Economics Consulting Services

Economic Impacts of a Biomass Power Project in Papua New Guinea

Report prepared for:

Markham Valley Biomass Limited,

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This Publication

This report describes the economic impact of a power project fuelled by biomass in the Lae region of Papua New Guinea. It evaluates the economic impacts this project will have on local and national economies, and compares these to a diesel-powered alternative.

Markham Valley Biomass Limited (MVBL) provided the information to assist in the preparation of this report and their support is gratefully acknowledged.

The project is in a comprehensive evaluation stage and the financial parameters are likely to change. However, the information provided by MVBL is based on many years of trials and feasibility studies and is considered a sound description of a biomass project in this location.

The estimates prepared by Economics Consulting Services are based on our best endeavours but should be regarded as broadly indicative only. No investments should be based on this report without independently verifying the information.

Given the pre-approval nature of the project, it is important to note that most numbers in the report have been rounded.

Abbreviations and Rates

1 USD = 3 Kina
km = kilometres
Km = millions of PNG Kina
ha = hectares
MW = Megawatt

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Executive Summary

This report has been prepared by Economics Consulting Services for Markham Valley Biomass Limited. It describes the expected economic impacts of a biomass based power station in the Lae region of Papua New Guinea.

The Ramu electricity grid is the most extensive in PNG and is growing but suffers from a lack of reliable capacity. There are significant benefits from any improvement in the capacity and reliability of the grid but the focus in this study is not on these benefits but on the incremental benefits of delivering reliable electricity using biomass as the primary energy source rather than the more common diesel fuelled power station.

Markham Valley Biomass Limited proposes a 30 Megawatt project fuelled by around 400,000 wet tonnes of biomass a year from sustainable biomass fuel plantations. The company has substantial trial areas and a large nursery and following five years of trials has selected two main species for commercial planting.

The Project is underpinned by a 25-year Power Purchase Agreement with PNG Power Limited with delivery of electricity from late 2019.

This will not be a highly profitable project. While it is intended that it will be viable, the emphasis is on increasing the Ramu Grid electricity supply in a sustainable way while creating a high level of local employment and local business involvement. Success will depend on the support of many small local landowners. Provisional agreements are in place covering 22,000 hectares of land.

Biomass has many advantages for the nation and region including:

- Replacement of imported diesel (or fuel oil) with a local energy source
- Substantial investment in plantations and power stations
- Large local employment for at least 25 years
- Major flow on landowner benefit, employment and economic impacts
- Transfer of best practice international plantation forestry skills to local settings
- Potential for associated enterprises such as timber veneers and plantation horticulture
- Significant increase in government taxation payments

Project plantation establishment phase

Establishment of the plantations and power stations involves an investment of K582m over seven years. The PNG share of the initial investment is estimated at K194m. The multiplier flow-through effect increases this impact in the economy to K437m.

The establishment workforce averages 570 jobs with 550 expected to be PNG workers. The flow on effect through the economy means a total of 23,000 job years of work are created over the seven years.

Total PNG household income is estimated at K120m and this will generate a total of K364m of household income in the economy. The multipliers are higher than other economies as the levels of leakage from the PNG economy is lower. This is due to a

lower proportion of household expenditure on imported goods and services such as household equipment and foodstuffs, motor vehicles and overseas travel.

Operations phase

Operating benefits are conservatively estimated over 25 years although the project may last longer depending on developments in renewable energy technology and storage.

Annual total project operating costs average K65.8m with PNG expenditure (wages, landowner payments and PNG consumables) of K45.3m a year. The annual expenditure in PNG will multiply through the economy to a total of K88m. Over the full 25 years, this represents a multiplier increase from K1,132m to K2,190m.

The plantation project will create 472 operations jobs of which 462 are expected to be PNG employees. The multiplier effect is to create a total of 2,560 jobs in PNG in each year of operation.

Project operating life household income is estimated at K29.6m a year or K740m over 25 years. The flow on effect is to create K1,838m in total over the operating life.

