SWITCH
ENERGY ALLIANCE

Switch Energy Alliance Case Competition

Papua New Guinea

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Executive Summary

Problem Overview

- Lack of electrification & reliable cooking fuel, far behind 2010 strategic initiative
- Environmental, cultural and geographical barriers to on-grid expansion
- Energy poverty severely hampering PNG's health, education and economic growth

Solution: On-Grid

- Predictive geospatial models suggest on-grid expansion is ideal for ~7% of population
- Hydropower is identified as the least levelized cost of energy source for on-grid
- Existing projects and partnerships set up meet on-grid demand in near and distant future

Solution: Off-Grid

- Implement community and household level solar solutions for geographically available areas
- Implement community level biogas system for cooking, lighting and electricity
- Set up biomass cooking best practices as a bridge solution before electric/biogas stoves

Solution: Financing

- Financing solution using a mix of subsidies, international partnerships and private sector
- Public and private sectors installing energy capacity collects fees upon meter usage
- With financing from grants and loans, revenue exceeds costs of project on an NPV basis

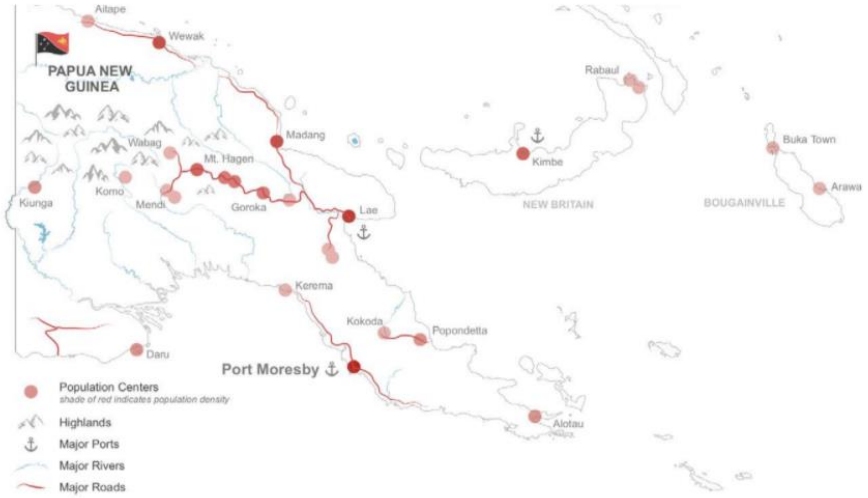
Solution: Culture

- Education of electrification benefits to rural villages, establishing communication
- Careful solicitation of energy solution followed by implementation at will of rural population
- Capable of co-existing with subsistent farming through biogas residue or solar irrigation

Problem Overview

Papua New Guinea (PNG) Overview

Key Development Indicators



GDP per Capita: $2,730

Population: 9,000,000

Rural Population: 88%

Access to Electricity: 13%

Avg. Monthly Rural Family Income: $400

Main Economic Sectors: Mining, Agriculture, Fishing

Modern Development Timeline

1975
Attains full independence from Australia

1977
Hosts first election since independence

1989
Bougainville separatist struggle begins following environmental destruction

1997
Bougainville struggle ends with truce

2009
PNG Vision 2050 national strategic plan initiated

2011
Political turmoil led to parallel administrations within PNG

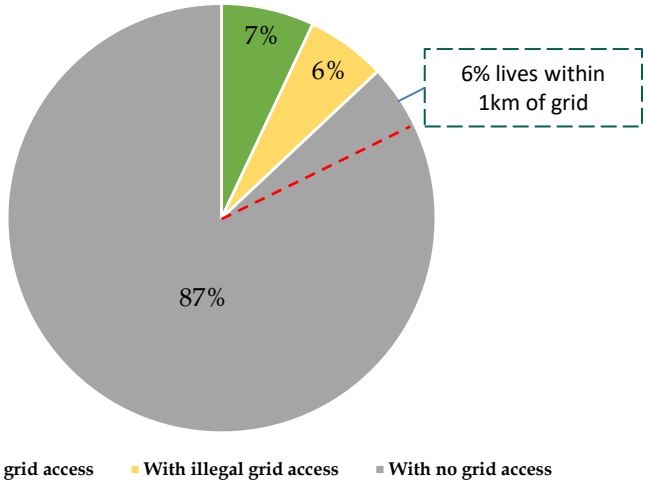
2016
China agrees to spend $4bn to build giant industrial park in PNG

1975 1980 1985 1990 1995 2000 2005 2010 2015 2020

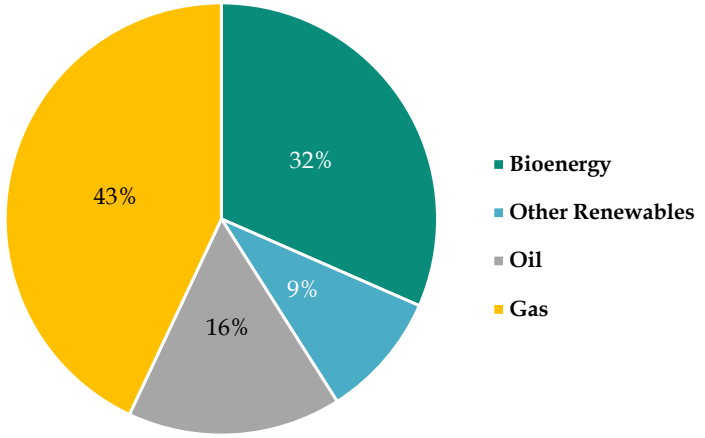
Sources: World Bank, PNG Treasury Department, BBC, EY

PNG Energy Availability

Electricity Access of Population



Total Primary Energy Supply



- Bioenergy is mostly wood from tropical forest

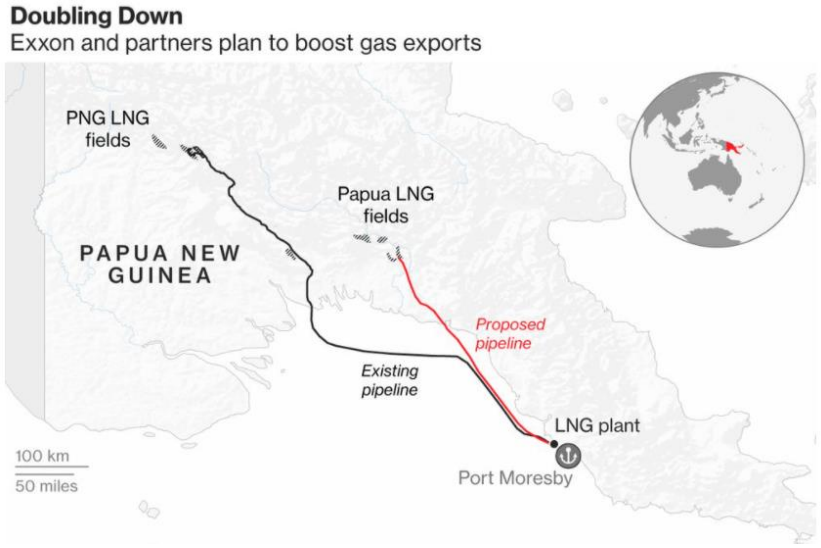
PNG Strategic Development Plan 2010-2030 vs. Reality

	Planned Results by 2020	Reality
Generation Capacity	• 1110 MW generation capacity • 67% from hydro and other renewables	• ~1000MW generation capacity • 34% from hydro and other renewables
Access to Electricity	• 31% household access to electricity • 10.5% growth target	• 13% household access to electricity • 0.5% growth rate
Cooking Fuels	• >50% of households use fuels like kerosene • Begin transition into electric stoves	• ~70% still uses wood/charcoal • Inadequate access to electricity stoves

Sources: Asian Development Bank (ADB), IRENA, PNG 2010-2030 Strategic Initiative

Natural Resource & Cultural Challenges

ExxonMobil Case Study



Background

- After decades of development, ExxonMobil successfully began to export LNG from PNG in 2014
- ~7.5 million tons of LNG exported annually, valued at $3.6bn, nearly 18% of PNG's GDP
- Progress on development of a 2nd field halted in 02/2020 due to disagreement of royalty terms

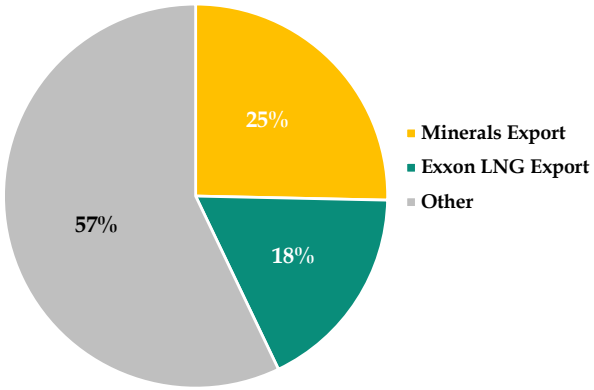
Implications on Energy Supply Potential

- The 7.5 million tons of LNG could generate ~95x the country's electricity if only used domestically
- Infrastructure already largely in place to extract equal amount of LNG in the second field (Elk-Antelop)
- Similar levels of significant extraction potential in the Pn'yang field, Western Gas field and Pasca Gas field
- There is no shortage of gas supply for energy generation

