Review of off-grid mini-hydro developments in PNG

Recommendations Report

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1. Introduction

Papua New Guinea (PNG) is an independent state occupying the eastern half of the island of New Guinea and approximately 600 surrounding islands. Located in the South Pacific, it is the third-largest island country in the world and the largest Pacific Island nation in terms of both land area (462,800 km²) and population (recorded to be just over 10 million in the 2024 census (National Statistical Office, 2025)).

PNG's landscape is striking but challenging—dense rainforest, rugged mountain ranges, and deep valleys give way to extensive river systems, floodplains, swampy lowlands, and coastal environments of mangroves and reefs. This complex terrain has contributed to PNG being one of the least urbanised countries globally, with an estimated 87% of the population living in rural and remote areas (SEL, ECA, 2017), many of which are geographically isolated.

The combination of difficult terrain and highly dispersed settlement patterns has contributed to PNG having one of the lowest levels of electricity access in the world. While estimates vary, only 13 to 21 percent of the population currently has access to reliable electricity—well below the Oceania regional average of 81 percent (World Bank, 2024). Access is also highly uneven, as electrification programs have historically prioritised major urban centres, where higher load densities support more efficient infrastructure utilisation and make grid extension more economically viable. Urban electrification is estimated at around 65 percent, compared to just 14 percent in rural areas (World Bank, 2024).

In this context, off-grid electrification presents a significant opportunity to expand access to electricity in rural and remote communities in PNG.

1.1 Project overview

Whilst off-grid mini-hydro systems have been a part of PNG's energy landscape since the 1960s, in recent years, off-grid electrification efforts have been dominated by solar systems.

Drawing on a desktop review of existing mini-hydro schemes in PNG, site visits to three operational systems, a case study of Nepal's successful mini-hydro program, a review of mini-grid good practice, and a high-level assessment of the NEA Off-Grid Small Power Systems Regulation 2025, this study presents the first evidence-based analysis of the off-grid mini-hydro sector in PNG.

It has two primary objectives:

1. Provide an informed assessment of the effectiveness of current processes in installing, operating and maintaining mini-hydro systems in PNG; and
2. Provide an implementation plan to improve the management of existing systems and inform the sustainable development of future off-grid mini-hydro projects.

Overall, it is envisaged that the findings of this review will be used to help owners of existing mini-hydro assets:

– Understand, based on lessons from successfully operated mini-hydro systems in PNG, how to improve planned and preventative maintenance activities.
– Gain the necessary support from key stakeholders to facilitate these maintenance activities.

As a result, it is anticipated that the findings of this review will, if effectively disseminated and acted upon, help facilitate improvements in the long-term performance and sustainability of existing mini-hydro systems in PNG.

In addition, it is hoped that the report may help expand mini-hydro's currently limited role in PNG's regional electrification efforts by providing stakeholders with the confidence to support the development of new off-grid mini-hydro projects in situations where it is the preferable option.

1.2 Economic and Social Infrastructure Program (ESIP)

The Economic and Social Infrastructure Program (ESIP) is a joint initiative by the Government of Papua New Guinea (GoPNG) and Government of Australia (GoA) to improve the prioritisation, quality, and sustainability of infrastructure investment in PNG.

Launched in 2018, it is an 8-year program (concluding at the end of 2026), primarily funded by Australia's Department of Foreign Affairs and Trade (DFAT), which focuses on four infrastructure sectors: energy (both on-grid and off-grid electrification), telecommunications, water and sanitation, and social infrastructure.

This project, which sits within the energy subsector of ESIP's program, was jointly funded by DFAT and the Foreign, Commonwealth and Development Office (FCDO).

2. The case for mini-hydro in PNG

2.1 Mini-hydro: an overview

Water flowing in a stream or river has both kinetic and potential energy. In a mini-hydro system, a proportion of that energy is extracted for electricity generation. The generation capacity of the scheme depends on the flow rate and head (the elevation difference between the penstock intake and the turbine).

Mini-hydro schemes are almost exclusively run-of-river, diverting only a portion of the river's natural flow through a turbine before returning it downstream. Consequently, flow is reduced only along the section of river between the intake and outlet, with no impact on communities downstream of the outlet.

A typical mini-hydro system begins at a small weir which slightly raises the river level to create an area of pondage. An intake structure, typically incorporating a gate for flow regulation and a trash screen for debris exclusion, then diverts a portion of the ponded water into the headrace channel. The water moves along the headrace channel to a forebay, where sediment settles out, before dropping down a penstock to the powerhouse. In the powerhouse, the falling water spins a turbine connected to a generator to produce electricity. After passing through the turbine, the water is discharged via a tailrace channel to an outlet and returned to the river downstream.

This layout can be seen in Figure 2.1.

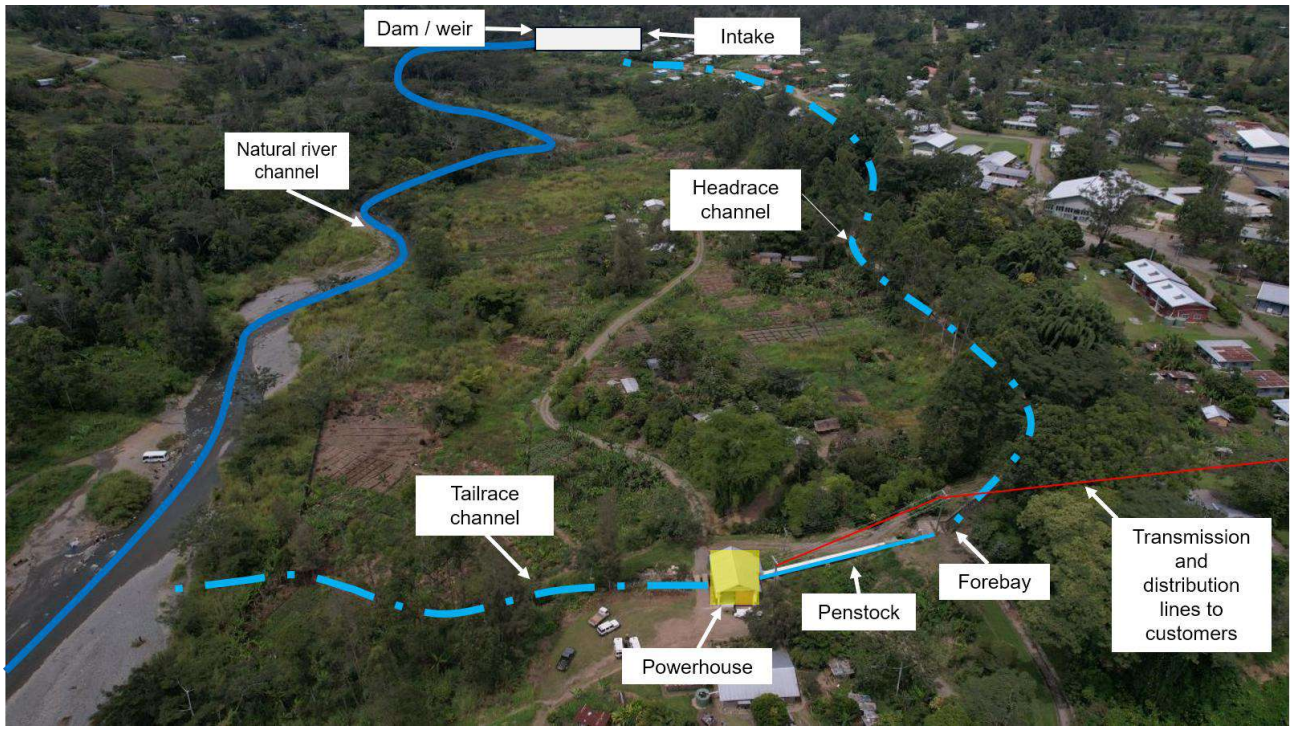


Figure 2.1 ***Aerial view of the Kudjip Nazarene Hospital mini-hydropower scheme demonstrating a typical mini-hydro run-of-river layout***

2.2 Mini-hydro in PNG: an overlooked opportunity

Off-grid mini-hydro systems—defined in this project as community-scale schemes typically ranging from 5 kW to 1 MW—can leverage PNG's high rainfall, steep catchments, and extensive river systems to deliver reliable renewable power as an alternative or adjunct to diesel and solar/battery-energy-storage-system (BESS) generation.

Historically installed and operated by a diverse range of stakeholders (including faith-based missions, community organisations, private enterprise and government departments), off-grid mini-hydro systems have been a part of

PNG's energy landscape since the 1960s. However, rapid declines in solar panel and battery costs over the past decade have seen mini-hydro increasingly overlooked in favour of solar/BESS, with no new schemes implemented since 2017.

Nevertheless, the absence of recent mini-hydro development does not mean the technology is unsuitable. In fact, the recent focus on solar/BESS risks overlooking mini-hydro in locations where it may be the more effective electrification solution.

2.3 Solar/BESS and mini-hydro in PNG's off-grid context

Both solar/BESS and mini-hydro technologies remain viable options for off-grid electrification in PNG, with suitability largely determined by local conditions.

Overall, solar/BESS systems are modular, largely location-independent, and can be predominantly prefabricated off-site. As a result, they typically require less site-specific engineering and civil works than mini-hydro schemes and can generally be deployed more quickly. While these reduced civil works requirements often contribute to solar/BESS being the preferred solution internationally, this advantage may be less pronounced in PNG, where community labour is frequently provided as an in-kind contribution.

A key limitation of solar/BESS systems is that solar panels only generate electricity during daylight hours, meaning capacity factors (the proportion of a system's theoretical maximum output that is actually generated) are typically lower. As a result, they require substantially greater installed capacity to deliver the same energy output as a mini-hydro scheme, which can operate continuously.

Solar/BESS systems also have shorter asset lives, with components such as batteries and panels requiring replacement over time. In PNG, the remote location of many off-grid systems can make the responsible disposal of end-of-life equipment difficult, creating long-term e-waste management challenges for asset owners. In contrast, well-maintained mini-hydro schemes can operate for many decades, with the mechanical nature of the systems enabling components to be repaired rather than replaced, reducing waste generation over the asset life.

A more detailed comparison between the generation technologies is provided in Table 2.1.

Table 2.1 Solar/BESS generation compared with mini-hydro generation in PNG'S off-grid landscape

Criteria	Solar/BESS	Mini-hydro
Preferred location	– Best suited to areas with strong solar irradiance	– Best suited to areas with reliable year-round water source and elevation difference
Installed capacity	– More installed capacity required to meet demand (lower capacity factor, less energy per kW installed)	– Less installed capacity required to meet demand (higher capacity factor; more energy per kW installed)
Asset life	– Typically up to ~30 years (panels: ~20-30 years, batteries: ~10–15 years) – Can result in long term e-waste challenges	– Long operational life if well maintained (often far exceeding solar systems)
Design	– Largely location-independent	– Location-dependent
Installation	– Faster to deploy with minimal civil works	– More site-specific, with greater civil works requirements
Operation and maintenance requirements	– No moving parts; relatively low maintenance requirements	– Moving parts require regular preventative maintenance – Civil works exposed to environmental risks (e.g. flooding, landslides)
Repairability	– Limited repairability often necessitates component replacement	– Mechanical nature of system increases repairability
Local content	– Low with virtually all components imported and only a small installation labour input	– High with all but generators, cabling and switchgear locally manufactured and high local labour content in civil works

Criteria	Solar/BESS	Mini-hydro
Land use requirements	– Land requirements scale with capacity (a small 5 to 10 kW system requires approximately 50 m2, whilst a 1 MW system requires 10,000 m2) – May occupy limited customary land parcels while benefiting wider communities, potentially increasing compensation expectations	– Scale less with size. On larger schemes, can use significantly less land than equivalent solar system – Dispersed footprint spanning multiple customary land parcels, spreading impacts across beneficiaries, potentially reducing compensation expectations

2.4 Advances in mini-hydro technology

Although few mini-hydro projects have been developed in PNG in recent years, the technology has continued to evolve globally. Many of the innovations that have transformed the renewable energy sector are equally applicable to mini-hydro.

For example, most modern wind turbines use asynchronous generators with inverter-based controls to provide a stable alternating current output. The same approach can be applied to mini-hydro schemes, providing a lower-cost alternative to conventional synchronous generators, gear boxes and belt drives, and mechanical governors. Advances in materials have also created new opportunities, with glass-reinforced plastics and high-strength extruded components offering advantages in weight, durability, transportability, and installation. Emerging manufacturing techniques, such as 3D-printed turbine runners, also have the potential to reduce costs and simplify component replacement.

In addition, prefabricated powerhouse units contained within shipping containers are being rolled out by multiple suppliers globally. These systems can be transported to site as complete, factory-tested packages, minimising on-site electromechanical installation works. By bringing many of the same modularisation benefits that have driven the rapid uptake of solar/BESS systems, they reduce construction risk, improve quality control, facilitate standardised operator training, and support faster, more repeatable deployment across multiple sites.

Ensuring these advancements are incorporated into future mini-hydro developments will be critical to improving the performance, competitiveness, and long-term sustainability of off-grid mini-hydro in PNG.

3. Community support: a key advantage for off-grid electrification in PNG

Approximately 97% of land in PNG is held under customary tenure, making land access a key consideration for infrastructure development. While multiple legal pathways exist for the registration of customary land, these processes are often complex, time-consuming and inconclusive, requiring careful coordination between communities, government agencies, and project partners. Consequently, strong stakeholder engagement is critical for all projects, with early engagement grounded in free, prior and informed consent needed to build trust and secure community support.

As on-grid projects typically provide little perceived direct benefit to the communities in which they are located beyond temporary construction employment, they often attract significant land compensation and vegetation damage claims. Community expectations for the financial value of these claims can be high, perhaps influenced in part by precedents established by extractive industry projects in PNG, but reflecting the high social value assigned to land.

By contrast, off-grid electrification projects offer a distinct advantage, as the communities hosting the systems are typically the same communities that benefit directly from the electricity supplied. This can reduce land-related tensions and compensation expectations while strengthening local ownership and support. This was evident during the project's April 2026 site visits to three operational off-grid mini-hydro schemes (refer to Section 6).

This advantage may be particularly relevant when comparing solar/BESS and mini-hydro. While both technologies can have significant land requirements at the scale typically required for community electrification, larger mini-hydro schemes often require substantially less land than an equivalent solar/BESS system. In addition, whereas solar/BESS systems typically concentrate land-use impacts on a relatively small number of landowners, mini-hydro schemes generally distribute impacts across a broader group of landowners, reducing the likelihood of a small number of individuals feeling they are bearing a disproportionate share of project impacts. Together, the smaller land footprint and more dispersed impacts of mini-hydro may reduce compensation expectations and opposition to project development.

4. PNG's electricity landscape

4.1 Key stakeholders in the electricity sector

4.1.1 National Energy Authority (NEA)

The National Energy Authority (NEA), established under the National Energy Authority Act 2021, is the independent regulator responsible for overseeing PNG's electricity sector (both on-grid and off-grid). Its core regulatory functions include:

– Economic regulation, covering the licensing of electricity undertakers and oversight of tariffs and power purchase agreements to support affordable, accessible, and reliable energy supply; and
– Technical regulation, encompassing compliance with electrical standards, safety enforcement, and the licensing of electricians.

In addition to its regulatory role, the NEA is also responsible for implementing national energy policy, including preparing implementation plans for the National Energy Policy 2017–2027 and developing programmes under the National Electrification Rollout Plan (NEROP).

Finally, the NEA is also tasked with project implementation across both the on-grid and off-grid sectors. In the off-grid sector, this includes identifying and assessing the feasibility of small to medium sized off-grid developments in rural areas across PNG.

As a result, in its current form, the NEA has a wide remit in the electricity sector in PNG, performing three core roles:

– **Regulator:** overseeing economic and technical aspects of the electricity sector, including licensing, tariffs, power purchase agreements, and compliance with standards;
– **Policy implementer:** translating national energy policy into implementation plans and programmes, including delivery of NEROP; and
– **Project delivery agency:** identifying, coordinating, and supporting the development of power projects across both on-grid and off-grid sectors.

To address these differing, and potentially conflicting, roles, the NEA has four Policy and Technical Divisions, as shown in Figure 4.1.

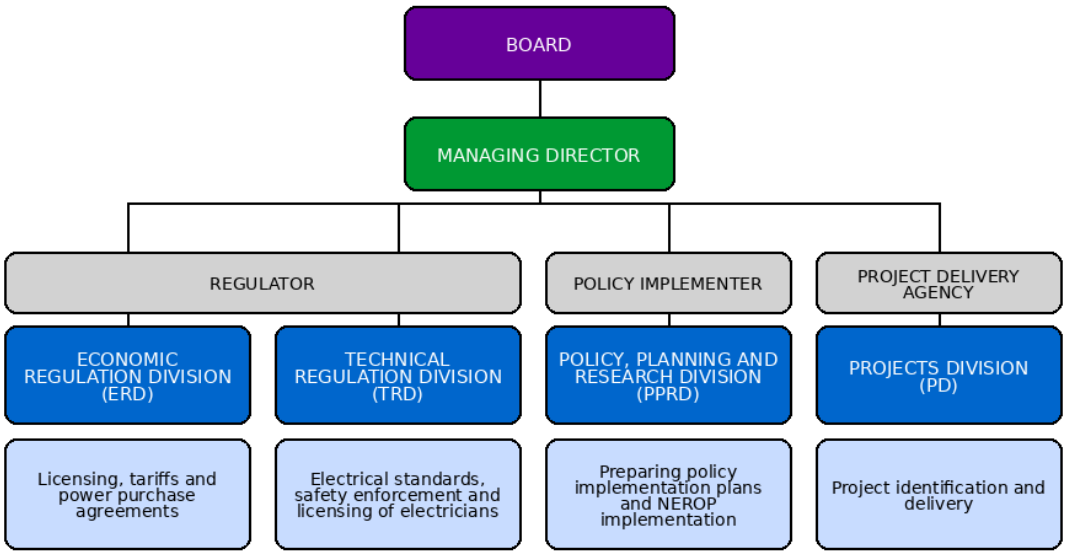


Figure 4.1 NEA Policy and Technical Divisions organisational structure after (NEA, 2026)

4.1.2 PNG Power Limited (PPL)

PNG Power Limited (PPL) is the state-owned utility responsible for on-grid electrification, wholly owned by the Government of Papua New Guinea. It does not provide off-grid electrification services.

4.1.3 National, Provincial, District and Local Level Government

Administratively, Papua New Guinea comprises 22 province-level entities (20 provinces, the Autonomous Region of Bougainville, and the National Capital District) subdivided into 89 districts and 326 local-level government (LLG) areas. These are administered through provincial governments, District Development Authorities (DDAs), and LLG administrations, respectively (Figure 4.2).

Provincial and district development is funded through annual national budget allocations administered by the Department of Finance via the Provincial Services Improvement Program (PSIP) and District Services Improvement Program (DSIP) (The National, 2026). Historically, these programs have provided at least partial funding for many electrification projects outside those delivered by PPL, donors, churches, NGOs, and educational institutions. While provinces and districts are each allocated PGK10 million annually, disbursements are often delayed or reduced; 2025 was the first year in which all received their full allocations (The National, 2026).

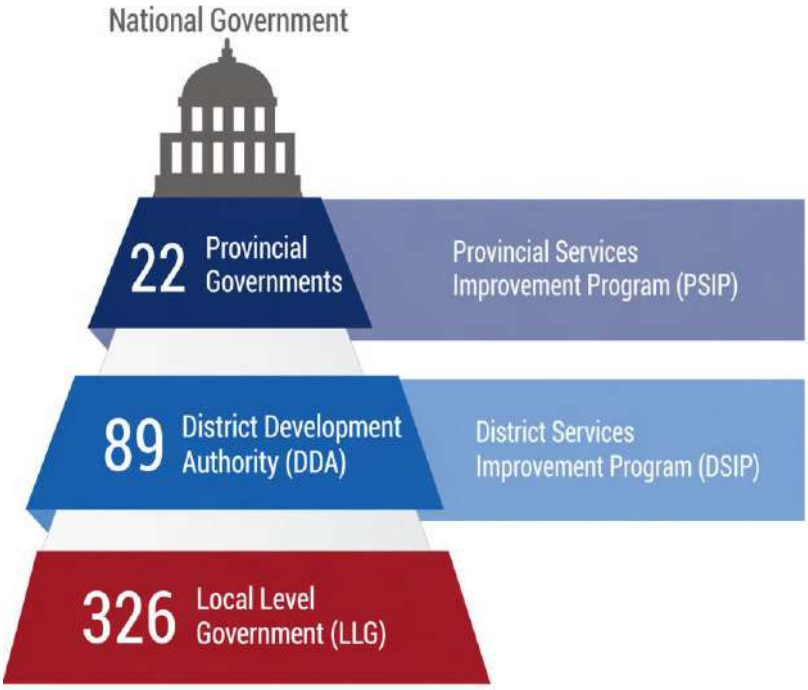


Figure 4.2 PNG Government structure after (USAID-PEP, 2022)

4.1.4 Donor agencies

Donor agencies have been active in PNG's energy sector for many years. Key donors agencies include multilateral development agencies such as the World Bank Group, the Asian Development Bank (ADB), and the United Nations Development Programme (UNDP), as well as bilateral agencies including Australia's Department of Foreign Affairs and Trade (DFAT), the United Kingdom's Foreign, Commonwealth & Development Office (FCDO), the Japanese International Cooperation Agency (JICA), the New Zealand Ministry of Foreign Affairs and Trade (MFAT), and the United States Agency for International Development (USAID).

Major donor-supported programmes in PNG's electricity sector include the PNG Electrification Partnership (PEP), which brings together funding from Australia, Japan, New Zealand, and the United States with the aim of expanding electricity access in Papua New Guinea, and the Pawarim Komuniti Partnership (PKP), funded by DFAT and FCDO to support access to clean off-grid energy in rural and remote communities.

Donor agencies provide essential funding, technical assistance, and capacity-building support to help develop and implement energy projects—particularly in rural and off-grid areas where commercial investment alone is often not viable.

4.1.5 Religious missions and church organisations

From as early as the 1950s, religious missions and church organisations have driven off-grid electrification in PNG. Demand was led by the need to power mission stations, schools, clinics, training centres and workshops. These organisations developed diesel power stations and, where feasible, mini-hydro schemes.

4.1.6 Non-governmental Organisations

Non-governmental organisations have played a smaller role in off-grid electrification in PNG with three projects to date. The NGOs behind these projects were: APACE (Appropriate Technology for Community and Environment Inc.), Friends of Faseu, and the Hans Wilsdorf Foundation.

