hybrid, electric) • Establish minimum fuel efficiency standards for air and sea transport • Promote the use of biodiesel and bioethanol fuels • Provide funding to support road maintenance and new road infrastructure development, with particular focus on connecting the country's main cities • Promote integrated public transport systems in main cities	DOT, DOW, NEA, CCDA, ICCC, NISIT, DoF, IEPNG, UPNG CORE, UNITECH SERI and ATCDI
Agriculture	Adopt EE measures and technologies for agricultural sector	• Establish energy data collection procedures; set EE benchmarks and targets • Implement a national energy audit program for agricultural enterprises • Design and implement a financial incentives program to help commercial and smallholder farmers make EE improvements • Promote farming methods that make use of agricultural residues and animal waste • Provide funding and TA to support distribution and market linkages across the agricultural value chain (cash crops, fisheries etc.) • Implement policies to reduce emissions from the forestry sector and to ensure sustainable land use, forest management, and agricultural practices	NEA, CCDA, ICCC, NISIT, DoF, Department of Agriculture and Livestock, National Fisheries Authority of PNG, PNG Forest Authority, IEPNG, UPNG CORE, UNITECH SERI and ATCDI

Sustainable cooling	Adopt measures to promote clean and efficient cooling technologies	• Develop a National Cooling Action Plan (NCAP); establish appropriate data collection procedures; set economy-wide and sector-specific EE benchmarks and targets in the sustainable cooling sector • Establish MEPS to ensure that refrigeration and air conditioning equipment is highly efficient and uses low GWP refrigerants • Set up an exchange program to recycle used equipment • Organize bulk procurement of high efficiency appliances to accelerate market penetration • Design and implement an EE financial incentives program targeting commercial, industrial and residential end-users	NEA, CCDA, ICCC, NISIT, DoF, IEPNG, UPNG CORE, UNITECH SERI and ATCDI

ANNEX 1: ENERGY EFFICIENCY BARRIERS AND RISKS

Energy Efficiency Barriers and Risks and Potential Technical Assistance Interventions

Barrier / Risk	Description	Potential TA Intervention
Policy and regulatory	• Insufficiently supportive policy, regulatory and/or financial incentives • Fossil fuel subsidies lower the cost of energy and mask the benefits of energy efficiency	• Develop a National Energy Efficiency Action Plan with long-term targets, supportive energy pricing schemes and market reforms, and integrated guidelines and standards to ensure policy coherence and provide clarity and predictability for EE market players • Implement or expand supportive EE policies and regulations (e.g., MEPS, labeling, building codes, demand side management etc.) and financial incentives (e.g., grants, subsidies, rebates, tax incentives, public funding programs etc.) • Analyze where subsidies for fossil discourage investment in / impede development of energy efficiency and low-carbon technologies
Monitoring and verification	• Poor data quality • Lack of enforcement of regulations/inability to verify energy performance standards	• Establish task force (e.g., within the NEA or CCDA) responsible for: (i) collaborating with the private sector to compile and regularly update a national database of critical EE market data that can be utilized by policymakers to make informed energy sector planning decisions based on accurate/updated market information and made accessible to interested EE project developers, investors and other key industry stakeholders (ii) implementing or expanding monitoring, verification and enforcement protocols to ensure compliance with MEPS (e.g., through appliance labeling) (iii) harmonizing national policies/standards with regional (ASEAN) standards
Licensing and permitting	• Costly licensing and permitting procedures for projects	• Develop improved systems for sharing and disseminating information to EE project developers and key stakeholders, including establishment of a “one-stop-shop” for national and local level permits and approvals
Project development	• Large number of small, dispersed projects which characterizes the EE market makes it difficult to finance and develop projects on a project-by-project approach • High pre-investment development and transaction costs, which results in a lack of well prepared, investment ready projects	• Take a programmatic approach to EE project financing that aggregates end-users and the demand for capital • Seek applications and prioritize efforts where there are compelling economics and motivated commercial sponsors/participants
Technical capacity	• Lack of local technical capacity associated with early-stage of development of EE equipment installation and service industry • Limited domestic lender/investor experience with EE	• Support establishment of technical certification and vocational training programs through government, private sector and/or academia for installation, operation and maintenance of EE systems • Support development of database of best practices/information sharing services to ensure skills transfer from international/regional initiatives • Provide TA and training to financial intermediaries on EE lending/investing

Financing	• Scarcity of available long-term capital • Wide range of financing structures needed to address EE financing needs of various end- use sectors	• Pursue dual international and domestic financing approaches • Design scalable financial products that meet the needs of specific target end-user sectors
End-user credit risk/payment	• Poor creditworthiness and non-payment / risk of delayed, reduced or non-payment by customer • Lack of collateral offered by EE equipment and other barriers to creating creditworthy financing structures	• Develop and implement credit enhancement mechanisms • Design programs for commercial financiers that use their existing capacities and meet their lending criteria and credit requirements
Currency	• Foreign exchange risk/uncertainty due to volatile local currency (unfavorable foreign exchange rate movements resulting in a domestic currency not being sufficient to cover debt/equity servicing (this is a major business risk in emerging and frontier markets, especially given that most EE projects and equipment purchases are denominated in hard currency) • Revenue for local EE projects is denominated in local currency (central banks typically apply restrictions on converting local currency into USD or EUR, which presents a risk for international developers or local companies holding USD/EUR debt)	• Source local currency denominated financing • Utilize currency hedging instruments (must be affordably priced to ensure that project remains bankable)
Macroeconomic	• Limitations and uncertainty related to conflict, political instability, economic volatility, weather events/natural disasters, legal governance, ease of doing business, crime and law enforcement, land rights etc. in emerging and frontier markets	• Utilize Political Risk Insurance and other risk-sharing products offered by insurance agencies and development banks
Technology	• Poor project / equipment design and/or performance risk	• Establish clear performance baseline (MEPS) for product quality and ban products that do not meet this threshold through robust monitoring, verification and enforcement (e.g., through penalties and incentives) • Support Energy Savings Insurance products backing EE project performance guarantees and commercial commitments

Consumer awareness	• Lack of public awareness, complicated technical information requirements and long project life-cycles associated with EE projects (aggregated benefits from EE accrue over a long period of time; slow and incremental change makes it challenging for policymakers to implement EE measures)	• Support capacity building of government institutions, trade and industry associations to develop and implement consumer awareness, marketing and education campaigns on the benefits and cost savings of EE products and the existence of related national programs (e.g., EE labeling scheme)
Novel business models	• Lack of understanding about EE pricing schemes and business models	• Support capacity building of government officials, regulators, FIs and other industry stakeholders about different pricing schemes offered by EE service providers
Donor coordination	• Lack of coordination between donor agencies/development finance institutions and government ministries leads to a lack of policy coherence.	• Support coordination of donor/DFI programs and initiatives in EE sector • Multi-sectoral approach; strategic timing of technical assistance provided by donor agencies/development partners

ANNEX 2: ENERGY EFFICIENCY MANAGEMENT APPROACHES

ANNEX 2A: Coordination of Energy Efficiency Initiatives

Coordinating Energy efficiency: Coordinating EE provides customers with better tools to understand, manage, and reduce electricity use. Such coordination can occur in at least four ways:

Combined program offerings: Customers could be offered both energy efficiency and demand response opportunities under the same program and provider umbrella; separate programs are the norm today.

Coordinated program marketing and education: Without merging the delivery of services at the program level, program sponsors (e.g., utilities) could package and promote energy efficiency and demand response in a closely coordinated or unified way. Energy efficiency and demand response can be complicated topics, requiring sophisticated customer effort and action, so program sponsors should offer education that addresses both topics under a broad energy management theme.

Market-driven coordinated services: Coordination need not occur only within the context of programs offered by utilities, public benefit organizations, or independent system operators (ISOs). Coordination of energy efficiency and demand response could also come about through the initiative of private firms that find a market among customers who are interested in reducing their energy costs. Our research and interviews with selected energy service companies (ESCOs) and curtailment service providers (CSPs) suggests that they are interested in this approach; we describe their initial steps in this direction.

Building codes and appliance standards: Building codes and appliance efficiency standards can incorporate preferred energy efficiency and demand response features directly into building design and infrastructure and appliance designs, enabling significant reductions in the costs to customers of integrating energy efficiency and demand response strategies and/or measures (e.g., global temperature setback controls, automated demand response, embedded controls in appliances).

At the provider level, utilities and grid operators should coordinate EE and demand response through

resource, budget planning, and rate design processes. This coordination is critical, as EE determines how much load is available to shift from a given customer; EE measures affect how much money the customer and utility have available to spend on demand response (and vice versa); and rate design, efficiency, and demand response collectively impact the load levels and profiles that supply resources need to serve.

Facilitating Coordination: There are several ways to encourage better coordination of EE and demand response initiatives:

Regulators can direct utilities and grid operators to coordinate the programs more effectively and support rate designs that facilitate energy efficiency and demand response.

Demand-side management (DSM) program goals can be articulated more specifically to address both energy efficiency and peak load reduction goals.

Customer education about energy efficiency can be broadened to explain demand response and its benefits to the customer.

Government “lead by example” programs can demonstrate the value of coordinating energy efficiency and demand response, particularly with respect to the impact of enabling technologies that serve both purposes.

Building codes and appliance efficiency standards can incorporate technology improvements and functionalities that integrate and improve both efficiency and load controllability.

ANNEX 2B: ***Potential Activities under the Framework for Leapfrogging Markets to Energy-Efficient and Climate Friendly Initiatives***

PNG Energy Efficiency Roadmap: Key Components and Activities

Component	Activities
Component 1: National EE Roadmap Action Plan has been agreed by government, businesses, consumer groups, and other stakeholders	• Conducting market assessments on energy generation, distribution, and end-use consumers (e.g., industrial, commercial, agricultural, transport, and building sectors) • Submitting one inception report and conducting consultations with relevant stakeholders (e.g., government, manufacturers, suppliers, consumer groups, environment groups) to communicate the gaps of the market assessment and pave the way for development of a national EE Roadmap action plan • Strengthening capabilities of stakeholders who will be involved in the project • Convening finalization workshop to incorporate feedback for the national EE Roadmap action plan • Developing knowledge management tools and means of collecting lessons learned across the entire project
Component 2: Policy framework for energy-efficient products has been developed or enhanced	• Based on the market assessment, adapting the Efficiency Model Regulations/Procurement Specifications for all types of appliances and equipment • Organizing a consultation process with national government officials and relevant stakeholders regarding new policies and programs • Convening regional harmonization workshops to gain commitment of countries to implement minimum energy performance standards and labelling programs in a harmonized manner and collaborate on market monitoring and enforcement • Convening a communication campaign to raise awareness with relevant stakeholders
Component 3: Market surveillance system is in place as a compliance gateway and data gathering tool that informs policies and programs	• Developing a product registration system to track compliant electrical products (starting with appliances and equipment products) and support enforcement activities when non-compliant products are found • Conducting training and capacity building programs for customs officials, market surveillance authorities, and other stakeholders responsible for monitoring, verification and enforcement
Component 4: Responsible ministries are trained in proper disposal of inefficient products	• Training of NEA, CCDA and other key stakeholders in the collection / recycling industry to increase capacities for environmentally sound management and disposal of end of life products
Component 5: Strengthened climate finance strategies and project pipeline support the financing of energy-efficient products	• Developing a financial market assessment (in parallel with the general market assessment) and reviewing existing financial programs and business models that support purchase of all types of appliances and equipment • Developing and securing government commitment for procurement specifications • Convening stakeholder workshops with the aim of developing a financial mechanism and securing agreement with financial institutions/development banks on its implementation • Drafting one or more funding proposal(s) for the Green Climate Fund (GCF) and developing financial mechanisms suitable for PNG market characteristics (for example, retrofitting as a service, vendor-based financing or on-bill financing) of energy-efficient appliances and equipment products

Source: Adapted from United 4 Efficiency: Leapfrogging Markets to Energy-Efficient and Climate Friendly Initiatives

ANNEX 2-C: Bottom-Up Evaluation of EE Potential

Technical potential represents the theoretical maximum amount of energy use that could be displaced by efficiency, without regard to non-engineering constraints such as costs and the willingness of energy consumers to adopt the efficiency measures. It often assumes immediate implementation of all technologically feasible energy saving measures, with additional efficiency opportunities assumed as they arise.