Alternative electricity sources

In comparison with a diesel fuelled power station, the biomass project involves a far higher investment in PNG, greater employment and much higher household income. The key difference is that the biomass plant has a local plantation as the fuel source rather than imported diesel. The large workforce involved in the timber plantation operations means vastly greater local expenditure (in PGK) and employment of PNG nationals. This is not surprising as MVBL selected biomass as the fuel source that would provide the greatest local impacts.

In round terms, the biomass project involves a K336m higher investment, creates 385 more jobs over the establishment phase and 452 more jobs during each of the 25 years of operations than a diesel or fuel oil alternative.

The effective impact of the Biomass project is conservatively estimated to result in a reduction over a 25-year period of 1,340 million litres of heavy fuel oil or diesel.

Net savings in annual fuel oil or diesel purchases are estimated at K39m in a typical operating year at an oil price of USD 52 per bbl (savings will be higher at higher oil prices).

Reduced reliance on diesel based electricity generation will also reduce the carbon dioxide emissions created in diesel generation. Assuming 0.750 tonnes of carbon emissions per MWh, the biomass fired power station will reduce CO2 by 4.5 million tonnes over the life of the project.

Other PNG benefits

A taxation estimate has been made for this project to provide an order of magnitude to the project impact. This estimate is intended as an indication only and will not be the final amount. The estimate is K740m over the project life.

Improved road access will be developed during construction to facilitate movement of materials and people. This will improve access in the region which presently suffers from poor road infrastructure.

It is anticipated that horticulture crops will be grown by landowners between the trees in the plantations providing real potential for produce sales in the Markham Valley. Early plantings have been seen good sales from the trial tree areas.

Summary of project impacts (2 x `15MW)

Parameter	Amount
Establishment phase expenditure Expenditure in PNG Flow on output impact	K582m K194m K437m
Establishment phase impacts: Direct PNG employees National jobs (including multiplier impact) Household income National household income (with multiplier)	 3,830 job-years 23,000 job-years K120m K364m
Operations phase impacts: Annual direct PNG expenditure Annual direct PNG impact (with multiplier) Total direct PNG expenditure National expenditure impact (with multiplier) Direct jobs National jobs (including multiplier impact) Total household income Total national household income (with multiplier)	 K45.3m K88m K1,132m K2,190m 462 FTE positions a year 2,560 FTE positions a year K740m K1,838m
Power price cost savings for PNG Power	K39m p.a. during period that biomass displaces fuel oil
Company tax paid over project life (to 2045)	K740 million
CO_2 mitigation*: per year over project life (25 years)	 140,000 tonnes 4,500,000 tonnes
Diesel consumption avoided over project life*	1,340 million litres

Chapter 1

1. Introduction

1.1 Overview

This report has been prepared by Economics Consulting Services for Markham Valley Biomass Limited (MVBL). It describes the expected economic impacts of a biomass power project in the Lae region of Papua New Guinea (PNG).

The power project is a result of a focus by the original project proponents on competitive renewable energy utilising biomass. The focus on tree species that have been genetically selected to optimise energy yields under specific soil and environmental conditions. The biomass is used to produce fuel for power projects where base load power can be economically provided.

Markham Valley Biomass Limited will develop this 30 Megawatt (MW) project in the Markham Valley near Lae. The power plant is to be fuelled by around 175,000 bone dry metric tonnes of biomass a year from plantations in the area. The company has established substantial trial plantation areas and a large nursery. Following five years of trials and selection, the company has selected clones of *Eucalyptus pellita* as the focus of production with potentially *Acacia Crassicarpa* on some soils.

The Project is underpinned by a 25-year Power Purchase Agreement signed with PNG Power Limited (PPL) in December 2015. That agreement requires delivery of electricity from late 2019. The PPA has all the necessary State and MVBL approvals, including ICCC and Kumul Holdings (formerly IPBC) approvals. The project will provide power into the nearby 132kV section of the Ramu Grid.