4.1.7 Educational Institutions

Educational institutions have also played a role in mini-hydro development. In particular, the University of Technology in Lae (UniTech) and the Appropriate Technology and Community Development Institute (ATCDI) were active during the 1980s. Such organisations could provide technical support during site selection, design and operations from their existing capabilities, but also capacity building such as training, general education and potentially employment of graduates.

4.2 On-grid electrification

As the utility responsible for on-grid electrification, PPL owns and operates three main grids, which service PNG's largest urban centres, and 17 standalone provincial mini-grids, which serve PNG's provincial centres (also known as C-centres).

The three main grids are the:

– Port Moresby Grid;
– Ramu Grid; and
– Gazelle Peninsula Grid.

The Port Moresby Grid serves the country's capital and largest city, Port Moresby; the Ramu Grid supplies the principal economic and industrial centres in the Momase Region and Highlands (including the country's second-largest city, Lae); and the Gazelle Peninsula Grid serves East New Britain Province. The total installed capacity across these grids is approximately 450 MW, comprising a roughly even split between hydropower and thermal generation. Details of the three main grids can be found in Table B.1 in Appendix B.

Beyond these main grids, electricity supply in provincial centres is instead provided by a series of standalone mini-grids. All but two of the 17 provincial mini-grids are diesel-powered, with two, Kimbe and Bialla, operating on a combination of diesel and hydropower. All 17 charge a uniform regulated tariff. However, this uniform tariff is set at a level which means that all 17 grids operate at a significant loss (USAID-PEP, 2022). As a result, responsibility for these systems has historically passed between PPL and provincial governments due to their lack of commercial viability at the regulated tariff levels. Details of the 17 standalone provincial mini-grids are provided in Table B.2 in Appendix B.

Figure 4.3 shows the location of PPL's three main grids and 17 provincial mini-grids.



Figure 4.3 Map of PPL's main grids and provincial mini-grids (PNG Power Ltd, 2016)

4.3 Off-grid electrification

With electrification efforts historically concentrated on urban centres, only about 11% of rural households are connected to a PPL network (World Bank, 2024), meaning approximately 7 million Papua New Guineans remain beyond the reach of the grid.

As defined in the NEA Off-Grid Small Power Systems Regulation 2025 (NEA, 2025), "off-grid" systems in PNG are those not connected to, or served by, PPL or any other Distribution Licensees.

Currently, off-grid electrification in Papua New Guinea is delivered through a combination of religious organisations, private entities, not-for-profits, donor agencies and government actors (primarily Provincial Governments and District Development Authorities). In the absence of a coordinated national implementation framework, these initiatives are typically undertaken on an ad-hoc basis.

To identify the potential scope of future off-grid electrification, geospatial least-cost modelling undertaken for the National Electrification Roll-Out Plan (NEROP) in 2016 found that off-grid and mini-grid solutions were the least-cost option for 20 to 35% of PNG's unelectrified population. However, the modelling assumed diesel-based mini-grids, biasing results toward grid extension. Under lower-cost generation renewable scenarios (e.g. hydro or solar hybrid systems), mini-grids are likely to play an even greater role (SEL, ECA, 2017). USAID-PEP extended this analysis by incorporating socioeconomic factors, identifying communities with the highest demand potential based on asset ownership. It found that mini-grids could serve 24 percent of unelectrified households. Taken together, the analysis underscores off-grid electrification as a key pathway to expanding electricity access in PNG.

5. Existing mini-hydro schemes in PNG

The desktop review undertaken for this report represents the most comprehensive dataset of mini-hydropower systems in PNG compiled to date, bringing together previously fragmented information to provide a robust evidence base for understanding the current state of the sector and informing future development.

In total, 64 existing mini-hydro systems in PNG (typically ranging from 5 kW to 1 MW) were identified. This is comprised of 62 off-grid systems and two PPL-operated systems (Lake Hargy and Ru Creek in West New Britain), which, while technically outside the scope of this study, have been retained due to the valuable operational insights they provide.

A further 20 pico-hydro systems (less than 5 kW) were identified during the desktop review, however, these were excluded from the analysis as they are beyond the scope of the study.

The locations of the 64 identified schemes are shown in Figure 5.1 (with the two dark blue markers representing PPL-operated systems). The distribution indicates that mini-hydropower development in PNG is concentrated on the mainland, with relatively limited development in island provinces.

Full details of all 64 mini-hydro schemes are provided in Appendix A.

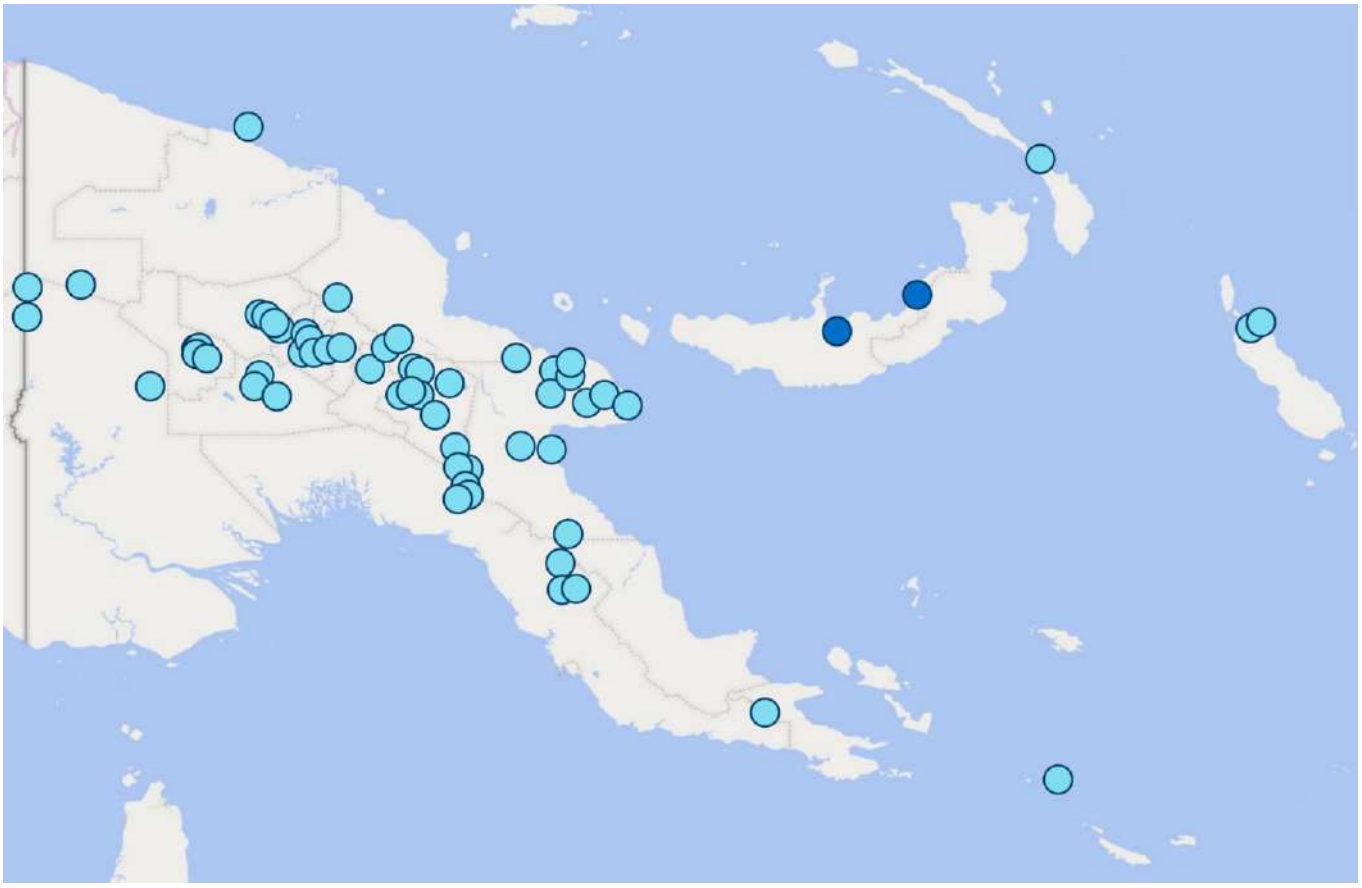


Figure 5.1 ***Location of the 64 mini-hydro schemes identified in the desktop review (light blue: off-grid schemes, dark-blue: PPL-operated schemes)***

The reason for the concentration of schemes on the mainland becomes apparent when the dataset is overlaid on a topographic map (Figure 5.2). The spatial distribution is strongly aligned with the more mountainous regions of the country, where higher available head improves the economic viability of mini-hydropower developments.

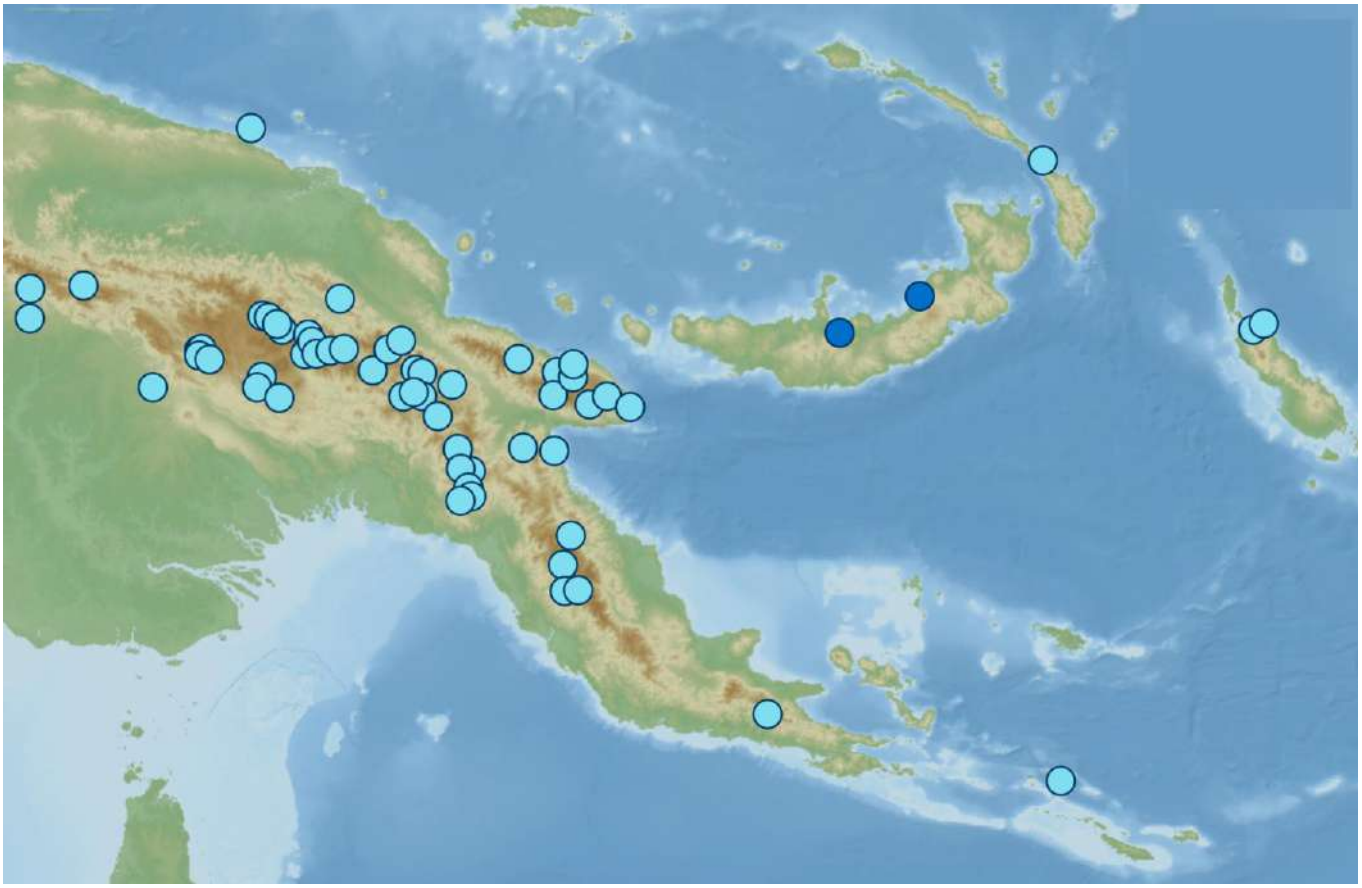


Figure 5.2 Mini-hydro schemes overlayed on topographic map of PNG

5.1 System developers

Developers of mini-hydropower systems in PNG have been categorised into six groups for the purpose of this desktop review:

- **Government**: Includes national, provincial, district, and local-level governments, typically funding and delivering schemes as part of public service provision.
- **Religious missions**: Mission organisations developing systems to support health, education, and community services in remote areas.
- **Not-for-profits**: NGOs and donor-supported organisations implementing schemes as part of development or community support programs.
- **ATCDI/Unitech**: Academic and technical institutions involved in the design, development, and implementation of small-scale hydropower systems (primarily to provide students with hands-on experience).
- I**nfrastructure Tax Credit Scheme (ITCS)**: A government program introduced in 1992 that allows eligible private companies, typically in the resource sector, to fund approved infrastructure projects and offset these expenditures against their tax obligations.
- **Private**: Commercial developers or individuals implementing schemes to generate electricity for their commercial enterprises (e.g. hotels or farms).

Figure 5.3 presents the number of systems developed by each category of developer. Religious missions account for the largest share of schemes (37), followed by government entities (13). Together, these two categories represent the clear majority of systems identified, indicating that mini-hydropower development in PNG has been driven primarily by mission-led and public sector delivery. The remaining four categories of developer each account for only three to four schemes, suggesting that private, institutional, and tax-credit-supported development pathways have so far played a relatively limited role.

This highlights a significant opportunity for increased donor engagement to support the mini-hydropower sector in PNG.

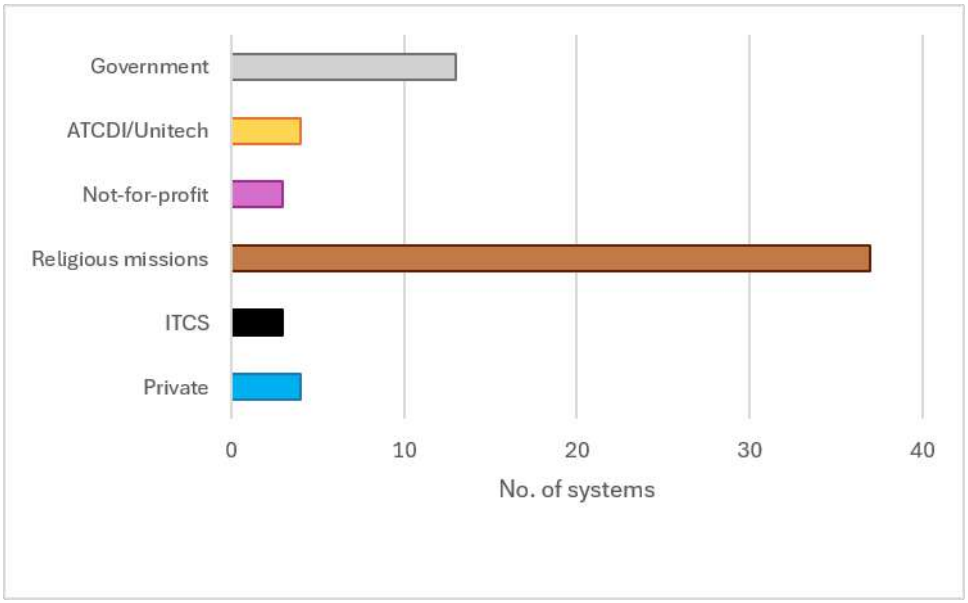


Figure 5.3 Number of mini-hydro projects developed by each category of developer

The geographical distribution of systems developed by each category of developer is shown in Figure 5.4. Schemes developed by religious missions are concentrated in the Highlands region, while those developed by other categories are more evenly distributed across the country. The exception is schemes developed under the ITCS program, which, unsurprisingly, are clustered around major mine sites.

The clustering of mission-developed schemes in the Highlands appears to reflect established mission networks and service corridors, particularly in remote inland regions where these organisations have long-standing operational presence. By contrast, ATCDI/UniTech schemes are not concentrated around Morobe Province, where the institution is based, but are instead geographically dispersed. Government-developed schemes also show a broad national distribution, including coastal and island regions, reflecting a wider geographic mandate.

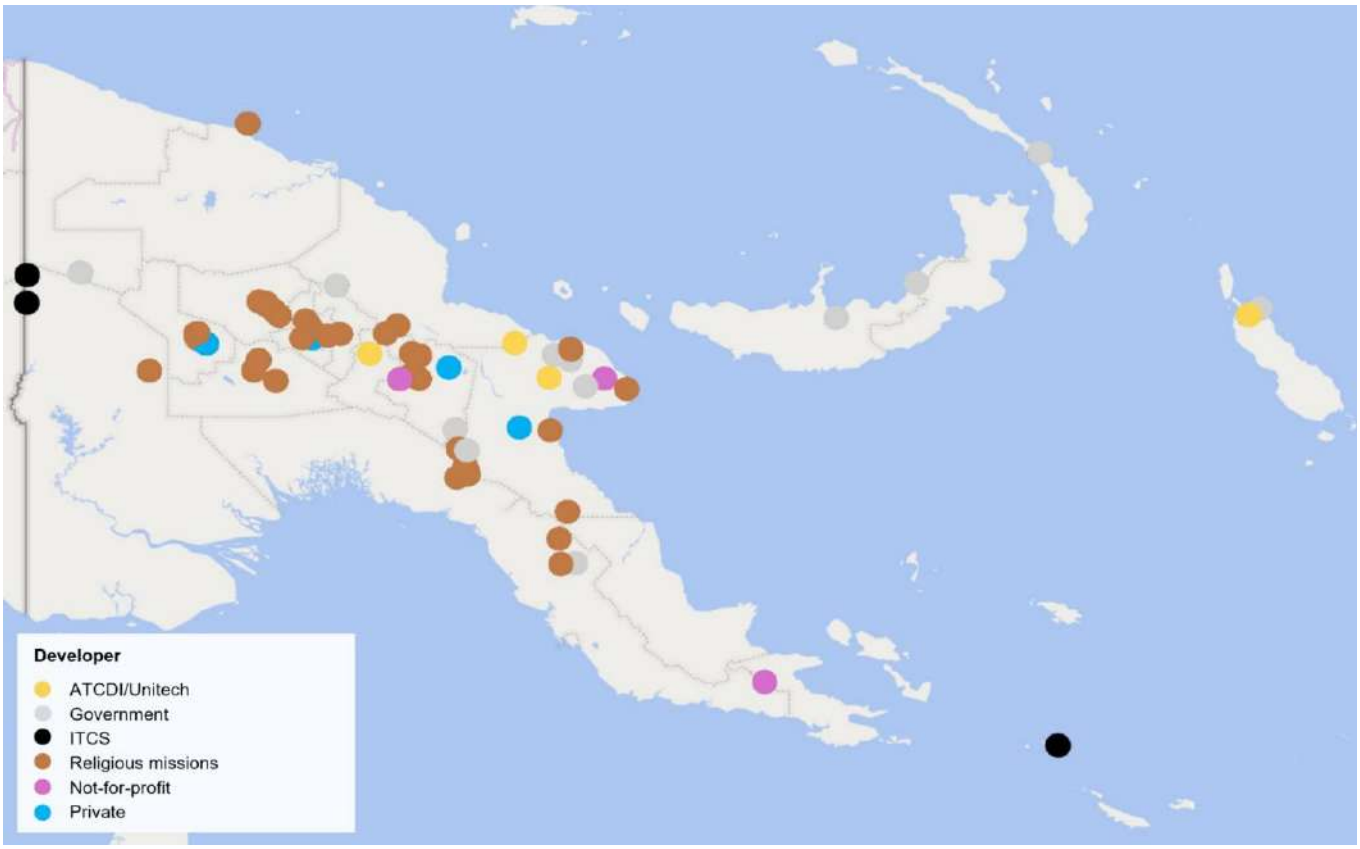


Figure 5.4 Geographical distribution of mini-hydro schemes categorised by system developer

Figure 5.5 shows how system developer and installed capacity have varied over time, providing insight into the chronological progression of the mini-hydropower sector in PNG. The figure indicates that early development was driven primarily by religious missions, which account for the majority of the earliest recorded schemes. Government later became more active, particularly from the late 1970s onward, and was involved in several higher-capacity developments. From the 1980s onward, the developer base widened further, with not-for-profits, ATCDI/UniTech, private developers, and ITCS-supported projects appearing in the record. Taken together, the figure suggests that PNG's mini-hydropower sector evolved from a relatively narrow, mission-led base into a more diverse development landscape involving a broader mix of government, institutional, and private actors.

The figure also highlights that almost all schemes fall below 300 kW in capacity, with the exception of the two PPL-operated schemes, which are significantly larger.

Of note is the absence of any new schemes since 2017, indicating that there has been little to no development activity in the mini-hydropower sector for almost a decade.

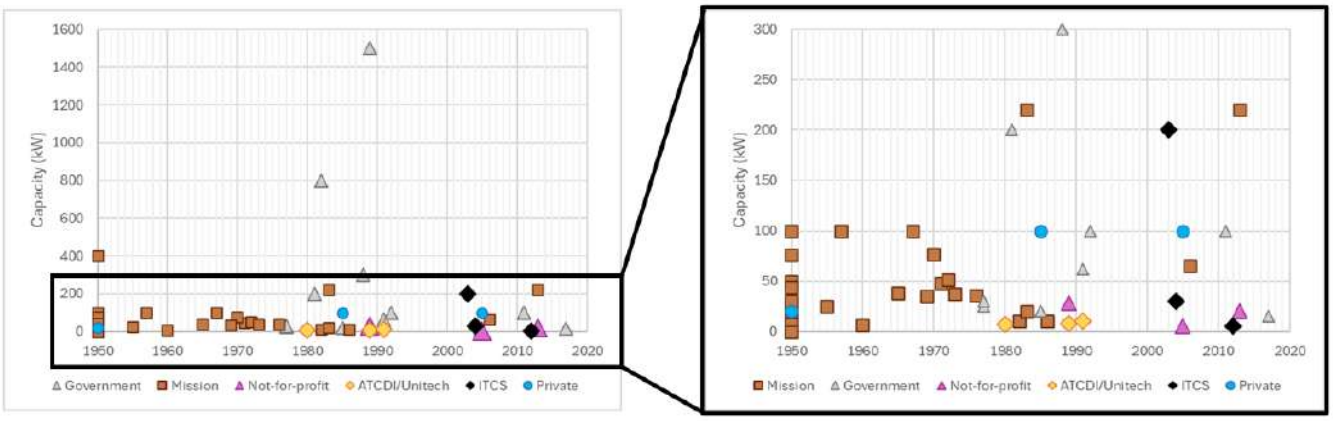


Figure 5.5 Capacity and commission year of schemes categorised by type of developer

Note: Some systems lacked recorded commissioning dates; however, in all cases the earliest available records were from 1976, 1980, or 1984. To distinguish these systems from those with documented commissioning dates, a dummy commissioning date of 1950 was assigned for plotting purposes. Where system capacities were unknown, a value of 0 kW was assigned for plotting purposes.