Economic potential refers to the subset of the technical potential that is economically cost-effective. Definition of "economic potential" can vary to some degree by study. Economic potential can be estimated by evaluating technology upfront cost, operating costs (including energy prices) and product lifetime and discount rate and comparing these results to a conventional alternative source/supply of energy. Another method is to consider consumer preferences in addition to consumer out-of-pocket expenditure when evaluating the economic potential. Both technical and economic potential estimates assume immediate implementation of efficiency measures without regard to technology adoption process or real-life program implementation. In addition, these estimates do not always reflect market failures or barriers that impede EE and often fail to capture transaction costs (e.g., administration, marketing, analysis, etc.) beyond the costs of efficiency measures. Another key factor determining economic potential is the level of aggregation at which the cost effectiveness evaluation is applied. Applying the cost test at lower levels of aggregation (e.g., at the measure or program level, rather than the sector level) will typically lead to lower economic potential when evaluating a portfolio of programs.

Market potential (or "achievable" potential) refers to the subset of economic potential that reflects the estimated amount of energy savings that can realistically be achieved, taking into account factors such as technology adoption process, market failures or barriers that inhibit technology adoption, transaction costs, consumer preferences, social and institutional constraints, and possibly the capability of programs and administrators to ramp up program activity over time.

Program potential refers to the subset of market potential that can be realized given specific program

funding levels and designs. Program potential studies can consider scenarios ranging from a single program to a full portfolio of programs.

ANNEX 2D: Top-Down Management Approach

Technology alone cannot achieve optimal savings, but when coupled with operations and maintenance practices, as well as management systems, it can lead to significant reductions. The figure below illustrates how to integrate organizational, technological and behavioral change through a continuous and a dynamic process. Integrating an energy management culture with operational and technological actions is essential for optimal results. Employee behavior is also a crucial because it puts people in the "feedback loop" and is supported by recognition of results.

Energy Efficiency Behavioral Change

Source: Energy Efficiency Trends in Canada, 1990 – 2008

Organize a Team: It is important to obtain a commitment from top management, and to organize a team composed of key players. Assign responsibility for implementing the EE programs to team members.

Obtain top management commitment: Ongoing support from top management is key to the success of the EE programs. Management should already have developed a comprehensive energy management

plan that includes training and awareness. When management leads the program and requests support from the employees or staffs, the credibility of the program is enhanced. Communication from top management promoting the EE program is one way of demonstrating commitment.

Appoint an energy efficiency program manager*:* Appointing a "manager" to represent the EE program is crucial to achieving the objectives. The manager should be someone who is enthusiastic and committed to ensuring that energy efficiency is a high-profile activity and be responsible for overseeing planning and implementation. This individual must have the resources and authority to carry out the EE program with full support from the top management. The program manager should be prepared to become the spokesperson for the EE program – someone who is recognized and publicly associated with energy initiatives in an organization.

Formation of Energy Efficiency Team*:* When forming the energy efficiency team, be sure to include individuals who have a wide range of skills, interests and knowledge from various areas, be it public or private organizations. This practice will ensure a solid understanding of the diverse energy-consuming activities throughout the organization and provide spokespeople who represent a range of EE programs under respective departments. Members of the EE team should include representatives from different departments or groups in the organization. Once formed, the team will now be given a corporate mandate on objectives, goals, targets and sustainable decision- making to implement identified EE programs.

Establish Baselines:

Establish a baseline of energy consumption: By knowing how and where energy is used, and by whom, it is easier to focus on the activities that will generate the best results. Information about how your organization consumes energy establishes an energy consumption baseline for setting objectives and targets for the EE programs. It also helps establish some of the indicators against which the program can be evaluated. An energy-use analysis or energy audit highlights energy savings opportunities through low-cost or no-cost measures that building users can easily implement.

Establish a baseline of energy efficiency awareness*:* The success of the EE programs can be measured

by how it facilitates energy reduction initiatives and by the increased level of energy efficiency awareness in the organization's workplace. To evaluate the success at a later stage, one must determine a baseline of energy efficiency awareness before the EE program begins. To develop this baseline, distribute a brief questionnaire to determine the general level of knowledge of energy issues and efficiency measures within the organization. Administer the questionnaire again after you implement the program and compare the results to help determine the overall success of the EE program – a comparison of baselines data against data after EE programs being implemented.

Formulate Objectives:

Support energy savings objectives*:* It is important that the program supports the energy savings objectives in the energy management plan (e.g., to reduce energy use by a specific amount or percentage over a specified period). So how does awareness support these objectives? In many cases, it will be difficult to determine exactly if, or how, specific awareness activities are responsible for energy savings, but management can agree to a set of indicators. For example, having a specific number of employees to take training in each quarter can be accepted as an indicator of an improvement in building operations and occupant behaviors.

Establish awareness and communications objectives*:* Setting objectives to change the level of awareness and alter employee behavior is essential to the long-term success of the EE program. The change can be measured against the awareness baseline that was established using the questionnaire. Specific objectives will vary depending on the size, type and location of the organization and a range of other variables. The energy efficiency team, in conjunction with top management, determines what constitutes realistic and obtainable goals. It is also important that the objectives are measurable and doable. Setting a time frame for energy savings can make the objectives easier to evaluate.

Develop a Communication Plan: A well-thought-out and executed communications plan is an effective tool for implementing an energy efficiency awareness program. Assigning team members with communications experience to take the lead when developing the plan will ensure effective use of

existing internal resources. Encourage buy-in by assigning tasks to team members and by ensuring that roles and responsibilities are understood and accepted by all

Recognition and Awards:

***Activities**:* Activities such as competitions, challenges and contests combined by departments, by sections, and or building zones with awards programs can encourage and motivate staff to participate in the energy efficiency program.

***Awards**:* Awards programs help build momentum, generate interest and motivate behavioral change. The energy efficiency team can give awards or prizes as incentives for participating in activities, or to recognize significant contributions. The team can also solicit support from the top management to obtain awards or incentives. Awards can range from small items such as compact fluorescent lamps, T-shirts and setback thermostats to larger items such as energy efficient appliances, or even cash incentives from the energy savings generated from the EE programs in the case of some developing countries like the Philippines.

Implement. After finalizing the communications plan, the next step is to get the message out. Implementing the EE program takes commitment, energy, time, enthusiasm and imagination. Promote the EE program launch at least two to four weeks in advance by using posters, newsletters and other communications tools.

***Monitor, Evaluate, Report and Follow Through*.** Evaluating the program against its original objectives will help determine if it is effective by identifying what works and what does not and will highlight which tools and activities best encourage changes in behavior. Frequent evaluations throughout the roll-out of the program will provide the information needed to adapt the program and plan future activities to achieve the desired results.

***Evaluate the approaches**:* Comparing variables about the new level of awareness against the baseline of energy efficiency awareness will provide insight into whether the program is on course.

Monitor and report results*:* Evaluation of the program will provide data on the energy use patterns of the organization over time. Illustrate the progress with easy-to-read bar graphs and pie charts and provide concrete examples. Regular reporting on the progress of the program enhances its effectiveness. This will let the participants know that their efforts really do make a difference.

Follow through*:* Building awareness is a continuous work. To maintain interest in the energy efficiency program, continue to reinforce the team's messaging by providing regular updates to the top management, the team members, the staffs and building users through newsletter articles, displays and management meetings. These updates will sustain the momentum of the program, reinforce new behaviors and lead to the continuous improvement of the overall programs. Throughout the implementation, the team will adapt elements of the program to respond to the organization's changing needs. As the awareness level changes, so should the messaging as learnt from experience and adapt the program as it goes. Use the information from your evaluations and observations to redirect the program.

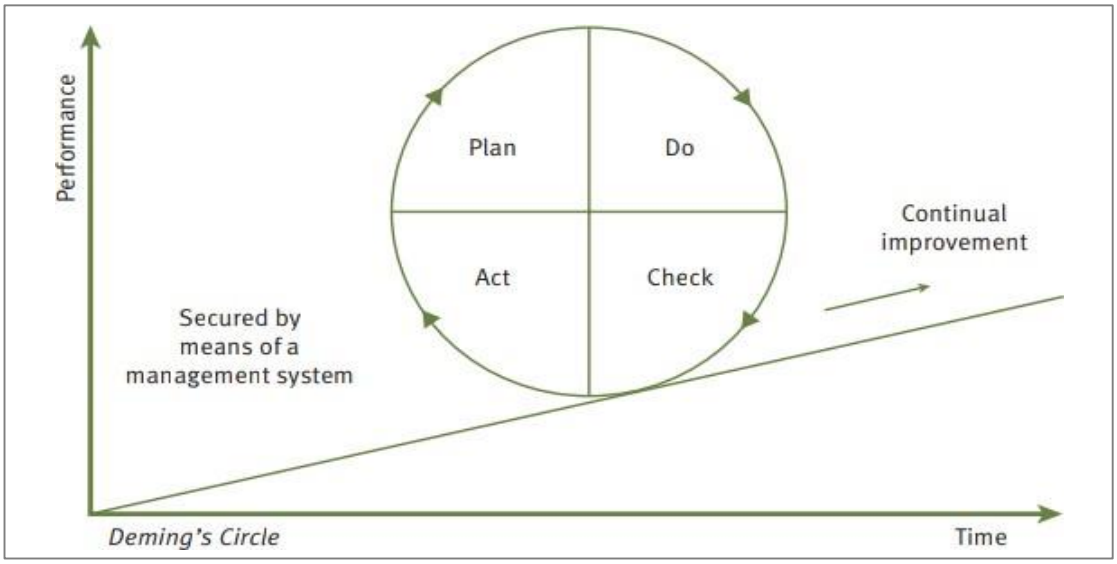
ANNEX 2-E: ***Energy Management Systems (EnMS) ISO50001***

World energy consumption continues to rise – it has more than doubled in the last 40 years and is projected to increase an additional 30% by 2040. What's more, energy is the major contributor to climate change, making up nearly 60% of the world's greenhouse gas emissions. A study commissioned by the Climate Works Foundation, a non-governmental organization that leverages the power of collective philanthropy in the fight against climate change, showed that improving energy efficiency and reducing carbon growth in the industrial and buildings sectors alone could save over USD 3.2 trillion in public health-related expenses.