Aspects of Failure & Future Challenges

- Poor terms negotiated for the first field, including:
  - Huge forgone tax revenue
  - 5% of gas for domestic use vs. 15% desired
  - Foreseeable future land ownership disputes
- Exxon failed to meet some of its promises including:
  - 15% GDP growth vs. double GDP promised
  - Expenditure overshoot of $3.3bn, largely subsidized by PNG government
- Ex-prime minister resigned as a result of the scandal, negotiation difficulties with new government

Natural Resources' Role in Economy

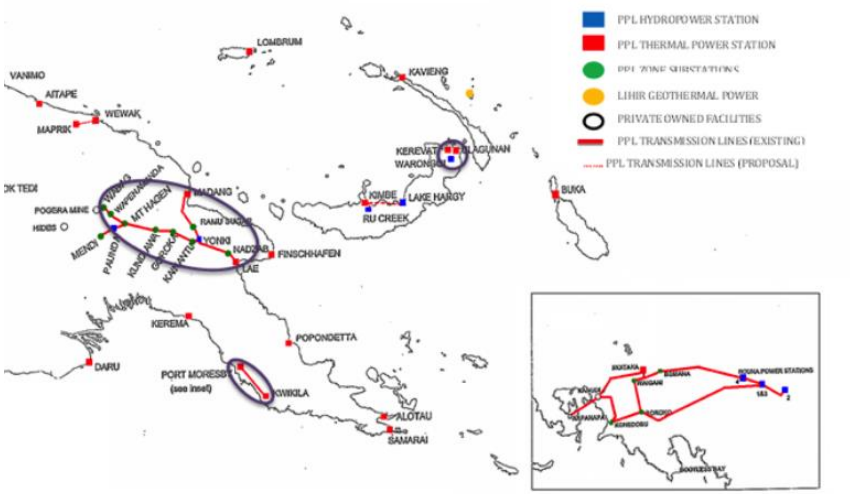


- Mining & resources makes up nearly half of the country's economy

Sources: ExxonMobil Investor Presentations, IRENA, PNG-LNG Project, PNG Industry News

Current Energy Infrastructure

Current Energy Infrastructure



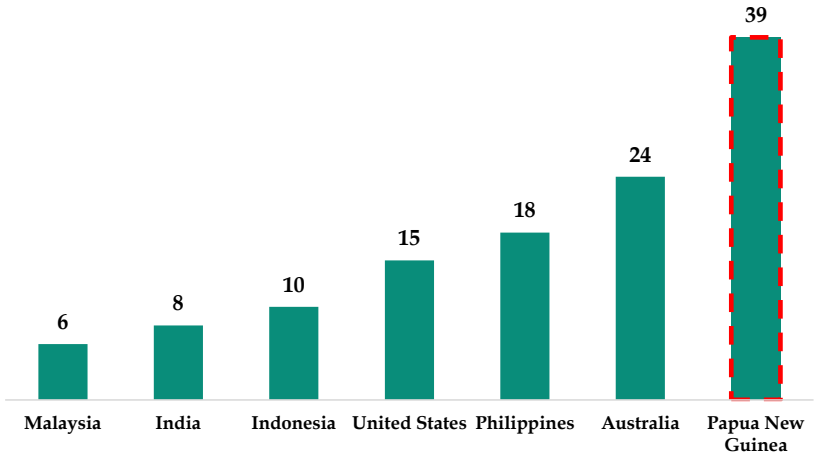
Public Sector

- Three main grids operated by PNG Power Ltd (PPL)
  - Ramu – coastal and central
  - Port Moresby – capital district
  - Ganzelle Peninsula – off from mainland
- 19 small grids for provincial centers
- **300MW capacity**

Private Sector

- Independent power producers (IPP)
- Mainly generated by and serving the mining sector
- **280MW capacity**

Electricity Affordability (¢/kWh)



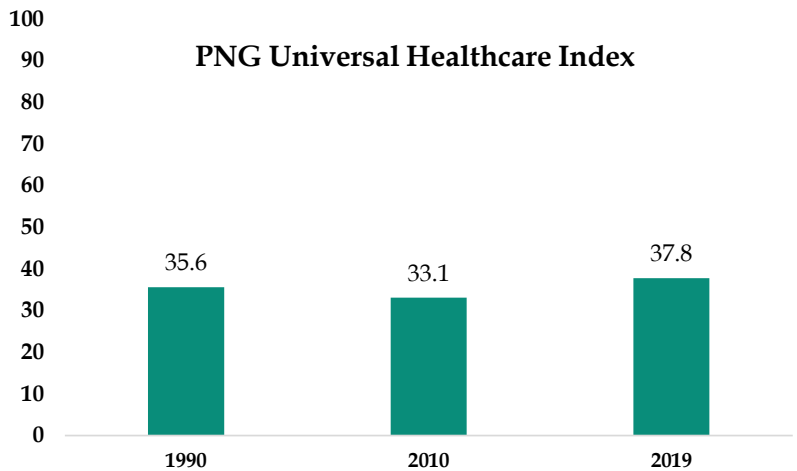
On-Grid Challenges

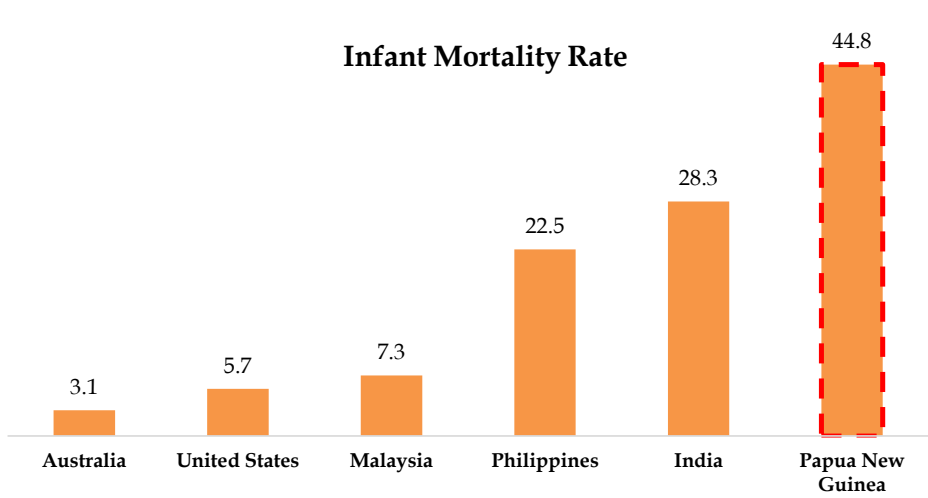
Overall Geography	• 75% tropical forest • Scarcely populated
Grid Reliability	• 42 power outages per month – 5x more than nearby islands • <65% installed capacity available from hydro
Land Policy	• 97% of land under customary tenure, nearly all unregistered • Prior uprisings from environmental destruction

Sources: Papua New Guinea University of Technology, ADB, World Bank, PNG Government

Effects of Energy Poverty

Energy Poverty Impact On Health





PNG have the **lowest life expectancy** among pacific islands due to:

1. Doctors struggle to provide clinical **services after sunset**
2. Life saving examinations & **operations cannot be performed** without good lighting
3. Medication, blood supply and **vaccines cannot be stored** in proper conditions
4. Facilities **cannot power equipment** such as X-rays and incubators
5. Poor power leads to indoor biomass/kerosene usage which can lead to significant **air pollution problems (**2nd cause of death & disabilities in developing countries)

Energy poverty also have significant adverse impact on education, economy and environment

Sources: United Nations, Macrotrends

Cultural Challenges

Cultural Diversity and Ensuing Difficulties

800+ Languages

Spoken among the 9mm people

300+ Tribes

Coexisting, highly diverse

600 Islands

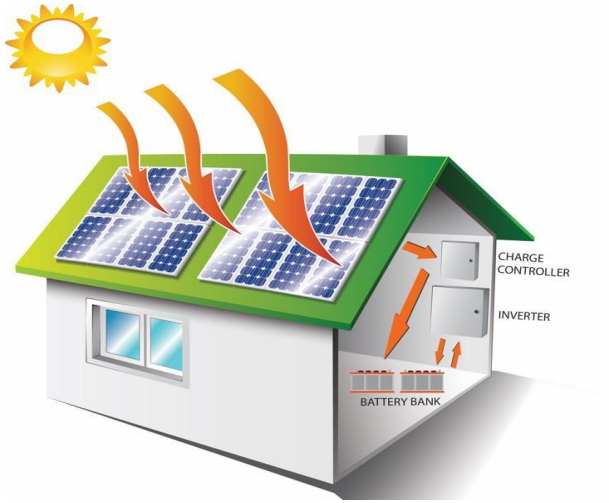
With inhabitants in PNG

40%

Below the poverty line, primitive tools

- Transportation to highly isolated communities
- Potential reluctance of rural tribes to accept proposed technology
- No "one size fits all" solution