5.2 Operating status

The operational status of schemes categorised by developer category is presented in Figure 5.6. Excluding schemes operated by PPL, there are only eight operating off-grid mini-hydropower systems in PNG. ESIP and GHD conducted site visits to three of these systems.

Of the 11 commissioned government schemes, four remain operational; however, this includes Ru Creek and Lake Hargy, which are operated as part of PPL's provincial mini-grid network.

The majority of schemes developed by religious missions are no longer operational, although the operational status of 12 schemes remains unconfirmed. Across all other developer categories, operational schemes are also limited, with only one not-for-profit scheme and two privately developed schemes currently in service.

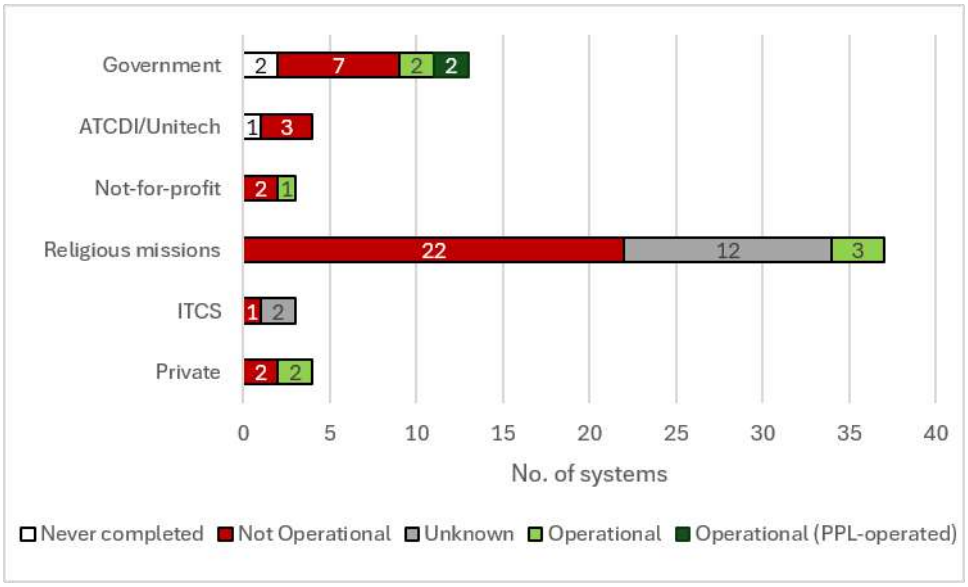


Figure 5.6 Breakdown of schemes by type of developer and operational status

The geographical distribution of operational mini-hydropower systems is shown in Figure 5.7. All operational schemes, except the two PPL-operated schemes in West New Britain, are located within the Highlands Region and Morobe Province.

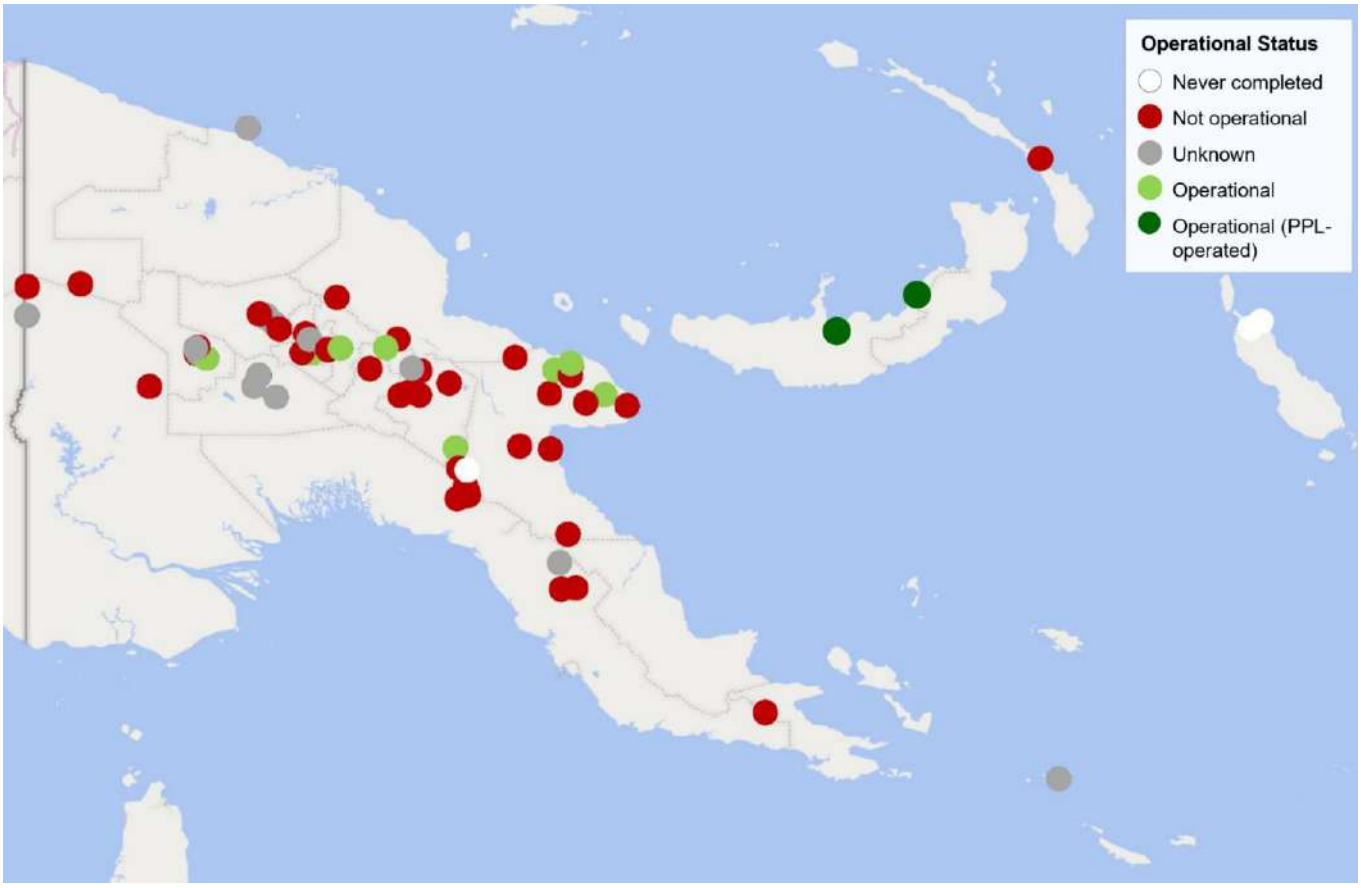


Figure 5.7 Geographical distribution of mini-hydro schemes categorised by operational status

Figure 5.8 indicates a strong relationship between commissioning date and current operational status, with the vast majority of operational mini-hydropower schemes concentrated among more recent developments. Almost all schemes commissioned prior to 2000 are either non-operational or have an unknown operational status. The only exceptions are the two PPL-managed schemes (Lake Hargy and Ru Creek), one religious mission scheme established prior to 1976, and one privately developed scheme.

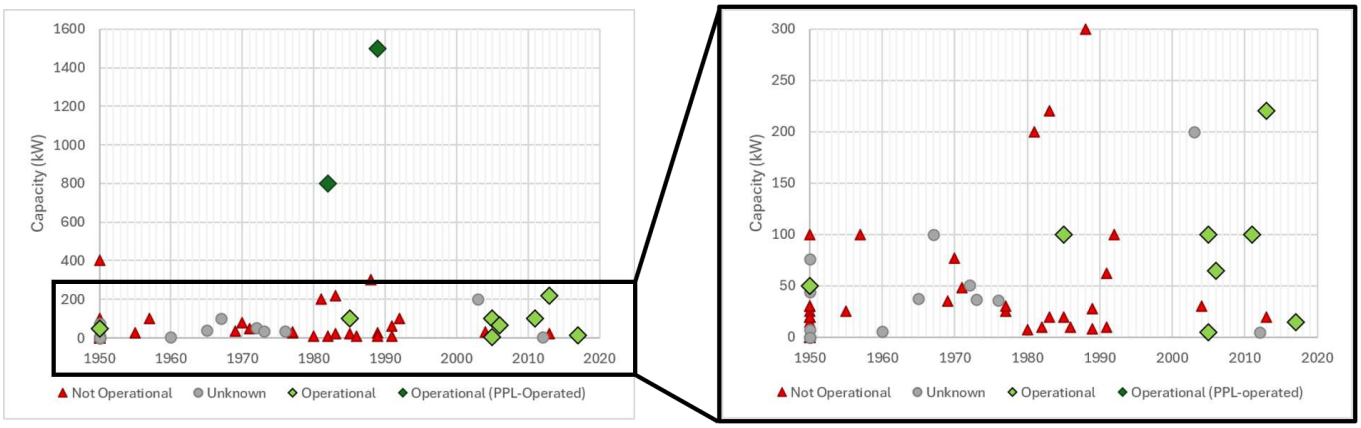


Figure 5.8 Capacity and commission year of schemes categorised by operational status

The concentration of schemes with unknown status prior to 1980 consists predominantly of mission-developed systems, as illustrated in Figure 5.9. Given that a large number of mission schemes commissioned during this period are confirmed to be non-operational, it is likely that these schemes with unknown status are also no longer in service.

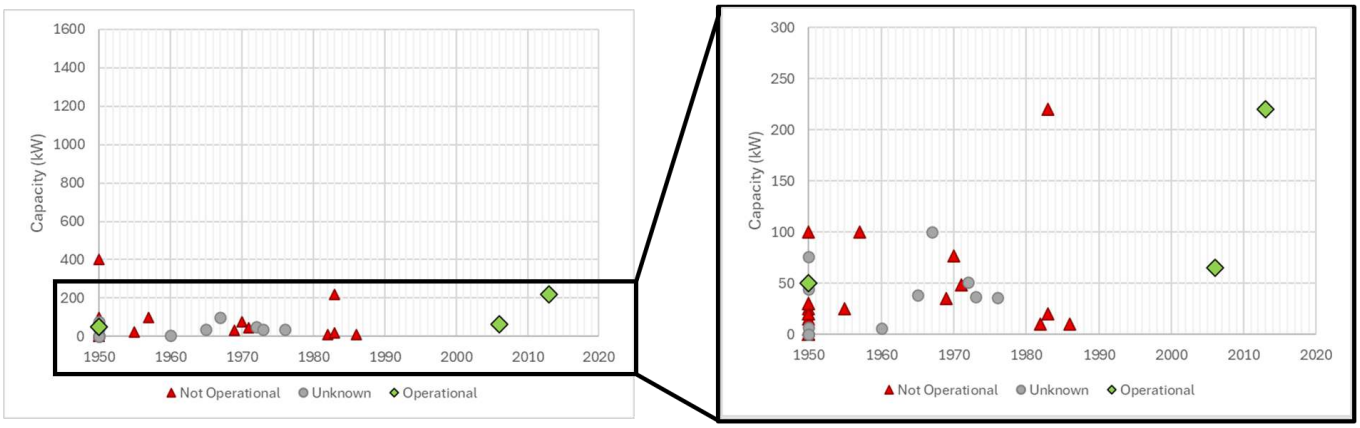


Figure 5.9 Mission-only capacity and commission year categorised by operational status

Figure 5.10 presents scheme capacity by developer category and operational status. Operational off-grid mini-hydropower systems (not including those owned and operated by PPL) range from 5 kW to 220 kW, indicating that capacity alone is not a reliable predictor of long-term operability.

The plot also portrays the range in capacities typically constructed by different developers. Mission and Government developers have constructed schemes across the widest capacity ranges, whereas ATCDI/UniTech and not-for-profit developments are confined to systems below 50 kW.

Schemes which remain operational are spread evenly throughout the developer's constructed capacity ranges (or do not have adequate sample size), making it difficult to draw correlations into optimal scheme sizes for each category of developer. Across most developer categories, both operational and non-operational schemes occur within similar capacity bands, suggesting that factors other than installed capacity—such as institutional support, maintenance arrangements, and site context—are likely to be more important determinants of long-term performance.

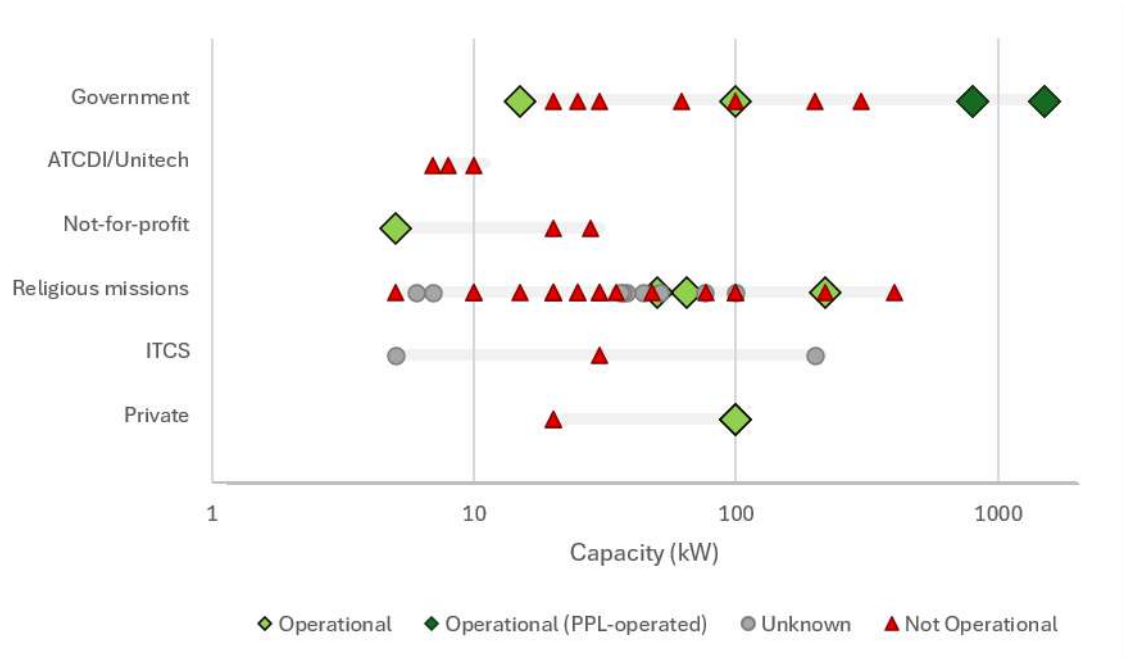


Figure 5.10 Capacity and operational status of schemes by developer

5.3 Causes of system failure

Using all available information, a failure mode analysis was conducted on non-operational mini-hydro systems to provide insight into the dominant reasons for off-grid system failure. Four primary failure modes were identified:

– Operation and maintenance
– Natural disaster
– Design
– Funding

In cases where multiple failure modes occurred concurrently, all relevant causes were recorded. As a result, the total number of recorded failure modes may exceed the number of schemes assessed.

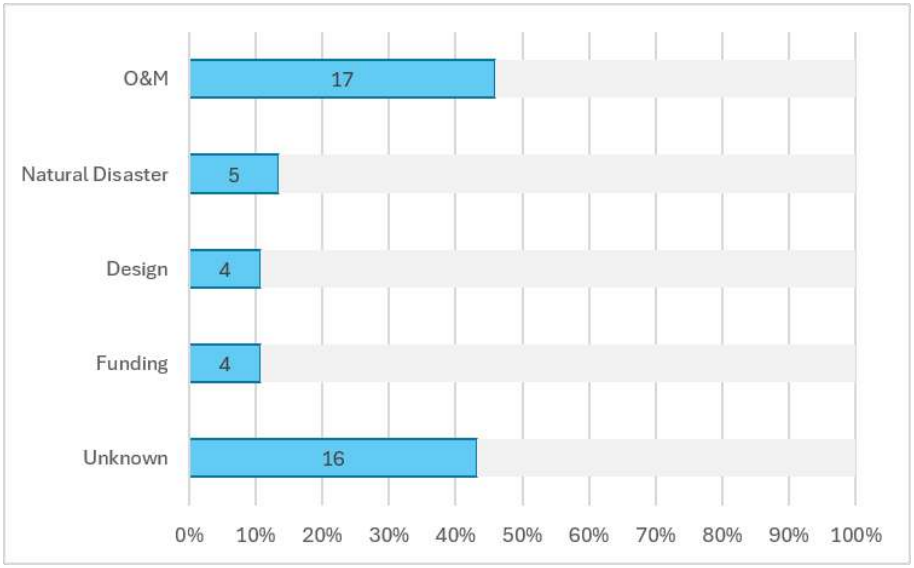
Table 5.1 Failure mode categories

Primary failure mode	Description	Common examples
Operation and Maintenance	Failure arising from inadequate system management and maintenance, including loss of skilled personnel.	• Departure of trained operators without replacement • Lack of preventative maintenance leading to system failure
Natural disaster	Catastrophic damage caused by extreme or unforeseen natural events.	• Landslides damaging or destroying infrastructure • Flooding washing away weirs or intake structures
Design	Inherent design deficiencies resulting in poor system performance and reduced reliability.	• Inadequate intake design • Improper electrical/mechanical control mechanisms
Funding	Insufficient or withdrawn funding preventing effective operation, maintenance, or repair.	• Withdrawal of external funding support • Inability to finance repairs or replacements
Unknown	Cause of failure could not be determined based on available information.	N/A

Overall, across the 37 non-operational schemes identified in the desktop review, operations and maintenance (O&M) failures are by far the dominant cause of system failure in Papua New Guinea, accounting for 17 cases (46%)—significantly exceeding all other failure modes.

While funding constraints often limit the ability to repair systems following failure, they are not, in many cases, the primary driver of failure across the schemes reviewed. This may appear counterintuitive; however, the evidence from the desktop review indicates that many systems operated poorly for an extended period prior to failure. As a result, community confidence in the scheme was eroded, reducing the willingness to mobilise the financial and institutional resources required for repair.

Natural disasters (primarily landslides and flooding) were the primary cause of failure in five cases, while poor system design was the primary contributor in four cases.



Note that multiple factors may contribute to system failure. As a result, percentages do not add up to 100%.

Figure 5.11 Primary failure modes of all 37 non-operational schemes captured in the desktop review

A more detailed breakdown is provided for specific developer categories—Government, ATCDI/UniTech, and religious missions—where the available data allows meaningful, evidence-based insights into the primary causes of system failure.

5.3.1 Government

Three national government initiatives to develop off-grid mini-hydro projects have been implemented in PNG.

The first initiative, undertaken by the Department of Works under the Government Works Programme, developed two micro-hydro schemes to supply the C-centres of Simbai (Madang Province) and Kabwum (Morobe Province). The schemes, rated at 30 kW and 25 kW respectively, were commissioned in 1977 and justified largely on the basis that they would generate electricity more cheaply than diesel generators. Following completion, both were transferred to the Department of Finance for management as government assets. However, maintenance issues at Simbai and flood and landslide damage at Kabwum led to both schemes becoming inoperable by 1986.

The second initiative, the Provincial Mini Hydropower Programme, was implemented by Elcom (the precursor to PPL) between 1981 and 1989 with financing from the Asian Development Bank. The programme targeted four schemes to supply minor centres: Kimbe (Ru Creek), Namatanai (Sohun), Bialla (Lake Hargy), and Tinputz. Three schemes were ultimately constructed: Ru Creek (800 kW), Sohun (200 kW), and Lake Hargy (1,500 kW). Of these, Ru Creek and Lake Hargy remain operational. Although intended as the first phase of a broader rollout, the programme was not expanded due to the poor financial performance of the commissioned schemes. This was largely attributed to uneconomic tariffs imposed under the uniform tariff regulatory regime, which reduced Elcom's appetite for further mini-hydro investment.

The third initiative, the Diesel Replacement Programme (1988-1992), sought to replace diesel generation with mini-hydro in Dauli (Hela Province), Woitape (Central Province), and Telefomin (Sandaun Province). In all cases, government support declined shortly after commissioning, leaving local institutions without the technical, financial, or managerial capacity required for long-term operation. At Telefomin, the scheme was transferred to the District Administration immediately after commissioning without ongoing operational or maintenance support, leaving it ill-equipped to manage the system. Similarly, at Woitape, the departure of key staff just two years after commissioning undermined an initially effective management arrangement, and the scheme subsequently fell into disrepair.

Table 5.2 provides a summary of these three national government initiatives.

Table 5.2 Summary of government initiatives to develop off-grid mini-hydro projects

Government Initiative	Implementation period	Number of schemes developed	Number of schemes commissioned	Number of operational schemes	Main challenges
Government Works Programme	1977	2	2	0	Maintenance problems and natural disasters
Provincial Mini Hydropower Programme	1981 - 1989	4	3	2	Poor financial performance resulting from uneconomic tariffs
Diesel Replacement Programme	1988 - 1992	3	3	0	Maintenance problems.

In addition to the three national government initiatives, two provincial governments have also developed mini-hydropower schemes: the Morobe Provincial Government (1985 and 2017) and the Eastern Highlands Provincial Government (2011). In 1985, Morobe Provincial Government initiated the Morobe Provincial Hydropower Programme, with the 20 kW Ogerang scheme intended as the first of a series of developments. However, cost overruns and maintenance challenges discouraged further expansion of the programme. In contrast, the more recent schemes—the 100 kW Marawaka system (2011) and the 15 kW Yalumet system (2017)—remain operational.

Overall, seven of the 11 commissioned government-developed schemes are no longer operational, with operations and maintenance (O&M) failure identified as the primary cause (Figure 5.12).

In particular, the dataset indicates that post-construction management was often limited, with government entities typically funding initial capital works but providing insufficient support for ongoing operation (e.g. failing to attract qualified operators due to inadequate financial incentives, or to invest in sufficient technical capacity building within communities). This resulted in prolonged periods of poor performance, leading to component failure, system unreliability, and erosion of community confidence.