Brief history and overview of energy management systems

The United Nations Industrial Development Organization (UNIDO) recognizes that industries around the world need to mount an effective response to climate change. Access to energy is becoming more costly and environmentally damaging, and the era of cheap energy is coming to an end in many countries. The effective use of the energy management system will help organizations of all sizes (and in particular SMEs) to manage their energy use in a sustainable way. This will result in reduced costs, reduced environmental impact, and increased competitiveness. This can be achieved by adopting a systematic approach to energy management, which is based on the Plan-Do-Check-Act cycle for continual improvement. This process tries to make the method of implementing an Energy Management System (EnMS) as simple as possible. **Figure 2E-1** shows the principle of continuous performance improvement through the Plan-Do-Check-Act cycle. The energy management system approach has a long and proven record of success across all industry sizes and sectors.

Figure 2E-1: Overview of Energy Management System

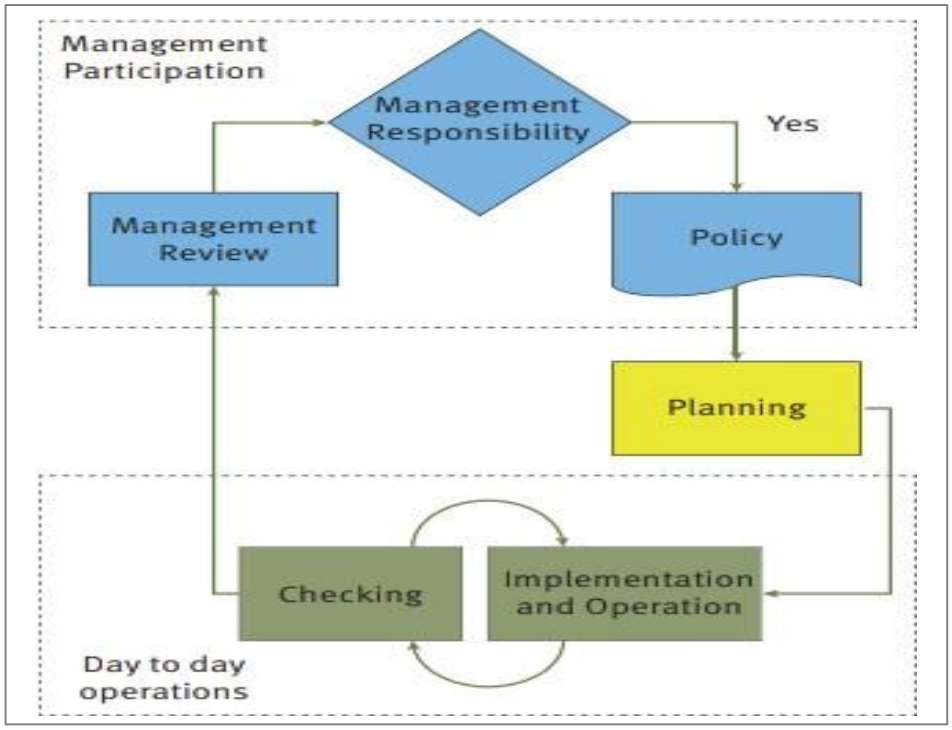


Source: United Nations Industrial Development Organization

What is energy management?

Energy management is affecting organizational, technical and behavioral actions in an economically sound manner, with the objective to improve the energy performance of your organization. Energy management means systematic attention to energy, with the objective of continually improving the energy performance of your organization and maintaining these achieved improvements. It ensures that your organization continually passes through the cycle of making policy (including evaluation of objectives), planning actions, implementing actions and checking results, reviewing progress and updating policy and objectives, as required.

Figure 2E-2: Plan-Do-Check-Act Approach



Source: United Nations Industrial Development Organization

The Plan-Do-Check-Act (PDCA) approach is reflected in existing standards, as shown in **Figure 2E-2** above. This figure includes all the main elements of the energy management system. The implementation of an energy management system is not an objective in itself. What matters are the results of the system: energy performance improvement by anchoring attention to energy in daily practice. Whether an energy management system works depends on the willingness of the organization to manage energy use and energy costs, and to make the necessary changes to their day-to-day operations to facilitate these improvements and cost reductions.

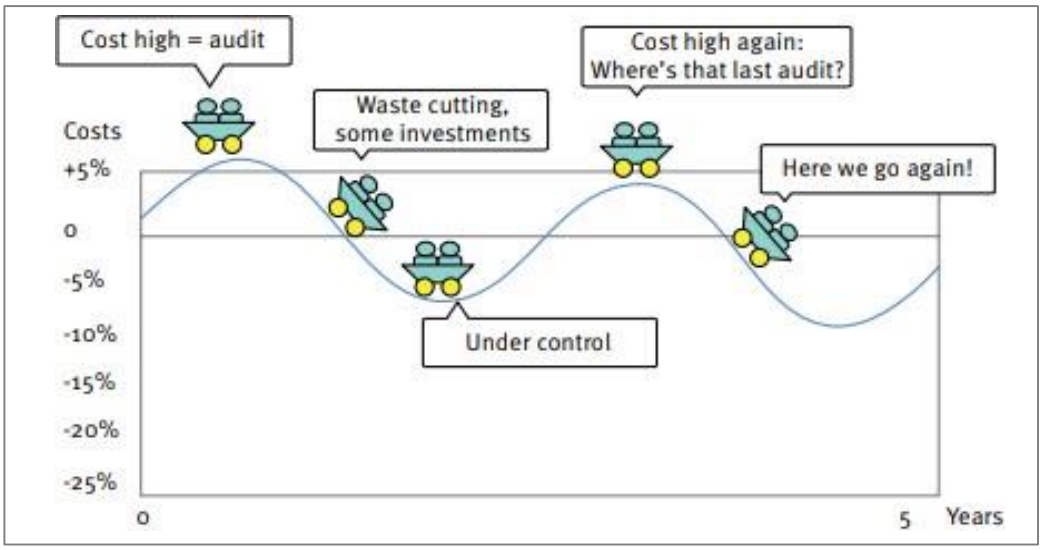
Figure 2E-2 provides a simplified overview of an EnMS. It shows an overall cycle beginning with management responsibility and commitment. This is shown as a decision point, and without it the system will have difficulty in being effective. The cycle continues through development of a policy, planning, implementation and operation, checking and management review. The three activities of management responsibility, policy and management review are grouped to indicate that these are the activities that involve the top management, and where support for the EnMS is built. The task of getting real

management commitment is critical to the success of an effective energy management system. Day-to-day operations and monitoring of performance are grouped, as these are the activities that are carried out to continuously improving your energy performance and ensure that it is sustained.

Why manage energy?

It is well known that many companies are reluctant to focus on energy management or to invest in energy efficiency measures. Nevertheless, there are many good examples that prove that a systematic approach to managing energy performance can be successfully combined with the priorities of companies in both public and private sectors.

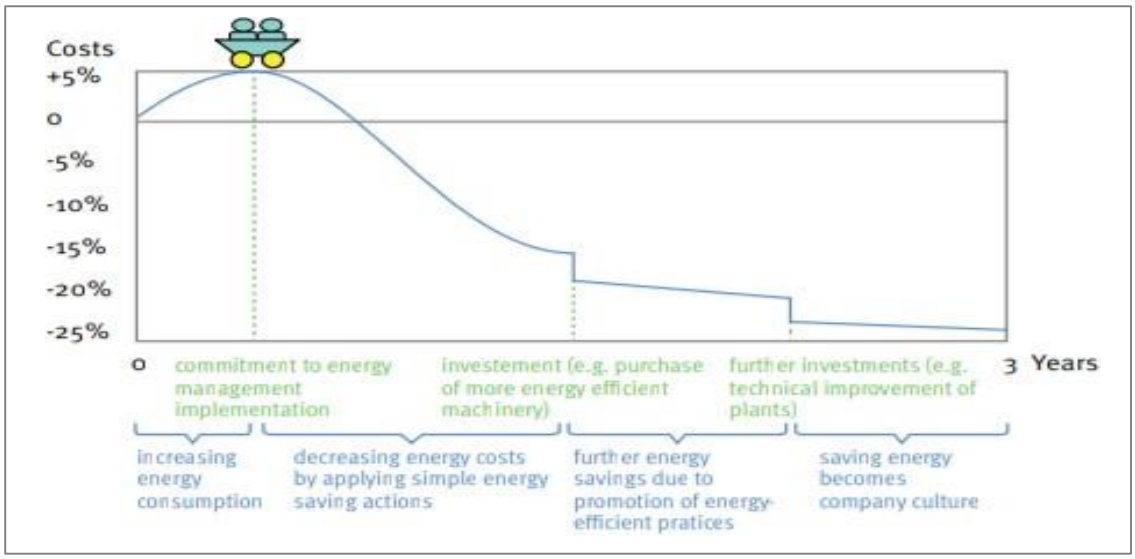
Figure 2E-3: Results of Ad-Hoc Energy Management



Source: United Nations Industrial Development Organization

Figure 2E-3 above shows how energy costs behave over time when organizations occasionally implement energy savings actions in response to rising costs. Energy costs will continue to cycle and go out of control if an organization does not manage its energy use on a daily basis and make it part of normal business operations.

Figure 2E-4: Results of A Systematic Energy Management Process



Source: Sustainable Energy Authority of Ireland

Figure 2E-3 and **Figure 2E-4** above shows how energy costs are affected by different approaches to energy management. As illustrated in **Figure 2E-4**, with a focus on continuous improvement through an energy management system, energy performance improvements can be maintained, and costs continue to decline over time. A systematic energy management approach offers the following benefits:

Direct benefits*:* Energy cost savings; prioritization of no cost and low-cost energy saving opportunities in day to day operations; reduced greenhouse-gas emissions; reduced exposure to changing energy prices; reduced carbon footprint; increased security of supply by reducing dependence on imported fuels; increased energy awareness among staff and greater participation; greater knowledge of energy use and consumption; opportunities for improvement; informed decision-making processes, and reduced uncertainty as future energy use is better understood

Indirect benefits*:* Positive publicity, improved corporate image, improved operational efficiencies, improved maintenance practices, improved safety and health.

General requirements

Self-Assessment. One of the first activities to be undertaken when implementing an energy management

system within an organization is to check the existing level of energy management in the company. The purpose of such self-assessment is to identify the main priorities for the organization regarding the implementation process. The key questions are:

- Does the top management know that significant energy cost savings can be achieved by simple low-cost measures without necessitating financial investment?
- Is the top management committed to energy cost reduction, and is there an energy policy in place agreed on by top management? Have roles, responsibilities and authority been identified for all persons having an influence on significant energy uses, and is this documented?
- Have the significant energy uses been quantified and documented?
- Has a baseline of energy performance been established against which progress can be measured?
- Have indicator(s) or metrics been identified to use in measuring progress against your baseline?
- Have the organization's energy objectives and targets been identified and documented?
- Have energy action plans been established?
- Is the energy management system evaluated at least once a year and are improvements made based on the results of the evaluation?

