Technical Services to improve availability of, and access to, financing for renewable energy and energy efficiency initiatives in the energy generation and end-use sectors in Papua New Guinea

Task 1.4: Estimation of GHG emission reduction for sample Renewable Energy (RE) and Energy Efficiency (EE) initiatives

Submitted to United Nations Development Programme

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November 2021

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List of acronym, abbreviations, and units

AFLOU	Agriculture, Forestry and Other Land Use
AR 5	IPCC Assessment Report 5
AR 6	IPCC Assessment Report 6
BESS	Battery Energy Storage System
CCDA	Climate Change and Development Authority
DPE	Department of Petroleum and Energy
EE	Energy Efficiency
ERP	Enterprise Resource Planning
ESCO	Energy Service Company
ESMAP	Energy Sector Management Assistance Program
EU	European Union
FREAGER	Facilitating Renewable Energy and Energy Efficiency Applications for Greenhouse Emission Reduction Project
GDP	Gross Domestic Product
GHG	Greenhouse Gases

GEF	Global Environment Facility
HV	High Voltage
ICCC	Independent Consumer and Competition Commission
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
ISO	International Organization for Standardization
KCHL	Kumul Consolidated Holdings Limited
km	Kilo meter
kW	Kilo Watt
kW_p	Kilo Watt Peak
kV	Kilo Volt
kWh	Kilo Watt Hour
LCOE	Levelised Cost of Electricity or tariff
LED	Light Emitting Diode
LULUCF	Land Use, Land-Use Change and Forestry
LV	Low Voltage
MEPS	Minimum Energy Performance Standards
MV	Medium Voltage
MW	Mega Watt
MWh	Mega Watt Hour
NASA	National Aeronautics and Space Administration
NDC	Nationally Determined Contribution
NEROP	National Electrification Rollout Plan
NPV	Net Present Value
PGK	Papua New Guinea Kina
PNG	Papua New Guinea
PPL	PNG Power Limited
PNGDSP	Papua New Guinea Development Strategic Plan
RE	Renewable Energy
ROE	Return on Equity
SHS	Solar Home System
SPV	Solar Photo Voltaic
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
WBCSD	World Business Council for Sustainable Development
WRI	World Resource Institute

1. Introduction

1. Introduction

1.1 Background

Earth’s greenhouse gases trap heat in the atmosphere and warm the planet, a phenomenon essential for life on earth. The main gases responsible for the greenhouse effect include carbon dioxide, methane, nitrous oxide, and water vapor (which all occur naturally), and fluorinated gases (which are synthetic). Due to human activities post-industrialization, the constituent of the atmosphere has been changing with the increased percentage of greenhouse gases in the atmosphere leading to the phenomenon called climate change.

Global warming and climate change have emerged as the most important environmental issues ever to confront humanity. This concern arises from the fact that our everyday activities may be leading to changes in the earth’s atmosphere that have the potential to significantly alter the planet’s heat and radiation balance. “Climate change” and “global warming” are often used interchangeably but have distinct meanings.

As per NASA, global warming is the long-term heating of Earth’s climate system observed since the pre-industrial period (between 1850 and 1900) due to human activities, primarily fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earth’s atmosphere. The term is frequently used interchangeably with the term climate change, though the latter refers to both human- and naturally produced warming and the effects it has on our planet. It is most commonly measured as the average increase in Earth’s global surface temperature.

Impact of climate change

Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since AR5. Example, temperature of 49.5 ^oC in Canada last month and large-scale forest fire in Australia, Greece, US. Based on IPCC Assessment Report 6, the present global temepratures has increased 1.1 ^oC relative to 1850 – 1900. Figure illustrating change in global temperature relative to 1850 – 1900 is provided in figure below along with possible climate futures.

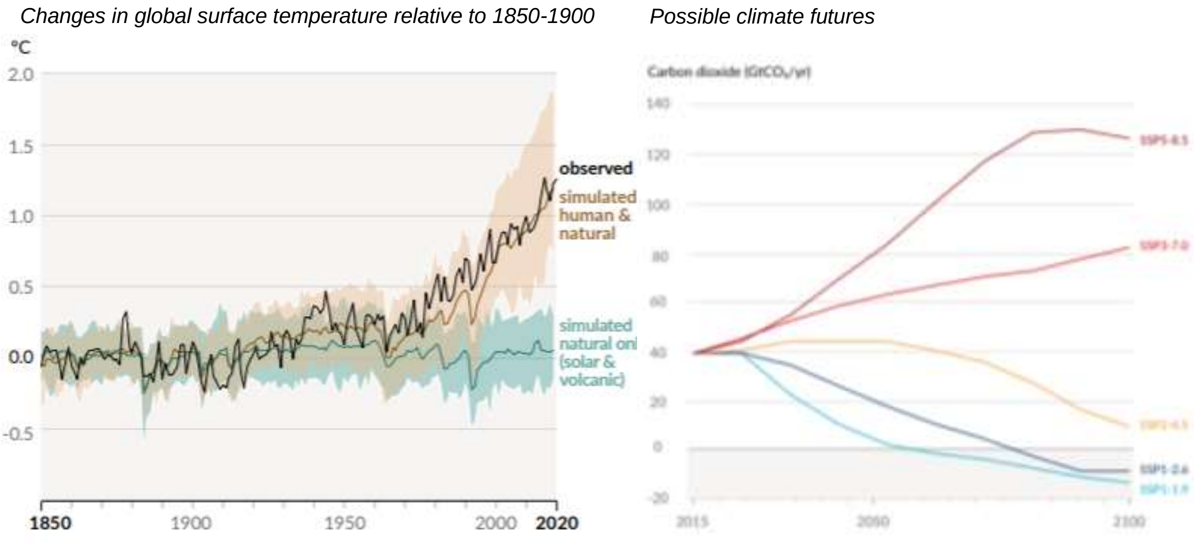

Figure 1 Global surface temperature relative to 1850 - 1900 and possible climate futures (IPCC AR6)

According to the Intergovernmental Panel on Climate Change (IPCC), broad forcings that drive nearly all human-caused greenhouse gas emissions include population size, economic activity, lifestyle, energy use, land use patterns, technology, and climate policy: The burning of coal, oil, and natural gas to produce electricity and heat accounts for one-quarter of worldwide human-driven emissions, making it the largest single source. The figure below provides a sector-wise breakup of total GHG emission globally[1].