In some cases, these issues were compounded by underlying design weaknesses—often introduced to reduce initial costs—which, when combined with inadequate maintenance (in instances magnified by funding constraints resulting from the implementation of uneconomic tariffs), contributed to system failure.

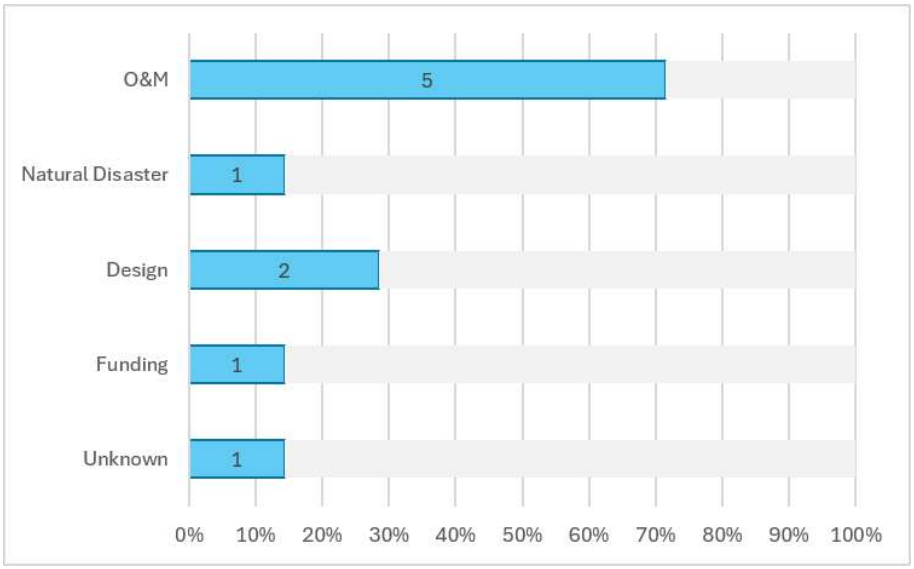


Figure 5.12 Causes of failure for non-operational Government schemes

5.3.2 Religious mission schemes

Table 5.3 presents the operational status of mission-developed schemes by mission affiliation. Of the 37 religious mission-developed schemes captured in the desktop review, 3 are operational, 22 are confirmed to be non-operational, with the operational status of the remaining 12 unknown.

Table 5.3 Operational status of mission-developed schemes in PNG

Religious mission affiliation	Total number of schemes	Operational status		
		Operational	Not operational	Unknown
Catholic	11	1	6	4
Lutheran	8	1	6	1
Seventh Day Adventist	6	0	3	3
Evangelical Church of Papua	2	0	1	1
Church of the Nazarene	1	1	0	0
Highland Christian Mission	1	0	1	0
Summer Institute of Linguistics	1	0	1	0
United Church	1	0	1	0
Unknown	6	0	3	3
Total	**37**	**3**	**22**	**12**

For schemes with sufficient data, most (eight) failures were attributed to operations and maintenance (O&M). In many cases, missionaries responsible for operating the systems departed without adequate handover to local communities, leading to progressive disrepair.

For many schemes—particularly those developed prior to 1975—the causes of failure are not well documented. However, given the prevalence of O&M-related failures among comparable schemes, these developments are likely to have experienced similar issues.

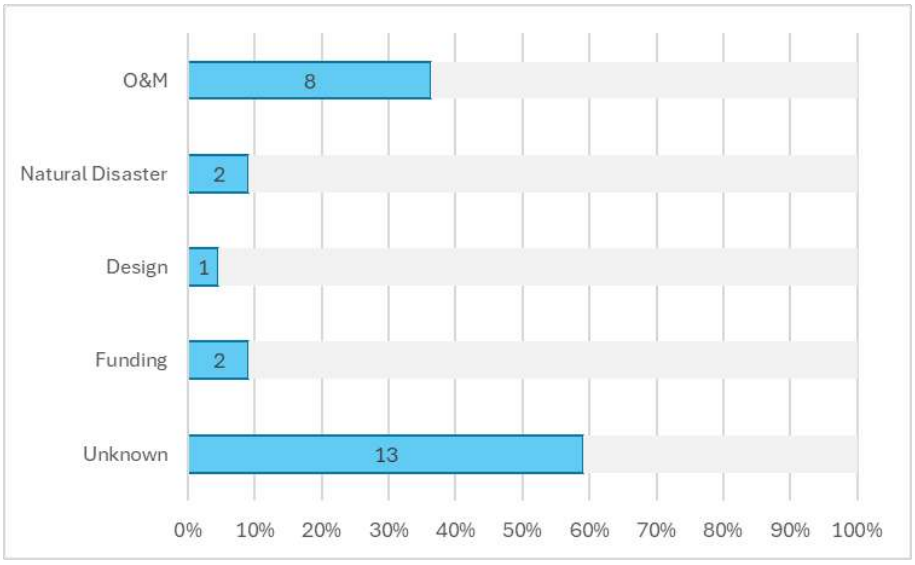


Figure 5.13 Causes of failure for non-operational Mission schemes

5.3.3 ATCDI/UniTech

ATCDI/UniTech developed four mini-hydro projects. Three of the four projects were constructed, but none remain operational today.

The primary purpose of these schemes was to provide hands-on engineering experience for final-year mechanical engineering students. They were driven primarily by student learning objectives, with electricity provision a secondary outcome.

Consequently, limited emphasis was placed on long-term operation and maintenance. As students were based in Lae rather than within the host communities, their ability to provide ongoing support following commissioning was restricted. Local stakeholders also lacked the technical capacity and financial resources to sustain or repair the systems.

As a result, schemes suffered long outages when components broke, with the repairs dependent on the availability of the students or university staff to return to site.

This is reflected in Figure 5.14, with a lack of maintenance identified as the primary cause of failure.

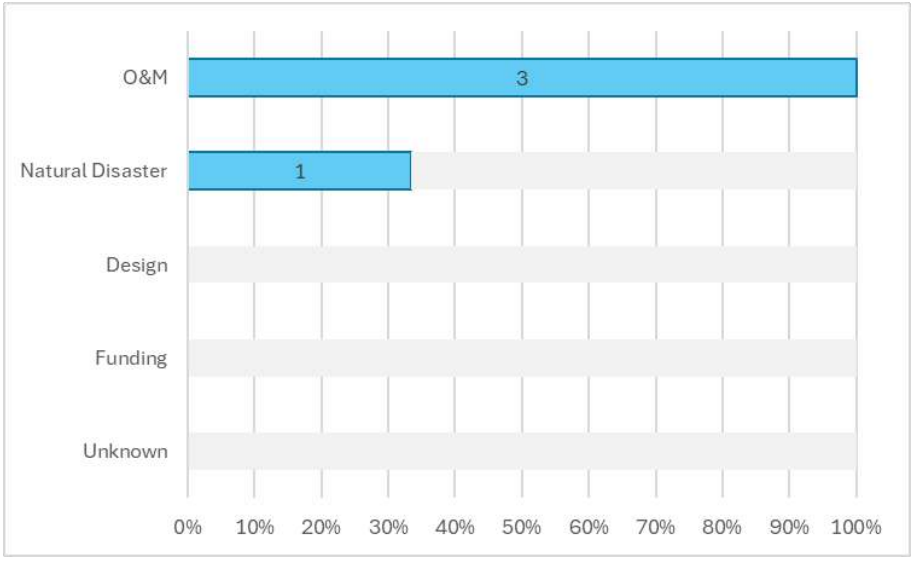


Figure 5.14 Causes of failure for non-operational ATCDI/Unitech schemes

6. Site assessment summary

Of the eight operational non-PPL mini-hydro schemes identified through the desktop review, three (approximately 40%) were visited as part of this study.

The three schemes visited, highlighted in yellow in Figure 6.1, were the:

– Kudjip Nazarene Hospital mini-hydropower scheme
– Gatop mini-hydropower scheme
– Rondon Ridge Lodge mini-hydropower scheme

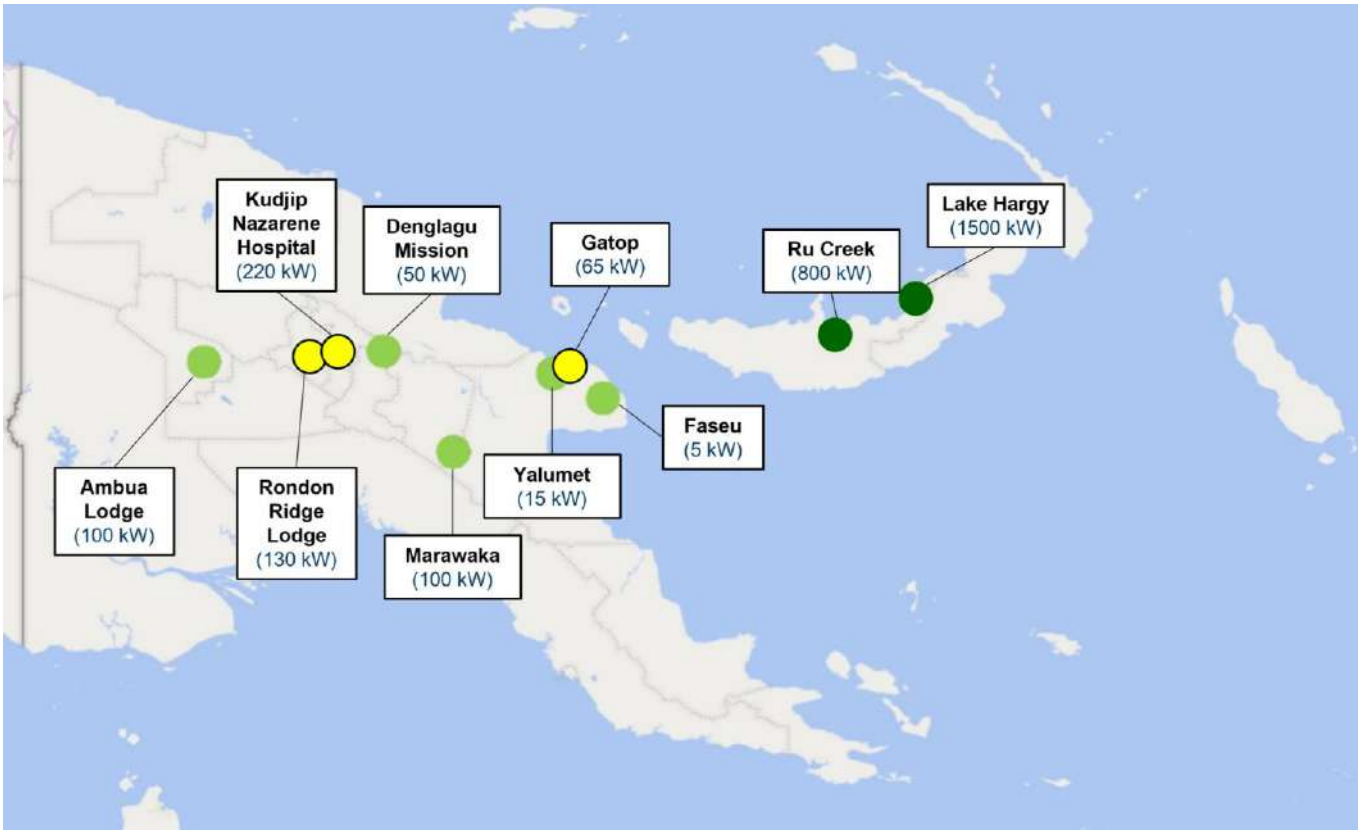


Figure 6.1 Site visit locations (yellow: visited schemes, dark green: PPL-operated mini-hydro schemes)

Summary details of the three schemes are provided in Table 6.1, with the three systems discussed in detail below in Sections 6.1, 6.2 and 6.3, respectively.

Table 6.1 Site visit scheme details

Scheme name	Nominal capacity (kW)	Commissioned	Overview
Kudjip Nazarene Hospital	220	2013	Owned and operated by Nazarene Health Ministries. Supplies electricity to a 135-bed Provincial General (Level 5) hospital, a primary school, a secondary school, and a nursing college located within the mission compound.
Gatop	65	2006	Developed by a German missionary, the system is now operated by staff from the Gatop workshop, representing an almost unique successful transition of operational responsibility for an off-grid mini-hydro system from a religious mission to the local community. Supplies electricity to three villages: Gatop, Etep and Wasu. Including Etep Hospital, schools, a mission station, and private enterprises (inc. Gatop workshop and a coffee estate).
Rondon Ridge Lodge	130	2005	Owned and operated by Trans Niugini Tours. Supplies electricity to Rondon Ridge Lodge (reducing energy costs by approximately PGK 600,000 per annum) and the surrounding community.

6.1 Kudjip Nazarene Hospital mini-hydropower scheme

6.1.1 Overview

The Kudjip Nazarene Hospital is a 135-bed Provincial General (Level 5) hospital in Jiwaka Province. Established in 1967, it is operated by Nazarene Health Ministries (NHM). It is the only church-run facility in PNG formally recognised as a Level 5 Provincial Hospital. In 2022 it recorded 57,579 outpatient visits, treated 7,244 inpatients, completed 2,866 deliveries (of which 341 were caesarean sections), performed 1,008 major surgeries (not including C-section), 473 minor surgical procedures, and 6,722 nutritional feeds (Nazarene Health Ministries, 2023).

Following the decommissioning of the original 80 kW mini-hydro system in 2007, the hospital relied on PPL grid supply and diesel generation. The grid supply was unstable, with large voltage excursions (including overvoltage events up to 390 V on a nominal 240 V supply) causing hospital equipment failure, while reliance on diesel was costly.

In 2011, the hospital received PGK 10 million (equivalent to approximately USD 4 million in 2011) from the PNG–Australia Incentive Fund to construct a 220 kW mini-hydro system to supply electricity to the hospital, the hospital's nursing college, a primary school and a high school. Completed over two and a half years, it was commissioned in 2013.

Overall, the mini-hydro system provides electricity to approximately 4,000 individuals across the hospital, primary school, secondary school, a nursing college, administrative office complexes, a workshop, and residential properties. This includes around 1,200 residents on site (comprising staff, missionaries, and their families), approximately 300 hospital inpatients (including caretakers), around 160 hospital outpatients (and their caretakers), as well as primary school students and staff (approximately 2,000 and 50, respectively) and high school students and staff (approximately 400 and 10, respectively).

Peak demand on the mini-grid has gradually increased over time, now reaching approximately 195 kW for around three hours each evening (6–9 pm). The hospital accounts for roughly 70 kW of this load, including 36 kW from the boiler alone.

Table 6.2 summarises the key characteristics of the Kudjip Nazarene Hospital mini-hydropower scheme, with the following sections providing further details.

Table 6.2 Kudjip Nazarene Hospital mini-hydropower scheme

Years in service	13 years (commissioned 2013)
Operational regime	24/7
Capacity	220 kW (peak demand 195 kW)
Head	15 m
Turbine	Cross-flow (Germany)
Backup	Two diesel generators
External support	**Technical:** Construction supported by five volunteer linesmen from the United States. No ongoing external technical support. **Financial:** Access to the international church network provides a mechanism for funding major repairs when required.
O&M staff	One full-time employee, five part-time staff
Tariff	Metered electricity consumption. Monthly revenue is approximately double routine O&M costs, with surplus funds reserved for major repairs and asset replacement.
Unplanned outages	Approximately 6 months of unplanned outages over 13 years of operation, primarily associated with a multifunction relay failure (2014; 2-month outage) and generator failure (2026; 4-month outage).
Future upgrades	**Supply-side:** Increase peak supply through the addition of a 60 kWh battery (20 kW for 3 hours during the evening peak). **Demand-side:** Investigate smart meters to encourage reduced household consumption during peak demand periods.

6.1.2 System description

The mini-hydro system is a run-of-river scheme which comprises of a large concrete weir to maintain headwater levels, a 1,200 m concrete-lined headrace channel, a forebay, a large-diameter penstock, a powerhouse housing the turbine-gearbox-generator assembly, and a tailrace channel. There is no desilting facility at the intake or a low-level outlet for desilting of the pondage. The scheme operates with a head of 15 m.

At the core of this system is a 220 kW Ossberger (cross-flow) turbine, designed and manufactured in Germany. To streamline procurement and simplify the supply chain, the Nazarene Health Ministries procured the turbine, gearbox, and generator as an integrated package from Ossberger. The system was designed by Ossberger based on the head and flow rate measurements provided to them by Nazarene Health Ministries. The turbine is equipped with a hydraulic governor that automatically adjusts water flow in response to load changes to maintain constant generator speed and hence the generated frequency.

Power generated by the system is supplied in accordance with ANZ standards, delivering both standard single-phase (230 V) power for residential use and three-phase (415 V) power for commercial and industrial loads, including the hospital's heavy machinery, at a system frequency of 50 Hz. The network is formed almost entirely from overhead lines.

6.1.3 Construction

Construction was completed over two and a half years. This included the civil works (including the weir, headrace channel, penstock, powerhouse structure), mechanical installation (including the turbine and generator assembly, and gate installation), and the distribution and transmission lines. Approximately 400 workers were employed over the construction period, with almost all (98%) locals from Jiwaka Province (IRENA, 2024).

Five volunteer linesmen from the United States supported installation of the transmission and distribution network across two deployments in 2013 and 2014. During these deployments, they trained locally based staff to undertake maintenance and network expansion from 2014 onwards.



Figure 6.2 Kudjip weir



Figure 6.3 Aerial view of Kudjip penstock and powerhouse

6.1.4 Operational regime

The Church aims to operate the mini-hydro scheme consistently 24 hours per day, 365 days per year. The system is supported by two backup diesel generators: a primary 200 kW (250 kVA) unit and an 88 kW (110 kVA) emergency unit. The primary generator supplies the hospital within seconds of an outage, while power to the wider campus is restored after approximately 10 minutes.

6.1.5 Community overview

Electricity generated by the mini-hydro system is currently confined to facilities and residences within the mission compound, with no provision of power to surrounding communities outside the mission boundaries.

The Kudjip Nazarene Mission community is a well-established, semi-urban settlement, with most hospital, school, and mission staff residing within or near the compound, creating a highly integrated, service-oriented community. The settlement comprises approximately 190 residential properties and around 40 institutional facilities, including educational establishments, healthcare services, and mission-related infrastructure.

The mission was originally established in 1954 as a Bible translation school, forming the foundation for subsequent institutional development. The Kudjip Nazarene Hospital and the mini-hydro scheme were later established in 1967, significantly expanding the scope of services provided within the area.

Consultations with long-serving staff indicated that the development of both the hospital and the mini-hydro system was supported through collaborative efforts involving local community members, with social issues associated with the operation of the mini-hydro system minimal.

6.1.6 Land ownership

The original 80 kW scheme was constructed on customary land under informal “handshake” agreements. From the 1970s onwards, these were formalised through state leases, and the current system now spans multiple land parcels held by the Nazarene Church under 99-year government leases.

To date, there have been no reported grievances, disputes, or land-related conflicts between the Nazarene Mission and the customary landowners. The relationship remains stable, with continued recognition and respect for the original understanding under which the land was made available to the mission.

6.1.7 Tariff

Ongoing funding is generated through tariff charges based on metered electricity usage. Approximately 230 locally manufactured meters—one installed in each house and building—measure consumption in kWh. The tariff is set at 63 toea/kWh, compared to approximately 100 toea/kWh charged by PPL to Easipay customers (PNG Power Ltd, 2025). Payments are made at the end of each month, with users settling their bills in person at the office alongside rent.

All buildings on the hospital campus are connected to the mini-grid, with new buildings connected during construction. No eligibility criteria are applied. Each connected property is equipped with individual meters to facilitate accurate billing. Nazarene Health Services manages the metering system, billing processes, and payment collection.

Payment arrangements differ between customer groups. Residential households are billed on a fortnightly basis, while institutions are invoiced monthly. Households can make payments through electronic transfer or card-based transactions, whereas institutions typically utilize cheque or electronic payment methods.

Electricity costs for households vary depending on consumption levels, with fortnightly payments typically ranging between PGK 20 and PGK 150. Institutional electricity expenses are significantly higher due to greater energy demand.

Most customers are salaried government employees with stable incomes (e.g. approximately PGK 40,000 per annum for a nurse), distinguishing the customer base from more typical rural community contexts. Therefore, non-payment of tariffs is relatively rare. However, disconnections are enforced after repeated non-payment using

the breaker installed in each meter box, with approximately three of the 190 connected households disconnected at any given time.

Overall, the average monthly revenue of the system from customer tariffs is approximately PGK 12,000. This exceeds the average monthly operation and maintenance costs of approximately PGK 6,000. Tariff revenue in excess of operating costs is accumulated in a reserve fund, which is used to finance major repairs where possible.



Figure 6.4 Household meter boxes at Kudjip

6.1.8 Maintenance activities

Operation and maintenance is undertaken by a small on-site team, comprising one full-time operator supported by five additional staff who contribute to operation and maintenance of the mini-hydro system alongside other responsibilities. To ensure 24/7 coverage, each team member undertakes one night shift per week. In addition, an on-call operator is available at all times to manage the network, while clearance of the trash screens at the intake to the headrace channel is carried out by two personnel assigned from the security workforce.

6.1.8.1 Regular maintenance activities

Regular maintenance activities include greasing bearings, clearing intake trash screens, and trimming vegetation near overhead powerlines. As the majority of the mini-hydro system—including the weir, headrace channel, forebay, penstock, powerhouse, and transmission and distribution network—is located within the government lease, maintenance access is largely unrestricted.

During high-flow periods, sediment is transported along the headrace channel and settles in the forebay. In the wet season, this accumulated sediment requires clearing approximately once per month, necessitating shutdown of the mini-hydro system to allow the forebay to be drained and accessed by a small excavator. In addition, annual

maintenance of the turbine and generator takes up to a week per year. During these planned outages, the backup diesel generators are used to supply the network.

The overall cost of performing this regular maintenance, including staff salaries, is approximately PGK 6,000 per month. This is entirely covered by the revenue from customer tariffs (approximately PGK 12,000 per month).

6.1.8.2 Irregular maintenance activities

Soon after commissioning in 2013, a scour hole developed at the downstream toe of the diversion weir. To limit further erosion, a concrete apron was installed at the toe in 2016; however, erosion continued downstream of the structure. The apron was subsequently extended in 2017, which resolved the issue. These works were undertaken while the scheme remained operational. The total cost of installing the apron was estimated to be approximately USD 15,000 (equivalent to approximately PGK 50,000 in 2017).