Securing top management commitment

It is crucial that any effective energy management system has the full commitment of top management of the organization. This commitment can be demonstrated by signing the energy policy, but in general more is needed from top management to make successful energy management possible. To get full commitment and support, it is important to convince top management that having an EnMS is an advantage for the organization (energy saving, cost saving, etc.). The business case for energy management implementation designed to assist in securing management support. This can be completed by adding some convincing data and information on: (a) Trends of energy use, energy costs and other energy related issues; (b) Saving data estimations from available generic saving measure data; (c) Benchmarking data from the sector our organization is part of; and (d) Case studies describing energy

management achievements.

The commitment is more than a statement of support - it should establish accountability among managers involved in the implementation of the system and should require regular reporting on progress. Minimum requirements for showing top management commitment are: (a) Establishing an energy policy (and implement and maintain it); (b) Appointing a management representative (and identifying the additional core personnel required to successfully develop and implement the organization's EnMS); (c) Providing resources (time, budget, personnel and information); (d) Developing, agreeing and communicating all the roles, responsibilities and authorities that will apply to each task involved in developing, implementing and operating the EnMS. The importance of this activity cannot be over-emphasized; (e) Communicating the importance of energy management to the organization; (f) Establishing energy objectives and targets;

(g) Making on-going decisions as required to support the improvement of energy performance; and (h) Conducting management reviews.

Having the full commitment of the top management does not mean that other organizational priorities are compromised. It means that energy performance issues are correctly prioritized and fit within overall objectives and challenges.

Build the business case. Before a company can start to implement an energy management system, it has to get the commitment of the top management. For this commitment, the manager will ask about the current status of the company's energy situation. Top management must be convinced that there is a benefit in improving the energy situation before deciding to implement an energy management system. By presenting the business case for the energy management system, the status of energy use and related issues is established, which provides a starting point for the development of an energy management policy. Necessary information for the business case includes: the total amount of energy consumed, divided into fuels and electricity; energy prices; production data for the purpose of knowing growth or reduction rates in the future; and if relevant benchmarks are available for the organizations sector, which

can provide evidence that improvement is achievable. The business case should include an estimation of the potential energy efficiency improvement and energy savings, along with the corresponding increase in operational profitability. It should also include an estimate of implementation costs in terms of human, financial and technical resources. It is important to emphasize to the top management that this is a significant change management process for most organizations and not a technical project.

Establish scope and boundaries. It is necessary to define what will be covered by the EnMS. Sometimes an organization will decide not to include some aspects. Examples of the decisions to be made on scope and boundaries are: (a) Are all the buildings in the facility to be included? (b) Are all factories in the organization to be included? This will only apply if a system is being developed at a corporate level. It's possible the organization chooses to pilot the concept in one or a small number of facilities.

Appoint the management representative. The management representative is responsible for the establishment, implementation and improvement of the energy management system. He or she is appointed by top management and given the required authority and necessary resources to accomplish the task of implementation.

The time of the energy management representative doesn't have to be exclusively devoted to the implementation of the energy management system. In practice, he or she frequently also fills a function which has a very strong relation with energy management (e.g., engineering manager, environmental manager, production manager, operations manager, etc.). The management representative should have the following responsibilities at a minimum: Implementing the energy management system; Reporting to top management on the performance of the energy management system; Reporting to top management on the energy performance of the organization; Formation of an energy management team whenever appropriate and possible; and Plan and direct energy management activities. The following skills are needed in the energy management team: High-level communication, including liaison, negotiation/consultation skills; Facilitation for managing meetings and team activities; proven experience in project management; an understanding of energy costs and the tariff structures available;

Familiarity with engineering systems and energy efficiency technologies; and Knowledge and experience of change management. These skills are often split between the management representative and the energy manager if the structure of the organization has both roles separated.

Roles, responsibility and authority. The successful implementation of an energy management system will require the commitment and effort of staff at every level of the organization. In the planning phase, it needs to identify the people who have both a direct and indirect effect on energy use within the organization and the training needs for those staff. For each of the job titles that are identified, list the roles and responsibilities in terms of the EnMS, starting with the top level of management and working through the rest of the organization.

When documenting roles and responsibilities, it is important to clearly define who has authority for which elements of the EnMS. This will avoid any conflict or misunderstanding between, for example, production and maintenance. The management representative should ensure that each person involved in improving the energy performance of the organization clearly knows their own role, what their responsibilities are and what level of authority they have in support of the EnMS.

Establish the energy management team. Depending on the size of the organization, establishment of an energy management team might be considered. The purpose of forming an energy management team is to engage the various departments or work units of the organization (e.g., procurement, production, facilities) in the development and implementation of the EnMS. The energy management team provides visible evidence of the importance of cooperation across the organization to ensure the success of the EnMS and is often the first concrete step in changing the culture of the organization with respect to the

energy. The role of the team is to assist the energy management representative throughout the process of implementing the energy management system.

Define the energy policy. It is essential that any effective energy management system has the full support of the top management of the organization. The purpose of the energy policy is to document the organization's commitment and overall approach to energy management at a high level. It does not need to have any detail on how the organization will manage its energy use. It forms the basis for all other parts of the EnMS. The level of complexity of the energy management system will vary depending on the scale and complexity of the organizations energy using activities. It is not necessary, or desirable, that the EnMS is overly complicated and/or bureaucratic. The policy needs to be signed by top management to demonstrate its commitment to the EnMS. The policy should require the following: (a) It needs to be appropriate to the nature and scale of the organization's energy use; (b) It needs to be reviewed and updated regularly (e.g., annually) to ensure that it remains relevant. This review will usually be part of the regular management review of the overall EnMS; and (c) It needs to be communicated to all employees and contractors to demonstrate to them that the senior management is committed to its energy management system.

Energy planning. Energy planning requires translating the commitment and energy policies into objectives, targets and action plans. Planning is a key step in putting an energy management system in place. It is fundamental to know how much energy is being used, where, and for what purpose. Most organizations have good knowledge of the breakdown of their cost base, but few seem to understand where their energy is being used. This energy planning process will be conducted initially as part of the implementation of the energy management system, and relevant parts will be updated on an on-going basis as required: (a) Access energy bills and energy sub-meter data (if available); (b) Trending and data analysis will be employed to check past energy use to maintain an understanding of use, consumption and performance. Budgets for future years will be developed, typically annually; (c) Energy use and consumption will be analyzed to identify and quantify the significant energy users (SEUs). This will be updated regularly; (d) Each SEU will have its driving factors identified, quantified and analyzed.

Regression and other analysis will be used to determine the effects of the energy driver(s). This will be updated regularly; (e) Baselines and EnPIs will be developed including the development of a metering plan to add any additional energy meters that may be required. Where possible EnPIs will be based on regression analysis. They will be updated regularly; and (f) Operation, maintenance, design and procurement activities related to each SEU will be reviewed for effectiveness including development of a measurement plan for any critical operating parameters. All personnel who might affect the energy performance of each SEU will be assessed to ensure that adequate levels of competence are in place.

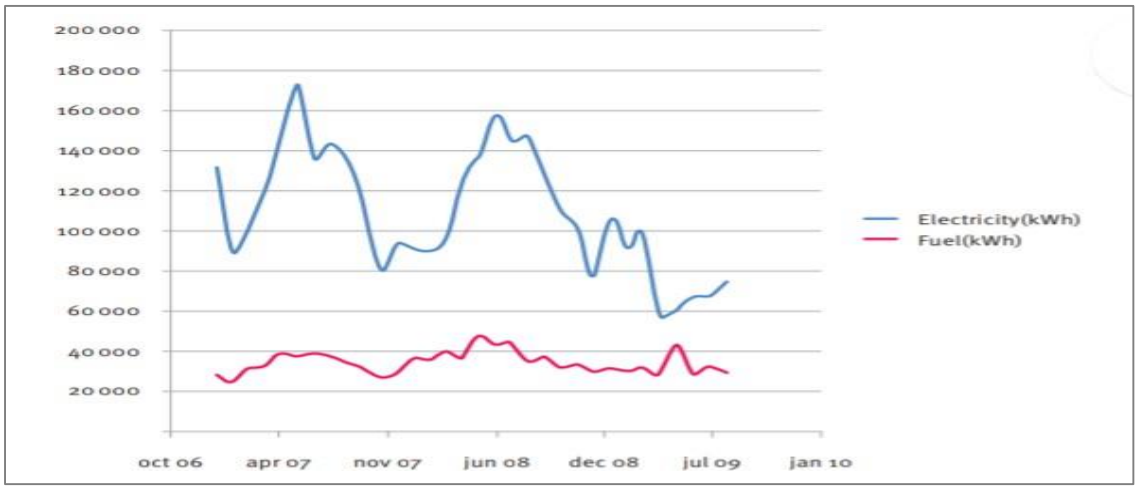
Technical energy audits (assessments) and inspections will be carried out occasionally as required to identify additional energy saving opportunities, in addition to those identified on a day-to-day basis. The potential for renewable and alternative sources of energy will be considered. In addition to the above sources of improvement opportunities, all staff and colleagues are encouraged to suggest opportunities. Development of action plans will include ensuring that objectives and targets are met. Selection of opportunities for inclusion in action plans will include consideration of all the above items in addition to technical feasibility, legal and other requirements and financial appraisal. Training plans will also be developed for those with the potential to influence the energy performance of the organization.

Energy review. An energy review is a documented analysis of energy efficiency, energy use, and energy consumption based on data and other information, leading to identification of areas of SEUs and opportunities for energy performance improvement. The methods and criteria by which it is produced should also be documented. The energy review will help to establish energy performance indicators (EnPI's), energy baseline(s) (see below) and objectives and targets for improvement.

Acquire and analyze energy data. The purpose is to establish your energy use and trends in absolute terms. Ideally the past three years of energy bills would be used to establish these trends. One useful method is to develop annualized trends of energy use. You will also need to be aware of current energy sources and how much energy you expect to use in the coming period. **Figure 2E-5** shows the trend of monthly energy use of a factory. It indicates a seasonal effect and a baseload in each energy use, i.e.,

about 60,000 kWh for electricity and 25,000 kWh for fuel use. In this case fuel use is shown in kWh. Some organizations do this to allow clear comparison, while others use GJ.