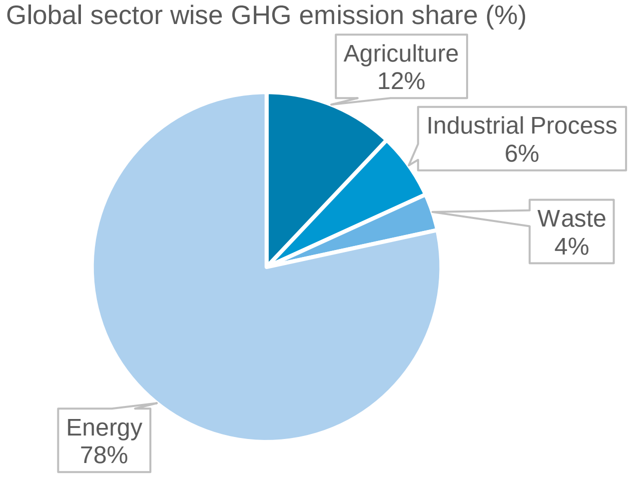

Figure 2 Global emissions - Sector wise distribution. Source: WRI 2018

GHG emissions of PNG

In PNG, of the non LULUCF sectors, in 2015 the energy sector contributed 87.5 percent to total GHG emissions of 13,477 Gg $CO_{2\ eq}$, followed by the waste sector (6.5 percent), agriculture (5.9 percent), and IPPU (0.2 percent). In 2000, the energy sector contributed 83.9 percent to total GHG emissions, followed by agriculture (9.1 percent), waste sector (6.9 percent), and IPPU (0.01 percent). Energy consumption and production of natural gas have increased rapidly from 2000 to 2015, resulting in an 88.2 percent increase in energy sector emissions.[2]

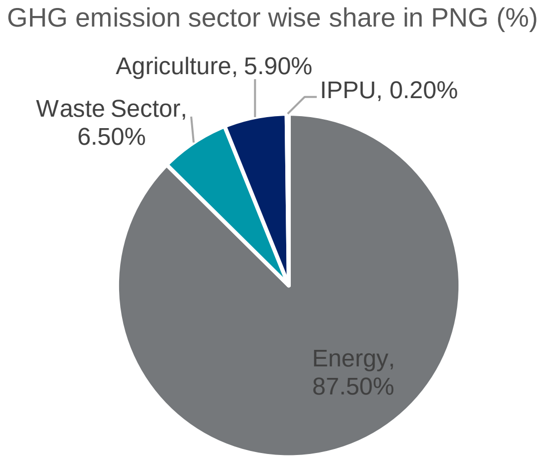

Figure 3 GHG emission of PNG - Sector wise distribution

[1] https://www.climatewatchdata.org/embed/ghg-emissions%3FbreakBy%3Dsector%26chartType%3Dpercentage%26end_year%3D2018%26sectors%3Dtotal-excluding-lucf%26start_year%3D1990
[2] https://unfccc.int/sites/default/files/resource/Papua%20New%20Guinea%20BUR1%20Final%20Version.pdf

Energy generation is the largest source of greenhouse gas (GHG) emissions globally, and efforts to reduce GHG emissions often focus on the energy sector. Renewable resources, such as solar, wind, and hydropower, offer potential GHG emissions savings compared to fossil fuels such as coal or petroleum. On the demand side, Energy Efficiency retrofitting/measures can reduce the GHG emission in both demand side as well as supply side segment of energy.

Climate Action - Paris Agreement

Recognizing the contribution of GHG emission the climate change and its impact, in 2015, 196 Parties came together under the Paris Agreement to transform their development trajectories so that they set the world on a course towards sustainable development, aiming at limiting warming to 1.5 to 2 ^{0}C above pre-industrial levels. Through the Paris Agreement, the Parties also agreed to a long-term goal for adaptation – to increase the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production. Additionally, they agreed to work towards making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.

The Paris Agreement (Article 4, paragraph 2) requests each country to outline and communicate their post-2020 climate actions, known as their NDCs. NDCs embody efforts by each country to reduce national emissions and adapt to the impacts of climate change. Parties shall pursue domestic mitigation measures, to achieve the objectives of such contributions. Each climate plan reflects the country's ambition for reducing emissions, taking into account its domestic circumstances and capabilities.

To enhance the ambition over time, the Paris Agreement provides that successive NDCs will represent a progression compared to the previous NDC and reflect its highest possible ambition. Hence, all Parties are supposed to submit the next round of NDCs (new NDCs or updated NDCs) by 2020 and every five years thereafter (e.g. by 2020, 2025, 2030), regardless of their respective implementation time frames.

NDC commitment of PNG

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. For 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.

Importance of GHG accounting

To manage GHG emission, measuring it is important. Carbon accounting or greenhouse gas accounting refers to processes used to measure how much carbon dioxide equivalents an entity or state emits. It is used by states, corporations, and individuals to estimate their GHG emissions and in some cases to create the carbon credit commodity traded on carbon markets (or to establish the demand for carbon credits). Countries, cities, and organizations measure their emissions to build more effective emissions reduction strategies, set measurable and more ambitious emission reduction goals, and track their progress more accurately and comprehensively.

1.2 GHG accounting

GHG accounting protocols are developed to help the entity or state prepare its GHG inventory through the use of standardized approaches and principles. Both business and other stakeholders benefit from converging on a common standard. For businesses, it reduces costs if their GHG inventory is capable of meeting different internal and external information requirements, and facilitates benchmarking by increasing consistency and transparency in GHG accounting and reporting among various companies. For others, it improves the consistency, transparency, and understandability of reported information, making it easier to track and compare progress over time.

Standards of GHG accounting

To calculate and report GHG emissions, the following standards and protocols are applicable. These provide generic guidance for calculating and reporting an organisation's carbon footprint:

- **Greenhouse Gas Protocol on Corporate Accounting and Reporting by World Resource Institute (WRI) / World Business Council for Sustainable Development (WBCSD)** - The Greenhouse Gas Protocol Initiative is a multi-stakeholder partnership of businesses, non-governmental organisations (NGOs), governments, and others convened by the World Resources Institute (WRI), a U.S.-based environmental NGO, and the World Business Council for Sustainable Development (WBCSD).
- ISO 14064-1:2006 Specification with guidance at the organisation level for quantification and reporting of greenhouse gas emissions and removals: The ISO 14064 standard is part of the ISO 14000 series of International Standards for environmental management, and provides governments, businesses, regions and other organisations with a complimentary set of tools for programs to quantify, monitor, report and verify GHG emissions. The ISO 14064 standard supports organisations to participate in both regulated and voluntary programs such as emissions trading schemes and public reporting.
- For national GHG inventories, guidance is provided by the Intergovernmental Panel on Climate Change (IPCC) methodology reports.