The Ramu Grid in Morobe Province is the largest grid network in PNG. Demand is growing and there is substantial potential to replace private (off grid diesel) generation and sell to new customers. There will be significant benefits from upgrading the electricity supply in this grid but these are not quantified in this study as these benefits can be realised from any upgrading of the grid generation.

This will not be a highly profitable project. While the companies involved intend that it will be viable, the emphasis is on increasing the Ramu Grid electricity supply in a sustainable way while creating a high degree of local employment and local business involvement. Success will depend on the support of small local landowners, who are visibly committed to and supportive of the project.

The focus of this study is on the benefits to the PNG economy, local landowners and businesses of providing the electricity using biomass. The report also considers the incremental impacts of local plantation timber as fuel rather than imported diesel along with some environmental benefits. The impacts are separated into the short and capital intensive establishment and construction phase, and the much longer operating period during which most of the benefits arise.

Chapter 2

2. Background

2.1 Location

The PNG Biomass Power Project is proposed for the Markham Valley inland from Lae (Figure 1). The power station will supply electricity into the Ramu Grid which runs from Lae into the Highlands at the top of the Valley. This is the largest grid in PNG and has seen consistent expansion in demand for many years, but has suffered from unreliable generation.

The project is in Morobe province which is the most populous province in PNG. Lae, the capital of the Province, is the second largest city in PNG and the largest port.

Figure 1: Project location - schematic

Source: Aligned Energy

Land use in the Markham Valley is predominantly subsistence agriculture with some small-scale cash cropping. The Valley did support extensive cattle grazing properties based on imported Kunai grasses and it is these grassland areas that will be used for the timber plantations. There is no displacement of subsistence agriculture land.

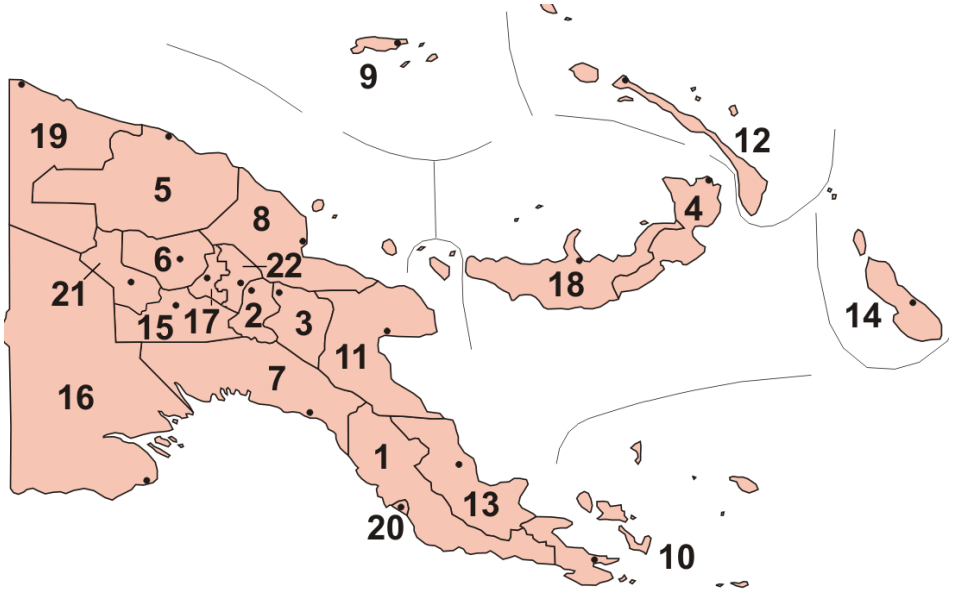
2.2 National context

PNG is the largest country and the largest economy in the Pacific Islands. Geographically, it can be broadly categorized into highlands, flat coastal plains, large river systems and islands. The population of close to 8 million is concentrated in the Highlands and river systems.

Politically, PNG is divided into twenty provinces, one autonomous province and the National Capital District (Figure 2). The provinces are branches of the national government.

The population is very dispersed with the Morobe province (number 11 in Figure 2) providing only 9% of the PNG population despite being the most populous of the provinces. Over the 21 years from 1990 to 2011, the Morobe population grew from 380,000 to 675,000.