Implementation Difficulties – Precedent



World Bank Asia Sustainable and Alternative Energy Program – Solar Home Systems:

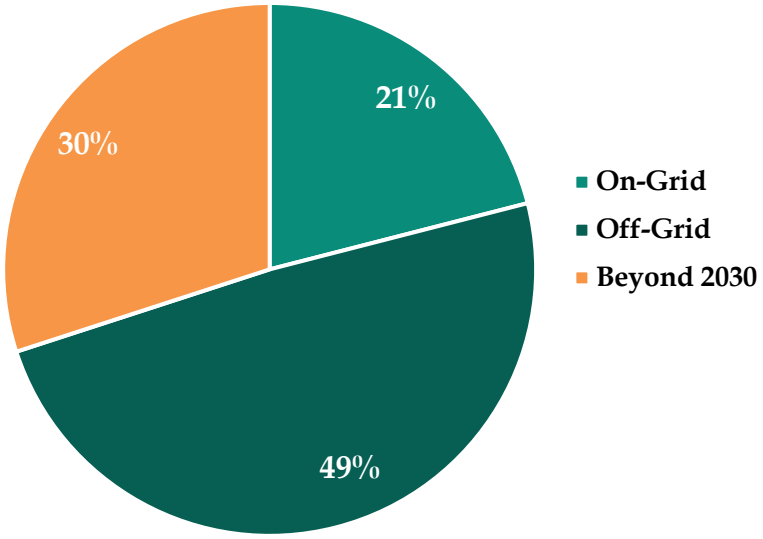
- System included panel, light, stove and charger. Average cost $1,000
- Families can opt-in and governments covered partial cost
- 400,000+ units sold to rural families
- Successful in China, Laos, Mongolia
- Failed in PNG, only country with inadequate project management and execution

Sources: World Bank, ADB, PNG Government

Solution Methodology

Solution Methodology

Least Cost, Most Feasible Solution to 70% Electrification By 2030



Least Cost Methodology	• Levelized Cost of Energy (LCOE) is a measure of the average net present cost of electricity generation for an energy source over its lifetime • Allows the comparison of different technologies of unequal life spans, project size, different capital cost, risk, return, and capacities
On-Grid	• Hydropower at scale
Off-Grid	• Solar where feasible • Biogas in western highlands

Sources: United Nations, Macrotrends

Electrification Task Force (ETF)

Supporting Policy Initiatives

National Public Private Partnership Policy	• Expresses long term financial commitment by the public sector • Allows the private sector to recoup the cost of their investment
Electricity Industry Policy	• Strategic objective of government to improve access to electricity services • Also includes improving reliability of current electricity supply • Ensuring affordability to consumers, regardless of demographics
National Energy Policy	• 100% electricity usage from renewable sources by 2050 • Aims to meet energy needs at least-cost, with consideration to the environment

ETF Purpose

- ETF represents an **independent task force** with support from PNG's governmental institutions (DPE) and foreign development interests
- Expands greatly upon under-staffed rural electrification services team to **accelerate electrification rates**
- **Contracts with under-utilized private markets** with relevant expertise and willingness to drive change
- Funded entirely through generated revenue, concessionary loans, and relatively small amounts of grants
    - Avoids over-burdening PNG's budget and contributing to financial distress (such as that from the COVID-19 pandemic)
    - Avoids re-allocating money from other impactful projects
- Avoids direct integration within government, which in the past has been inefficient
- Can be dissolved when private market participation levels increase due to expanding market opportunities
    - Expected dissolvement year is 2030, when 70% of electrification is achieved and financial feasibility is proven

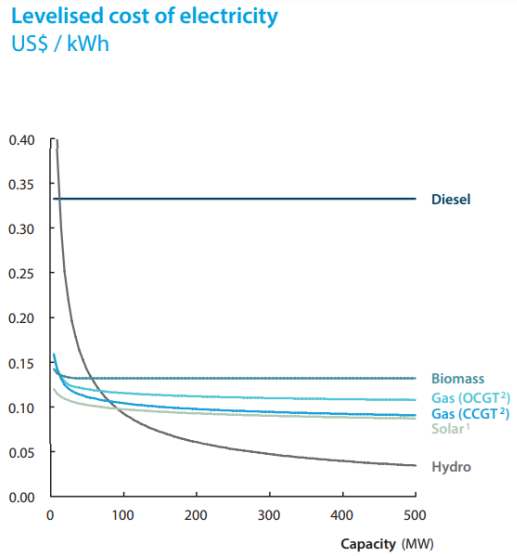
Sources: Papua New Guinea Strategic Development Plan, Columbia Earth Institute, World Bank

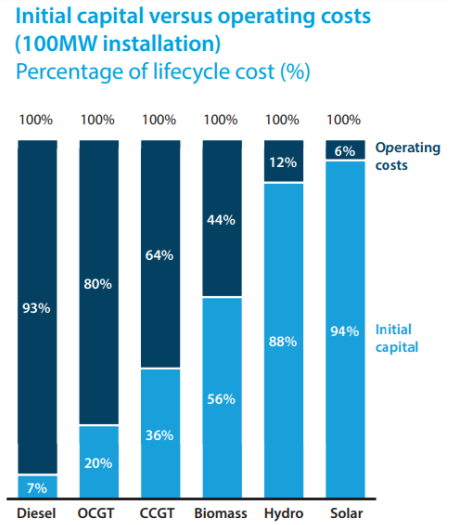
Solution: On-Grid

On-Grid Solutions

On-Grid Levelized Cost of Electricity

- For on-grid solutions, cost of electricity falls as scale increases
- Consideration for initial investment costs versus ongoing operating costs
- For scales up to 100MW, solar is the least-cost solution
    - For scales greater than 100MW, hydropower is the least-cost solution





On-Grid Improvements

	Intensification	Extension
Households Connected	291,168 (improving existing connections)	142,082 (new connections)
Average Households Connected/Improved (2021 through 2029)	32,352/year	15,787/year
Total Investment Cost	$150,000,000	$150,000,000
Average Investment Cost per Year	$16,666,667	$16,666,667
Average Investment Cost per Household	$515.17	$1,055.73

Key Points

- On-grid solutions will **power approximately 21% of PNG** by 2030
    - This percentage represents the conclusions of numerous least-cost procedural studies and geospatial predictive modeling
- Current grid solutions available are unreliable and require rehabilitation
- Grid extensions to households within 1km represent a least-cost expansion for **~142,000 households**
- For additional on-grid power generation, **hydropower represents the least-cost solution**

Source: EY, Asian Development Bank, Columbia Earth Institute, PNG DPE, World Bank

Planned New Generation

New Planned & Undergoing Projects (Independently Financed)

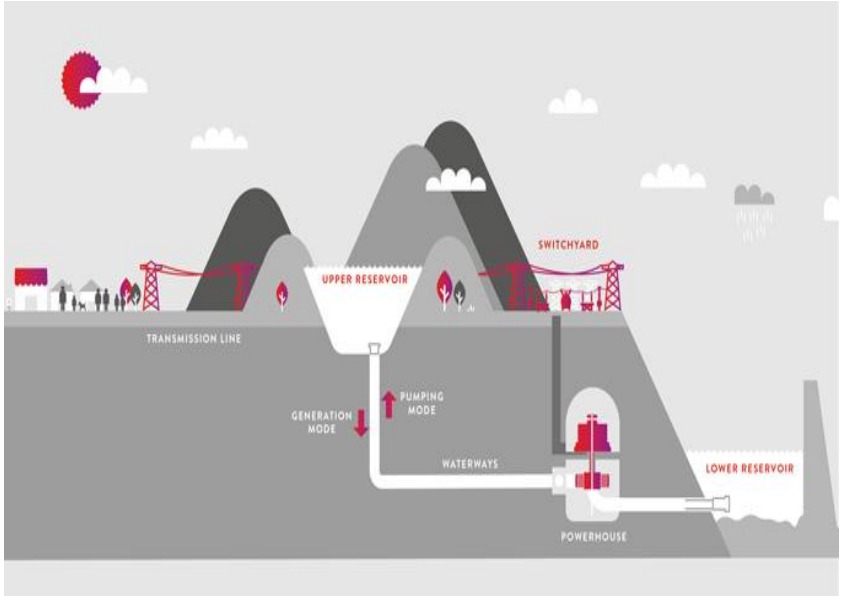
Project Name	Estimated Cost ($)	Estimated Generation
Karimui (Hydropower)	$2bn	1800MW
Port Moresby Power Station (Gas)	$98m	57MW
Purari Partnership (Hydroelectric)	$5bn	1800MW
Edevu (Hydropower)	$200m	50MW

Minimum Planned New Generation Capacity & Demand

Generation Source (MW)	2020	2025	2030	2040
Hydropower	240	2,090	2,990	2,990
Geothermal	48	48	48	48
Natural Gas	84	141	141	141
Diesel	228	228	228	228
Total Capacity	600	2,507	3,406	3,407
Total Demand	800	1200	1800	2700