1.3 Principles of GHG accounting

GHG accounting and reporting practices are continuously evolving along with advancing knowledge on the science of climate change. The GHG protocol and ISO 14064 standards advise that GHG emissions inventories be carried out in accordance with the following principles:

Relevance - For an organisation's GHG emissions inventory to contain information that users might need for making "informed" decisions. Therefore, organisations must identify appropriate boundaries that reflects the economic reality of their business operations.

Completeness - All relevant emission sources within the chosen inventory boundary should be accounted for so that a comprehensive and meaningful inventory is compiled. Any limitation should be transparently recorded and justified.

Consistency - The GHG inventory should be compiled in a manner that ensures that the overall emissions estimate is consistent and comparable over time. Changes in the inventory boundary, data or any other factor affecting an emissions estimates, need to be transparently documented and justified.

Transparency - Information needs to be recorded, compiled, and analyzed in a manner that enables internal reviewers and external verifiers to attest to its credibility. Specific exclusions or inclusions need to be identified and justified, assumptions disclosed, and appropriate references provided for the methodologies applied and the data sources used.

Accuracy - Data should be sufficiently precise to enable intended users to make decisions with reasonable assurance that the reported information is credible. Uncertainties in measurements, recording and calculations should be reduced as far as practicable.

1.4 GHG accounting methodology

The GHG accounting methodology provides systematic steps for accurately measuring GHG emission. It is also designed to avoid duplication of inventories. Key steps in the approach and methodology of GHG accounting have been depicted in the figure below:

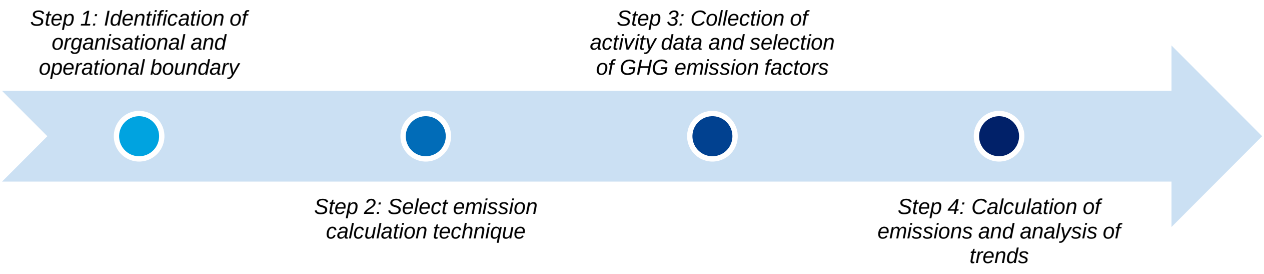

Figure 4 GHG Accounting Methodology

Brief about above mentioned is provided in subsequent sections.

Step 1: Identification of organisational boundary and operational boundary

Business operations vary in their legal and organisational structures. The organisational boundary is defined to identify the section of an organisation's business for which the GHG emissions are to be estimated. It also defines the methodology for consolidating the emissions from individual sites at the organisational level. The operational boundary (of an organization) identifies which emission sources are to be included in the GHG inventory such that there is no double counting of emissions between two different sites or organisations.

- **Organisational boundary:** The organisational boundary for assessment and disclosure of GHG emissions is defined based on a company's business operations and legal structure. A company may hold wholly owned operations, joint ventures, subsidiaries etc. For corporate reporting of GHG emissions, largely two distinct approaches to define organisational boundary are available.
  - ✓ **Equity Share** - A company accounts for GHG emissions from operations according to its share of equity in the operation.
  - ✓ **Control** - A company accounts for 100 percent of the GHG emissions from operations over which it has control – either financial control or operational control. As per the GHG protocol and ISO 14064 guidelines, the organisational boundary of a company that wholly owns and operates all of its operations remains the same, irrespective of the consolidation approach employed. A company has operational control over an operation if the former or one of its subsidiaries has the full authority to introduce and implement policies relalted to operation.
- **Operational boundary:** This boundary defines the scope of direct and indirect emissions for operations that fall within a company's established organisational boundary. The ISO 14064-1:2006 Standard and GHG Protocol define three "scopes" for GHG accounting and reporting purposes. These mark a distinction between direct and indirect emission sources, with the aim to improve transparency. Such delineation provides utility for different types of organisations and different types of climate policies and business goals. These three "scopes" are:
  - ✓ **Scope 1 — Direct emissions**: These are emissions that occur from sources that owned or operationally controlled by the company. Scope 1 emission is mandatory to report.
  - ✓ **Scope 2 — Electricity and other indirect emission sources**: These include emissions that occur due to purchased energy (in the form of electricity, steam, heat and cooling) from the grid or district heating or cooling systems. Scope 2 emissions are mandatory to report.
  - ✓ **Scope 3 — Other indirect emission sources**: These occur due to company activity but the sources are not owned or controlled by the company e.g. emissions from the transport of vendors to provide services to the company. Scope 3 emissions are voluntary for companies

to report. Illustrative figure showing various type of emission for a specific industry is provided below:

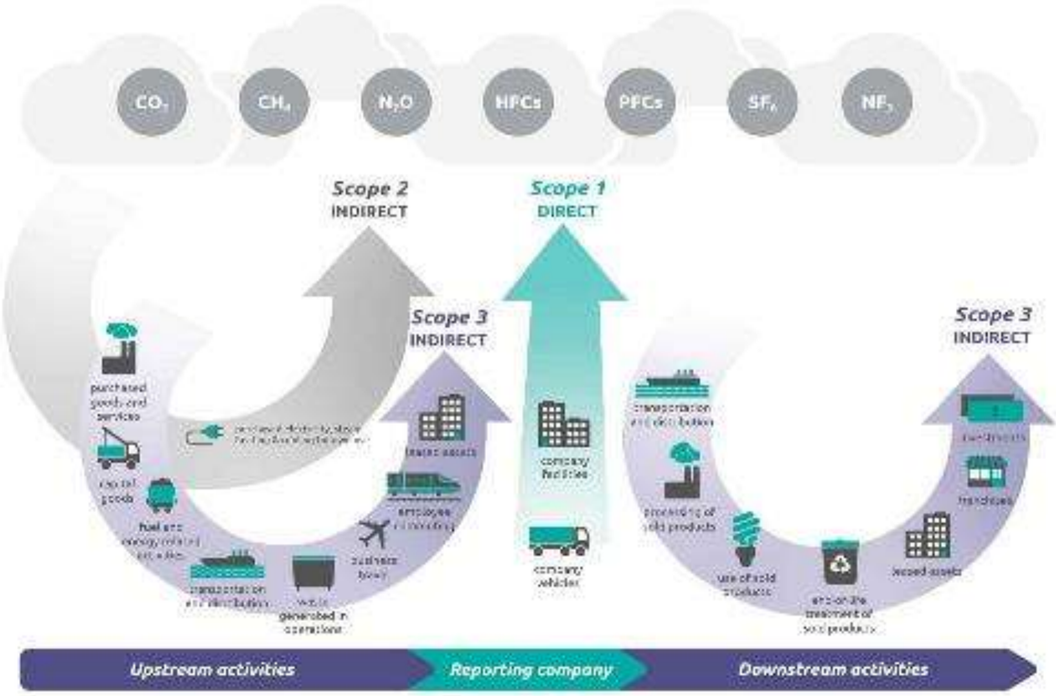

Figure 5 Illustration of scope 1, scope 2 and scope 3 emissions

Step 2: Select emission calculation techniques

There are a number of techniques to calculate emission that are generated from usage of various resources (fuels, electricity etc.) for business activity. Each emission calculation technique have different level of accuracy, data requirement, cost and effort requirements. Therefore, it is important to Identify a suitable calculation methodology that can provide reasonably accurate results within the budgeted cost and effort; and within the restriction of data available.

Step 3: Collection of activity data and selection of GHG emission factors

Depending on the calculation technique selected, data on quantity of resource used and associated emission factor need to be collected. Such data is generally collected from multiple sources such as electricity bills, fuel purchase invoices, equipment maintenance logs, and, occasionally, from the reporting organisation’s ERP systems. At times, data availability also governs the choice of calculation techniques.

Emission factors are constants used to convert resource consumption quantity (responsbile for emission) into their corresponding GHG emission quantity. Emission factors are available from a number of published sources such as IPCC, World Bank and in national governments publications.

Step 4: Calculation of emissions and analysis of trends

Using the selected calculation technique and emission factors, GHG emissions for individual sites are calculated. These are then aggregated based on the selected consolidation methodology (depending on the method employed to determine the organisational boundary) to provide a GHG emissions estimation at the organisational level.

An analysis of temporal trends may help set an ambitious yet, realistic goal for the future. A source-wise analysis helps identify low-hanging fruits for implementing interventions for emission reductions, as well as highlight key areas with the most potential for emission reductions. Benchmarking and comparison of emissions intensity with other market players may also provide a direction for setting future targets and goals.

1.5 About the project

To overcome barriers related to low electrication level and to promote adoption of energy efficiency and renewable energy technologiees,UNDP in partnership with the Global Environment Facility is implementing the Facilitating Renewable Energy and Energy Efficiency Applications for Greenhouse Emission Reduction Project or FREAGER (the 'Project'). The project aims to demonstrate the potential of renewable and energy efficient technologies in PNG. It will be delivered under four components. Together they will aim to demonstrate a range of renewable energy and energy efficient technologies to encourage their broader replication and up-take. Figure below depicts the four components

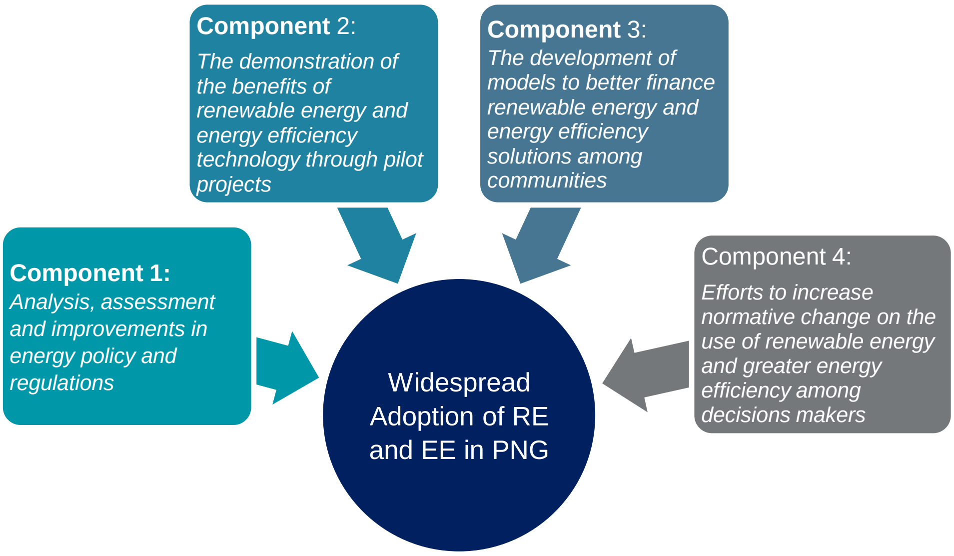

Figure 6 Components of UNDP FREAGER project

Component 1: Analysis, assessment and improvements in energy policy and regulations

This project component envisages development, enforcement and implementation of national and provincial energy policies, plans, and standards to promote the application of renewable energy and energy efficiency technologies.

Component 2: The demonstration of the benefits of renewable energy and energy efficiency technology through pilot projects

This component involves the work directed towards technical-commercial viability and capacity in the application of energy efficiency technologies and development of feasible RE-based energy systems in the country. A number of pilot projects is planed to be implemented to demonstrate viable renewable energy (PV, solar, small hydro) and energy efficiency applications.

Component 3: The development of models to better finance renewable energy and energy efficiency solutions among communities

This component aims to improve an availability of, and access to, financing for renewable energy and energy efficiency initiatives in the energy generation and end-use sectors. The energy efficiency initiatives will primarily target industrial energy users, and social buildings.

The component will carry out a capacity building program for the banking sector, investors in the commercial/private sector (including PPL), and government officials regarding the equity and debt financing of community-based renewable energy mini-grids and of energy efficiency, including building and industrial retrofits and residential appliance and lighting replacement.

It will provide technical support to PPL for the setting up of an "ESCO" fund to finance the upfront costs of energy efficiency retrofits at large electricity consuming customers, who will then pay PPL back based on monthly verified electricity savings. The project will also provide technical support for the setting up of a loan fund at a commercial bank in PNG to finance community-based mini-grid systems.

Component 4: Efforts to increase normative change on the use of renewable energy and greater energy efficiency among decisions makers.

This component will involve the work to improve awareness of, and information about renewable energy and energy efficiency applications in the energy generation and end-use sectors, aiming towards behavioural change. Inter alia, this component will involve development of the database on renewable resources and pipeline renewable energy projects in PNG, as well as development of courses and materials made available for the education sector to promote renewable energy and energy efficiency.