6.1.8.3 Inventory of spare parts

To minimise the impact of unplanned outages, Nazarene Health Ministries undertook an audit of system components that cannot be sourced locally in PNG and subsequently procured spares for these items. This ensures that, in the event of a failure, components can be readily replaced, reducing outage duration by eliminating the need to wait for parts to be shipped.

6.1.9 Unplanned outages

Unplanned outages experienced by the mini-hydro system are summarised below. Notably, prior to 2026, only one outage exceeding one week occurred over 13 years of operation.

6.1.9.1 Water availability

Nazarene Health Ministries limits abstraction to 80% of river flow for the mini-hydropower scheme. During low-flow periods, this constraint results in system shutdowns due to insufficient water availability, occurring approximately four to five times per year, typically for one to two days per event. The diesel backup generators are used during these outages.

6.1.9.2 Multifunction relay (MFR) - 2014

The multifunction relay (MFR), an integrated protection and control device that protects the system and manages automatic switching between generation sources, failed in 2014 after only one year of operation.

A replacement could not be sourced locally so had to be procured from overseas. In addition, the original model was no longer manufactured, meaning a direct replacement was not available and an alternative unit had to be selected.

Delivery from Germany took approximately two months, with a specialist required to be flown in to assist with installation. The total replacement and installation cost was approximately USD 15,000 (equivalent to approximately PGK 40,000 in 2014).

6.1.9.3 Generator - 2026

The generator, provided by Ossberger in 2013 as part of the turbine-gearbox-generator package, failed at the end of February 2026 after only a fraction of its expected 20 to 25-year design life. Following the failure, the generator was removed and transported to a workshop in Mt Hagen for rewinding at a cost of PGK 47,000 (approximately USD 11,000). The repaired generator was reinstalled during the first week of June 2026, returning the scheme to operation after approximately four months offline.

In parallel, Nazarene Health Ministries has engaged Ossberger regarding procurement of a new generator, with a quoted cost of EUR 35,000 plus EUR 5,000 for shipping (approximately PGK 200,000). The new generator is currently being manufactured in Italy, with delivery expected in October 2026.

Nazarene Health Ministries hopes that this dual approach of retaining the repaired generator and procuring a new unit will provide redundancy and reduce the risk of future outages, thereby improving the long-term reliability of the scheme.



Figure 6.5 *Kudjip powerhouse (with generator removed for repair)*

6.1.10 Waste management

In general, damaged components from the mini-grid are disposed of in landfill. Where there is a risk of accidental reuse, some items are incinerated in the hospital incinerator. Materials suitable for recycling are reused where possible; for example, used oil is repurposed for wood treatment.

6.1.11 Long-term sustainability considerations and planned future upgrades

With peak demand now reaching approximately 195 kW and continuing to increase, the system is approaching the mini-hydro capacity of 220 kW. Nazarene Health Ministries is therefore exploring options to both increase peak supply and reduce peak demand to optimise the use of available generation capacity.

To increase peak supply, Nazarene Health Ministries has invested approximately USD 35,000 (approximately PGK 150,000) in battery storage and a power management system. The installation includes a 60 kWh battery designed to store excess electricity generated during the day and discharge it during periods of higher demand, typically in the evening. This enables energy to be shifted from times of surplus to times of peak demand, effectively increasing available capacity during peak periods. In practice, the system is intended to provide an additional 20 kW for approximately three hours during the evening peak, increasing effective system capacity from 220 kW to 240 kW.

To reduce peak demand, Nazarene Health Ministries is also considering the introduction of smart meters for residential connections. Although still at a conceptual stage, this is expected to influence customer behaviour and help reduce peak demand. No cost estimates have been prepared for this option to date.

6.2 Gatop mini-hydropower scheme

6.2.1 Overview

The Gatop mini-Hydropower Scheme (MHPS) is a nominal 65 kW system that supplies electricity to three villages—Gatop, Etep and Wasu—in the Tewae-Siassi District of Morobe Province. The area is not near to, or serviced by, a PPL grid.

The scheme was initiated in 2002 by a German missionary associated with the Evangelical Lutheran Church of Papua New Guinea (ELCPNG) to provide power to the Lutheran mission station at Gatop. Construction was completed over a four-year period with support from the Lutheran church community (including an electrical engineer Risto Rometsh, an employee of Ergon Energy, from Australia).

Funding was sourced through the German missionary's family and church network back home in Germany, primarily Mission One World of Bavaria. Some funds, estimated to be approximately PGK 100,000 to PGK 150,000, were also provided by the Local Level Government.

The scheme was commissioned in December 2006.

Following commissioning, the network was progressively expanded. Etep Hospital (a Level 3/4 Health Centre serving a catchment population of over 100,000 people) was connected in 2008, whilst, in 2015, a 13 km transmission line was completed, extending the mini-grid to the coastal village of Wasu, connecting Wasu Secondary School and Wasu LLG offices.

In its current form, the Gatop MHPS caters for Gatop Workshop (inc. rice mill), Etep Rural Hospital (20 staff houses and hospital facilities), Wasu Secondary School (with 28 staff houses, dormitories, and other secondary school facilities), Kalalo Primary School (with 17 staff houses and classrooms), Alang Daom Coffee Estate, Gatop Mission Station (with Ukata District staff residences and a Young Women Leaders Training School), Wasu LLG offices, and several households and shops near the grid. Etep Rural Hospital is a key health facility serving an extensive catchment population of over 100,000 people.

Table 6.3 summarises the key characteristics of the Gatop mini-hydropower scheme, with the following sections providing further details.

Table 6.3 Gatop mini-hydropower scheme

Years in service	20 years (commissioned 2006)
Operational regime	24/7
Capacity	Installed capacity of 300 kW but generation flow-limited to 65 kW (operating at ~30 kW since 2023 gearbox failure)
Head	63 m
Turbine	Cross-flow (Germany)
Backup	No system level backup. Individual customers rely on their own backup diesel generators.
External support	**Technical:** Retired electrical engineer from Ergon Energy, Australia with longstanding ties to the mission station. **Financial:** None.
O&M staff	~12 Gatop workshop staff (original missionary departed in 2015)
Tariff	Metered electricity usage. Revenue does not cover routine O&M costs and is therefore supplemented by income from the workshop.
Unplanned outages	Approximately 12 months of unplanned outages over 20 years of operation, primarily associated with a 2023 powerhouse flood that damaged the generator. Gearbox failure in 2023 reduced generation capacity by 50%, limiting supply capacity and resulting in the disconnection of Wasu.
Future upgrades	**Supply-side:** Planned replacement of the gearbox and upgrades to the intake, electronic load controller, and load bank; however, implementation is currently constrained by limited financial capacity. **Demand-side:** None.

6.2.2 System description

Gatop MHPS is a run-of-river scheme which utilises a creek running through the Etep Hospital compound. The scheme comprises of a small weir, an intake structure, forebay, a single 600 m long penstock, powerhouse housing the turbine and generator, and a tailrace channel which ties back into the original creek downstream. The system has a 63 m operating head. Both the weir pondage and the intake pondage operate effectively as desilting basins, with the low weir in the creek readily overtopped during high flows and probably contributing to removal of silt.

The scheme is centred on three approximately 100 kW cross-flow turbines, providing a nominal installed capacity of 300 kW. The turbines were designed in Germany, with key steel components fabricated there before being transported to PNG for on-site assembly and welding.

A single penstock supplies the turbine house, where it trifurcates into three branches, each feeding an individual turbine.

Originally, the three turbines were connected to a single 420 kVA generator manufactured in Italy. However, the scheme is flow-limited, such that operating all three turbines concurrently causes the forebay level to drop and air to be drawn into the penstock. As a result, only one turbine is typically operated at a time, with a second used intermittently or maintained as a standby unit. Components from the third turbine are also occasionally used as spares to replace failed parts in the operating units. Consequently, actual generation capacity is limited to approximately 65 kW, despite the installed capacity of 300 kW.

The system does not utilise a hydraulic governor to regulate turbine speed in response to load changes. Instead, it employs an electronic load controller (ELC) with a homemade dump load (heating elements), which maintains stable operation by diverting excess electrical energy when demand falls. It also utilises an Automatic Voltage Regulator (AVR) to adjust the generator's excitation and maintain a constant output voltage as load changes. The electricity generated by the system is supplied at 230 V single phase.

The existing transmission and distribution network covers more than 20 km with the lines spanning 3 km from Etep to Gatop, and 13 km from Etep to Wasu. The majority of transmission and distribution components were donated by Ergon Energy in Queensland and Country Energy (now known as Essential Energy) in New South Wales.

These donations consisted primarily of functional equipment—such as transformers and circuit breakers—that had been decommissioned in Australia due to changes in technical standards.



Figure 6.6 Aerial view of Gatop hydropower scheme



Figure 6.7 *Gatop weir, intake and forebay*



Figure 6.8 Gatop penstock



Figure 6.9 Gatop powerhouse

6.2.3 Construction

Construction was completed over a four-year period with support from the Lutheran church community, including an Australian-based electrical engineer from Ergon Energy with ties to the Church.

6.2.4 Operational regime

Gatop MHPS is operated continuously, except during routine maintenance activities which require the mini-hydro to be shut down, and during unplanned outages. Although the overall scheme does not have any backup diesel generators, individual customers—namely Etep Hospital, Wasu High School, and Gatop Mission Station—do have backup generators which they use during outages.

6.2.5 Community overview

The combined population of the Gatop and Etep communities is estimated to range between 2,500 and 3,000 people, excluding the population of Wasu Station and surrounding villages. The area has access to basic enabling infrastructure, including mobile network coverage, a road link connecting Etep and Gatop to Wasu Station, and a community jetty operated by Lutheran Shipping Services, which supports transportation and access to coastal areas.

The majority of residences and institutional services that are connected to, and directly benefit from, the Gatop mini-hydro system are associated with the hospital and mission operations. These individuals typically have formal and stable income streams.

In contrast, the broader surrounding communities, which at this time are connected to the mini-hydro, rely primarily on subsistence livelihoods, supplemented by small-scale cash cropping—particularly cocoa, coffee, and vanilla—as well as fishing activities in coastal areas such as Wasu.

Despite limited direct access to electricity, surrounding communities expressed strong support for the mini-hydro system and its associated services. Community members recognised indirect benefits, including improved service delivery, greater economic exposure, and broader development opportunities across the Wasu Local Level Government area.

6.2.6 Land ownership

The Gatop MHPS is located on registered freehold land owned by the Evangelical Lutheran Church of Papua New Guinea (ELCPNG), while the transmission and distribution network is constructed across customary land.

Initial engagement with landowners during construction secured access for vegetation clearance and line corridors. No disputes over land or water access have been reported since commissioning.

6.2.7 Tariff

In general, consumers pay for electricity supplied by the Gatop MHPS, with metered tariffs introduced in 2010 (each connected residence now has a meter box similar to the Easipay system).

Historically, electricity tokens were purchased and loaded onto the meter boxes using physical cards. However, due to accessibility and convenience challenges, the scheme has transitioned to a digital recharge system, improving payment efficiency and service delivery.

Tariff levels vary across the network due to the scheme’s incremental development and the legacy arrangements established with different customer groups.

Residential customers pay a tariff of 75 toea/kWh. While this is higher than the rate applied at Kudjip, it remains significantly below the approximately 100 toea/kWh charged by PPL to Easipay customers (PNG Power Ltd, 2025). Overall, this means that the average tariff paid by each household is approximately PGK 30 per month. The primary income source for residential customers is agriculture.

In contrast, properties at the Gatop Mission were initially provided with free electricity. Following the departure of the original missionary in 2015, a flat rate of PGK 20 per connection per month was introduced. However, monthly meter readings indicate actual consumption values closer to PGK 60–70 per household, suggesting that mission residents are currently paying below cost.

Similarly, Etep Hospital previously received free electricity. However, in April 2026, operators began charging the hospital, as the loss of revenue following the disconnection of Wasu customers rendered the scheme financially unviable without it. At the time of the site visit, the hospital had yet to pay its first bill.

Whilst non-payment of electricity bills is generally not a significant issue, around 2015–2016 a group of residents in Etep refused to pay for electricity, arguing that the scheme relied on water resources under customary ownership. This resulted in a temporary, community-wide refusal to pay. In response, the primary operator, James Zoriong, convened a public meeting and explained that continued non-payment would render the scheme financially unviable and force its closure. The community subsequently relented and agreed to resume payment.

Connections to the mini-hydro system are facilitated and managed under the leadership of Mr. James Zoriong, a UniTech engineering graduate from nearby Kabwum who resides at the Gatop Mission station and manages the Gatop workshop.

Installed meters comprise a mix of prepaid units (similar to PPL's Easipay meters) and conventional post-paid meters, with an approximate split of 30% prepaid and 70% post-paid. Prepaid meters are used selectively for customers with a history of non-payment, while persistent non-payers may be disconnected from the mini-grid.

Overall, average monthly revenue from tariffs is approximately PGK 2,000, which is insufficient to cover operation and maintenance costs. As a result, income from the workshop (from conducting activities such as milling and welding) is required to supplement revenue and fund operator wages. The scheme is therefore only financially viable at current tariff levels due to the workshop, with a key incentive for ongoing operation being that workshop staff rely on electricity from the mini-hydropower system to sustain their income.



Figure 6.10 Prepaid residential meter at Gatop

6.2.8 Maintenance activities

The original missionary departed Gatop in 2015; however, unlike many mission-driven schemes identified in the desktop review, Gatop MHPS did not fall into disrepair. Instead, staff from the Gatop workshop assumed

responsibility for its operation and maintenance, driven both by commitments made to the original missionary and by their reliance on the mini-hydropower system to sustain their livelihoods.

Operation and maintenance is led by Mr James Zoriong. In total, approximately 12 permanent workshop employees support maintenance of the mini-hydro system, supplemented by a further 14–20 casual staff engaged as required. Wages for permanent employees are drawn primarily from workshop income, rather than from revenues generated by the mini-hydropower system.

External support is also provided by an Australian-based electrical engineer from Ergon Energy with historical ties to the scheme.

6.2.8.1 Regular maintenance activities

Regular maintenance activities include greasing bearings, clearing intake trash screens, and trimming vegetation near overhead powerlines.

Vegetation can occasionally obstruct the intake trash screen, particularly during heavy rainfall. This is cleared manually, often with assistance from hospital security staff at Etep.

Although the transmission and distribution network is primarily located on customary land, most lines are installed at heights that avoid vegetation encroachment. Where maintenance is required, communities generally provide access without seeking compensation.

6.2.8.2 Irregular maintenance activities

Over time, calcium deposits accumulate on the internal surface of the penstock, reducing its effective diameter, restricting flow, and consequently lowering the power output of the scheme. When this becomes significant—typically after around 10 years of operation—the system is shut down and the affected section of penstock is removed and replaced. The removed section is then dried and mechanically cleaned to remove the calcium deposits before potential reuse.

Similarly, the turbine runners also experience calcium build-up and require periodic cleaning, typically every three years. However, with three turbines available, individual runners can be taken out of service and cleaned without shutting down the system.

6.2.9 Unplanned outages

6.2.9.1 Generator failure and replacement

In 2023, flooding in the powerhouse damaged the original 420 kVA generator. It was subsequently replaced with a smaller 70 kVA unit, also manufactured in Italy, while the original generator was shipped to Lae for repairs. The reduced capacity was considered adequate given the flow limitations of the scheme. However, the change required modifications across the system, resulting in approximately one year of outage before power supply was restored.

6.2.9.2 Gearbox failure

In September 2023, the German-manufactured gearbox—used to increase the turbine speed to match the generator's operating speed—failed. Workshop staff attempted to repair the unit but were unable to restore it to operation, and a replacement has not yet been procured due to limited financial capacity. System output has consequently fallen to approximately 30 kW, which is insufficient to supply all three villages and has resulted in the disconnection of Wasu from the mini-grid. As a result, Wasu Secondary School has reverted to diesel generation and now consumes approximately one drum of diesel every three days, at an estimated annual cost of PGK 20,000 to PGK 30,000.

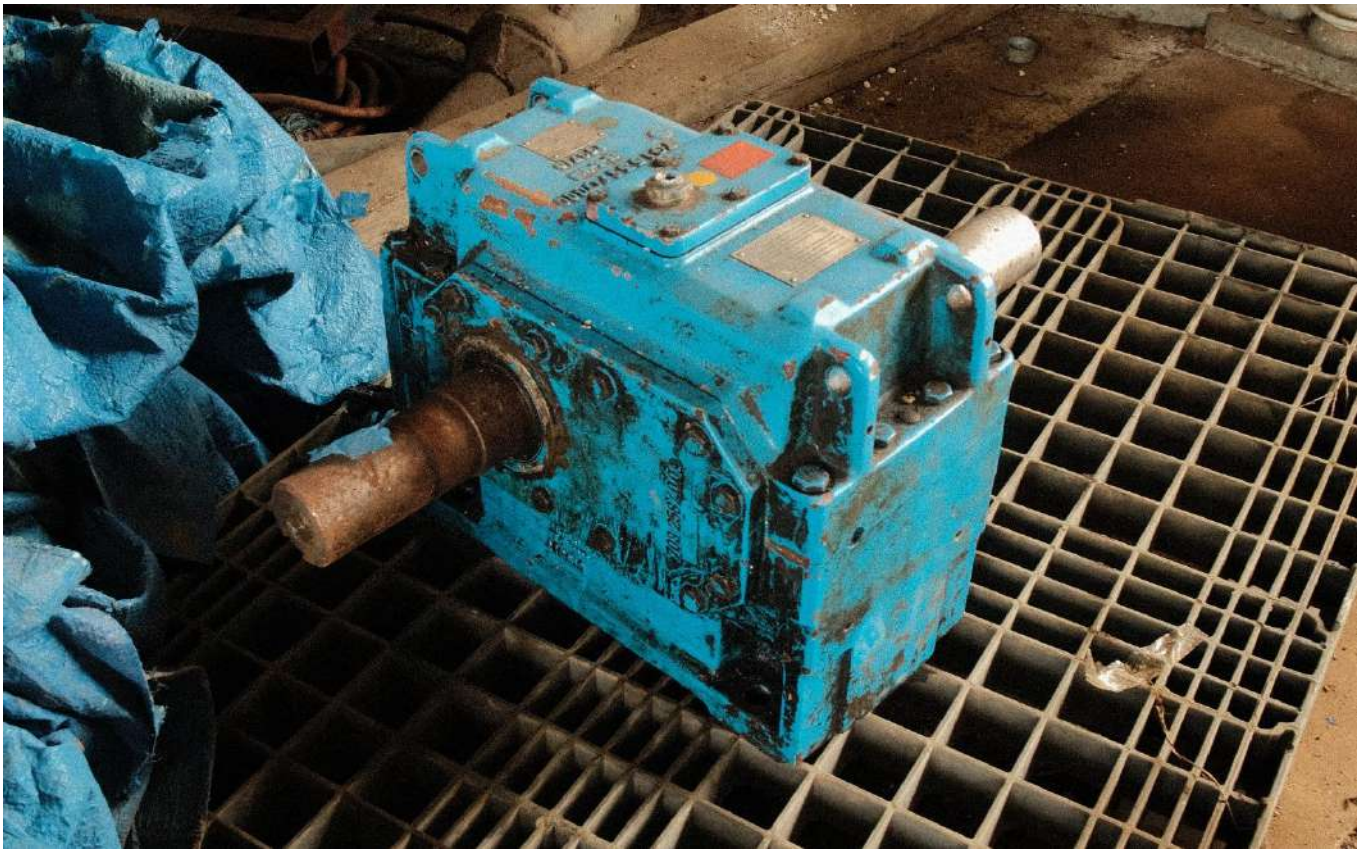


Figure 6.11 Failed gearbox at Gatop

6.2.10 Waste management

In general, damaged components from the mini-grid are disposed of in landfill.

6.2.11 Long-term sustainability considerations and planned future upgrades

Government presence and support in the Etep/Gatop/Wasu area remain minimal. Despite this, the Gatop mini-hydro system has remained operational, in some form, since 2006. This is despite the departure of the original German missionary in 2015. This is a result of staff from the Gatop workshop assuming responsibility for the system's operation and maintenance, driven both by commitments made to the original missionary and by their reliance on the mini-hydropower system to sustain their livelihoods. As a result, the system represents an apparently unique successful transition of operational responsibility for an off-grid mini-hydro system in PNG from a religious mission to the local community.

However, despite the best efforts of the Gatop workshop staff, the system does have limitations. Whilst, overall, the scheme is regarded as a reliable source of electricity, there is a clear need for system upgrades to enable it to operate at its full design capacity.

For example, the coastal village of Wasu (including Wasu Secondary School) was disconnected from the mini-grid in 2023 as a result of the gearbox failure. In addition, Etep Rural Hospital is unable to use donated equipment (including a GeneXpert machine, X-ray systems, operating theatre equipment, and vaccine refrigeration units) as their energy demands exceed the current capacity of the mini-hydro system.

Key system bottlenecks which limit the mini-hydro systems' capacity include:

- **Water availability:** the scheme is currently flow-limited, with the existing intake and penstock configuration restricting flow and preventing full utilisation of the installed generation capacity; and
- **Electrical control capacity:** the existing electronic load controller (ELC) and load bank are only capable of handling outputs on the order of 30 kW.

To address these constraints, planned upgrades include improvements to the intake and penstock to increase flow, including the construction of a new intake further upstream—before the creek splits—to access a greater volume of water. Supporting this, ongoing flow monitoring is being undertaken to develop a flow duration curve and inform the design of these upgrades. Additionally, upgrades are planned for the ELC and load bank to enable higher generation capacity. The long-term target is to increase output to approximately 200–250 kW.

These upgrades would enable the reconnection of Wasu and expansion of supply to additional households and neighbouring villages. However, progress remains constrained by limited financial capacity, with the primary operator, Mr James Zoriong, in partnership with ELCPNG, actively exploring funding options to support implementation.

6.3 Rondon Ridge Lodge mini-hydropower scheme

6.3.1 Overview

Rondon Ridge Lodge is a tourism facility located just outside Mt Hagen in Western Highlands Province. It is owned and operated by Trans Niugini Tours, which is in turn owned by Sir Bob Bates. The mini-hydropower system at Rondon Ridge is one of two operated by the company, the other being located at Ambua Lodge.

Commissioned in 2005, the lodge has been powered by the mini-hydro system since opening. The scheme was privately financed at an estimated cost of approximately AUD 135,000 (equivalent to around USD 100,000 or PGK 300,000 in 2005), comprising approximately AUD 75,000 for the turbine, generator and governor, AUD 30,000 for the penstock, and AUD 30,000 for the transmission infrastructure.