Takeaways

- Independently financed projects estimated to be completed before 2030 fulfill projected on-grid energy demand
- Projects include cost of connecting to the grid and any grid modifications required
- At **~15,000MW potential capacity**, hydropower in PNG has excess energy production capabilities
- Partnerships such as the one with Australia on the Purari river offer foreign capital and customer bases to finance future long-term hydropower projects in PNG

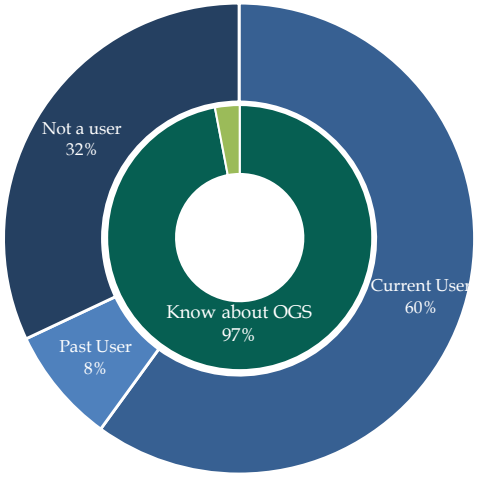


Source: PNG Energy Developments, Origin Energy, Environmental Resource Management, PNG Development Strategic Plan, IRENA

Solution: Off-Grid

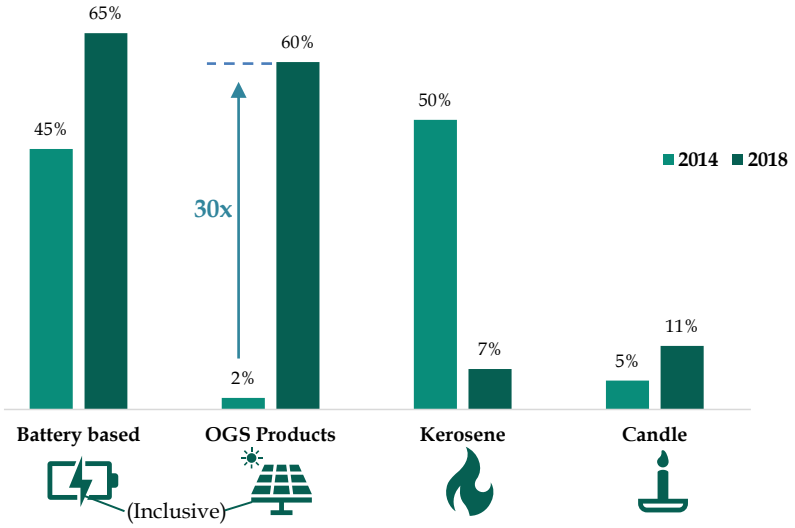
Viability of Off-Grid Solar (OGS)

Awareness & Usage of OGS

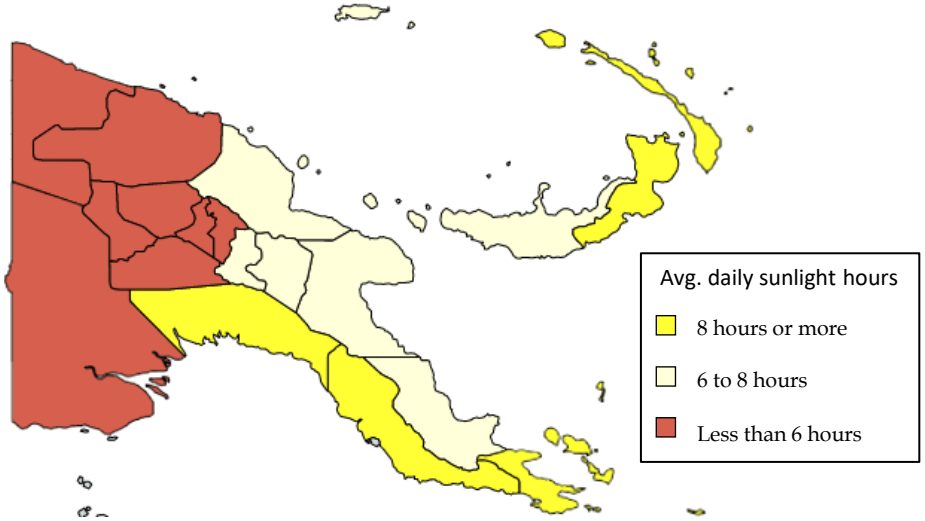


- Most current OGS are for single-lights and charging phones

Off-Grid Household Lighting Products



Geographical & Technical Feasibility of Solar



- Estimated population of 5,000,000 with 6+ hours of solar exposure not within grid range, equivalent of:
  - 1mm families (average size 5)
  - 16,500 villages (average size 300)
- "Modeling showed that cost of **extending grid** to connect a PNG village 5km away was **more expensive than any stand along option"** - EY
- Existing network of department stores known as "lot shops" selling solar panels

Sources: Lighting Pacific, Climates To Travel, EY

OGS Economic Feasibility

Community/Village Centers

Community annual electricity needs	(kWh)
3 Large fridges	1,800
Area Fans & Air Conditioning	2,500
10 Fluorescent lights 8hrs/day	750
Other potential needs	1,950
Total	**7,000**
Daily total	*19.2*
Average daily sunlight hrs:	6
Solar Pannel Watts Needed:	**3,196**

	Unit Cost	Bundle Cost
(300 watt) X 14	$100	$1400
(4.8 kWh) X 5	$450	$2,250
Shipping & Installation		$500
Cost per Community/Village:		**$4,150**
Est. # of Villages		16,536
Community centers total cost		**$68.6m**

Family Homes

Family Annual Electricity Needs	(kWh)
One Small Fridge	400
Two 75w Fans 3hrs/day	150
Two Fluorescent Lights 8hrs/day	150
Other Potential Needs	500
Total	**1,200**
Daily Total	*3.3*
Average daily sunlight hrs:	6
Solar Pannel Watts Needed:	**548**

	Unit Cost	Bundle Cost
(300 watt) X 3	$100	$300
(4.8 kWh) X 1	$450	$450
Shipping & Installation		$200
Electric Cookware		$80
Cost per Family:		**$1,030**
Est. # of Homes		**855,756**
Family Homes Total Cost		**$881.4m**

- All electric products are assumed to be **shipped from China**, where nearly all existing solar products comes from
- Additional taskforce/consulting fees noted independently in financing section

Sources: United Nations, Alibaba.com, EnergyUseCalculator

Illustrative OGS Implementation Timeline

Implementation - Public Private Partnership

Phase 1: Set Up Task Force, Import Panels and Training

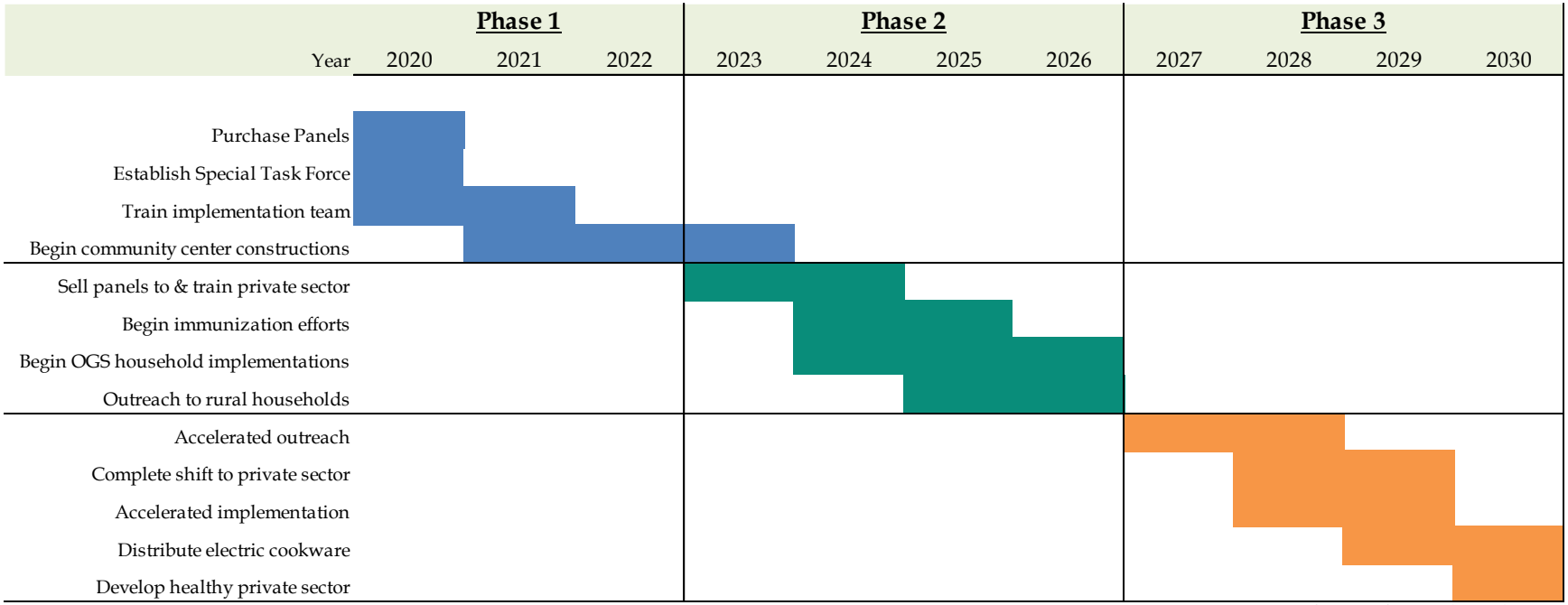
1. Purchase panels needed for community centers ($61mm), contract the rest ($794mm)
2. Establish special task force supported co-headed by ADB, PNG government, Australia and other NGOs
3. Task-force to train ~500 community center implementation team
4. Begin construction of community centers, all subsidized by government (16,500)