This report provides outcome of the task related to “Cost comparison of grid extension with off grid RE in context of PNG 2030 Vision 2050 electricity access goals”. The report is divided in three chapters, chapter 1 provides background about power sector, current challenges, potential solutions, and introduction of FREAGER project. Chapter 2 provides detail about the methodology. Chapter 3 provides assumptions used in developing financial model and estimation of levelized transmission tariff to compare grid extension with RE based mini grid options and findings of the study.

1.6 About the report

This report is prepared as part of component 3, development of models to better finance renewable energy and energy efficiency solutions among communities. This report is prepared as an outcome for Task 1.4 i.e. Estimation of GHG emission reduction for sample RE and EE initiatives. This report contains sections on a brief background on GHG accounting. It also contains a section on the methodology adopted for the calculation of potential GHG emissions from select EE and RE initiatives. Subsequently, the report provides two cases (one for EE and another RE initiative) to explain calculation for GHG avoidance/savings from RE and EE initiatives.

2. Methodology used

2. GHG emission calculation methodology

The objective of this task is to estimate the GHG emission avoided in the project area on implementation of two projects, one related to renewable energy (installation of Solar Photovoltaic based power generation) and another regarding replacement of existing lighting system with energy efficient LED lighting.

The GHG emission saved, from above mentioned projects, will be the difference between GHG emission that shall have occurred in the absence of the project and the emission generated by the implementation of the project. The figure below represents the calculation of avoided emissions:

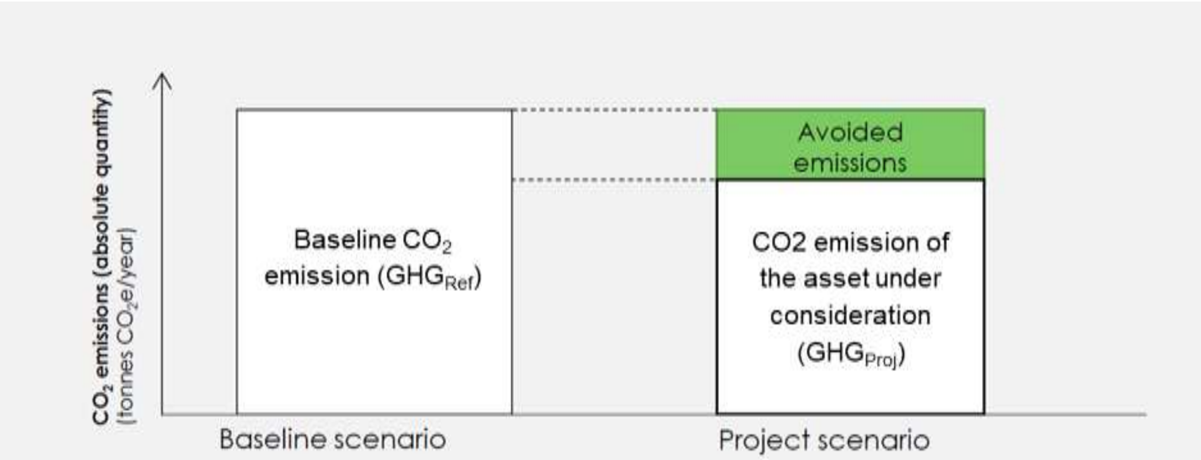

Figure 7 Illustration of GHG emission reduction

Hence, the absolute emission avoidance can be represented as follows:

$$\Delta GHG_{abs} = (GHG_{Ref} – GHG_{Proj})$$

Where,

ΔGHG_{abs} = Absolute GHG avoidance due to operation of the RE or EE project
GHG_{Ref} = the emissions that would occur in the absence of the project (Ref). or baseline case
GHG_{Proj} = the emissions from the project activity (Proj) or proposed case

Example of Energy efficiency intervention

The above terms can be understood by considering an illustrative EE project of replacing inefficient cooling systems with energy-efficient cooling systems in a locality/township. The GHG emission occurred before implementation of the initiative i.e. while using inefficient cooling systems will be $GHG_{Ref.}$ As a result of the new EE initiative, the emission would reduce as an efficient cooling system will consume less electricity in comparison to baseline case, while delivering same cooling effect. This new emission shall be $GHG_{Proj.}$ The difference between electricity consumption in baseline case and proposed case multiplied by grid emission factor shall be the absolute GHG avoidance i.e $\Delta GHG_{abs.}$ The equation for this example is given below for different electricity supply cases

Case 1: When supply is from grid only

$\Delta GHG_{abs.}$= (Electricity consumption with inefficient AC – Electricity consumption of energy efficient AC) X Grid emission factor[3]

[3] The emission factor for grid electricity shall be considered 0.82 t CO2/MWh which is derived from the Draft National Energy Efficiency Roadmap.

Case 2: When supply is from grid and diesel based backup

In this case, as the supply is mix of grid electricity and electricity generated from Diesel based back up system, the replacement of cooling system (AC) will result in both grid electricity as well as diesel. The equation for GHG emission reduction is provided belowHence,

$$\Delta GHG_{abs} = EF_{grid} \times U_{grid} + EF_{diesel} \times Q_{diesel}$$

Where,

EF_{grid} = Grid emission factor in PNG
U_{grid} = estimated unit of electricity avoided from the grid in kWh, due to installation of energy efficient cooling system
Q_{diesel} = Quantity of diesel combustion avoided due to the project
EF_{diesel} = Emission factor of Diesel Fuel Oil

Determining EF_{grid} and EF_{diesel}:

The emission factor for grid electricity shall be considered 0.82 t CO_2/MWh which is derived from the Draft National Energy Efficiency Roadmap.

Emission factor for diesel fuel oil (DFO) is derived from the following calculation:

EF_{diesel} = Net Calorific Value of DFO × Default emission factor of DFO × Conversion factor of DFO (specific density)

Net Calorific Value of DFO = 43 GJ/t[4]

Default emission factor of diesel oil = 72.6 Kg-CO_2/GJ[5]

Conversion factor of DFO = 0.82 Kg/litre

Hence,

EF diesel = 43 GJ/t × 72.6 Kg-CO_2/GJ × 0.82 kg/litre = **2.56 Kg CO_2 /litre**

Above calculations are made based on the guidance provided by the Intergovernmental Panel on Climate Change (IPCC) methodology reports.

[4] IPCC 2006 volume 2 Energy
[5] IPCC 2006 volume 2 Energy

3. Renewable Energy Initiative Example

3. Renewable Energy Initiative Example

3.1 Renewable Energy in PNG

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 several barriers are hindering the development of large-scale renewables. 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.

Renewable energy and energy efficiency technologies present a particularly compelling win-win opportunity in the case of PNG. Aside from the potential to reduce current and avoid future GHG emissions, these technologies may hold viable solutions to address: PNG's power sector challenges such as:

- Nation's very low levels of energy access,
- High costs of diesel power generation that create losses in all of the national power provider's (PPL's) 29 township diesel centers, and
- Local air pollution from combustion of fossil fuels.