Since commissioning, the system has demonstrated a high level of reliability, with only a single unplanned outage reported over more than 20 years of operation. Over this period, Sir Bob Bates estimates that the use of mini-hydropower, in place of diesel generation, has reduced energy costs by approximately PGK 600,000 per annum.

Table 6.4 summarises the key characteristics of the Rondon Ridge mini-hydropower scheme, with the following sections providing further details.

Table 6.4 Rondon Ridge mini-hydropower scheme

Years in service	21 years (commissioned 2005)
Operational regime	**Wet-season:** 24/7 **Dry-season:** Reduced flows require intermittent operation in 3-hour periods.
Capacity	130 kW (typical demand ~50 kW)
Head	70.6 m
Turbine	Turgo (Australia)
Backup	Single diesel generator
External support	**Technical:** None. **Financial:** None.
O&M staff	One full-time employee
Tariff	No tariff currently in place, as the scheme is financially justified through diesel fuel savings at the lodge. However, connected households have expressed a willingness to pay for electricity.
Unplanned outages	Single one-day outage over 21 years of operation, associated with an underground cable fault.
Future upgrades	**Supply-side:** No upgrades currently planned. **Demand-side:** No upgrades currently planned.

6.3.2 System description

The Rondon Ridge Lodge mini-hydropower scheme is a 130 kW system designed around a head of 70.6 m and a design flow of 235 L/s. It is equipped with a twin-jet Turgo impulse turbine designed by Tamar Hydro in Tasmania, coupled to a 200 kVA AVK generator operating at 415/240 V and 50 Hz.

Water from multiple small streams is collected via several aqueducts, which are partially lined and partially unlined. There are no desilting facilities upstream or built into the forebay which therefore requires draining and mechanical removal of silt. Water is conveyed to a large forebay at the upstream end of the penstock, which is screened. From there, water is transmitted to the powerhouse through an approximately 800 m long buried PVC penstock, installed as a simple, straight run with no major bends.

The system supplies the lodge through a 415 V/50 Hz three-phase 70 mm² underground cable, with typical demand of around 50 kW.

In addition to supplying the lodge, the mini-hydro system also supplies electricity to approximately eight junction boxes. These junction boxes are located up to approximately 500 m from the powerhouse and connected to the powerhouse by underground cabling. Each junction box typically serves five to six households within the Rondon community. Community facilities such as schools, churches, and bible colleges also connect into these junction boxes.

Any generation in excess of Lodge and Rondon community demand is controlled by an electronic load controller (ELC), which diverts surplus energy to a water heater acting as a dump load. The recovered heat is then utilised for underfloor heating within the main lodge building.



Figure 6.12 Aerial view of Rondon Ridge (looking downhill from the forebay in the foreground towards the powerhouse in the background)



Figure 6.13 Rondon Ridge powerhouse



Figure 6.14 Rondon Ridge forebay

6.3.3 Construction

The construction of the mini-hydro project required a workforce of approximately 30 workers over a period of 12 months, primarily drawn from the local workforce.

6.3.4 Operational regime

Operation of the scheme is influenced by strong seasonal flow variability. During the wet season, sufficient flow is available to operate the mini-hydro continuously.

However, in the drier season, inflows are insufficient to sustain 24/7 operation, meaning the scheme must instead operate intermittently. Water is first allowed to accumulate in the forebay, enabling approximately two to three hours of generation before water levels drop and the system must be shut down to allow the forebay to refill. This cycle is repeated throughout the day, effectively operating in a manner analogous to a storage battery.

This can lead to voltage and current fluctuations during start-up and shut-down which, in the past, has resulted in damage to the communities' electrical appliances such as cooking equipment, laptops, and televisions. However, the community has adapted by avoiding leaving appliances plugged in at these times.

To maintain supply to the lodge when the mini-hydro is not operating, a diesel generator is used to supplement generation, minimising interruptions and optimising fuel use. Changeover between hydro and diesel is controlled remotely from the lodge, although overall operation remains largely manual. During diesel operation, connected Rondon community members do not receive electricity.

6.3.5 Community overview

The community around Rondon Ridge Lodge is the Rondon community. Encompassing Wards 10 and 30 within the Hagen Rural Local Level Government (LLG), the population of the Rondon community is estimated at approximately 5,000 people. The majority of households rely on agriculture as their primary source of livelihood and main economic activity. Local farmers actively supply fresh produce to retail outlets in Mt. Hagen, including Tininga Supermarket, which contributes positively to household incomes and overall economic wellbeing.

Household income levels in the community are relatively strong for a rural setting. Most households earn a minimum monthly income of approximately PGK 5,000. Households with greater access to land and expanded farming activities report higher income levels, typically ranging between PGK 10,000 and PGK 15,000 per month.

Access to basic services in Rondon is improving. The community has reliable telecommunications coverage, and road access has improved through recent sealing works funded by government and private contributions (including Sir Bob Bates). Water is supplied via an untreated piped system from nearby springs established in 2012 with support from AusAID and UNICEF, although some households continue to use streams and creeks.

Electricity is supplied by the mini-hydro system to eight junction boxes within 500 m of the powerhouse. Households and community facilities near these junctions can connect, resulting in partial electricity access across the community.

As confirmed through consultations with local leaders, no significant social issues or community impacts associated with the mini-hydro operations were reported. Indeed, community members are actually highly supportive and actively protective of the mini-hydro system, reflecting its value to their daily lives and livelihoods.



Figure 6.15 Typical community household structures connected to Rondon Ridge

6.3.6 Land ownership

The powerhouse and penstock are located on customary land. However, Sir Bob Bates has not experienced any land access issues. This is likely because the community benefit from the mini-hydro (and the presence of the Lodge more generally), whilst all cables associated with the mini-hydro scheme are buried underground, minimising impacts to the community.

6.3.7 Tariff

Electricity is provided to connected Rondon community members free of charge when the mini-hydro system is operating, with no tariffs applied. While households have expressed willingness to pay for power, with an affordable expenditure range of approximately PGK 20 to PGK 50, Sir Bob Bates has not pursued a formal payment model, as the scheme's financial sustainability is derived from cost savings achieved relative to diesel generation.

6.3.8 Maintenance activities

6.3.8.1 Regular maintenance activities

Two regular maintenance activities are undertaken at the scheme. Vegetation management is required at the intake, where debris can accumulate in the stilling pond, particularly following periods of heavy rainfall. This issue is more pronounced at Rondon Ridge than at Ambua, likely due to historical logging in the area, which has resulted in increased loose vegetation. During heavy rain events, the intake is inspected and cleared manually as required.

Sediment accumulation in the forebay is also managed through periodic maintenance. Over time, silt builds up and must be removed to maintain effective operation, with cleaning typically conducted every three to six months.

6.3.8.2 Irregular maintenance activities

As most system components are buried, unplanned maintenance requirements are minimal. The forebay also performs effectively in removing sediment, as evidenced by the turbine runner not having required replacement to date.

6.3.8.3 Spares

Sir Bob Bates maintains a well-stocked inventory of spare parts, including a turbine runner, an electronic load controller, electrical cables, penstock pipe sections, rubber O-rings for the penstock, and static switches.

6.3.9 Unplanned outages

6.3.9.1 Burnt out cable

A couple of years after commissioning, an underground cable fault occurred. While the exact cause is unknown, it is believed to have resulted from progressive water ingress into damage sustained during construction. The outage was brief—lasting only a day or so—as the affected section was isolated and replaced using spare cable already held on site by Sir Bob Bates. This remains the only unplanned outage unrelated to water availability in the history of the scheme's operation.

6.3.10 Waste management

In general, damaged components from the mini-grid are disposed of in landfill. However, very few components have failed in the mini-grid since its establishment in 2005.

6.3.11 Long-term sustainability considerations and planned future upgrades

Sir Bob Bates is widely regarded as a respected and influential figure within the Rondon community, having earned strong local trust through long-term engagement and leadership. His development vision is broadly supported by local stakeholders. However, concerns have been raised regarding long-term governance, particularly succession planning, as there is currently no clear pathway for ownership and operation of the mini-hydro system following his eventual departure. This reflects similar challenges observed in Section 5.

There are no planned future upgrades of the mini-hydro system at Rondon Ridge Lodge.

7. Mini-hydro in Nepal – a case study

Nepal's mini- and micro-hydropower sector is a mature model of community-based rural electrification, well suited to dispersed, mountainous regions with highly diverse linguistic populations. It has delivered widespread access to clean, renewable electricity—with 407 hydro-powered mini-grids identified in 2022 (Energy Sector Management Assistance Program, 2022).

This case study draws on the book "Lights Beyond the Grid" by Nepalese hydropower engineer Devendra Adhikari (Adhikari, 2023) and an interview held with the author in April 2026.

The success of mini-hydropower in Nepal is underpinned by three key factors, explored in the following sections:

– sustained government support;
– an enabling policy environment; and
– a vibrant domestic private sector.

7.1 Sustained government support

Sustained government support was critical to the development of Nepal's mini-hydropower sector. Delivered primarily through the Agricultural Development Bank of Nepal (ADB/N) and later the Alternative Energy Promotion Centre (AEPC), this government backing helped drive widespread uptake of mini-hydropower through financial, technical, and institutional support .

7.1.1 Agriculture Development Bank of Nepal (ADB/N)

Established in 1968 as a state-owned development bank, the Agricultural Development Bank of Nepal (ADB/N) was mandated to support agricultural productivity and rural development through the provision of institutional credit. From 1981, this mandate expanded to include the promotion of rural electrification through mini-hydro, which accelerated following the introduction of government subsidies in 1985.

In its financing role, ADB/N combined concessional loans and government subsidies to support mini-hydro development, typically financing up to 80% of project costs. By 1992, it had invested NPR 90 million in mini-hydro developments—equivalent to approximately USD 5 million in 2024 terms—accounting for more than 80% of mini-hydropower installations at that time.

Beyond financing, ADB/N acted as a technical development agency responsible for end-to-end project delivery. It:

– Actively promoted mini-hydropower within rural communities, raising awareness and stimulating demand
– Established five Appropriate Technology Units (ATUs) across five regions which supported communities throughout the mini-hydro project lifecycle (including site surveys, technical and financial feasibility assessments, connecting communities with domestic manufacturers and developers, supervision during construction, and post-commissioning technical assistance and training for community-based operators).
– Supported domestic manufacturers by providing technical support and training, whilst also creating a reliable pipeline of demand for the private sector by adopting a pre-qualification system which required communities to select their system developer from only pre-approved manufacturers and developers.

Despite catalysing the mini-hydropower sector, ADB/N supported projects experienced financial, technical, and operational challenges. Common issues included weak financial performance (often compounded by a lack of productive end-uses for electricity), design and construction shortcomings, and limited post-commissioning support. As a result of these challenges, by 1998 only 27% of schemes were fully operational, with 46% operating partially or experiencing problems, 9% temporarily closed, and 18% permanently closed. These shortcomings highlighted the need for improved quality assurance, structured delivery processes, and ongoing support.

7.1.2 Alternative Energy Promotion Centre (AEPC)

Established in 1996, the Alternative Energy Promotion Centre (AEPC)—independent from the national grid utility (Nepal Electric Authority)—became the central coordinating body for the development and implementation of renewable energy initiatives, particularly in rural and off-grid areas.

7.1.2.1 Energy Sector Assistance Program

The Energy Sector Assistance Program (ESAP) was AEPC's flagship program for expanding rural electrification. Delivered in two phases (1999–2007 and 2007–2012) with support from multiple international donors, ESAP focused on increasing and sustaining electricity access in communities unlikely to be reached by the national grid. A central component of the program was the deployment of micro- and mini-hydropower systems in rural communities.

7.1.2.2 ESAP Phase One (1999-2007)

ESAP Phase One consisted of five programs, including a mini-hydropower component targeting smaller schemes (<100 kW).

It developed standardised technical and project management guidelines covering feasibility, design, construction, commissioning, operation and maintenance, and tariff setting. In parallel, it developed the Renewable Energy Subsidy Policy (1999), which linked subsidies to generation capacity and remoteness.

Additionally, ADB/N's five Appropriate Technology Units (ATUs) were expanded into a network of seven Regional Centres, providing lifecycle support, including feasibility assessment, stakeholder coordination, financing support, and quality verification.

To accelerate domestic technical capacity, two private companies—one for eastern Nepal and one for western Nepal—were initially selected as exclusive implementation partners, ensuring a sufficient project pipeline to justify investment in mini-hydropower capabilities. As the success of early entrants attracted additional firms, ESAP deliberately transitioned away from the two-company model to facilitate broader private sector participation. By the end of Phase One, the sector had expanded significantly, with 52 installation companies and 45 consulting firms active in survey and design.

To further support technical capacity, ESAP also facilitated international training for Nepalese technicians and consultants in Switzerland, Indonesia, and India.

Overall, Phase One delivered 69 mini-hydro systems (3–70 kW) and 130 pico-hydro systems (<3 kW), providing electricity to approximately 16,500 households across 35 districts.

7.1.2.3 ESAP Phase Two (2007-2012)

ESAP Phase Two expanded the scale and ambition of the program. Scheme capacity limits increased to 1 MW, whilst the program also began aligning mini-hydro development with long-term planning (including eventual integration into the main grid).

Significant subsidies were provided for communities looking to electrify, with 75 percent subsidies provided for projects constructed by the cooperatives at the village level, and 90 percent subsidies for community-based electricity distribution systems. Further subsidy mechanisms were introduced to support projects in 13 very remote areas where the existing subsidy had been found to be insufficient.

Overall, ESAP Phase Two significantly increased deployment, delivering 442 mini-hydro systems with a total capacity of 6,347 kW, providing electricity to 65,500 households.

7.1.3 Structured project implementation framework

By its conclusion in 2012, ESAP Phase Two had addressed many of the shortcomings of ADB/N's original rural electrification efforts in rural Nepal. Part of this success was down to the incremental development of a structured project implementation framework, refined over time based on the experiences of the ADB/N and AEPC. A summary of the final structured project implementation framework is shown below in Figure 7.1.

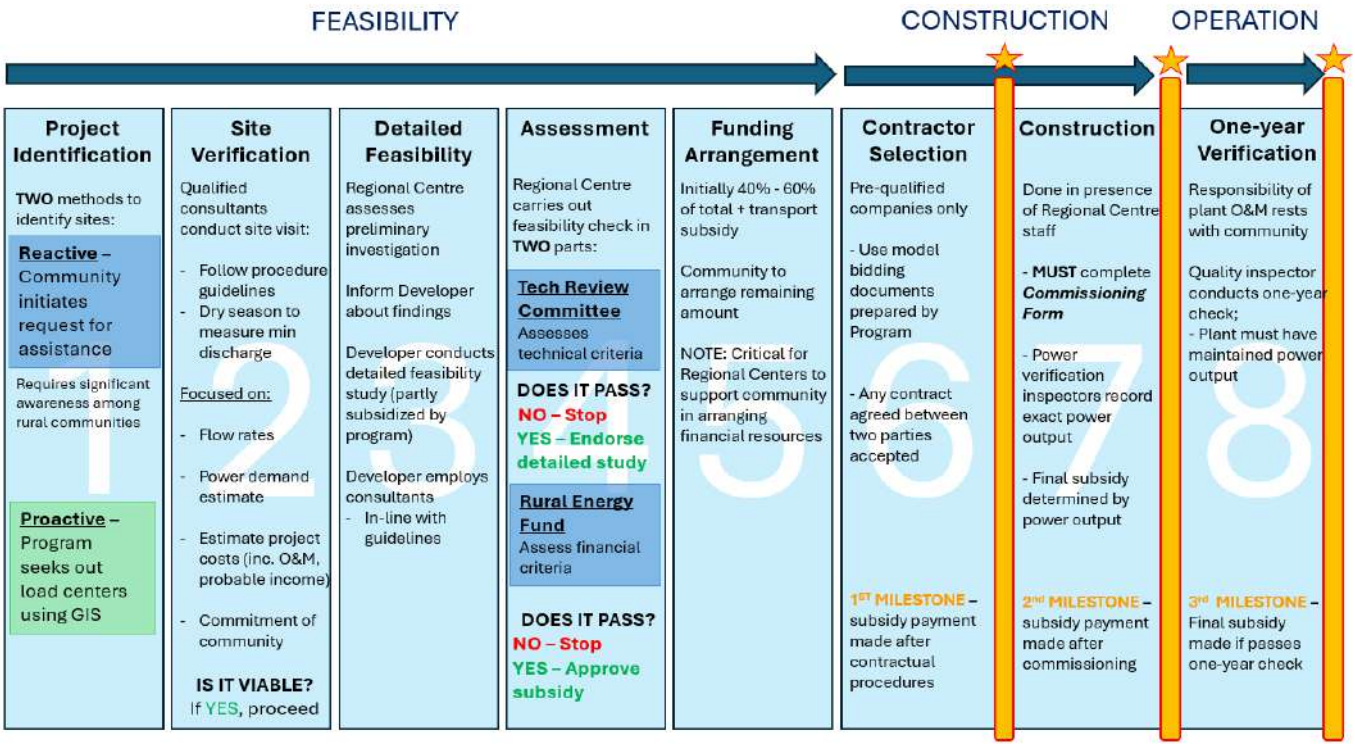


Figure 7.1 Structured project implementation framework used in Nepal for the development of off-grid mini-hydro schemes

7.2 Enabling policy environment

In parallel with the sustained government support detailed in Section 7.1, an enabling policy environment supported the development of the mini-hydropower sector through progressively lighter regulation. In 1984, electricity generation was delicensed for schemes up to 100 kW, reducing barriers to entry. As the sector matured, this threshold was further increased, with schemes up to 1MW required only to notify the relevant government authority rather than obtain formal licensing.

7.3 Vibrant domestic private sector

The combination of sustained government support (Section 7.1) and an enabling policy environment (Section 7.2) enabled the emergence of a capable domestic private sector.

This was reflected in the development of two manufacturing hubs in Kathmandu (serving eastern Nepal) and Butwal (serving western Nepal), with early capability established by three private companies. As the sector grew, additional firms entered these hubs, expanding manufacturing capacity. At its peak, the Nepal Micro-Hydropower Development Association (NMHDA), established in 1992, represented around 80 firms.

As the number of firms increased, technical capability also improved. This was reflected in incremental advances in turbine design and performance, as well as an expanding range of domestically manufactured components, including electronic load controllers from 1989.

Together, this growing domestic capability enabled efficient and cost-effective delivery across the project lifecycle—from survey and design to manufacturing and installation. It also improved the affordability and accessibility of maintenance and repair, supporting the long-term sustainability of mini-hydro schemes.

7.4 Summary

Nepal has developed a mature, community-based mini-hydropower sector, with over 400 hydro-powered mini-grids supporting rural electrification in remote regions (Energy Sector Management Assistance Program, 2022). This has been driven by the growth of a capable domestic private sector, an enabling policy environment, and sustained government support.

Key lessons from Nepal's mature mini-hydro sector include:

- **Community led delivery:** Communities initiate, co-finance, own, and operate schemes, supported by regional centres providing lifecycle technical and operational support.
- **Regional Centres:** A dispersed network of regional centres provide support throughout the mini-hydro project lifecycle. Support includes feasibility assessment, stakeholder coordination, financing, and verification of installation quality.
- **Domestic supply chain:** Local manufacturers and developers deliver design, installation, and maintenance, reducing costs and improving reliability.
- **Enabling policy environment:** Progressive regulatory reforms lowered barriers to entry and encouraged private sector participation.
- **Blended financing:** Subsidies, concessional finance, and community contributions improved affordability and uptake.
- **Structured program delivery:** A structured implementation framework was developed and refined over time based on the experience of ADB/N and AEPC.

8. Mini-grid good practice

The Energy Sector Management Assistance Program (ESMAP) is a global knowledge and technical assistance program administered by the World Bank that supports low- and middle-income countries to develop sustainable energy solutions. The following section draws on ESMAP's *Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers* (2022), to outline high-level good practices for mini-grid development, highlighting key considerations for achieving financial sustainability, operation & maintenance, and community engagement. It should be noted the report does not exclusively discuss mini-hydro powered mini-grids, however the key points provided in the following subsections are relevant to all mini-grids, and applicability to mini-hydro is as discussed below.

8.1 Financial sustainability

For a mini-grid to be viable, it must be financially sustainable. Most commonly, this requires that revenue from customer tariffs at least exceeds the full cost of operation, including routine maintenance, sustaining capital and operator salaries, even if construction capital finance is not required to be remunerated. Tariff revenues should support sustaining capital through the gradual accumulation of a reserve fund to cover major repairs, overhauls, obsolescence and unforeseen expenditures. Where a developer operates a portfolio of mini-grids, reserve funds can be pooled to accelerate capital accumulation and diversify risk across assets. Alternatively, if insurance or other pooled risk funds are available, tariffs need to cover the premiums.

Achieving this depends on meeting two key financial conditions:

1. The community must be willing to pay for the electricity provided; and
2. The community must have the capacity to pay tariffs at the levels outlined above.

To ensure these requirements are met, mini-grids need a minimum level of customer density, along with electricity demand that is aligned with the system's generation capacity. As a result, financial sustainability hinges on a well-defined business model and tariff structure, informed by a thorough understanding of the customer base.

A relatively consistent level of demand throughout the day ensures efficient use of the mini-grid by increasing the load factor and reducing spilling. Identifying and promoting productive uses of electricity (PUE) is central to achieving this for two reasons. First, income-generating appliances typically require more power than household appliances, increasing overall demand. Second, they are generally used during the day, when household demand is lower, thereby improving load factor and overall system utilisation.

Analysis by the Energy Sector Management Assistance Program (ESMAP) indicates that increasing the load factor of a mini-grid from 22 per cent to 40 per cent—through stronger daytime consumption by businesses and commercial users—can reduce the cost of electricity production by approximately 25 per cent. Typical productive uses include workshop machinery, agro-processing (e.g. cooling, drying and food processing), and telecommunications infrastructure.

However, electricity demand does not automatically increase with the introduction of a mini-grid; it must be actively developed through strong community engagement to promote productive uses of electricity.

One approach, first developed by companies such as OMC Power in India, is the Anchor–Business–Community (ABC) model. Under this model, the developer first secures an anchor customer (e.g. a workshop, agro-processing facility, telecommunications tower, school, or hospital), before identifying—and, in some cases, actively supporting the development of—business customers (e.g. shops and small enterprises). Ideally, the anchor customer consumes a significant share of the available energy, providing a stable and substantial revenue stream that reduces reliance on more variable household demand, thereby improving overall project viability. The size of generation is typically determined primarily by the demand requirements of the anchor load.