Figure 2E-5: Trends of Energy Use

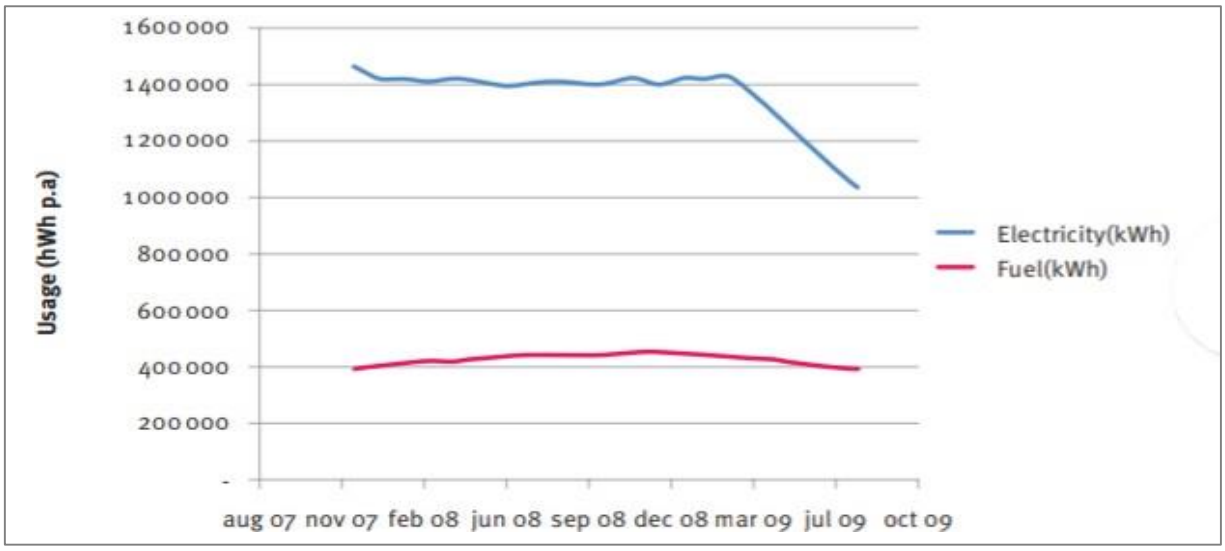


Source: United Nations Industrial Development Organization

The trend in **Figure 2E-6** shows the same data, but on an annualized basis (i.e., each point on the trend is the total of the previous 12 monthly bills). This comparison allows you to see overall trends of usage and is very useful for forecasting and budgeting usage. The data in **Figure 2E-6** shows very stable usage in recent years but a reduction in electricity use on recent months. For your organization's facility, it needs to understand the underlying causes for these trends and changes.

Determine significant energy use. In order to identify SEUs, one need to know how much energy each process or system uses. In an ideal world, it will have energy sub-meters fitted to all large energy users and can then simply use these meters to quantify the consumption of each use. In reality, few or none of the uses will be sub-metered. In that case, there needs way of estimating their consumption. The organization need to carry out this activity for each energy source, i.e., electricity and each fuel type. In some cases, it may be more appropriate to think in terms of processes or systems rather than pieces of equipment.

Figure 2E-6: Annualized Energy Trends

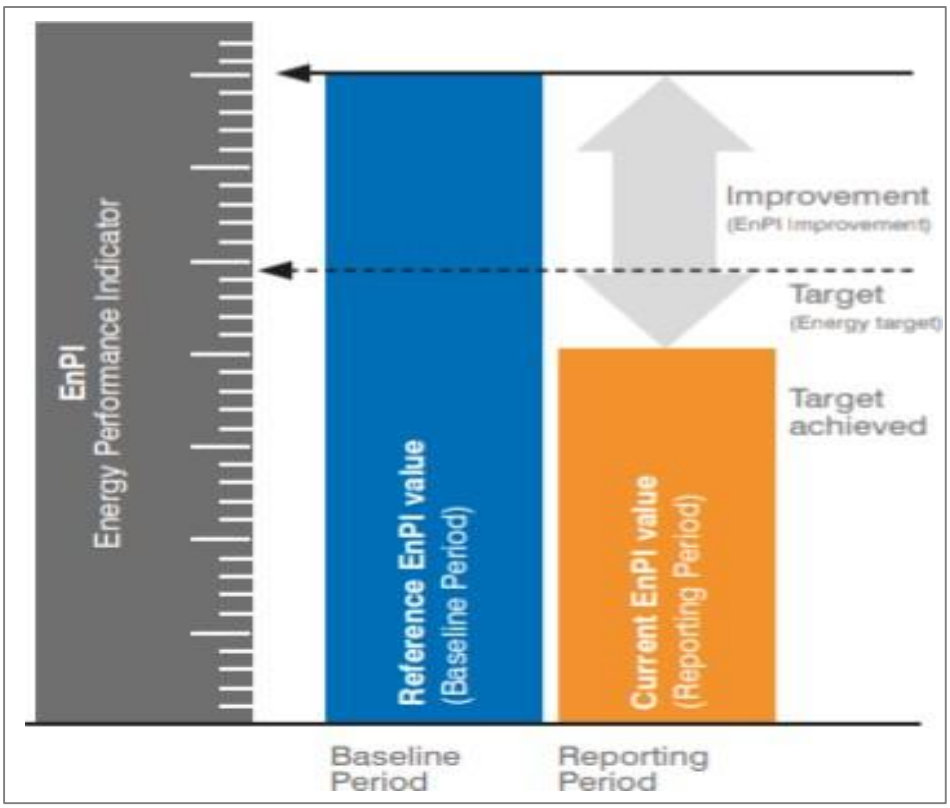


Source: United Nation Industrial Development Organization

Establish an energy baseline and Energy Performance Indicators An EnPI is an analysis or "ruler" that is used to compare energy performance before (reference EnPI value) and after (resultant or current EnPI value) the implementation of action plans and other actions as shown in **Figure 2E-7**.

At the simplest level, the baseline could be the total amount of electricity and other fuels used in the year ending before the EnMS is implemented. The advantage of this approach is that future use is simply compared with this baseline year. The disadvantage is that it ignores the effects of the driving factors. For example, production output could have increased or decreased significantly, and this could be the reason for the change in energy use rather than any actual change in energy performance. Another simple and often used baseline is to choose a measure of specific energy consumption such as kWh per unit of output. This has the advantage that it is simple and appears to offer the opportunity to compare with other similar organizations as a benchmark. The Standard says that an energy baseline should be established using the energy review (above). Where there are variables that have been identified, the baseline should be normalized.

Figure 2E-7: Understanding Energy Performance Indicators



Source: Global certification body (NQA)

The most common and simplest energy performance indicator is conformance to financial budgets. The overall purpose of the energy management system is to improve energy performance and to continually improve this performance. Ideally, it will have at least one high level EnPI for each energy source (electricity, fuel, etc.) at the top level to indicate that overall are in control. This is often very difficult depending on product and energy driver mix.

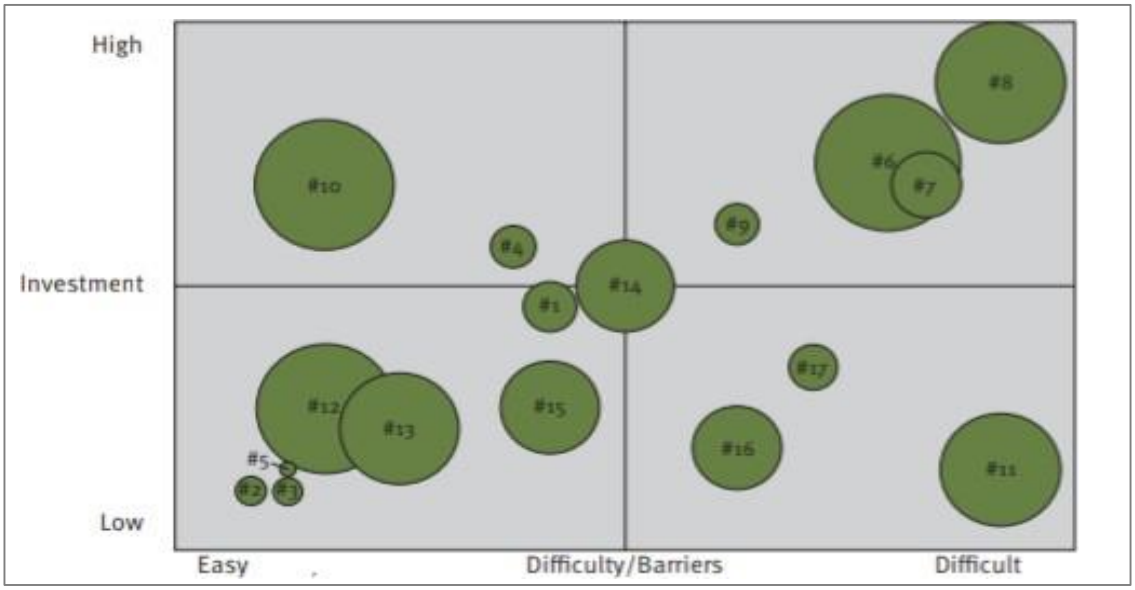
Identify opportunities for improvement. The energy opportunities list should include the following for each opportunity: (a) Identification number; (b) Short description of each opportunity (should be a specific as possible); (c) Service of opportunity, i.e. steam, electricity, management, compressed air, etc.;

(d) Potential savings in terms of energy, money, carbon emissions and other benefits; (e) Responsible person to bring the opportunity to a close; (f) Status of opportunity, (idea, approved, cancelled, postponed, progress, complete; (g) Dates, as there are a number of important dates in the life cycle of

each opportunity including origination, due for completion, completion; and (h) Method of verification of savings (i.e. how will you know that the opportunity has achieved its predicted savings?).

The diagram in **Figure 2E-8** shows all available opportunities plotted on a bubble diagram based on technical difficulty against investment cost. The size of the bubbles is proportional to the amount of savings. Those items in the bottom left section are low cost and technically easiest and should normally be completed first. Surprisingly, this is very often not the case, as many engineers tend to like a challenge and may prefer to prioritize the difficult and high-cost opportunities. From the organizations point of view, this is poor management of resources. A bubble diagram of this type is a good aid but it is not critical to use this type of diagram.

Figure 2E-8: Prioritization of Opportunities



Source: United Nations Industrial Development Organization

Establish energy objectives and targets. Objectives tend to be long term and less specific than targets. One example of an objective might be to train all utility operators in the energy aspects of their roles over the next two years. Targets should support the achievement of objectives, i.e., each objective will probably have a number of targets associated with it. This is specific, measurable, achievable, relevant

and timed. The framework that the objectives and targets fit in is provided for in the ISO50001 in that they shall be documented.

1. Implementation and operation

Develop action plans. It is important to translate all other preparatory/planning work into action plans for the coming period, typically one year. These plans will form the basis of your energy saving activities. Please note that action plans are not entirely lists of technical investment projects, and will include housekeeping, management and organizational activities. The action plan is the specific action that will be taken to improve energy performance. Actions in this context are those activities that you are going to complete in the coming period.

Develop day-to-day operations. This is a very critical part of the EnMS (and is often neglected), as it determines how your organization will operate the energy using equipment and where there is often significant opportunity to affect the organization's energy performance. Many organizations assume that if they purchase energy efficient equipment, then their operations will automatically be energy efficient; however, this is not the case. In some instances, less efficient equipment operated well will consume less energy than more efficient equipment operated badly. It is possible to operate boilers, refrigeration plant, air compressors, pumping systems, in such a way that they consume much more energy than they need to. As a result, how your equipment and energy using processes are operated can have a very significant effect on your energy performance. It is critical that all significant energy uses are operated and maintained in the most energy efficient way feasible.