Commitments under various plans

With 37.5% population living below the national poverty line[6] and a 15% electrification rate, the PNG government has made it imperative to develop its RE resources to improve living standards and drive higher economic growth. Various commitments of PNG for development of RE sector is provided below:

- NDC includes renewable energy as an opportunity to mitigate GHG emission.
- In the "Papua New Guinea Development Strategic Plan 2010-2030", the government set an ambitious target of achieving 100% of power generation from RE sources by 2050, and increasing electrification rates to 70% by 2030.
- The PNG Government recognizes this as a major development priority and is one of the objectives of the Vision 2050 development plan.

RE potential in PNG

PNG is richly endowed with renewable energy sources that can meet the Vision 2050 target of PNG. A study by Bloomberg New Energy Finance ranked PNG in the top 10 for potential renewable resources, with about 2.5 GW of estimated potential but only 2% of it exploited[7]. Summary of RE potential and utilization at PNG is given in the table below:

Table 1 Renewable energy potential and utilization in PNG

RE Energy	Potential	Capacity realized
Hydropower	15000 MW	230 MW
Geothermal	21.9 TWh	53 MW (2015)
Solar Energy	1244 TWh	Most applications are stand-alone PV systems in rural areas and by telecommunication companies
Ocean Energy	Not Estimated	-
Bioenergy	Not Estimated	-
Wind Energy	Mapping in progress	-

[6] https://www.adb.org/countries/papua-new-guinea/poverty
[7] https://oxfordbusinessgroup.com/analysis/expanding-role-renewable-energy-png

Solar Energy

Solar energy is among the largest potential renewable energy resources in Papua New Guinea due to its close proximity to the equator where the country experience sunshine all year around. Solar Energy has the potential for 1,244TWh per year[8]. Average insolation in much of the country estimated to be between 4.5 and 8 hours of sunshine daily.

Solar radiation at a particular site is difficult to measure using satellite data due to PNG's mountainous terrain, which causes the amount of solar energy available at a given location to vary widely. Solar PV appears to be best suited for the country's coastal and southern regions vis-à-vis the highlands, where cloud cover is generally high. There is significant solar potential in the capital, Port Moresby (more than 2,000 hours of sunshine per year), 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. Map providing solar power generation potential of PNG is given below.

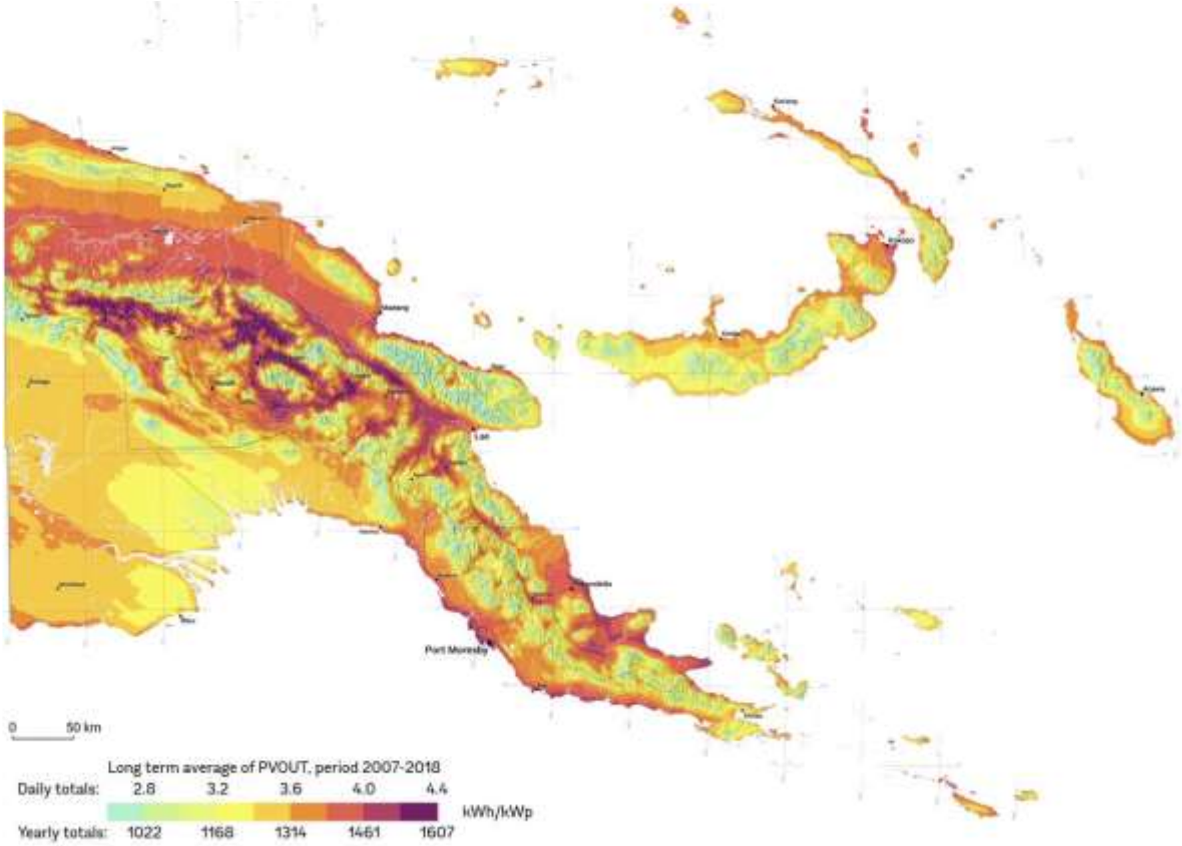

Figure 8 Solar potential map of PNG (ESMAP)

Present usage of SPV in PNG

PNG is gradually developing experience with solar home systems (SHSs) and solar water heaters but has limited experience with PV mini-grids or large grid-connected PV systems. Solar home systems (SHSs), which provide solar photovoltaic (PV) power (via conversion of sunlight to electricity) to a single household or building, have been demonstrated in PNG is used widely in PNG. However, there is no demonstration of PV mini-grid system in PNG which has potential of serving multiple buildings in day and night (with battery system) and also support income-generating uses of electricity which is not possible in case of SHSs.

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[8]https://apec.org/-/media/APEC/Publications/2017/12/Peer-Review-on-Low-Carbon-Energy-Policies-in-Papua-New-Guinea/217_EWG_Peer-Review-on-Low-Carbon-Energy-Policies-in-Papua-New-Guinea.pdf

3.2 Sample SPV project details

For estimating GHG emission avoidance from the sample RE project, a small-scale solar photovoltaic (PV) project in the Natamani Town has been considered.