Figure 2: PNG Provinces



Source: www.mapsofworld.com

PNG is a very diverse country ranging from villages dependent on subsistence and small cash-crop agriculture to modern urban areas in Port Moresby (capital), Lae, Madang, Wewak, Goroka, Mt Hagen, and Rabaul.

Around 85% of the population live in farming areas and 15% in urban areas. The population is growing rapidly at about 2.1% per year. The population is skewed towards young people with a small number of older people and a relatively low proportion of people in the working age years of 15 to 64.

PNG is rich in natural resources, including oil, gold, copper and nickel. Natural resource extraction accounts for 60% of Gross Domestic Product (GDP) and a large share of government revenue. Agriculture is important due to the high degree of subsidence living and the high level of employment.

Merchandise exports were dominated by minerals including LNG and condensate with 81% of the value in the June quarter of 2016 followed by agriculture (11%).

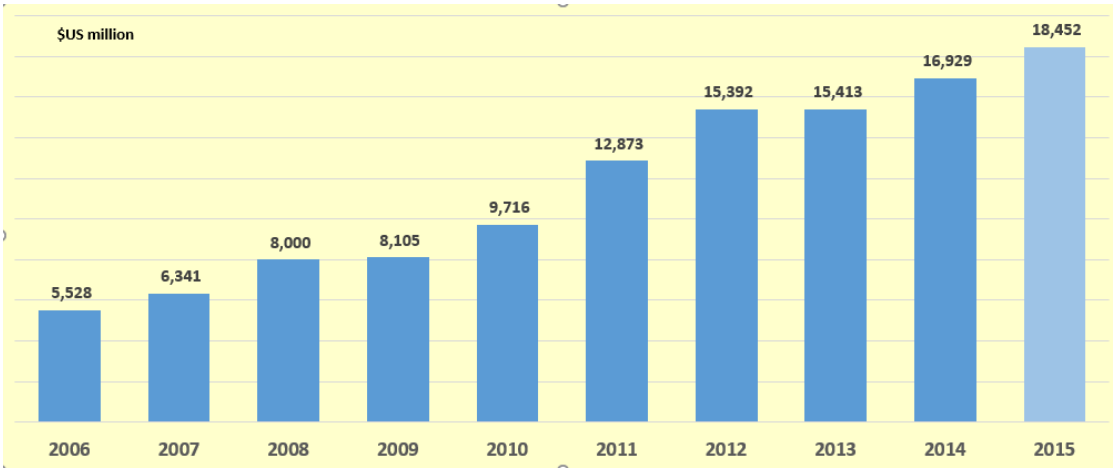
Manufactured goods dominate imports (69%) while fuels and mining goods make up 18%. Transport and power generation fuels are large imports.

Revenues from natural resource exploitation have resulted in high government spending and a construction boom. PNG has a long history of resource development and considerable experience in construction of civil engineering, mining and oil and gas processing projects.

The commercial sector has a narrow employment base, consisting of workers engaged in mining, a relatively small manufacturing sector, public sector employees and service industries including finance, construction, transport and utilities and retail. Migration to major city centres in the past decade has contributed to urban unemployment and social problems[1] although the country is lightly urbanised by world standards.

Despite resource riches, PNG is one of the poorer and more isolated countries in the world. However, the economy has been growing consistently in recent years reaching an estimated $US18.5 billion in 2015 (Figure 3). Growth is forecast to continue at rates of more than 7% driven by resource sector construction.

Figure 3: PNG Real GDP ($US million)



2.3 Economic context

Morobe Province has substantial economic potential with considerable scope for further development[2]. The population is growing at an average rate of 2.7% per year. Lae is a major industrial centre and hosts the country's largest import and export port.

The provincial economy is dominated by primary production including agriculture, forestry, and mining and to a lesser extent fishing. Agriculture is the dominant employment sector. Agricultural production can be segregated into traditional subsistence farming, smallholder cash crop and large-scale plantations. As the agricultural sector matures there is a strong desire by Government to involve the rural population in the development and operation of commercial agriculture.