In contexts where securing a single anchor load is challenging—particularly in rural economies dominated by subsistence agriculture and small-scale artisanal activity—developers can instead aggregate multiple business customers to perform a similar role. This reduces reliance on any single customers and improves revenue resilience and overall project stability.

Overall, this approach of targeting anchor and business loads ensures the mini-grid receives a stable and predictable revenue stream, which in turn enables households to be connected at more affordable tariff levels (as the anchor and business load tariffs are able to subsidise the connection and consumption tariffs for households).

Another key consideration for developers, alongside the ABC model, is the profile of rural households connecting to the mini-grid. In PNG, there are at least two broad groups with distinct electricity demand characteristics. The first comprises informal rural households—primarily subsistence farmers—who make up approximately 97% of the rural population. Energy use in this group is low, typically limited to lighting and device charging. The second group includes formally employed professionals, such as nurses, teachers, local government officials, and church pastors. These households generally exhibit higher electricity consumption, reflecting greater appliance ownership (e.g. refrigerators and televisions).

The relative composition of these groups has important implications for system design. In communities dominated by informal households, developers may need to place greater emphasis on anchor and business loads to underpin demand and revenue. In contrast, where a higher proportion of formally employed households is present, reliance on anchor loads becomes less critical.

8.2 Operation and maintenance

The ESMAP Handbook highlights that effective operation and maintenance are critical to the long-term performance of mini-grids. Most systems require a local operator to monitor performance and adjust operation in response to changing demand. Robust maintenance practices rely on continuously assessing system performance, promptly identifying faults, and ensuring that the necessary skills, tools, and spare parts are available to resolve issues efficiently.

A key constraint in many contexts is the limited availability of skilled technicians. Some developers have addressed this by establishing dedicated training programmes—for example, Husk Power in India trains over 100 technicians each quarter to support its operations. In parallel, maintenance systems must ensure that commonly failing components are readily available; maintaining an inventory of high-risk spare parts allows operators to respond quickly to equipment failures and minimise downtime.

8.3 Community engagement

Effective community engagement is fundamental to the long-term success of mini-grids and must be embedded across the entire project lifecycle, from design through to operation and maintenance. Insufficient engagement has been widely identified as a key contributor to project underperformance and failure, reflecting the substantial effort required to build trust, raise awareness, and educate communities.

Successful engagement begins with a clear understanding of the local socioeconomic, cultural, and environmental context, typically informed through multiple site visits to identify appropriate technical solutions and opportunities for productive uses of electricity. Early and continuous involvement of the community helps improve system design, avoid disputes, gain local support, mobilise local contributions (in cash or kind), and strengthen local ownership, all of which contribute to operational sustainability.

Central to this process is effective communication, delivered through trusted and accessible platforms, and providing accurate, balanced, and comprehensive information on the benefits, costs, and limitations of the mini-grid. Strong awareness and engagement can significantly influence demand: satisfied customers promote the service within their social networks.

Increasingly, developers are also recognising the importance of inclusive and gender-responsive engagement strategies. Women often play a critical role in promoting services and reaching end-users, given their strong community networks and understanding of household energy needs. However, participation in consultations and decision-making can be constrained by social norms and time constraints. Addressing these barriers through more inclusive engagement approaches not only improves equity but also strengthens demand, enhances decision-making, and maximises the development impact of electrification.

Table 8.1 Key community engagement activities over the project cycle (after ESMAP, 2022)

	Design and planning	Promotion and information	Financing and procurement	Implementation and construction	Registration and connection	Operations and maintenance
Community engagement activities	Assess community energy needs, expectation and demand Build community awareness Identify local stakeholders (inc. system operators) Develop a portfolio of prospective customers Estimate customers willingness to pay and ability to pay Prepare a mini grid design that is: socially inclusive, technically sound, and financially viable	Provide clear and accurate information on services, tariffs and benefits Leverage community structures, including women's networks, to disseminate information Build energy literacy, including billing, safe use, basic maintenance, and grievance mechanisms Showcase early adopters and successful use cases to build trust and stimulate uptake Assist registration	Establish financial model to strengthen demand forecasts Mobilise community contributions (cash and in-kind, e.g. labour and materials) Facilitate access to finance for connections and productive-use appliances Obtain more robust data on demand, customer profiles, and load characteristics Prepare project documentation Ensure regulatory compliance	Recruit and engage local labour for construction and installation activities Engage prospective customers during project delivery to support early uptake	Support customer registration and connection processes	Train local operators in system operation, maintenance, and safety Encourage productive uses to increase load and revenue Ensure reliability and functionality Strengthen service capacity
Target groups	Community members Local leaders and authorities Financial institutions Government agencies	Community members	Financial institutions Investors Government agencies	Service providers Local businesses Labourers	Households Businesses Operators	Households Businesses Operators

8.3.1 Community engagement practices in other countries

One innovative approach to strengthening community engagement is the Mini-Grid Stories initiative. Piloted in India, this program enabled mini-grid developers, along with small business owners, households, and other community members, to use a smartphone application to record short videos documenting their experiences. The application guided users in developing their stories, including reporting on the impacts of mini-grid electricity on their livelihoods. Once uploaded to an online platform, these videos could be viewed or downloaded for offline use,

providing developers with a practical tool to demonstrate the transformative benefits of mini-grids to prospective customers.

Targeted institutional mechanisms can help ensure inclusive engagement. Where local electrification committees offer women equal access to leadership roles, their influence in decision-making is significantly strengthened. Nigeria's Rural Electrification Agency has formalised this approach by mandating women's representation in local mini-grid governance structures, supported by women-only consultations to ensure their perspectives are captured.

8.3.2 Community engagement practices in PNG

The community engagement practices outlined above reflect approaches adopted in other countries within the mini-grid sector to promote meaningful community participation, foster local support, and ensure equity and inclusion. In the context of PNG, these approaches must be carefully adapted to reflect the country's unique socio-cultural landscape, characterised by high cultural diversity, geographical remoteness, limited connectivity, restricted access to essential services, language barriers, and varying levels of literacy.

As a result, community engagement practices in PNG are not uniform but instead vary significantly depending on the specific characteristics of each community. The following summaries provide brief illustrations of the engagement approaches observed across the three mini-grid systems visited in April 2026, complemented by additional examples and insights shared by subject matter experts during stakeholder consultation sessions.

8.3.2.1 Rondon Ridge Lodge, Western Highlands Province

At Rondon Ridge in Western Highlands Province, the mini-grid system is privately owned and operated by an expatriate with a long-standing relationship with the people of the Rondon and Kuta Range areas. A critical success factor in establishing the system was his early engagement with community elders and traditional leaders, recognising and respecting the local leadership structure that underpins decision-making in PNG.

Through these engagements, he clearly communicated his vision of developing an eco-tourism hub that would connect the Rondon and Kuta Range communities to broader economic opportunities within PNG and internationally. This transparent dialogue enabled the establishment of a mutual understanding, whereby the community supported the initiative in anticipation of shared benefits, including improved access to telecommunications, roads, electricity, and water supply.

Over time, the delivery of these services has materialised, reinforcing community trust and strengthening the relationship between the asset owner and local stakeholders. This is reflected in the strong sense of local ownership, with communities actively protecting and supporting the mini-grid system and associated developments.

8.3.2.2 Kudjip, Jiwaka Province

The Kudjip mini-hydropower scheme in Jiwaka Province is owned and operated by the Church of the Nazarene. Its establishment is deeply rooted in religious faith and a shared commitment to advancing the Church's mission within the community. Papua New Guinea is widely recognised as a Christian nation, where institutions affiliated with churches are often regarded with a high level of respect, trust, and moral authority.

The presence of the Kudjip Nazarene Hospital, alongside the mini-hydro scheme, demonstrates the effectiveness of engaging credible and trusted institutions to build and sustain strong community relationships. This approach not only facilitates initial community acceptance but also fosters long-term support across generations, highlighting the importance of partnering with institutions that hold enduring social and cultural significance rather than focusing solely on short-term engagement outcomes.

8.3.2.3 Gatop, Morobe Province

The Gatop mini-hydropower scheme is located in the Tewae-Siasi District of Morobe Province, PNG. Due to the remoteness of the area and lack of road access, the site is primarily accessed by helicopter, which presents a significant logistical challenge for the operation and maintenance of the facility.

Similar to the Kudjip mini-hydro scheme, Gatop was established by Lutheran missionaries to support their mission in the region, which includes the provision of essential services alongside their religious work. The mini-hydro scheme currently plays a critical role in powering the Etep Rural Hospital, which serves a population of over 100,000 people across the Tewae-Siasi, Kabwum, and Rai Coast districts in Morobe and Madang Provinces. The hospital represents the nearest Level 4/5 health facility for these districts, making it a vital piece of social infrastructure.

According to local leaders and community members, the mini-hydro scheme is essential to maintaining the hospital's operations and ensuring the delivery of consistent and reliable healthcare services. Despite the rural and isolated setting, the combined presence of the hospital and the mini-hydro system has significantly improved community access to quality healthcare, education, and associated economic opportunities.

This case provides a strong example of effective project synergy, where the integration of energy infrastructure and social services creates tangible and sustained benefits for local communities. Such outcomes foster long-term community recognition, ownership, and support, reinforcing the value of aligning infrastructure investments with essential service delivery for lasting development impact.

8.4 Regulatory framework

Supportive regulation is critical to scaling mini-grid development. Key regulatory decisions directly shape how—and whether—the mini-grid sector grows. When done well, it can complement policy by providing clarity and guidance on how mini grids can be deployed effectively, thus incentivizing investment. While improved policies and regulations to support mini-grids do not automatically lead to more private-sector investment, ESMAP has found a statistical correlation between the number of mini-grids installed and planned in a country and the quality of that country's regulatory and policy framework for mini-grids.

An effective framework should create an enabling environment that promotes reliable service delivery at the lowest cost-recovery tariffs. It must provide predictability for investors and developers, while retaining sufficient flexibility to adapt as the market matures.

The five key regulatory decisions, detailed in Table 8.2, are market entry, retail tariffs, service standards, technical standards, and the relationship between the main grid and the mini-grid. In the table, the options progress from light regulation options on the left of the document to heavier regulation options on the right.

Table 8.2 Key regulatory decisions (after ESMAP, 2022)

	Regulatory approach (in general regulatory requirements increase in stringency from left to right)				
Market entry	**Increasing regulatory stringency →→→→

	Regulatory approach (in general regulatory requirements increase in stringency from left to right)				
Interconnection procedure	**Small power distributor**	**Small power producer**	**Small power distributor plus small power producer**	**Coexistence of main grid and mini-grid**	**Asset buyout**
	Mini-grid retains its distribution assets (and becomes a Small Power Distributor). Generation assets are transferred to the utility, sold to a third party, or abandoned.	Mini-grid's distribution network is transferred to the utility or abandoned. The Small Power Producer produces and sells power to the utility.	Mini grid retains its distribution and generation assets. Mini grid meets customer demands by generating itself, buying from the main grid, or both. Mini grid can sell its excess power to the main grid.	Main grid and mini-grid are physically separate but operate in the same service area.	Utility purchases all or some of the mini grid's assets and operates, decommissions, or abandons them.

In practice, a phased approach to regulation is often preferred as a market develops. In a fledgling mini-grid setting, light regulation may be enough to achieve good service at the lowest possible tariffs. However, when mini-grids gain market power, heavier regulation may be required to ensure an adequate quality of service at the lowest possible tariffs. Mini-hydro generally makes use of monopoly assets or assets in the common on an often exclusive basis. Exclusive access to water over an advantageous reach of the river justifies the imposition of obligations of a duty of care for the environment and the community, and access to power of reasonable quality at reasonable tariffs, and this provides social license for regulation. The phasing in of regulation is illustrated in Table 8.3.

Table 8.3 Three phases of evolutionary regulation (after ESMAP, 2022)

Area	Start	Threshold 1	Medium term	Threshold 2	Long term
Entry	Registration	Five years after first mini grid is registered Number of customers served reaches a certain level (e.g. 40%) Average consumption reaches a certain level (e.g. 40% main grid)	Registration	Fifteen years after first mini grid is registered Number of customers served reaches a certain level (e.g. 80%) Average consumption reaches a certain level (e.g. 80% main grid)	Permit/license
Tariff	Willing buyer–willing seller		Efficient new-entrant price cap		Individualized cost-based tariff
Service standards	Reporting		Differentiated regulated standards		Main grid-level standards
Technical standards	Safety standards; Optional grid-compatible standards		Safety standards; Optional grid-compatible standards		Safety standards; Optional grid-compatible standards
Subsidies	Implicit subsidies; Capital subsidies		Capital and/or connection subsidies		Connection or energy subsidies (if needed)

9. NEA Off-Grid Small Power Systems Regulation 2025

The National Energy Authority Off-grid Small Power Systems Regulation 2025 (the Regulation) establishes Papua New Guinea's first comprehensive regulatory framework for off-grid electrification. It sets out provisions across key areas including market entry, retail tariff setting, service standards, technical standards, and interconnection procedures, providing a structured basis for the development and operation of off-grid systems.

9.1 Market entry

The Regulation offers two pathways for service providers—Registered Service Providers and Licensed Service Providers—each with distinct regulatory requirements, operating conditions, and levels of oversight. A comparison between the two pathways is provided in Table 9.1. Developers can pursue a Registration or Licence to install, own, operate and maintain a system provided that the proposed service area is Off-Grid[1]; and, if within the Distribution Licensee's[2] Exclusivity Area, is one of the following (i) not within the Distribution Licensee's extension plan; and (ii) in an Underserved Area[3]. The obvious challenge arising from the limitation on a Registered Service Provider nominating a site physically within the Distribution Licensee's Exclusivity Area is that not all parts of that area may contain viable customers for the Distribution Licensee because of the comparative cost of grid extension. And yet the Registered Service Provider is restricted in providing power to those customers.

Table 9.1 Comparison of regulatory requirements for Registered and Licensed Service Providers

	Registered Service Provider	Licensed Service Provider
Regulatory status	Registration	License
Regulatory complexity	Lower	Higher
Maximum combined generation capacity	1 MW	1 MW
Location	Must be outside Distribution Licensee's Exclusive Area	Can operate within Distribution Licensee's Exclusivity Area (if not within Distribution Licensee's Expansion Plan)
Exclusive rights to distribute and retail electricity	Not permitted	Permitted
Allowable voltage	– Extra-Low Voltage (ELV): Up to 50 V AC / 120 V DC – Low Voltage (LV): Up to 1,000 V AC / 1,500 V DC	– Extra-Low Voltage (ELV): Up to 50 V AC / 120 V DC – Low Voltage (LV): Up to 1,000 V AC / 1,500 V DC – High Voltage (HV): Exceeding 1,000 V AC / 1,500 V DC
Form	Form 2A – Registration Form	Form 2B – License Form
Protection if grid arrives	No compensation entitlement	Eligible for compensation

[1] "Off-grid" means not connected to or served by PPL or any other Distribution Licensee.

[2] "Distribution Licensee" means PNG Power Ltd (PPL), the national utility company, or another electricity distributor, licensed by the National Energy Authority to operate a Distribution Network in Papua New Guinea

[3] "Underserved Area" means an area within a Distribution Licensee's Network with an existing Distribution System with poor or insufficient reliability.

	Registered Service Provider	Licensed Service Provider
Regulatory requirements	No additional requirements	– Community agreement executed – Land secured and permits obtained – Tariff approved by NEA – Health and safety requirements complied with

Table 9.2 Market entry requirements adopted by the NEA in the NEA Off-Grid Small Power Systems Regulation 2025

	Regulatory approach (in general regulatory requirements increase in stringency from left to right)				
Market entry	**Increasing regulatory stringency →→→→

For example, Schedule 4 requires that all LV system components be installed, operated, and maintained by a licensed electrician. While this reflects an appropriate emphasis on safety and quality, the availability of suitably qualified personnel within, or willing to relocate to, many of the communities where off-grid electrification is most critical may be limited. As such, the current framework may benefit from a more phased approach to regulation, whereby requirements are calibrated to sector maturity.

It is understood by the authors that, while the Regulation has been formally issued, the NEA is actively reviewing its provisions and considering revisions in response to stakeholder feedback. As part of this process, elements of the technical standards may be refined to support more practical implementation.

Table 9.5 Technical standards adopted by the NEA in the NEA Off-Grid Small Power Systems Regulation 2025

	Regulatory approach (in general regulatory requirements increase in stringency from left to right)				
Technical standards	**Increasing regulatory stringency →→→→

time. In the interest of fostering an enabling environment for off-grid electrification and supporting PNG's electrification objectives, it will be important that these fees are set at levels that do not unduly constrain project development.

9.6.3 Retrospective regulation

It is understood by the authors that the NEA intends to apply the Regulation retrospectively to existing mini-grids. This approach sits somewhat in tension with the principle of phased regulation, whereby more stringent requirements are typically introduced progressively as markets mature.

10. Recommendations

The key recommendations proposed to support development of off-grid mini-hydro in Papua New Guinea reflect the findings from the desktop review, site visits, regulatory review, Nepal case study, and review of mini-grid good practice. It should be noted there is some interaction and overlap between the recommendations.

10.1 Establish a suite of frameworks to support off-grid electrification in PNG

To support the implementation of off-grid electrification in PNG, a suite of complementary frameworks covering project delivery, community engagement, and financial sustainability would provide crucial benefits. Together, these frameworks would provide a structured and consistent approach to project development and implementation.

10.1.1 Off-grid electrification project delivery framework

A standardised project delivery framework should be developed for off-grid electrification projects in PNG, drawing on lessons from the Nepalese framework detailed in Section 7.1.3.

The framework would reasonably include:

- **Defined project stages**, with clear activities and deliverables at each stage;
- **Go/no-go decision points**, where technical and financial viability are assessed before proceeding; and
- **Milestone-based funding**, with payments linked to project milestones and a final payment contingent on demonstrated operational performance over a defined period.

Together, these measures support consistent project delivery, reduce implementation risk, and provide a foundation for scaling up off-grid electrification programs in PNG.

10.1.2 Community engagement framework

Community ownership is critical to the long-term success of off-grid electrification projects in PNG. Projects that fail to secure and maintain genuine community support are unlikely to achieve long-term success, often experiencing land access challenges, compensation disputes, poor tariff recovery, and difficulty sustaining operation and maintenance activities.

A standardised community engagement framework developed and applied throughout the project lifecycle would guide stakeholder engagement, support community ownership, manage expectations, and minimise land-related disputes. The framework would be applied from initial project identification through to long-term operation and maintenance.

Key elements of the framework should reasonably include:

- **Adopt a bottom-up approach**, with only communities actively seeking electrification considered for project development. By ensuring projects arise from local demand rather than external intervention, communities are more likely to develop a sense of ownership, reducing compensation expectations and the risk of land-related disputes.
- **Require early, transparent, and continuous engagement**, ensuring communities are well informed and able to participate in decision-making in line with free, prior and informed consent. Effective engagement helps build a shared understanding of project benefits, obligations, and responsibilities while managing expectations.
- **Build trust between communities and project developers.** Where appropriate, this may include engaging credible and trusted local institutions and leadership structures, including faith-based organisations and traditional leaders, which often play a central role in community decision-making in PNG.

– **Identify the most appropriate land access pathway**, whether through customary land arrangements, Incorporated Land Groups (ILGs), or land acquisition mechanisms. The implications of each approach for project governance, community acceptance, and compensation claims should be carefully assessed.
– **Establish mechanisms for ongoing community participation**, such as local electrification committees, mini-grid management committees, and user groups, to build local capacity while strengthening local ownership, accountability, and long-term support.
– **Ensure inclusive participation**, providing meaningful opportunities for women to participate in consultations and decision-making.

In developing the community engagement framework, lessons should be drawn from the successful approaches observed during the three mini-hydro site visits, as well as community engagement models successfully applied in other sectors in PNG.

10.1.3 Financial sustainability assessment framework

Alongside community support, financial sustainability is essential to long-term project success, with weak revenue generation and poor tariff recovery often contributing to premature scheme failure. While capital funding for off-grid projects in PNG can often be sourced from government programs or donor funding, these funding sources cannot generally be relied upon to support long-term operation, maintenance, major repairs, or asset replacement. As a result, financial sustainability should be a key go/no-go decision criterion during project development.

Only projects that demonstrate a credible pathway to funding routine operation and maintenance, operator salaries, major repairs, and future asset replacement are genuinely feasible. A standardised financial sustainability assessment framework developed for application during the feasibility stage of the broader project implementation framework would support this assessment.

Key factors that would be assessed include:

– **Community size and customer density**, to ensure a sufficient revenue base;
– **Community willingness and ability to pay** electricity tariffs;
– **Productive uses of electricity**, which increase demand and improve system utilisation (where opportunities are limited, developers should work with communities to identify and develop productive uses that support income generation and project viability);
– **Anchor loads**, such as hospitals, schools, telecommunications infrastructure, workshops, and agro-processing facilities, which provide stable demand and underpin project revenue; and
– **Household demand characteristics**, including the proportion of formally employed households and expected appliance ownership.

10.2 Support the development of domestic technical capacity

10.2.1 Establish regional support centres

PNG's geographic isolation and challenging terrain create significant barriers to the delivery and long-term operation of off-grid electrification projects. To address this, a decentralised system of regional support centres should be established to provide local delivery support, training, field supervision, troubleshooting, and ongoing O&M assistance to communities where off-grid electrification is being implemented. The centres could provide support for all off-grid electrification technologies (diesel, solar/BESS and mini-hydro).

Drawing on Nepal's Appropriate Technology Units and later Regional Centres (Section 7), these centres could:

– Support feasibility assessments and project design;
– Provide construction supervision and technical assistance;
– Support commissioning and performance testing;

– Coordinate engagement between communities, developers, and financiers;
– Support long-term operation and maintenance through locally based technicians; and
– Provide career pathways and training opportunities to build technical capability within the sector.

Strategically locating centres in major regions (e.g. Highlands, Momase, and Islands) would improve access to technical support, reduce project delivery risks, and strengthen the long-term sustainability of off-grid electrification programs.

10.2.2 Capacity building

The long-term success of off-grid electrification in PNG depends on developing local technical, operational, and management capability. While mini-grid systems require technically competent operators, they also rely on personnel with skills in billing, financial management, and governance.

To address current capacity constraints, the Government of PNG, provincial authorities, and development partners working in lockstep to implement targeted training programs covering system operation and maintenance, electrical trades, financial administration, and governance, would provide maximum benefit. Training programs are best structured to create long-term career pathways for operators, technicians, and managers within the off-grid sector.