Namatanai is a town on the island province of New Ireland in Papua New Guinea. It is the second-largest settlement on the island and is connected to the largest and provincial capital of Kavieng by the Boluminski Highway. The map below indicates the location of project area:

Figure 9 Location of sample SPV project on PNG map

The selected area, has potential to generate 3.8 kWh – 4 kWh of electricity on daily basis from installed capacity if 1 kWp. Annual generation potential from 1 kWp system is 1387 kWh – 1461 kWh. The capacity of the SPV plant considered for this study is 200 kW. The annual electriclity generated from the SPV project will avoid usage of electricity supplied from grid. The solar map of the area, with location of SPV plant marked with black circle is given in the figure below:

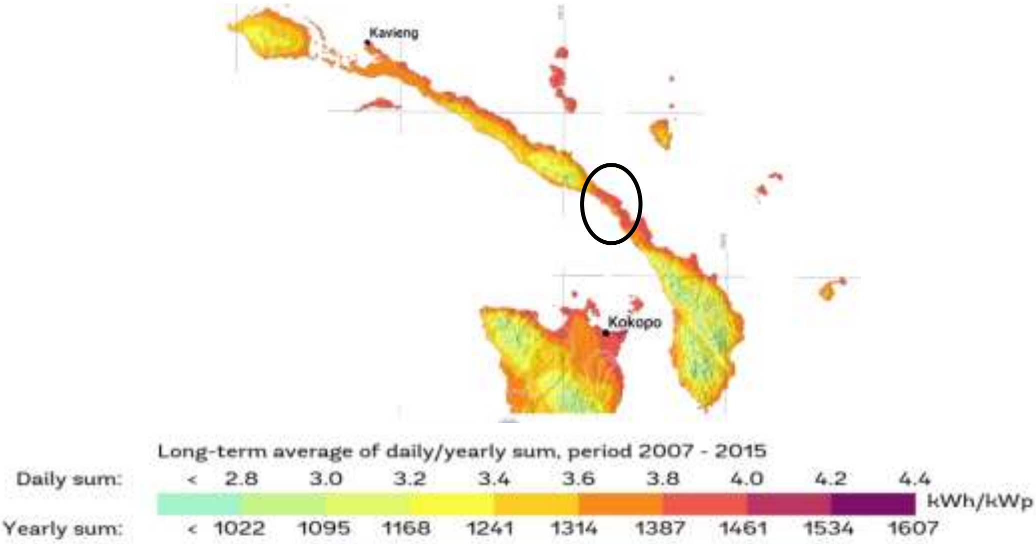

Figure 10 Location of 200 kW SPV in PNG map

3.3 GHG Calculation of sample SPV project

The proposed 200 kW Solar photovoltaic project is expected to avoid electricity consumption from Grid. In baseline case, the GHG emission will include the emission generated for supplying electricity grid. The electricity supplied to grid includes supply from hydro projects as well as diesel based system.

Equation for estimation of GHG emission in baseline case is provided below:

$$GHG_{Ref} = EF_{grid} \times U_{grid}$$

Where,

GHG_{Ref} is GHG emission in baseline case
EF_{grid} is grid emission factor for PNG
U_{grid} is the quantity of electricity used in baseline case.

The electricity used in baseline case is considered as 277400 kWh, which is same as SPV generation potential of 200 kW SPV at Natamani Town. Equation providing quantum of electricity us provided below:

$$U_{grid} = 1387 \text{ kWh} \times 200 \text{ kWh} = 277400 \text{ kWh or } \mathbf{277.4\ MWh}$$

The emission factor for the grid in PNG (EF_{grid}) is considered 0.82 tonne of CO_2 per MWh based on the draft National Energy Efficiency Roadmap.

Hence,

$$GHG_{Ref} = 0.82 \text{ t CO2/MWh} \times 277.4 \text{ MWh}$$
$$\mathbf{GHG_{Ref} = 227.47\ tonne\ of\ CO_2}$$

GHG emission in proposed scenario

Solar photovoltaic does not envolve any emission during power generation, therefore, GHG emission in the project scenario is assumed as zero.

$$GHG_{Proj} = 0$$

GHG emission reduction

$$\Delta GHG_{abs} = GHG_{Ref} - GHG_{Proj}$$

$$\Delta GHG_{abs} = 227.47 - 0$$

$$\mathbf{\Delta GHG_{abs} = 227.47\ tonne\ of\ CO_2\ per\ year}$$

Result

Installation of Solar photovoltaic system of 200 kW to replace existing grid based supply results in annual GHG emission reduction of 227.47 tonne CO_2 per year

Important Consideration

1. *The IPCC guidelines are referred for the calculations (IPCC 2006 volume 2 Energy)*
2. *Distribution loss has not been accounted for in the calculation*
3. *The average daily/yearly sum of electricity production from a 1 kW peak grid-connected solar PV power plant has been taken from the World Bank's solar resource map, calculated for a period of 12 years.*

4. Energy Efficiency Initiative Example

4. Energy Efficiency Initative

4.1 Energy Efficiency in PNG

The energy sector in Papua New Guinea (PNG) relies heavily on fossil fuels, including substantial production, consumption and export of oil and gas. Energy demand 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.

Investment in the PNG's energy sector has been primarily focused on electricity access and improving power supply. This has resulted in limited take up of Energy Efficiency projects in various sectors of economy. Energy efficiency reduces greenhouse gas emissions, improves national energy security, and provides cost savings for energy users across all sectors.

Initatives in energy efficiency domain

In 2020, PNG 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. In NDC, PNG identifies EE as a relatively low cost easily implemented option but still, EE is not implemented at a large scale for various reasons including financial constraints.

PNG is in a nascent stage in terms of EE initiatives, there are many opportunities for Papua New Guinea to achieve energy savings and to reduce GHG emissions through the application of EE measures. A study undertaken in 2020 – the United Nations Environment Programme's (UNEP) United for Efficiency (U4E) Country Savings Assessment – aims to show 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 150 million (PGK 525 million) and reduce over 410,000 tons of annual CO2 emissions (equivalent to the emissions from 230,000 passenger cars)[9]. 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.