Phase 2: Public private partnership to implement household level OGS

1. Task force offers to train & sell panels to private sector businesses at discount
2. Begin immunization and quality of life improvements through village centers
3. Outreach to rural households to install OGS, modeled by community centers
4. Families elect to install solar power through local, private businesses (1mm targeted) in 6 years

Phase 3: Complete transfer of implementation to private sector

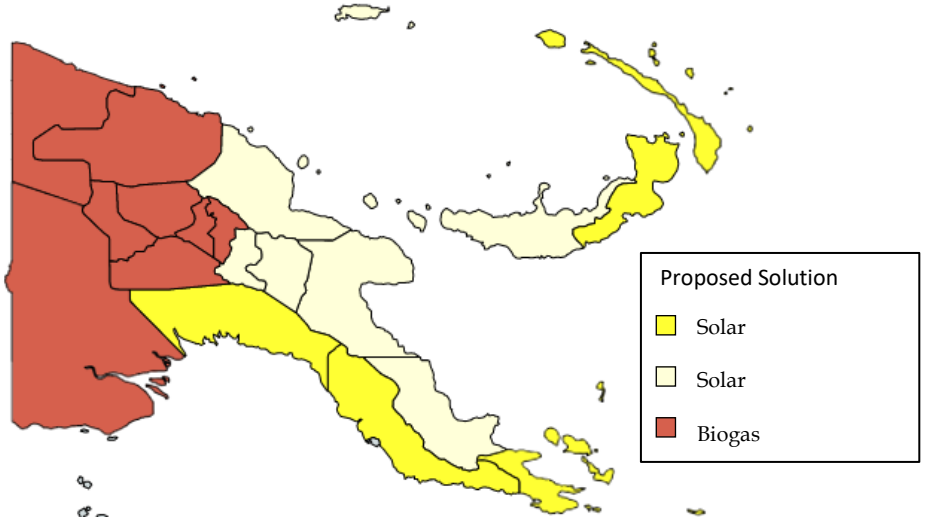
1. Accelerated community outreach, more persuasive electrification marketing
2. Complete shift to private sector distribution/implementation
3. Accelerated implementation through economies of scale in private sector
4. Potentially distribute electric cooking stoves to households
5. Develop healthy renewables private sector



Sources: ADB, Prior Estimates

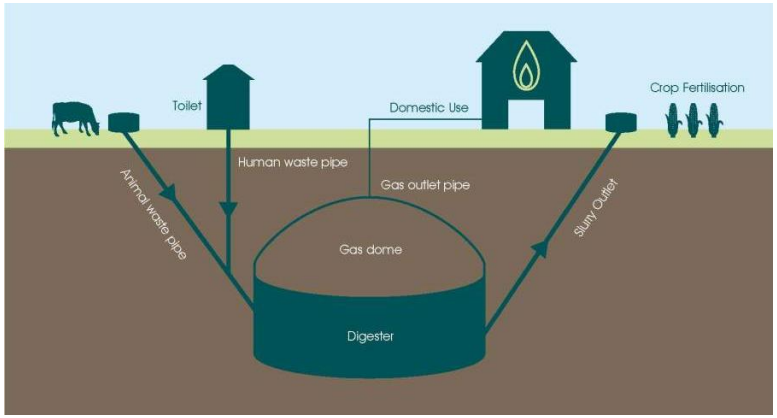
Rationale For Biogas Solution

Geographical Challenges In Non-Solar Regions



1. Known as the "Western Highland" region with heavy rain and forest, **not ideal for solar or wind, or grid extension**
2. Uneven distribution of lakes and lack of technical sophistication makes **hydro and geothermal unreliable**
3. Extraordinarily diluted population with **highly isolated low-income villages** (<$400/month, 7,600 villages)
4. **Lack of trust in foreign investments** due to environmental destruction and previous Exxon development issues
5. Heavy usage of biomass as cooking fuel leading to **mass deforestation**

Logistical Overview



- Can be used for lighting and cooking standalone, can generate electricity with biogas engines

Viability of Biogas

1,360,000

Pigs are in the targeted region, 60% of all pigs in PNG

180

Pigs per 300 people village, plenty of biogas fuel

Germany & India

Already have mass-scale implementations of biogas communities

Sources: IRENA Biogas Survey, Lighting Pacific

Biogas Economic & Technical Feasibility

Supply of Biogas Fuels

Biogas Energy Technical Feasibility	
Est. # of Village Pigs	1,800,000
Est. % of Pigs Owned by Target Villages	60%
Estimated # of pigs available	1,080,000
Est. # of Rural Villages in Target Region	6,008
Avg. # of Pigs Per Village	180
Average Weight of Pigs (kg)	43.5
Liters of Biogas per kg of Pig per Day	30
Energy Potential per 1,000 liters (kWh)	1.7
Daily Energy Potential per Pig (kWh)	2.22
Daily Energy Potential Per Village (kWh	**399**

2X >

Demand of Biogas Fuels

Family Annual Electricity Needs	(kWh)
One Small Fridge	400
Two 75w Fans 3hrs/day	150
Two Fluorescent Lights 8hrs/day	150
Other Potential Needs	500
Total	**1,200**
Daily Total	3.3
Average Village Size	300
Average Families of 5 per Village	60
Daily energy need per village (KWh)	**197**

Qualitative & Quantitative Analysis

Foundation	2,500
Digester	4,600
Effluent Storage	1,900
Roof	1,500
Gas Pump	700
Boiler	600
Hydra-Ram Manure Pump	4,900
Mason/Consultant Cost	4,000
Biogas Electric Engine	5,000
Cost of Grid Distribution (Barbwires)	1,400
Est. Cost per Village	**27,100**
Biogas Project Total Cost	**162,823,213**

Pros:

- Highly affordable even to rural regions at $450 per family
- Minimum maintenance cost
- 100% renewable materials with no plastic waste
- Also solves cooking problem (methane)

Cons:

- Require high level of expertise
- Potential cultural barriers to use of system
- May need diesel to start off engine
- Susceptible to heavy flood

Illustrative Biogas Implementation Timeline

Implementation: Training & Consulting Program

Phase 1: Import Engines, Seek Consultants & Train Locals

1. Establish department of biogas within task force; contract to import biogas engines needed from China ($3.7m)
2. Employ ~500 locals across the western highland region, hire international biogas experts/consultants to train locals on integrating the electricity converting engine
3. Launch awareness program to educate rural villages on biogas electricity capabilities
4. Begin implementation of biogas systems without engine; transform local lighting & cooking fuel usage

Phase 2: Fully Activate Biogas System Potential

1. Implement electrical engines to biogas systems
2. Initiate financing solution on a village level upon completion of biogas system construction
3. Continued support and education on utilization of biogas system, from lighting, cooking fuel, electricity to agriculture
4. 70% of mountainous region villages (~5300) electrified

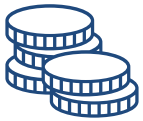
Biogas system without electric engine | **Installation of Engines For Complete Ecosystem**

2020 | 2022 | 2025 | 2028 | 2030

Case Study: Penn State Digester

100 Cows

Used in their digester, roughly equal to 180 pigs



$20,000

Upfront cost, without engine included

876m Btu

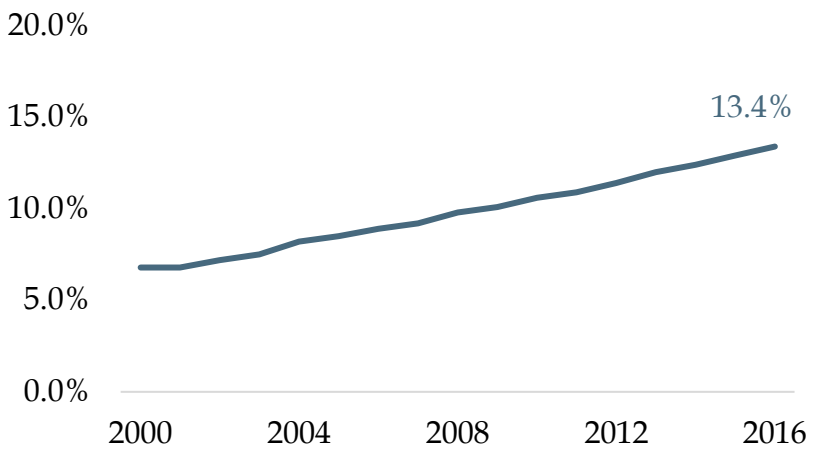
Of energy generated in 1 year

- Plant produced 60% methane, at 22 MJ/m^2, **in line with our assumptions**
- Outputs mainly used for powering heaters
- The plant was not used to generate electricity, however, using conversion of energy, the electricity potential is:
  - Optimistic estimate: **704 kWh daily**
  - Conservative estimate: **200 kWh daily**
- Even in the most conservative case, **biogas can power the entire village**