If established, the regional support centres recommended in 10.2.1 could play a central role in coordinating and delivering these training initiatives.

10.2.3 Support domestic industry

The long-term sustainability of PNG's mini-hydro sector will depend on the development of a capable domestic private sector able to support the full project lifecycle, from design and manufacturing through to installation and maintenance. Nepal's experience demonstrates that local industry development can improve cost efficiency, responsiveness, and system sustainability. In PNG, stronger domestic capability would reduce reliance on external providers, improve access to maintenance and repair services, and help avoid prolonged outages such as the four-month outage experienced at Kudjip following the generator failure in February 2026 (Section 6.1.9.3).

Steps which support domestic industry development include:

– Support of the growth of local contractors, fabricators, and suppliers through targeted investments and participation in project delivery;
– Provision of technical training and accreditation programs;
– Maintaining a consistent pipeline of projects to sustain private sector participation and justify private sector investment in mini-hydropower capability. During the sector's early stages, consideration should be given to pre-qualifying a small number of implementation partners and directing work through them to accelerate capability development; and
– Encouraging the formation of industry associations to coordinate standards, advocacy, and knowledge sharing

10.3 Careful selection of pilot projects to catalyse the sector

The success or failure of the first projects in an off-grid electrification program will have an outsized influence on future sector development. Successful pilot projects build community confidence, government support, developer interest, and funding availability, creating positive momentum for further investment and project delivery. Conversely, poorly performing early projects risk undermining confidence in off-grid electrification and slowing sector growth (as detailed in Section 5.3.1, where successive government initiatives lost momentum following problems experienced by early systems).

For this reason, strategically selected projects provide the greatest benefit. Early projects selected based on the likelihood of long-term success and prioritising communities will have:

– Strong community support;
– A credible pathway to long-term financial sustainability; and
– A credible pathway to developing local technical capability.

Project selection may involve a national outreach and awareness campaign inviting communities to submit expressions of interest for electrification. Satellite-based screening tools could then be used to assess factors such as population density, demand potential, and resource availability, supporting the prioritisation of communities with the highest likelihood of success. The assessment should also consider access constraints, proximity to external support (e.g. the Regional Centres suggested in Section 10.2.1), and the community's ability to develop and retain the local technical capability required for long-term operation and maintenance.

10.4 Strengthen government support for off-grid electrification

10.4.1 Enabling regulatory environment

An enabling regulatory environment is critical to scaling off-grid electrification. Through the establishment of the National Energy Authority (NEA) as the independent energy regulator in 2021, and the NEA's publication of the *National Energy Authority Off-grid Small Power Systems Regulation 2025* (the Regulation), the Government of Papua New Guinea has already taken important steps towards supporting off-grid development.

When assessing the regulation in its current form against the five key market decisions (Section 9), it was identified that the Regulation does, in many ways, create an enabling environment for developers in PNG, with four of the five key regulatory decisions—market entry, retail tariffs, service standards, and the relationship between the main grid and the mini-grid—categorised as enabling.

However, with regards to technical standards, the Regulation sets relatively high standards which, while supporting quality and safety, may limit practical implementation. As such, a more phased approach to technical regulation, in which requirements evolve as PNG's off-grid sector matures, may be appropriate to ensure that certain aspects of the Regulation do not inadvertently become a barrier to development.

In addition, uncertainty remains regarding the level of administrative fees (particularly the annual generation fee, which could affect a project's long-term financial sustainability) to be charged by the NEA, as well as the extent to which the Regulation will be applied retrospectively to existing mini-grids. Both decisions have the potential to significantly influence the regulatory environment for off-grid systems in PNG.

It is understood that, while the Regulation has been formally issued, the NEA is actively reviewing its provisions in response to stakeholder feedback. This provides an opportunity to refine technical standards, clarify administrative fees, and confirm the treatment of existing mini-grids. The outcomes of this process will play an important role in determining whether PNG's regulatory framework continues to support, rather than constrain, off-grid electrification.

10.4.2 Off-grid electrification authority

Large-scale off-grid electrification programmes are typically coordinated by a dedicated rural electrification agency or off-grid electrification authority as the needs of rural communities, particularly those outside the formal economy, are quite different to urban populations. No equivalent institution currently exists in PNG. While the NEA is increasingly performing aspects of this role, it also retains responsibility for sector regulation, potentially blurring the distinction between sector development and independent oversight.

As PNG's off-grid sector expands, coordinated national oversight will be critical to ensuring projects are delivered consistently and meet appropriate technical and operational standards. A dedicated off-grid electrification authority, or a clearly defined equivalent function within an existing agency, established to provide quality assurance, technical governance, and coordination of development activities would greatly benefit the sector.

Key responsibilities could include:

- **Developing standardised design guidelines**, including "deemed-to-comply" system configurations;
- **Reviewing project designs** to ensure compliance with established technical standards or adequate justification for departures from those standards;
- **Providing independent technical oversight and quality assurance** to confirm that systems have been designed, constructed, commissioned, and operated in accordance with approved standards and guidelines;
- **Managing inspection, commissioning, and verification processes**; and
- **Coordinating national and international funding** to support off-grid electrification programs.

11. Conclusion

Drawing on a desktop review of existing mini-hydro schemes in PNG, site visits to three operational systems, a case study of Nepal's successful mini-hydro program, a review of mini grid good practice, and a high-level assessment of the *NEA Off Grid Small Power Systems Regulation 2025*, this study presents the first evidence-based review of PNG's off-grid mini-hydro sector.

The review found that off-grid electrification will play a critical role in achieving PNG's electrification objectives, and that mini-hydro can and probably should continue to be considered alongside solar/BESS wherever it represents the best-fit solution. Importantly, the study demonstrates that long-term operation of mini-hydro systems is achievable in PNG, with successful schemes sharing common characteristics including strong community ownership, sustainable financing arrangements, local technical capability, and access to ongoing technical support.

To assist stakeholders, the report presents a suite of practical and actionable recommendations aimed at improving the performance and long-term sustainability of existing mini-hydro schemes, while reducing the risks associated with future developments. Collectively, these recommendations seek to increase confidence in the sector and support the expansion of mini-hydro's role in PNG's rural electrification efforts. This will help ensure mini-hydro is considered alongside other technologies and deployed where it represents the best-fit solution.

Ultimately, the future success of mini-hydro in PNG will depend on applying lessons from PNG's existing schemes and adapting proven international approaches to PNG's unique context. Where these lessons are successfully applied, mini-hydro has the potential to make a meaningful contribution to rural electrification and broader socio-economic development across PNG.

12. Scope and limitations

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Accessibility of documents

If this report is required to be accessible in any other format, this can be provided by GHD upon request and at an additional cost if necessary.

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Appendices

Appendix A

Summary table of off-grid mini-hydro schemes in PNG

Table A.1 Summary table of off-grid mini-hydro schemes in PNG

System name	System developer (category)	System developer (details)	Year commissioned	Generation capacity (kW)	Operational status	Turbine type	Design head (m)	Design flow (l/s)	Local Level Government	District	Province
Zenag Chicken	Private	Zenag Chicken	Pre-1980	20	Not operational	Pelton	50	Unknown	Mumeng Rural LLG	Bulolo District	Morobe Province
Barapa	Private	Unknown	Pre-1980	20	Not operational	Unknown	20	Unknown	Kamano No. 1 Rural LLG	Kainantu District	Eastern Highlands Province
Rondon Ridge Lodge	Private	Trans Niugini Tours	2005	130	Operational	Turgo	70.6	235	Mount Hagen Rural LLG	Mount Hagen District	Western Highlands
Ambua Lodge	Private	Trans Niugini Tours	1985	100	Operational	Turgo	80	250	Hulia Rural LLG	Komo-Magarima District	Hela Province
Kabwum	Government	Department of Works (Government Works Programme)	1977	25	Not operational	Crossflow	45	85	Selepet Rural LLG	Kabwum District	Morobe Province
Simbai	Government	Department of Works (Government Works Programme)	1977	30	Not operational	Turgo	15	315	Simbai Rural LLG	Middle Ramu District	Madang Province
Sohun	Government	Provincial Mini Hydropower Programme (ADB loan)	1981	200	Not operational	Unknown	15	Unknown	Namatanai Rural	Namatanai District	New Ireland Province
Ru Creek	Government	Provincial Mini Hydropower Programme (ADB loan)	1982	800	Operational	Unknown	Unknown	Unknown	Mosa Rural LLG	Talasea District	West New Britain Province
Tinputz	Government	Provincial Mini Hydropower Programme (ADB loan)	Construction never completed	200	Never completed	Unknown	Unknown	Unknown	Tinputz Rural LLG	North Bougainville District	Autonomous Region of Bougainville
Lake Hargy	Government	Provincial Mini Hydropower Programme (ADB loan)	1989	1500	Operational	Unknown	29	5500	Bialla Rural LLG	Talasea District	West New Britain Province
Ogeranang	Government	Morobe Provincial Government (Morobe Provincial Hydro Programme)	1985	20	Not operational	Crossflow	20	250	Burum-Kwat Rural LLG	Finschhafen District	Morobe Province
Dauli Teachers College (Tari)	Government	Government of Papua New Guinea - Energy Planning Unit of the Department of Minerals and Energy (Diesel Replacement Programme)	1988	300	Not operational	Crossflow	30	1330	Hulia Rural LLG	Komo-Magarima District	Hela Province
Woitape	Government	Government of Papua New Guinea - Energy Planning Unit of the Department of Minerals and Energy (Diesel Replacement Programme)	1991	62	Not operational	Pelton	157	60	Woitape Rural LLG	Goilala District	Central Province
Telefomin	Government	Government of Papua New Guinea - Energy Planning Unit of the Department of Minerals and Energy (Diesel Replacement Programme)	1992	100	Not operational	Crossflow	36.5	450	Telefomin Rural LLG	Telefomin District	Sandaun Province
Marawaka	Government	Eastern Highlands Provincial Administration	2011	100	Operational	Turgo	100	140	Yelia Rural LLG	Obura-Wonenara District	Eastern Highlands Province
Menyamya	Government	Government of Papua New Guinea	Construction never completed	Unknown	Never completed	Unknown	Unknown	Unknown	Kome Rural LLG	Menyamya District	Morobe Province
Yalumet	Government	Morobe Provincial Government (Provincial Services Improvement Program and District Services Improvement Program)	2017	15	Operational	Unknown	Unknown	Unknown	Deyamos Rural LLG	Kabwum District	Morobe Province
Atemkit	Infrastructure Tax Credit Scheme (ITCS)	Ok Tedi Mining Ltd.	2004	30	Not operational	Unknown	Unknown	Unknown	Star Mountains Rural LLG	North Fly District	Western Province
Ok Tarim	Infrastructure Tax Credit Scheme (ITCS)	Ok Tedi Mining Ltd.	2012	5	Unknown	Pelton	Unknown	Unknown	Star Mountains Rural LLG	North Fly District	Western Province
Misima	Infrastructure Tax Credit Scheme (ITCS)	Misima Mines Pty. Limited (MMPL)	2003	200	Unknown	Unknown	Unknown	Unknown	Louisiade Rural LLG	Samarai-Murua District	Milne Bay Province

System name	System developer (category)	System developer (details)	Year commissioned	Generation capacity (kW)	Operational status	Turbine type	Design head (m)	Design flow (l/s)	Local Level Government	District	Province
Agaun	Not-for-profit	APACE	1989	28	Not operational	Turgo	Unknown	Unknown	Daga Rural LLG	Alotau District	Milne Bay Province
Faseu	Not-for-profit	Friends of Faseu	2005	5	Operational	Unknown	48	Unknown	Hube Rural LLG	Finschhafen District	Morobe Province
Hogave	Not-for-profit	Hans Wilsdorf Foundation	2013	20	Not operational	Pelton	Unknown	Unknown	Mount Michael Rural LLG	Lufa District	Eastern Highlands Province
Baindoang	ATCDI/Unitech	ATCDI/Unitech	1980	7	Not operational	Pelton	150	8	Nabak Rural LLG	Nawaeb District	Morobe Province
Teptep	ATCDI/Unitech	ATCDI/Unitech	1989	8	Not operational	Crossflow	10	150	Nayudo Rural LLG	Raicoast District	Madang Province
Karagl Maragl	ATCDI/Unitech	ATCDI/Unitech	1991	10	Not operational	Crossflow	30	60	Mount Digine Rural LLG	Gumine District	Chimbu Province
Romsis	ATCDI/Unitech	ATCDI/Unitech	Construction never completed	10	Never completed	Pelton	50	Unknown	Selau/Suir Rural LLG	North Bougainville District	Autonomous Region of Bougainville
Kerau	Mission	Catholic	1960	6	Unknown	Unknown	Unknown	Unknown	Tapini Rural LLG	Goilala District	Central Province
Fane	Mission	Catholic	1982	10	Not operational	Crossflow	Unknown	Unknown	Woitape Rural LLG	Goilala District	Central Province
Kanabea Health Centre	Mission	Catholic	Pre-1984	100	Not operational	Francis	Unknown	Unknown	Kotidanga Rural LLG	Kerema District	Gulf Province
Bema Health Centre	Mission	Catholic	Pre-1980	20	Not operational	Francis	Unknown	Unknown	Kaintiba Rural LLG	Kerema District	Gulf Province
Hawabango Health Centre	Mission	Catholic	Pre-1980	Unknown	Not operational	Unknown	65	26	Kaintiba Rural LLG	Kerema District	Gulf Province
Kaintiba	Mission	Lutheran	Pre-1980	15	Not operational	Crossflow	8	290	Kaintiba Rural LLG	Kerema District	Gulf Province
Kwaplalim	Mission	Lutheran	Pre-1980	25	Not operational	Pelton	16.5	Unknown	Kome Rural LLG	Menyamya District	Morobe Province
Watut	Mission	Unknown	Pre-1980	400	Not operational	Francis	Unknown	Unknown	Watut Rural LLG	Bulolo District	Morobe Province
Busama	Mission	Unknown	Pre-1980	20	Not operational	Pelton	35	Unknown	Salamaua Rural LLG	Huon District	Morobe Province
Heldsbach	Mission	Lutheran	1971	48	Not operational	Crossflow	37	162	Kotte Rural LLG	Finschhafen District	Morobe Province
Kipu	Mission	Summer Institute of Linguistics	Pre-1980	5	Not operational	Francis	10	Unknown	Waria Rural LLG	Wau-Waria District	Morobe Province
Ulap	Mission	Lutheran	Pre-1980	Unknown	Not operational	Pelton	Unknown	Unknown	Wasu Rural LLG	Tewae-Siassi District	Morobe Province
Gatop	Mission	Lutheran	2006	65	Operational	Crossflow	63	Unknown	Wasu Rural LLG	Tewae-Siassi District	Morobe Province
Bundi	Mission	Catholic	1970	77	Not operational	Crossflow	49.5	210	Bundi Rural LLG	Usino Bundi District	Madang Province
Yagusa Highland Christian Mission	Mission	Highland Christian Mission	1983	220	Not operational	Pelton	268	112	East Okapa Rural LLG	Okapa District	Eastern Highlands Province
Rongo	Mission	Lutheran	Pre-1980	Unknown	Not operational	Unknown	Unknown	Unknown	Mount Michael Rural LLG	Lufa District	Eastern Highlands Province
Bena	Mission	Seventh Day Adventist	1983	20	Not operational	Unknown	51	48	Lower Benna Rural LLG	Unggai-Benna District	Eastern Highlands Province

System name	System developer (category)	System developer (details)	Year commissioned	Generation capacity (kW)	Operational status	Turbine type	Design head (m)	Design flow (l/s)	Local Level Government	District	Province
Goroka	Mission	Unknown	1965	38	Unknown	Crossflow	12	400	Goroka Urban LLG	Goroka District	Eastern Highlands Province
Denglagu Mission (Kegsugl)	Mission	Catholic	Pre-1976	50	Operational	Crossflow	10	Unknown	Mitnande Rural LLG	Kundiawa-Gembogl District	Chimbu Province
Kudjip	Mission	Church of the Nazarene	2013	220	Operational	Crossflow	Unknown	Unknown	South Waghi Rural LLG	Anglimp-South Waghi District	Jiwaka Province
Kulli	Mission	Catholic	Pre-1980	Unknown	Not operational	Unknown	Unknown	Unknown	Anglimp Rural LLG	Anglimp-South Waghi District	Jiwaka Province
Togoba	Mission	Seventh Day Adventist	Pre-1980	30	Not operational	Unknown	Unknown	Unknown	Mount Hagen Rural LLG	Mount Hagen District	Western Highlands
Rugli	Mission	Unknown	1955	25	Not operational	Pelton	140	Unknown	Mul Rural LLG	Mul-Baiyer District	Western Highlands
Paglum	Mission	Seventh Day Adventist	Pre-1984	76	Unknown	Unknown	24	390	Mul Rural LLG	Mul-Baiyer District	Western Highlands
Timin (Wapenamanda)	Mission	Lutheran	1957	100	Not operational	Crossflow	24	390	Wapenamanda Rural LLG	Wapenamanda District	Enga Province
Yaibos	Mission	Lutheran	1967	100	Unknown	Crossflow	26	475	Wapenamanda Rural LLG	Wapenamanda District	Enga Province
Irelya	Mission	Seventh Day Adventist	Pre-1980	Unknown	Unknown	Unknown	Unknown	Unknown	Wabag Rural LLG	Wabag District	Enga Province
Par	Mission	Seventh Day Adventist	Pre-1984	Unknown	Unknown	Francis	Unknown	Unknown	Ambum Rural LLG	Kompiam District	Enga Province
Sopas	Mission	Seventh Day Adventist	Pre-1984	30	Not operational	Turgo	40	Unknown	Wabag Rural LLG	Wabag District	Enga Province
Kagua	Mission	Unknown	Pre-1984	7	Unknown	Francis	2	Unknown	Kagua Rural	Kagua-Erave District	Southern Highlands Province
Mendi	Mission	Catholic	Pre-1980	44	Unknown	Crossflow	Unknown	Unknown	Mendi Urban LLG	Mendi-Munihu District	Southern Highlands Province
Det	Mission	Unknown	1972	51	Unknown	Crossflow	16	400	Poroma Rural LLG	Nipa-Kutubu District	Southern Highlands Province
Hoiebia	Mission	United Church	1969	35	Not operational	Crossflow	26	170	Tebi Rural LLG	Tari-Pori District	Hela Province
Asia Pacific Christian Mission (Tari)	Mission	Evangelical Church of Papua	1973	37	Unknown	Crossflow	5.6	840	Tari Urban LLG	Tari-Pori District	Hela Province
Saint Josephs Tari Secondary School	Mission	Catholic	1976	36	Unknown	Crossflow	6	710	Hulia Rural LLG	Komo-Magarima District	Hela Province
Mougulu	Mission	Evangelical Church of Papua	1986	10	Not operational	Turgo	Unknown	Unknown	Nomad Rural LLG	Middle Fly District	Western Province
St John’s Mission (Kairuru High School)	Mission	Catholic	Pre-1980	Unknown	Unknown	Unknown	Unknown	Unknown	Wewak Islands Rural LLG	Wewak District	East Sepik Province

Appendix B

Summary table of PPL-owned and operated main grids and provincial mini-grids

Table B.1 PPL-owned and operated main grids[4]

Grid	Main load centres	Installed capacity (MW)	Peak demand (MW)	Transmission line length (km)	Key generation plant			
					Owner	Type	Name	Installed capacity*
Port Moresby Grid	National Capital District and surrounding areas of Central Province	~250 MW	125 MW	170 km	PPL	Hydropower	Rouna Cascade	~62 MW
						Diesel	Moitaka	~30 MW
					IPP	Hydropower	Edevu	~54 MW
						Natural Gas	NiuPower	~58 MW
							Dirio Power	~45 MW
Ramu Grid	Lae, Madang, Yonki, Goroka, Kundiawa, Mt Hagen, Mendi, Wabag, Gusap, Minj/Banz	~178 MW	97 MW	720 km	PPL	Hydropower	Ramu 1 (Yonki)	~75 MW
						Hydropower	Paunda	~12 MW
					IPP	Hydropower	Upper Baiune	~2 MW
						Heavy Fuel Oil	POSCO PNG	~34 MW
Gazelle Peninsula Grid	Kokopo, Rabual, Kerevat	~22 MW	10 MW	75 km	PPL	Hydropower	Warangoi	~10 MW
						Diesel	Kerevat	~12 MW

* Nameplate rating, not accounting for lack of availability

[4] Table developed from multiple sources: (PNG Power Ltd, 2016), (PNG DPE, 2017), (IFC, 2021), and (USAID-PEP, 2022). Where sources conflicted, most recent source adopted.

Table B.2 PPL-owned and operated provincial mini-grids[5]

Region	Province	Grid name	Transmission line length (km)	Power stations	Generation type	Peak load (MW)	Estimated connections
Southern	Milne Bay	Alotau system	33	Alotau	Diesel	2.9	1,103
		Samarai system	0.4	Samarai	Diesel	0.1	62
	Northern	Popondetta system	22	Popondetta	Diesel	1.7	1,630
				Divune	Hydropower	3	Unknown
	Gulf	Kerema system	4	Kerema	Diesel	0.5	350
	Western	Daru system	6	Daru	Diesel	0.8	559
Highlands	Hela	Tari system	34	Tari	Diesel	0.7	632
Momase	Morobe	Finschhafen system	13	Finschhafen	Diesel	0.2	184
	East Sepik	Wewak system	169	Wewak	Diesel	4	2,207
		Maprik system	29	Maprik	Diesel	0.7	337
	Sandaun	Vanimo system	16	Vanimo	Diesel	2	284
		Aitape system	17	Aitape	Diesel	0.3	163
Islands	Manus	Lorengau/ Lombrum system	453	Lorengau/ Lombrum	Diesel	1.7	1,630
	West New Britain	Bialla system	37	Bialla	Diesel	0.5	2,253
			34	Lake Hargy	Hydropower		
		Kimbe system	42	Kimbe	Diesel	4.2	Unknown
				Ru Creek	Hydropower		
	New Ireland	Kavieng system	69	Kavieng	Diesel	1.9	929
	Autonomous Republic of Bougainville	Hutjena (Buka) system	30	Hutjena (Buka)	Diesel	1.9	2,463
		Arawa system	19	Arawa	Diesel	0.9	314

[5] Table developed from multiple sources: (PNG Power Ltd, 2016) (PNG DPE, 2017) (USAID-PEP, 2022). Where sources conflicted, most recent source adopted.



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