Maintenance. It seems fairly obvious that ineffective maintenance will increase the energy consumption of most technical systems and equipment. However, this rarely gets taken into account when planning maintenance activities. The main components for a maintenance management system that supports effective energy performance are as follows: (a) planned preventive maintenance should be carried out in accordance with the manufacture's recommendations. This will require planning, completion and recording of maintenance activities. This may be computerized or may not be as

appropriate to specific organizations; (b) The people carrying out the maintenance need to be aware of the impact of their work on the energy performance of the SEUs; and (c) Settings which will affect the energy performance of the equipment need to be known and set correctly.

Ensure competence and awareness of personnel. During the planning phase, identify the personnel who were most significant to your energy use, and decide on what level of training each would require in order to ensure that they are competent to carry out their roles, in so far as they impact energy performance. The implementation of this training is often the single most onerous activity in implementing a viable EnMS, both in terms of employee time attending training and in terms of cost of training providers. However, it is also the part where very considerable savings will be achieved if carried out effectively.

Awareness. All employees and contractors should be aware of the organization's commitment to improving your energy performance. This can be easily achieved by making the energy policy available and giving people regular updates on the progress. This does not need to be an overly onerous activity. Everyone should also be aware of the benefits to the organization of improved energy performance.

Training. All employees working on SEUs should be trained on any operating procedures or practices that affect the performance of their job and in particular their impact on energy performance. For example, boiler operators must be trained on the various operating parameters that they have control over and which affect boiler efficiency such as total dissolved solids, boiler pressure, combustion settings, manual blow down operations, use of heat recovery, etc.

Competence. This means that all relevant people are able to do their jobs on the basis of appropriate education, training, skills or experience. It is the responsibility of the management of the organization to ensure that all people working for it are competent to carry out their assigned roles and tasks.

2. Implementation of action plans.

Part of the day-to-day operation of the EnMS is to ensure that the items scheduled for completion in the

action plan are being addressed, completed and verified to be performing as expected.

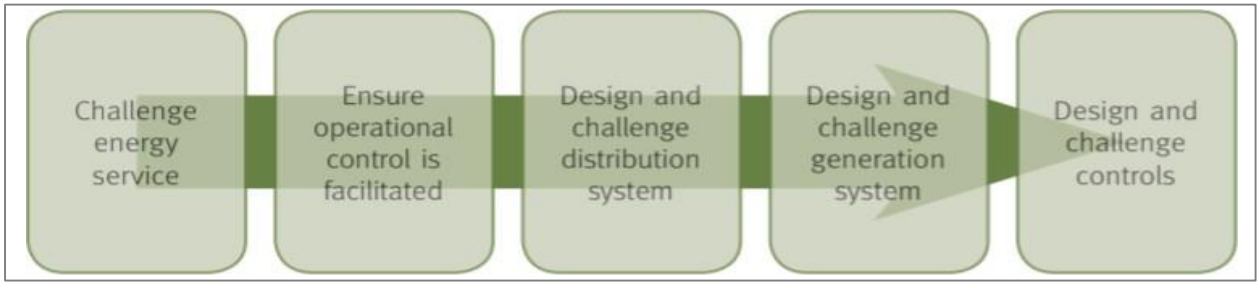
Design for energy efficiency: It is much easier and cheaper to design good energy performance into a new process or facility from the beginning than it is to retrofit it later. It is not all about adding extra technology to save energy, though this is part of the process. The major opportunity is in challenging the specification and size of what is required in the first instance.

Energy efficient design (EED): The following steps can be used to implement a systematic approach to EED as shown in **Figure 2E-9**.

Commissioning. Commissioning is an often-neglected step in projects. The goal is simple – to ensure that the installed equipment or system is operating as designed. It is not uncommon to find well designed and constructed facilities and buildings operating in a very inefficient manner, because the commissioning engineers do not understand the full complexity of the design.

Communication. Operational staff, engineers, supervisors, operators, etc. need to be fully conversant with the design intent of the systems that they are to operate.

Figure 2E-9: Energy Efficient Design Flow Diagram



Source: United Nations Industrial Development Organization, 2015

3. Monitoring and verifying improvements

Another key process in EnMS is determining whether the system is maximizing daily energy savings operations, and whether performance improvements are actually being implemented. In this phase, projected improvements of both the system and the energy performance are compared against reality to

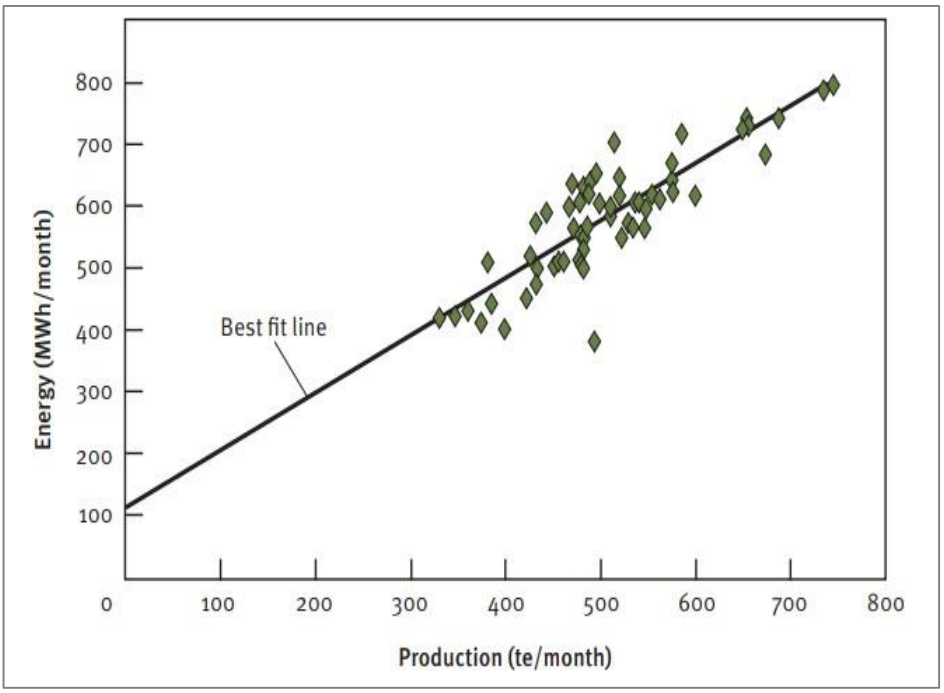
determine if the organization is genuinely improving performance. The answer to this question is of key influence on the (remaining) commitment of the organization to energy management.

Monitoring and measurement. The key characteristics of an energy management system that indicate successful energy performance improvement must be monitored and measured. These key characteristics include: (a) The outputs from energy planning including action plans; (b) Relation between significant energy uses and driving factors; (c) Energy performance indicators; (d) Effectiveness of the action plans in achieving objectives and targets; and (e) Monitoring of the effectiveness of operational control.

Analysis (monitoring and targeting). Analysis transforms data into useful information upon which action can be taken. Standard spreadsheets are quite adequate for many applications., and can be used to create different charts highlighting energy use vs. production, specific energy consumption vs. production, CUSUM graph (this technique provides a trend line, it calculates savings/losses to date and shows when the performance changes; CUSUM represents the difference between the baseline and the actual consumption data points over the baseline period of time), etc. Best fit lines (targeting) are used to predict expected energy consumption, and regular control (monitoring) highlights non-conformance of the process, leading to action to improve the performance.

There are three important features of the chart in **Figure 2E-10**: (a) Intercept, which is the energy that would still be required even if production was reduced to zero (in this case it is 113.5 MWh/month); (b) Slope, which is the amount of energy required to process each additional unit of production, leading to the process efficiency; and (c) Scatter, which is the distribution of the data points away from the best fit line, indicating the variation in energy per unit production from one period to another. Large differences between scatter and best fit lead to the conclusion of poor process control.

Figure 2E-10: Graph Representing Measured Data Including Best Fit Line



Source: United Nations Industrial Development Organization

Calibrate instruments. For reliable monitoring and measuring, equipment being used should provide data that is accurate (Is the measured 1 kWh really 1 kWh (or less/more)?) and repeatable (Does the equipment represent 1 kWh as 1 kWh every time it is being measured or do changes occur after repetitive monitoring or measurement?). A one-degree centigrade error in the evaporating temperature of a refrigeration plant can represent a 3 percent variation in energy use, which will be significant with a large plant. When determining the accuracy of your metering system, ensure that the meters in place are calibrated as required, and consider conducting a simple risk analysis: (a) How will I know my EnPI's and critical parameters are being monitored? (b) How can I know if these meters are accurate? (c) What are the critical instruments being used? (d) Can the instrument have a significant effect on energy usage/energy monitoring results if it goes out of calibration? (e) What is the likelihood of the critical instrument going out of calibration? (f) Is it possible to ascertain the accuracy of meters using data provided from other meters and including utility bill information?

Evaluate compliance with legal and other requirements. Routine checking is required of legal and other

compliance. The energy management team need to check if the organization is compliant with all relevant requirements. Consider scheduling multiple reviews a year based on the list of requirements to ensure that everything is in compliance.

Conduct internal audits. The purpose of an internal audit is to check that the EnMS is operating as designed. There is no point on having an EnMS if it is not going to be used effectively. An internal audit of an EnMS is an independent, systematic review of part or an organization's EnMS. The purpose of the audit is to determine if the plans, activities and procedures described in the system are being conducted in the manner which the EnMS requires.

Nonconformities, correction, corrective and preventive action. A non-conformance can be defined as failure to fulfil a specific requirement. Deviations from specific targets may not necessarily be a non-conformance, but they usually warrant investigation when the deviation is outside existing/planned values. The correction, corrective and preventive-action process is a means by which the organization can correct any deviations from the requirements of EnMS to ensure it meets the requirements of the system, as well as the commitment to continual improvement in the organization's energy policy. Issues that need to be raised in the corrective and preventive-action process can be identified from several sources in your EnMS, including (i) results of internal and external audits; (ii) results of evaluations of compliance reviews; (iii) failures to reach specified targets in monitoring and measurement processes; (iv) failures to comply with operational control procedures, as identified in site inspections; and (v) failures to meet target dates relating to the energy management action plans. A corrective approach to this will start at root cause and finish at an appropriate and satisfactory sustainable solution. It should also provide top management with an overview of the status of the correction, as well as corrective and preventive actions. The energy team will therefore need to manage these actions to ensure easily accessible data for this reporting process. The used terms in this process are defined as follows

- Nonconformity - non fulfilment of a requirement;
- Correction - action to eliminate a detected nonconformity;

- Corrective action - action to eliminate the cause of a detected nonconformity; and
- Preventive action - action to eliminate the cause of a potential nonconformity

4. Continuous improvement

In the context of continual improvement, the expectation is that improvements occur periodically and over time. The rate, extent and timescale of actions that support continual improvement are determined by the organization, in light of its context, economic factors and other circumstances. Energy performance improvement can be demonstrated in several ways, such as: reduction in normalized energy consumption for the scope and boundaries of the EnMS; and progress toward an energy target(s) and management of the SEUs. A risk-based philosophy means that an organization can be better prepared for the impacts of uncertainty (e.g., stable power supply), which in turn means greater resilience. Moreover, risk-based thinking implicitly results in continual improvement, as an organization is always examining potential influences and changes.