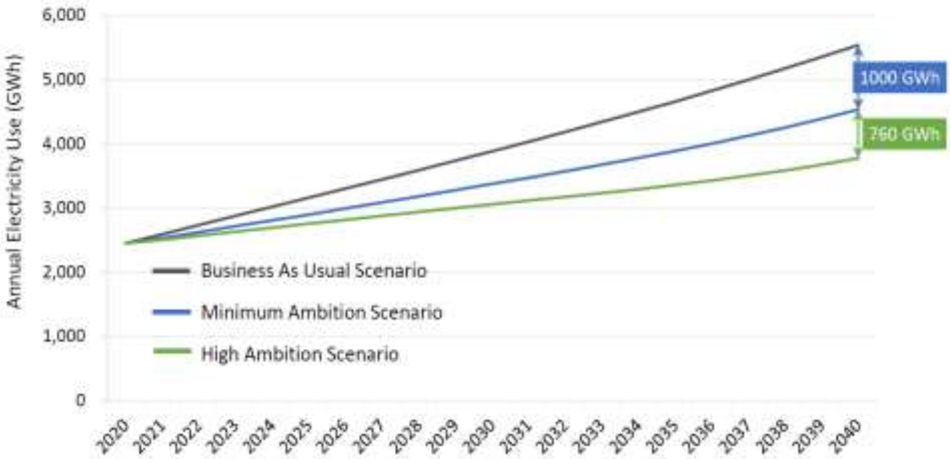

Figure 11 Energy saving potential under different scenario

[9] https://united4efficiency.org/wp-content/uploads/2020/11/PNG_U4E-Country-Saving-Assessment_All_Oct-20.pdf

4.2 Sample energy efficiency project initiatives

Under FREAGER project, sample energy audits were conducted in two township areas in PNG which are Wewak Township and Maprik Area. The energy audit also identified energy conservation measures (ECMs) in domestic, commercial and municipal consumers categories. The ECMs included:

Domestic
- Installation of LED lighting
- Installation of energy efficient refrigeration system

Commercial and Industrial (Industry, Hospital, Bakery, College)
- Installation of LED lighting
- Installation of energy efficient referigeration and HVAC system

Municipal (street lighting)
- Installation of LED lighting

Figure 12 Energy conservation measures identified in township energy audits

For sample calculation of GHG emission savings from Energy Efficiency initiatives, one of the Wewak township energy conservation measure have been selected. The details of sample energy efficiency initiative is provided in figure below

Replacement of street light at Wewake township

Figure 13 Existing and proposed lamp for street lighting

Wewak is the capital of the East Sepik province of Papua New Guinea. It is located on the northern coast of the island of New Guinea. The Wewak township is not connected to grid electricity and has an independent diesel generator-based electricity supply.

The sample energy efficiency initiative considered includes the emission savings by replacing 420 nos. of existing mercury vapour street lights (80 watt rating) with 45 watt LED lamps. Detailed analysis of this recommendation is provided in table below:

Table 2 Detailed analysis of replacement of Mercury Vapour lamp with LED for street lighting

Particular	Unit	Value
Existing		
Type of lighting		Mercury Vapour Lamp (MVL)
Power rating	Watt	80
Voltage	Volt	240
Light output	Lumens	3,400

Particular	Unit	Value
Luminious efficacy	Lumens/watt	43
Number of lamps used	Nos.	420
Operating hours per day	Hours	12
Operating days per annum	Days	365
Annual Electricity Consumption	**kWh/year**	**147,168**
Proposed		
Type of lighting		LED Lamp
Power rating	Watt	45
Voltage	Volt	240
Light output	Lumens	4,600
Luminous efficacy	Lumens/watt	102
Quantity	Nos.	420
Operating hours per day	Hours	12
Operating days per annum	Days	365
Annual Electricity Consumption	**kWh/year**	**82,782**
Energy Savings		
Annual Electricity savings	kWh/year	64,386

4.3 GHG Calculation of sample energy efficiency project

The Wewak township is not connected to electricity grid and it depends on diesel based mini grid for electricity supply. Considering this, the equation for GHG emission in baseline case will only include emissions due to use of diesel as fuel for power generation.

Baseline GHG emission (Business As Usual) is:

$$GHG_{Ref} = EF_{diesel} \times Q_{diesel\ ref}$$

$Q_{diesel\ ref}$ = Quantity of diesel used in baseline case
EF_{diesel} = Emission factor of Diesel Fuel Oil

$$EF_{diesel} = 2.56 \text{ Kg CO2 /litre}$$

Quantity of diesel is estimated with assumuption that the Specific electricity Generation Ratio (SEGR) of diesel based power generation system is 3 kWh per litre (similar to the SEGR provided in Wewak energy audit report). SEGR means the number of electricity units generated from a diesel based power generation system by consuming 1 litre of diesel. Therefore, 1 kWh of electricity is generated using 0.33 litre of diesel.

Hence,

$$GHG_{Ref} = 2.56 \text{ Kg CO2 /lit} \times 147{,}168 \text{ kWh/annum} \times 0.33 \text{ lit/kWh}$$[10]

$$\mathbf{GHG_{Ref}} = 124,\ 327.\ 52 \text{ Kg } CO_2 \text{ per annum or } \mathbf{124.33\ Tons\ CO_2\ per\ annum}$$

In case of baseline scenario i.e. continuing with existing mercury vapour street light results in emission of 124.33 Tonnes of CO_2 equivalent per year

[10] In Wewak, the number of liters consumed per kWh is 0.33. This is computed based on PPL Wewak's 2015 fuel use of 4,876,914 liters to generate 14,816,807 kWh.

Proposed case

Similarly, GHG emission in the project scenario is calculated i.e. when existing street lights are replaced by LED lamps.

$$GHG_{Proj} = 2.56 \text{ Kg CO2 /lit} \times Q_{diesel} = 2.56 \text{ Kg CO2 /lit} \times 82{,}782 \text{ kWh/annum} \times 0.33 \text{ lit/kWh}$$

i.e. GHG_{Proj} = 69, 934 Kg CO_2 / annum or **69.93 Tons CO_2 /annum**

In the case of the project scenario, i.e. when LED lamps are used in place of mercury vapour lights the annual GHG emission is estimated to be 69.93 tons CO_2 per year.

Absolute GHG reduction

$\Delta GHG_{abs} = (GHG_{Ref} - GHG_{Proj})$ = (124.33 – 69.93) Tons CO_2 / annum = **54.4 Tons CO_2 (e)/ annum**

Result

Replacement of the existing 420 nos. of Mercury Vapour lamp (80 watt rating) by 45 watt LED street light shall result into absolute GHG emission reduction of **54.4 Tons CO_2 (e) per year.**

Important Consideration

Following important considerations were made for estimating the GHG emission reduction opportunity for sample projects:

1. *The IPCC guidelines are referred for the calculations (IPCC 2006 volume 2 Energy)*
2. *Distribution loss has not been accounted for in the calculation*