Sources: Penn State, Energypedia, PNG Ministry of Agriculture and Livestock

Cooking Fuel

Population Access to Clean Cooking Fuel



Cooking Methods

- Primary method **is cooking over fire**
- High household air pollution
- Health concerns include **pulmonary and respiratory problems**
- Clean cooking solutions are expensive and inaccessible

Best Practices During Transition

- Transition to clean cooking fuels takes time; need for temporary solutions
- **Awareness:** Implementing educational program about the dangers of cooking with biomass
- **Practices:** Cook in ventilated areas and keep children's exposure to a minimum

Community Centers

- Community centers are implemented with priority
- Early access to centers provides structural support to health care and educational initiatives
- Centers provide a touch point for community outreach

Source: IRENA, UN SDGs, World Health Organization, PNG National Strategic Plan

Financing & Scalability

Financing Considerations

	Key Financing Considerations
Market Development	• Public-Private Partnerships (PPP) play a crucial role in **covering early-stage project risk and getting new markets to maturity** in developing countries • International private investors are unwilling to invest capital in high-risk countries such as PNG that lack developed markets and financial security
International Development Partners	• Choosing international partners is a key consideration to avoid future complications • Use of debt-trap diplomacy, notably by China, has been a downfall of other developing countries and has complicated previous projects in PNG
Subsidies	• There is little to **no precedent of rural electrification programs functioning without some form of subsidy** • Customers can not afford one-time upfront costs of implementation
Papua New Guinea Electrification Partnership	• Collaborative effort including Australia, Japan, New Zealand, and the United States to reach 70% electrification by 2030 • Countries have combined to offer **greater than $1.5bn in concessionary loans**
Grants and Loans	• Support from numerous foreign governments, USAID, Global Green Growth Institute (GGGI), Asian Development Bank (ADB), Global Climate Partnership Fund (GCPF), Abu Dhabi Fund for Development, and more • Grants represent international effort to electrify developing countries • Conservatively estimated to provide funding of **at least $20m per annum**

Source: U.S White House, University of Chicago, Global Green Growth Institute, Global Climate Partnership Fund, Lazard

Financing Roll-Out Plan

PNG Electrification Cost Financing Roll-Out Plan

$ amounts in '000s	2021	2022	2023	2024	2025	2026	2027	2028	2029		
Investment Costs											
Grid Intensification	(6,667)	(9,167)	(11,667)	(14,167)	(16,667)	(19,167)	(21,667)	(24,167)	(26,667)		
Grid Extension	(6,667)	(9,167)	(11,667)	(14,167)	(16,667)	(19,167)	(21,667)	(24,167)	(26,667)		
Community Centers	(68,624)										
Biogas Project	(7,237)	(9,950)	(12,664)	(15,378)	(18,091)	(20,805)	(23,519)	(26,233)	(28,946)		
Off-Grid	(39,175)	(53,865)	(68,556)	(83,246)	(97,937)	(112,627)	(127,317)	(142,008)	(156,698)		
Total	**(128,369)**	**(82,149)**	**(104,553)**	**(126,957)**	**(149,361)**	**(171,766)**	**(194,170)**	**(216,574)**	**(238,978)**		
Funding Sources											
Connection Charge Revenue	13,288	31,560	54,815	83,053	116,274	154,478	197,666	245,837	298,991		
Foreign Aid Grants	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000		
PNGEP Loans	125,000	125,000	125,000	125,000	(100,000)	(100,000)	(100,000)	(100,000)	(100,000)		
Total	**158,288**	**176,560**	**199,815**	**228,053**	**36,274**	**74,478**	**117,666**	**165,837**	**218,991**		
Household Electrification											
Grid Intensification	11,647	16,014	20,382	24,749	29,117	33,484	37,852	42,219	46,587		
Grid Extension	5,683	7,815	9,946	12,077	14,208	16,339	18,471	20,602	22,733		
Biogas	14,419	19,826	25,234	30,641	36,048	41,455	46,862	52,270	57,677		
Off-Grid	34,230	47,067	59,903	72,739	85,576	98,412	111,248	124,085	136,921		
Chargeable Households Connected	25,402	23,829	30,328	36,826	43,325	49,824	56,323	62,821	69,320	**2030 Goal**	**2040 Goal**
Total Households Connected	345,501	420,208	515,290	630,747	766,579	922,786	1,099,367	1,296,323	1,513,654	1,468,165	2,635,567
Total Households in PNG	1,824,000	1,852,524	1,881,495	1,910,918	1,940,802	1,971,153	2,001,979	2,033,286	2,065,084	2,097,378	2,774,281
Electrification Rate	**18.9%**	**22.7%**	**27.4%**	**33.0%**	**39.5%**	**46.8%**	**54.9%**	**63.8%**	**73.3%**	**70.0%**	**95.0%**

Assumptions

- PNG's sovereign guarantee will pass-through a conservative financing rate of 4.0%
- Urban households use approximately 2.5x the electricity of rural households
- There's an implementation and execution margin of error of 10%
- Implementation logistics make it that households connected increase by a factor of 15.0% per year
- A conservative average of five people per household
- Zero-interest loans of $125m provided for four years, repaid in five years
- Grants of $20m provided over lifetime of projects

Takeaways

- The project has a positive net present value over a nine-year lifespan, disregarding profits generated provided after 2030
- **Average cost of energy of $0.12/kWh** under proposed plan (current prices are $0.39/kWh)
    - **69% cheaper**, and more reliable
- After 2030, projects will be profitable and generate high returns encouraging private market participation
- Conservative assumptions and built-in failure rates allow for **considerable upside**

Source: Moody's, IRENA, PNG DPE, UN, Columbia Earth Institute, World Bank

Cultural and Sustainability Considerations

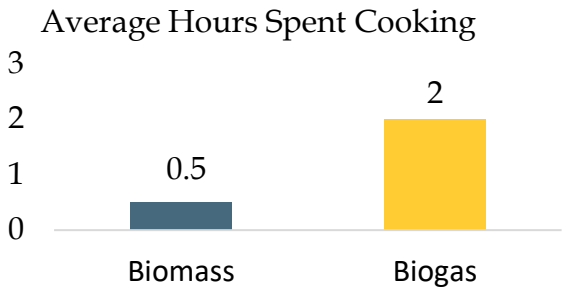
Cultural Considerations

Sensitivity to Indigenous Populations

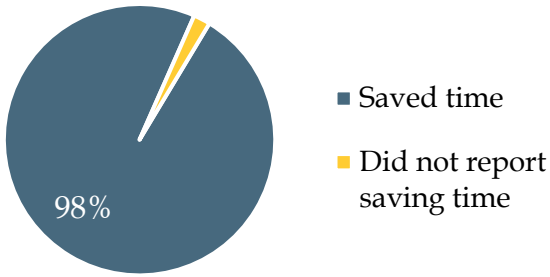
- Off-Grid Solutions will be on an **opt-in basis**, with no requirements for local people to enroll
- In the past, PNG tribes have been **receptive to solar projects**, but concerned about exploitative practices
  - emphasis on choice to participate, introduction to systems through community centers
  - no hidden fees, requirements, obligations
- **97% of PNG citizens are familiar** with solar systems
- Most have or are familiar with cell phones and need reliable energy to charge them

Unfamiliarity of Biogas Solutions

- 98% of global biogas users who interviewed in a World Bank study reported saving time in cooking
- 1-3 hours a week spent collecting wood or other fuel, **260-780 hours per year saved** per household by using biogas



- Successful in other rural communities around the world
- Low technology risk and easily maintainable
- **Widespread use** in India and China
  - reduced household expenditure
  - reduced time spent gathering supplies (e.g. wood)



Source: IRENA Biogas Survey, IWGIA, PNG Government Embassy, Lighting Pacific, New Zealand Foreign Affairs & Trade

Sustainability

What is the environmental impact of this plan?

- A majority off-grid solution is the **only environmentally conscious solution** for electrification in PNG
  - Significant on-grid expansions are not only environmentally destructive, they also aren't financially viable
- Farmers carry out around **46% of deforestation for lighting and cooking fuel**, which will be replaced by sustainable energy and clean cooking fuel
- Energy demand growth will be almost exclusively by supplied from renewable sources such as hydropower and solar
- 80% of Papua New Guineans are living by subsistence or semi-subsistence farming, with a strong desire to continue this lifestyle
  - Only feasible plan to protect biodiversity, land, and lifestyle

How does this plan help PNG to achieve the UN's SDGs?