Conduct management reviews. The purpose of the management review is to demonstrate to the top management how well the EnMS is working; highlight problem areas where there may be barriers to improvement; continue to build support for the system; and propose and agree plans for the coming period, usually the next year. The first management review should be held soon after completion of the initial planning phase, and then annually thereafter. In some organizations, this may be tied in with the annual budgeting process. It should be attended by all the members of the senior management team, including the management representative and the energy manager. Additional attendees may also be appropriate depending on how the EnMS is structured.

Inputs to the review. The energy manager or management representative will make a presentation to the top management team to update progress and seek support to improve the da-to-day operations.

In conclusion, analysis shows that implementation of ISO50001 across the commercial and industrial sectors globally could drive cumulative energy savings of approximately 62 exajoules by 2030, saving

over $600 billion in energy costs and avoiding 6,500 Mt of CO2 emissions. The projected annual emissions savings in 2030 are equivalent to removing 215 million passenger vehicles from the road.

ANNEX 3: MONITORING, VERIFICATION AND ENFORCEMENT PROTOCOLS

ANNEX 3-A: International Performance Measurement and Verification Protocol (IPMVP)

The International Valuation Organization (IVO) developed the International Performance Measurement and Verification Protocol (IPMVP) that provides the framework to help increase investment in energy and water efficiency, demand management and renewable energy projects around the world. Further, the IPMVP promotes efficiency investments by the following activities: (1) IPMVP documents common terms and methods to evaluate performance of efficiency projects for buyers, sellers and financiers. Some of these terms and methods may be used in project agreements, though IPMVP does not offer contractual language; (2) IPMVP provides methods, with different levels of cost and accuracy, for determining savings either for the whole facility or for individual energy conservation measures (ECM); (3) IPMVP specifies the contents of a Measurement and Verification (M&V) Plan. This M&V Plan adheres to widely accepted fundamental principles of M&V and should produce verifiable savings reports. An M&V Plan must be developed for each project by a qualified professional; and (4) IPMVP applies to a wide variety of facilities including existing and new buildings and industrial processes.

Several protocols and guidelines that were being developed for the MERVC in the energy sectors by governments, nongovernmental organizations, and international agencies believe that the U.S. DOE International Performance Measurement and Verification Protocol (IPMVP) is the preferred approach for monitoring and evaluating energy efficiency projects for individual buildings and for groups of buildings (Vine and Sathaye, 1997). The IPMVP covers many of the issues discussed in these guidelines, as well as offering several measurement and verification methods for user flexibility (Kats et al. 1996 and 1997; Kromer and Schiller 1996; U.S. DOE 1997). North America's energy service companies have adopted the IPMVP as the industry standard approach to measurement and verification. States ranging from Texas to New York now require the use of the IPMVP for state-level energy efficiency retrofits. The U.S. Federal Government, through the Department of Energy's Federal Energy Management Program (FEMP), uses the IPMVP approach for energy retrofits in Federal buildings. Finally, countries ranging from Brazil to the Ukraine have adopted the IPMVP, and the Protocol is being

translated into Bulgarian, Chinese, Czech, Hungarian, Polish, Portuguese, Russian, Spanish, Ukrainian and other languages. When completed, ASHRAEs GPC 14P guidelines will be used to modify and improve the IPMVP.

A key element of the IPMVP is the definition of two measurement and verification (M&V) components: (1) verifying proper installation and the measures potential to generate savings; and (2) measuring (or estimating) actual savings. The first component involves the following: (a) the baseline conditions were accurately defined and (b) the proper equipment/systems were installed, were performing to specification, and had the potential to generate the predicted savings. The general approach to verifying baseline and post-installation conditions involves inspections, spot measurement tests, or commissioning activities.

The IPMVP was built around a common structure of four M&V options (Options A, B, C, and D) as presented in **Table 3A**. These four options were based on the two components to M&V defined above. The purpose of providing several M&V options is to allow the user flexibility in the cost and method of assessing savings. A particular option is chosen based on the expectations for risk and risk sharing between the buyer and seller and onsite and energy-efficiency project specific features. The options differ in their approach to the level and duration of the verification measurements. None of the options are necessarily more expensive or more accurate than the others. Each has advantages and disadvantages based on site specific factors and the needs and expectations of the customer. Project evaluators should use one of these options for reporting on measured energy savings.

Table 3A: Overview of IPMVP M&V Options

M&V Options	How Savings Are Calculated	Initial Cost	Annual Operating Cost
Option A: • Focuses on physical inspection of equipment to determine whether installation and operation are to specification. Performance factors are either stipulated (based on standards or nameplate data) or measured. • Key performance factors (e.g., lighting wattage or motor efficiency) are measured on a snapshot or short-term basis. • Operational factors (e.g., Lighting operating hours or motor runtime) are stipulated based on analysis of historical data or spot/short-term measurements.	• Engineering calculations or computer simulations based on metered data and stipulated operational data. • Engineering methods/ short- term monitoring	0.5 - 3%	0.1 - 0.5%
Option B: • Intended for individual energy conservation measures (ECMs) (retrofit isolation) with a variable load profile. • Both performance and operational factors are measured on a short-term continuous basis taken throughout the term of the contract at the equipment or system level.	• Engineering calculations after performing a statistical analysis of metered data. • Engineering methods/end- use metering	2 - 8%	0.5 - 3%
Option C: • Intended for whole-building M&V where energy systems are interactive (e.g., efficient lighting system reduces cooling loads) rendering measurement of individual ECMs inaccurate. • Performance factors are determined at the whole-building or facility level with continuous measurements. • Operational factors are derived from hourly measurements and/or historical utility meter (electricity or gas) or sub-metered data.	• Engineering calculations based on a statistical analysis of whole-building data using techniques from simple comparison to multivariate (hourly or monthly) regression analysis. • Basic statistical models/multivariate statistical models	0.5 - 3% (utility bill analysis) 2 - 8% (hourly data)	0.5 - 3%
Option D: • Typically employed for verification of saving in new construction and in comprehensive retrofits involving multiple measures at a single facility where pre-retrofit data may not exist. • In new construction, performance and operational factors are modeled based on design specification of new, existing and/or code complying components and/or systems. • Measurements should be used to confirm simulation inputs and calibrate the models.	• Calibrated energy simulation/ modeling of facility components and/or the whole facility; calibrated with utility bills and/or end- use metering data collected after project completion. • Engineering methods/integrative methods	2 - 8%	0.5 - 3%

Source: Adapted from U.S. DOE (1997) and based on personal communication from Greg Katz, U.S. DOE, Dec. 18, 1998

Relationship to Other Programs / Documents / Protocols

International Performance Measurement and Verification Protocol (IPMVP). The U.S. Department of Energy's International Performance Measurement and Verification Protocol (IPMVP) is a consensus document for measuring and verifying energy savings from energy-efficiency projects (Kats

et al. 1996 and 1997; Kromer and Schiller 1996; USDOE 1997). For LBNLs MERVC guidelines, the IPMVP is the preferred approach for monitoring and evaluating energy-efficiency projects for climate change mitigation.

U.S. Federal Energy Management Program. The U.S. Department of Energy's Federal Energy Management Program (FEMP) was established, in part, to reduce energy costs to the U.S. Government from operating Federal facilities. FEMP assists federal energy managers by identifying and procuring energy-efficiency projects. Part of this assistance included the development of an application of the International Performance Measurement and Verification Protocol (IPMVP), for the U.S. Federal sector, which is called the FEMP Guidelines (U.S. DOE 1996).

U.S. EPA Conservation Protocols. The U.S. Environmental Protection Agency's Conservation Verification Protocols are designed to verify electricity savings from utility demand-side management programs for the purpose of awarding sulfur dioxide allowances under EPAs Acid Rain Program (Meier and Solomon 1995; U.S. EPA 1995 and 1996). LBNLs MERVC guidelines have incorporated aspects of EPAs guidelines.

U.S. ASHRAE GPC 14P. LBNLs MERVC guidelines are complementary to the work of the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) GPC 14P Committee that is currently writing guidelines for the measurement of energy and demand savings. When completed, these guidelines will be used to modify the IPMVP. In contrast to the ASHRAE document, which focuses on the relationship of the measurement to the equipment being verified at a very technical level, LBNLs MERVC guidelines are more general and discuss a variety of topics as they relate to monitoring, evaluation, reporting, verification, and certification.

World Banks monitoring and evaluation guidelines. The World Bank prepared monitoring and evaluation guidelines for the Global Environment Facility (GEF), a multilateral funding program created to support projects that yield global environmental benefits but would not otherwise be implemented because of inadequate economic or financial returns to project investors (World Bank 1994). The GEF

supports four types of projects: biodiversity preservation, pollution reduction of international waters, GHG emission reduction and, to a limited extent, the control of ozone-depleting substances. LBNLs MERVC guidelines have incorporated aspects of the World Bank guidelines.

USIJIs Project Proposal Guidelines. The U.S. Initiative on Joint Implementation (U.S. IJI) prepared project proposal guidelines for organizations seeking funding from investors to reduce GHG emissions (U.S. IJI 1996). The guidelines request information on the proposed project, including the identification of all GHG sources included in the emissions baseline as well as those affected by the proposed project, and net impacts. The guidelines also ask for additional information, such as the estimates of GHG emissions, including methodologies, type of data used, calculations, assumptions, references and key uncertainties affecting the emissions estimates. The estimates include the baseline estimate of emissions of GHG without measures and the estimate of emissions of GHG with measures. LBNLs MERVC guidelines have incorporated many aspects of the U.S. IJIs guidelines.

U.S. DOE's Voluntary Reporting of Greenhouse Gases. The U.S. Department of Energy (DOE) prepared guidelines and forms for the voluntary reporting of greenhouse gases (U.S. DOE 1994a and 1994b). The guidelines and forms can be used by corporations, government agencies, households and voluntary organizations to report to the DOE's Energy Information Administration on actions taken that have reduced emissions of greenhouse gases. The documents offer guidance on recording historic and current GHG emissions and emissions reductions. The supporting documents (U.S. DOE 1994b) contain limited examples of project analysis for the following sectors: electricity supply, residential and commercial buildings, industrial, transportation, forestry, and agriculture. Companies are allowed discretion in determining the basis from which their emissions reductions are estimated and can self-certify that their claims are accurate. LBNLs MERVC guidelines have incorporated aspects of DOE's guidelines.

California's Measurement and Evaluation Protocols. Protocols and procedures for the measurement and evaluation of California's utility energy-efficiency programs were developed in response to the

shareholder earnings mechanisms established for the four largest investor-owned utilities to acquire demand-side resources (CPUC 1998). The protocols are targeted to the evaluation of programs, rather than an individual building, and have very detailed requirements. LBNLs MERVC guidelines are more flexible than the California protocols but have incorporated some components of the protocols (e.g., quality assurance guidelines.

ANNEX 3-B: Industry Best Practices for Monitoring and Evaluation of Energy Efficiency Projects

For energy projects, the first step in measuring energy reductions is the measurement of gross energy savings – comparing the observed energy use of project participants with pre-project energy consumption. Several data collection and analysis methods are available which vary in cost, precision, and uncertainty. The data collection methods include engineering calculations, surveys, modeling, end-use metering, on- site audits and inspections, and collection of utility bill data. Most monitoring and evaluation activities focus on the collection of measured data; if measured data are not collected, then one may rely on engineering calculations and stipulated savings (as described in EPAs Conservation Verification Protocols and in DOEs International Performance Measurement and Verification Protocol). Data analysis methods include engineering methods, basic statistical models, multivariate statistical models (including multiple regression models and conditional demand models), and integrative methods. If the focus of the monitoring and evaluation is an individual building, then some methods will not be utilized (e.g., basic statistical models, multivariate statistical models, and some integrative methods), since they are more appropriate for a group of buildings.

Engineering methods

Engineering methods are used to develop estimates of energy savings based on the manufacturers technical information found on the equipment, in conjunction with assumed operating characteristics of the equipment. The two basic approaches to developing engineering estimates are engineering algorithms and engineering simulation methods. Engineering analyses need to be calibrated with onsite data (e.g., operating hours and occupancy).

Engineering algorithms are typically straightforward equations showing how energy (or peak) is expected to change due to the installation of an energy efficiency measure. The accuracy of the estimate depends upon the accuracy of the inputs, and the quality of that data entering an engineering algorithm can vary dramatically. Engineering building simulations are computer programs that model the performance of energy-using systems in residential and commercial buildings. These models use

information on building occupancy patterns, building shell, building orientation, and energy-using equipment. The input data requirements for the more complex simulation models are extensive and require detailed onsite data collection as well as building blueprints. Although engineering approaches are improving and increasing in sophistication, they cannot by themselves produce estimates of net project impacts. The engineering estimates generally produce estimates of gross impacts and do not capture behavioral factors such as free riders and project spillover. It is possible to incorporate free rider and spillover factors from surveys and other evaluation sources in order to calculate net impacts.

Basic statistical models for evaluation

Statistical models that compare energy consumption before and after the installation of energy efficiency measures have been used as evaluation methods for many years (Violette et al. 1991). The most basic statistical models simply look at monthly billing data before and after measure installation using weather normalized consumption data (this is particularly important where weather-dependent measures are involved - e.g., heating and cooling equipment, refrigerators, etc.). If the energy savings are expected to be a reasonably large fraction of the customer's bill (e.g., 10% or more), then this change should be observable in the project's bills. Smaller changes (e.g., 4%) might also be observed in billing data, but more sophisticated billing analysis procedures are often required. This method can be used for comparing changes in energy use for project participants and a comparison group. Statistical models are most useful where many projects (or one project with many participants) are being implemented.

Multivariate statistical models for evaluation

In project evaluation, more detailed statistical models may need to be developed to better isolate the impacts of an energy-efficiency project from other factors that also influence energy use. Typically, these more detailed approaches use multivariate regression analysis as a basic tool (Violette et al. 1991). Regression methods are simply another way of comparing kWh or kW usage across dwelling units or facilities and comparison groups, holding other factors constant. Regression methods can help correct for problems in data collection and sampling. If the sampling procedure over or under represents specific types of projects among either project participants or the comparison group, the regression equations

can capture these differences through explanatory variables. Two commonly applied regression methods are conditional demand analysis and statistically adjusted engineering models (Violette et al. 1991).

End-use metering

Energy savings can be measured for specific equipment and specific end uses through end-use metering (Violette et al. 1991). This type of metering is conducted before and after a retrofit to characterize the performance of the equipment under a variety of load conditions. The data are often standardized for variations in operations, weather, etc. End-use metering reduces measurement error (assuming the metering equipment is reliable) and reduces the number of control variables required in models. In addition, the meter can calculate the energy change on an individual piece of equipment in isolation from the other end-use loads.

Short-term monitoring

Short-term monitoring refers to data collection conducted to measure specific physical or energy consumption characteristics either instantaneously or over a short time period. This type of monitoring is conducted to support evaluation activities such as engineering studies, building simulation and statistical analyses (Violette et al. 1991). Examples of this type of monitoring that can take place are spot watt measurements of efficiency measures, run-time measurements of lights or motors, temperature measurements, or demand monitoring. Short-term monitoring is gaining increasing attention as evaluators realize that for certain energy efficiency measures with relatively stable and predictable operating characteristics (e.g., commercial lighting and some motor applications), short-term measurements will produce gains in accuracy nearly equivalent to that of longer-term metering at a fraction of the cost.

Short-term monitoring is a useful tool for estimating energy savings when the efficiency of the equipment is enhanced, but the operating hours remains fixed. Spot metering of the connected load before and after the activity quantifies this change in efficiency with a high degree of accuracy. For activities where the hours of operation are variable, the actual operating (run-time) hours of the activity

should be measured before and after the installation using a run-time meter.

Integrative methods

Integrative methods combine one or more of the above methods to create an even stronger analytical tool. These approaches are rapidly becoming standard practice in the evaluation field (Raab and Violette 1994). The most common integrative approach is to combine engineering and statistical models where the outputs of engineering models are used as inputs to statistical models. These methods are often called Statistically Adjusted Engineering (SAE) methods or Engineering Calibration Approaches (ECA). Although they can provide more accurate results, integrative methods typically increase the complexity and expense. To reduce these costs while maintaining a high level of accuracy, a related set of procedures has been developed to leverage high-cost data with less expensive data. These leveraging approaches typically utilize a statistical estimation approach termed ratio estimation that allows data sets on different sample sizes to be leveraged to produce estimates of impacts (see Violette and Hanser 1991).

Best methods

There is no one approach that is best in all circumstances (either for all project types, evaluation issues, or all stages of a particular project). The costs of alternative approaches will vary and the selection of evaluation methods should take into account project characteristics and the load type and schedule before the retrofit. The load can be constant, variable, or variable but predictable, and the schedule can either be known (timed on/off schedule) or unknown/variable. The monitoring approach can be selected according to the type of load and its schedule.

In addition to project characteristics, the appropriate approach depends on the type of information sought, the value of information, the cost of the approach, and the stage and circumstances of project implementation. The applications of these methods are not mutually exclusive; each approach has different advantages and disadvantages (**Table 3-B**), and there are few instances where an evaluation method is not amenable to most energy efficiency measures. Using more than one method can be informative. Employing multiple approaches, perhaps even conducting different analyses in parallel,

and integrating the results, will lead to a robust evaluation. Such an approach builds upon the strengths and overcomes the weaknesses of individual methods. Also, each approach may be best used at different stages of the project life cycle and for different measures or projects. An evaluation plan should specify the use of various analytical methods throughout the life of the project and account for the financial constraints, staffing needs, and availability of data sources.

Table 3B: Advantages and Disadvantages of Data Collection and Analysis Methods

Methods	Applications	Advantages	Disadvantages
Engineering Method	Individual buildings and groups of buildings	Relatively quick and inexpensive for simple engineering methods. Most useful as a complement to other methods. Methods are improving. Useful for baseline development.	Relatively expensive for more sophisticated engineering models. Need to be calibrated with onsite data. By themselves, not good for evaluation of spillover.
Basic Statistical Model	Primarily for groups of buildings	Relatively inexpensive and easy to explain.	Assumptions need to be confirmed with survey data and other measured data. Limited applicability. Cannot evaluate peak impacts. Large sample sizes needed.
Multivariate Statistical Models	Primarily for groups of buildings	Isolate project impacts better than basic statistical models.	Same disadvantages as for basic statistical models. Relatively more complex, expensive, and harder to explain than basic statistical models.
End-use Metering	Individual buildings and groups of buildings	Most accurate method for measuring energy use. Most useful for data collection, not analysis.	Can be very costly. Small samples only. Requires specialized equipment and expertise. Possible sample biases. Difficult to generalize to other projects. Does not, by itself, calculate energy savings. Difficult to obtain pre-installation consumption.
Short-term Metering	Individual buildings and groups of buildings	Useful for measures with relatively stable and predictable operating characteristics. Relatively accurate method. Most useful for data collection, not analysis.	Limited applicability. Using this method alone, energy savings cannot be calculated.
Integrated Methods	Primarily for groups of buildings	Relatively accurate.	Relatively more complex, expensive, and harder to explain than some of the other models.

Source: U.S. DOE, 1997

ANNEX 4: ENERGY EFFICIENT AND CLEAN COOLING PROGRAM CONCEPT

Refrigerator and Air Conditioner Replacement Program Concept for PNG

As described in **Section 2.3.2.5**, the adoption of energy efficient and clean cooling technologies is critical to the long-term success of PNG's energy efficiency and conservation efforts. As illustrated in **Figure 17**, according to UNEP's United for Efficiency country assessment, refrigeration and air conditioning (RAC) equipment makes up the largest share (84.1%) of PNG's cumulative energy savings potential through 2030, with air conditioners leading all appliances at 70.1% of total savings.

In PNG, a comprehensive program to promote the purchase of the high efficiency low-GWP refrigerant air conditioners can be implemented. Such a program could include financial incentives and rebate mechanisms for households and SMEs to offset the cost of the EE investment, coupled with supportive policies, laws and regulatory measures, including MEPS, compliance standards enforcement and programs to recapture refrigerants from old/used equipment. Such a program would support both the country's EE goals as well as the objectives of the Kigali Amendment to the Montreal Protocol and would results in significant emission reductions, energy savings and economic development co-benefits.

A RAC finance program is outlined below that is deemed a high impact area and intervention for the GoPNG and its development partners to pursue. It is envisioned that such a program would be led or supported by the proposed National Energy Efficiency Platform (see **Section 4.2.2.1**). The program design can be adapted to the specific needs and priorities of a specific province, as RAC equipment can be utilized across a wide range of sectors. For example, a rural energy access/cold chain component can be included in the program/developed to support smallholder farmers.

Finance and TA Support Mechanisms: The program should consider multiple finance mechanisms including (but not limited to):

- Utility on-bill financing to commercial, industrial and residential/household customers
- DFI funds can be utilized to offer concessional/low-interest loans to households and SMEs, in

partnership with local commercial FIs and MFIs (especially to reach customers in rural areas)

- Working capital and trade finance for RAC equipment importers, distributors and suppliers
- Technical assistance programs to adapt, design and implement the program on a national scale

Delivery Mechanisms: Marketing, outreach and delivery programs can be designed to:

- Implement a RAC bulk procurement program in cooperation with PPL, NEA, CCDA, ICCC, NISIT and other relevant agencies
- Address SME retailers with EE refrigerator programs aggregated via local distributors and retailers
- Market via social media campaign, mobile phone advertisement, radio, TV, and other relevant methods of communication/dissemination (e.g., via *wantoks*) marketed and co-branded with development partners (e.g., UNDP)

Supportive Policies: The RAC program should be supported by EE policies, regulations and incentive programs in line with PNG's strategic priorities and market conditions, including:

- As an initial legal measure, the Government of PNG can make it illegal to import used refrigerators, freezers and air conditioners. Next, NISIT could establish MEPS and launch a corresponding awareness raising/appliance labeling program for energy efficient RAC equipment, combined with compliance and enforcement mechanisms
- A recycling program for old/used RAC equipment, which allows end-users to trade in old RAC equipment and receive a rebate for the purchase of highly efficient equipment (see **Box 6**).
- Technical assistance, training and capacity building of implementing public agencies/staff (NEA, CCDA, ICCC, NISIT, provincial authorities etc.

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