- Implementation of off-grid solutions helps PNG work towards SDG 7 (detailing universal electricity access)
  - Biogas and Solar-Home solutions have experienced success in comparable countries
- Puts **PNG on track to achieve Vision 2050**: Electricity generation solely through renewable sources
- Widespread **electricity access acts in symbiosis with other SDG's**, providing structural support to education and health-related goals
  - Storage of vaccines
  - Reduction in maternal, infant and child mortality
  - Many related benefits of internet access
  - Reduction in crime as a result of after hour community lighting
  - Accelerated economic growth
  - Other tangential benefits

Source: ADB Power Sector Development Plan, PNG National Strategic Plan, UN SDGs, IRENA

Economic Benefits of Electrification

Estimated Benefits of Electrification at 70%

Country	GDP per Capita	Electrification	Urban	Rural	kWh Usage	Households
China	11	100%	100.0%	98.0%	3,292	1,353.3
Malaysia	22	99%	99.8%	98.0%	3,989	29.5
Vietnam	5	96%	98.5%	94.9%	1,207	86.1
Indonesia	9	94%	98.9%	89.4%	670	235.2
Korea, Rep.	32	93%	93.9%	90.5%	9,605	46.9
Philippines	6	83%	94.4%	72.8%	623	82.0
Singapore	75	73%	72.6%	64.3%	8,150	3.9
Lao PDR	4	66%	94.3%	52.0%	425	4.5
Myanmar	4	49%	92.0%	28.4%	146	26.0
Papua New Guinea	3	13%	63.3%	7.6%	426	1.1

>30% increase in GDP per Capita

from sectors with increased electrification

~50% reduction

in infant mortality rate aligning with Philippines' level

43% improvement

in labor force participation rate aligning with Philippines' level

>95% Renewable

energy sources, preserving and protecting the environment

Source: EY, CIA World Factbook, World Bank, PNG Department of Treasury

Appendix

Proof of 13% Electrification Rate

The leaders of Australia, Japan and New Zealand joined U.S. Vice President Mike Pence in signing the partnership accord, which aims to connect 70% of the population to electricity by 2030, up from 13% currently.

Lifting electricity supply has been identified as one of the key goals of the country's Development Strategic Plan. Launched in 2010, the policy called for 70% of the country's people to be connected to electricity within 20 years. It projected that achieving the 2030 goal would lift gross national income by 12% and GDP by 10%.

But progress has been extremely limited – with a lack of funding, a complicated government and regulatory regime, and the difficulty of delivering services in one of the world's most rugged and diverse countries, where four in five people live in traditional rural settings.

3. **Sector issues.** Despite ongoing improvements to the power sector, only 12%[5] of PNG's population has access to electricity, and grid penetration in rural areas is less than 4%. PNG's per capita consumption ratio of electricity is also one of the lowest in the world.[6] The country's

Source: Lowy Institute, ADB, Governments of Australia and New Zealand

Solar Panel & Battery Costs

Europe warehouse tax free price **solar panel 300w** all black mono **300w**...

US $72.60-$82.50 / Piece
30 Pieces (Min. Order)

8 YRS Bluesun Solar Co., Ltd.

Verified (73) | 96.4%

"Easy transaction" (5)

Contact Supplier

View larger image

Add to Compare Share

2.5kwh 4.8kwh 7.2 kwh 48V Lifepo4 Lithium ion battery li-ion lithium battery for home solar system

5.0 1 Reviews

2 - 19 Packs	20 - 49 Packs	>=50 Packs
$520.00	$480.00	$450.00

Battery Type: pack

Nominal Capaci... 2.5KWh 5KWh

Nominal Voltage: 48v

Shipping: Support Sea freight · Land freight

Lead Time:

Quantity(Packs)	1 - 20	>20
Est. Time(days)	15	Negotiable

Customization: Customized logo (Min. Order: 10 Packs)
Customized packaging (Min. Order: 10 Packs)
Graphic customization (Min. Order: 10 Packs) Less

Samples: $600.00 /Pack | 1 Pack (Min. Order) Buy Samples

Trade Assurance protects your Alibaba.com orders

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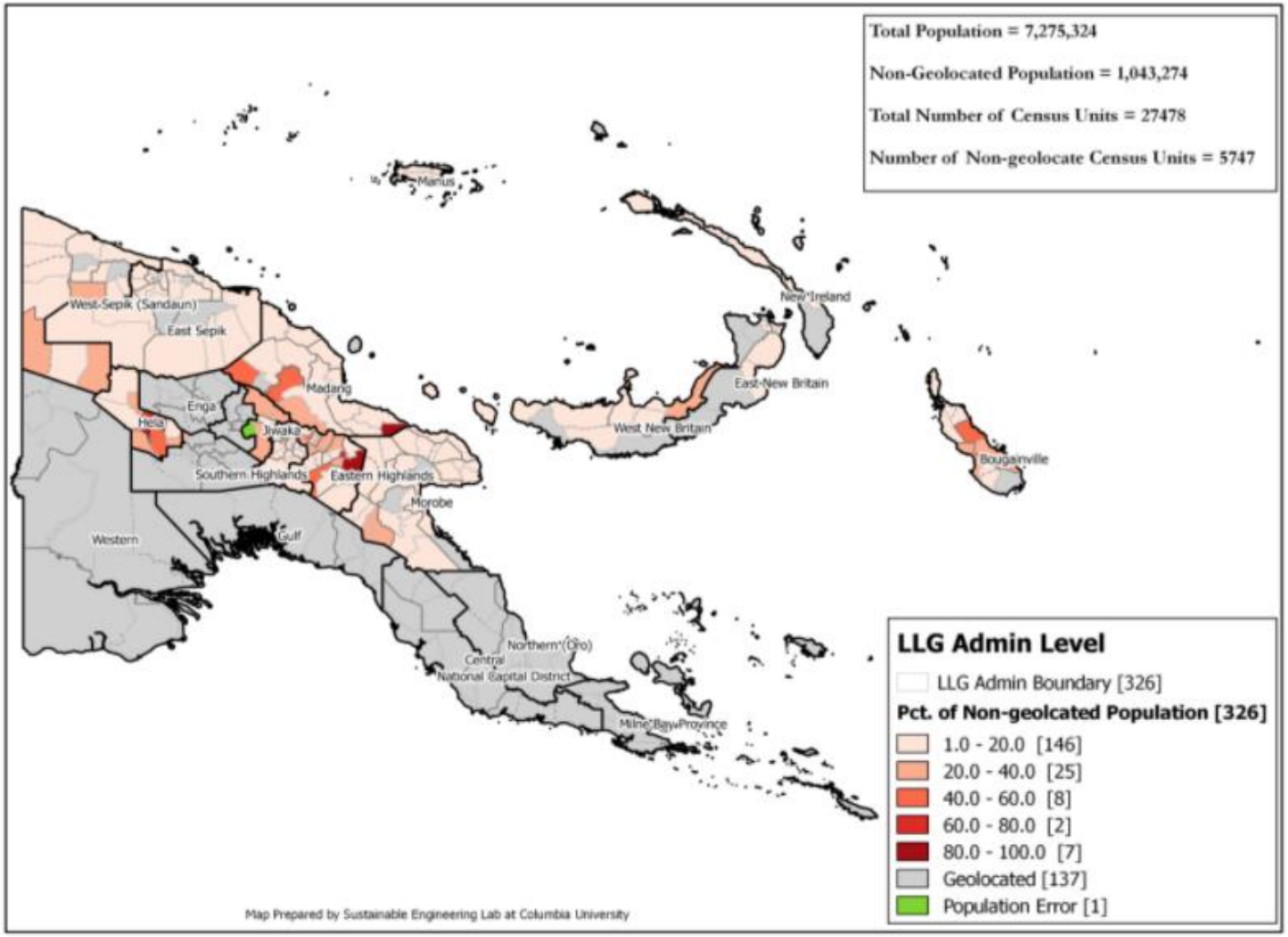
Payments: VISA T/T Online Transfer Pay WesternUnion WU

Source: Alibaba.com

Geospatial Model



Source: Columbia Earth Institute

PNG Pig Distribution

This is by far the dominant sector in which pigs are largely run free range scavenging but generally confined at night and fed food wastes, food crop surpluses, sweet potato and/or coconut. This production is a continuum of a 5,000-year tradition. The structure is differentiated by location. The highland provinces with 45% of the total rural households have 78% of households owning pigs. Four provinces have over 80% and Enga has 89%. Pigs/person ratios average 1.2 in the central highlands, dropping to 0.6 in the highland fringes. Utilisation is largely geared to ceremonial feasting. Lowland and island provinces have pig ownership ranging from 18 to 58% of rural households with pigs/person ratios averaging 0.3 for the inland lowlands and some coastal areas and 0.1 for most coastal areas and islands. Utilisation here tends to be more opportunistic with increasing live pig sales for cash needs. Nationally some 50% of pig owners have indicated some intent to sell pigs. In general, traditional smallholders have very little involvement in formal marketing. Their requirements may be to improve productivity rather than profitability. Some farmers may also keep other livestock, especially village chickens.

Source: Ministry of Agriculture and Livestock

Biogas Technical Feasibility

If the live weight of all animals whose dung is put into the biogas plant is known, the daily gas production will correspond approximately to the following values:

- cattle, buffalo and chicken: 1,5 liters biogas per day per 1 kg live weight
- pigs, humans: 30 liters biogas per day per 1 kg weight

Energy Production Potential

Appropriate feedstock for electricity-generating biogas plants is available in adequate quantity in many countries. Small and medium-size biogas plants could provide a considerable contribution to national electricity generation in such countries. However, in comparison to industrialised countries, only very few small and medium sized biogas plants are used for electricity generation in Africa, Latin America and even Asia.

Electricity production from biogas can be a very efficient method for producing electricity from a renewable energy source. However, this applies only if the emerging heat from the power generator can be used in an economically and ecologically sound way. The average calorific value of biogas is about 21-23.5 MJ/m³, meaning that 1 m³ of biogas corresponds to 0.5-0.6 l diesel fuel or an energy content of about 6 kWh. However, due to conversion losses, 1m³ of biogas can be converted only to around 1.7 kWhel.

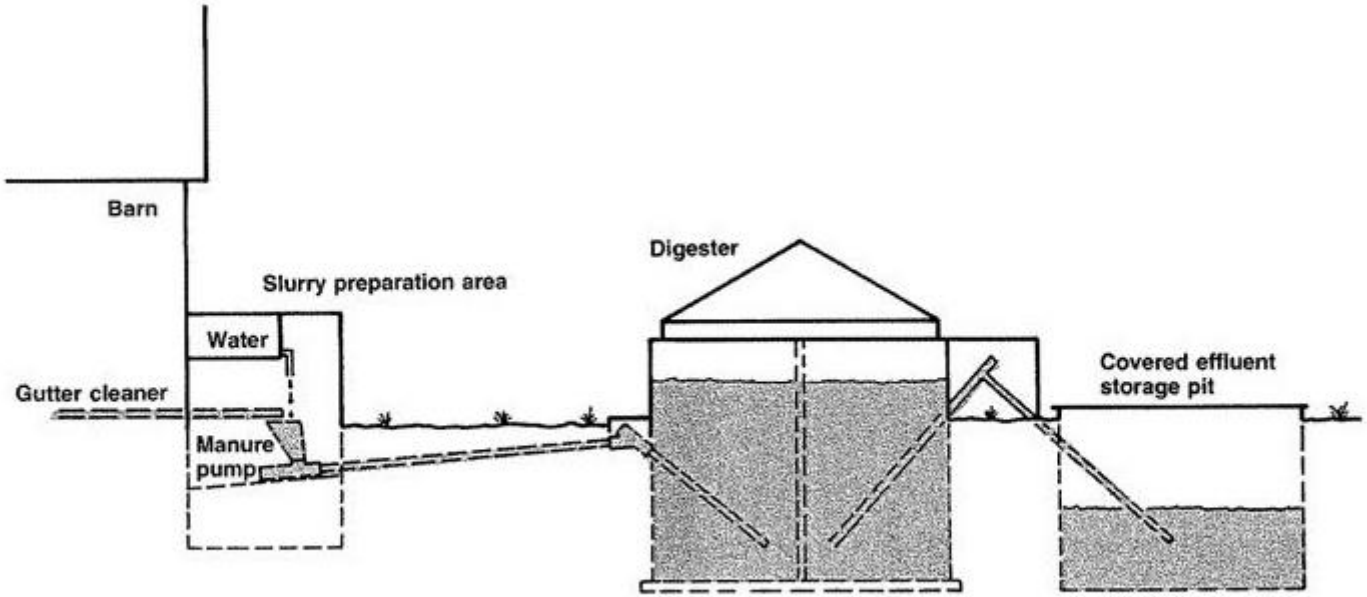
1,460,000 cubic feet (42,000 m^3 of biogas from the manure of 100 cows. This biogas has the energy value of 876,000,000 Btu (924,000 MJ).

If we know the energy value of conventional fuels, we can figure the equivalent price of conventional fuels to biogas by dividing the annual costs by the amount of fuel equivalent to the energy in the biogas produced:

Fuel	Energy per unit	Fuel equivalent to 876,000,000 Btu (924,000 MJ)	Equivalent price
Biogas	600,000 Btu/1000ft^3	1,460/1000ft^3	\$3.80/1000ft^3
	22.2 MJ/m^3	42,000 m^3	\$.13/m^3
Natural gas	1,000,000 Btu/1000ft^3	876/1000ft^3	\$6.34/1000ft^3
	37 MJ/m^3	25,000 m^3	\$.22/m^3

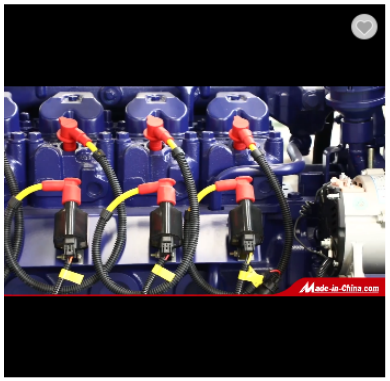
Source: PSU, Energypedia

Proposed Biogas Solution



Source: PSU

Biogas System Setup Cost



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Ready to Ship | In Stock | Fast Dispatch

Biogas Electric Generator Set Price 10kw 20kW 50kw 100kW 200kW 1mW for Bio Gas Power Plant Generation Hot sale products

5.0 1 Reviews 2 buyers

$4,400.00 - $270,000.00 / Set | 1 Set (Min. Order)

Output Type: AC Three Phase

Rated Power:		
	10KW/12.5kVA	$4,400.00
	20kW/25kVA	$5,300.00
	40kW/50kVA	$8,100.00

All 17 Options

Customization: Customized logo (Min. Order: 1 Sets)

Shipping time **45-90** days

Start Order

Contact Supplier

Call us

Add to cart

Gold Supplier

Weifang Haitai Power Machinery ...

Manufacturer, Trading Company

CN 9YRS 5.0

93.1% Response Rate

50,000+ for **5** Transactions

100.0% On-time delivery rate

Foundation (including sludge auger housing)	$2,500
Digester (including insulation)	4,600
Effluent storage	1,900
Roof (including insulation)	1,500
Gas pump	700
Boiler	600
Hydra-ram manure pump (including hydraulic unit)	4,900
Supplies and labor (estimated)	3,300
Total initial cost	$20,000

Source: Alibaba, PSU

Economic Benefit Estimation

1.1 Economic impacts of individual sectoral strategies by 2030

Sector	2030 Target	Increase in GNI (national income)		Increase in GDP (economic output)		Increase in tax revenue
		per cent	K'million	per cent	K'million	K'million
Land reform	Effective land reform	52.2	12,701	57.3	18,361	9,322
Law & order	55% fall in crime	61.7	15,027	48.2	15,450	6,230
Education	Quality education	7.2	1,910	9.6	3,520	960
Higher education	265,000 graduates	16.7	4,070	20.0	6,410	720
Road transport	Triple road network	8.9	2,170	8.9	2,850	770
Water transport	Triple capacity	4.2	1,030	3.7	1,200	390
Electricity	70% access	12.0	2,920	10.1	3,250	1,190
Agriculture	Internationally competitive	29.9	7,230	25.4	8,090	2,110
Fisheries	Double tuna revenues	0.3	80	0.1	23	60
Forestry	80% of exports processed	1.3	300	1.2	370	60
Oil	Maintain 2009 production	3.3	800	4.7	1,500	480
Gas	2 large projects	39.7	9,670	60.2	19,310	5,130
Mining	Double mining exports	8.0	1,930	10.9	3,480	790
Manufacturing	Triple production	23.8	5,760	22.9	7,300	2,200
Tourism	1.5 million tourists	30.0	7,320	21.2	6,810	2,440

1.2 Employment impacts of individual sectoral strategies by 2030

Sector	2030 Target	Increase in formal jobs		Increase in informal jobs		TOTAL
		Rural	Urban	Rural	Urban	
Land reform	Effective land reform	320,200	113,800	246,300	2,200	682,500
Law & order	55% fall in crime	46,700	373,600	173,200	6,300	599,800
Education	Quality education	9,600	5,800	2,300	-1,600	16,100
Higher education	265,000 graduates	33,200	143,800	29,900	1,400	208,300
Road transport	Triple road network	13,100	45,200	59,600	1,300	119,200
Water transport	Triple capacity	5,800	19,700	28,000	600	54,100
Electricity	70% access	22,000	49,200	30,300	-800	100,700
Agriculture	Internationally competitive	155,700	68,600	38,200	4,900	267,400
Forestry	80% of exports processed	-1,400	9,900	1,800	200	10,500
Fisheries	Double tuna revenues	-100	700	100	0	700
Oil	Maintain 2009 production	-2,400	5,500	-900	100	2,300
Gas	2 large projects	-20,200	79,900	-4,600	1,200	56,300
Mining	Double mining exports	1,100	30,800	7,800	400	40,100
Manufacturing	Triple production	28,800	74,000	71,500	3,200	177,500
Tourism	1.5 million tourists	-36,800	286,700	17,700	42,900	310,500

Source: 2010-2030 PNG Strategic Initiative