[1] Australian Department of Foreign Affairs and Trade website, July 2012
[2] Text extracted from Morobe Provincial Government website report, http://morobepng.com/sitebuildercontent/sitebuilderfiles/populaton_action_plan.pdf

Good incomes from the sale of betel nut, coffee and livestock products can be earned by those living in the Markham Valley, which has moderate to high land potential and good access to markets. More moderate incomes can be earned from fish, food, coconut and betel nut in the coastal areas around Lae. More remote areas generally have lower incomes. Other sources of income include mining, forestry and cattle.

Industrial development in the province is centred in Lae. Notable industries include meat processing, beverage and food manufacture, flour milling, cement processing and fish canning. Other major commercial activity are service industries such as transport, wholesale and retailing, oil and petrol distribution and cartage, hotels and mechanical, motor vehicle and electrical servicing.

Overall, the Morobe Province population is young and with a reasonably high level of literacy although less than 16% have completed education to year ten (Table 1). The proportion in wage earning employment is low but a high proportion in non-monetary work means that the workforce participation is relatively high. In terms of energy use, a very high proportion rely on wood as the primary source.

Table 1: Provincial Profile -

Category	Statistic
Annual population growth rate	2.7%
Median age, years (2000)	20
Life expectancy at birth, years	52
Literacy rate (2000)	61%
Completed year 10 schooling	15.6%
Employed (monetary), male / female	20% / 6.5%
Employed (non-monetary), male / female	53% / 69%
Labour force participation rate, male / female	68% / 64%
Households with wood as energy source	83%

Source: Morobe Province Population Action Plan, 2005 - 2010

2.4 Electricity supplies

PNG Power Ltd (PPL) is a government owned power authority responsible for generation, transmission, distribution and retailing of electricity throughout Papua New Guinea. It has 30 electricity systems with an installed generation capacity of over 300MW.

PPL has three large hydro based grid systems with total installed hydro capacity in PNG of 126MW[3]. The other smaller systems are run by thermal or diesel generation. Hydro accounts for 70% of the total electricity generation followed by light fuel oil (14%) and an Independent Power Producer (IPP) with 16%. Demand for electricity has grown by an average of 2.2% over the last ten years and this trend is considered to reflect partially a lack of reliable supply (constraining customer connections) which the Biomass IPP will help to correct.

[3] "Overview on PNG Power Limited National Power Supply", October 2014 PNG Power

PPL and the Government of PNG have stated that they are keen to pursue renewable alternatives to the use of imported diesel and fuel oil. This includes hydro, solar, wind and bio-energy. Official Government Policy also encourages the use of renewable power generation, and of landowner benefits/involvement in the generation supply chain[4].

PNG has 280MW of private capacity including a 65MW station on the Hides gas field for the Porgera gold mine and a 54MW geothermal plant for Lihir Gold.

The most extensive grid is the Ramu system that runs through the Markham Valley from Lae to the Highlands and Madang. It has two thirds of the PPL generation capacity and supplies Lae, Madang and Gusap in the Momase Region and the Highlands centres of Wabag, Mendi, Mt Hagen, Kundiawa, Goroka, Kainantu and Yonki (Figure 4).

Figure 4: PNG Power Networks

The main source of generation in the Ramu Grid is the Ramu Hydro Power Station with 75MW of installed capacity. This station is based on water storage in the Yonki dam which was commissioned in 1991. Additional hydro energy is supplied by Pauanda, a run-of-river station in the Western Highlands Province with a nominal capacity of 12MW, and from the recent Yonki Toe-of-Dam project, which has a capacity with its current configuration of 6MW. Power is also purchased when required from the privately owned Baiune Hydro Power Station at Bulolo and varies between 1 to 2MW depending on availability.

Back up generation for transmission line outages, energy and peak demands are met by diesel plants at Madang, Lae, Mendi, Wabag, Kundiawa and Goroka. These plants serve as stand-by units.

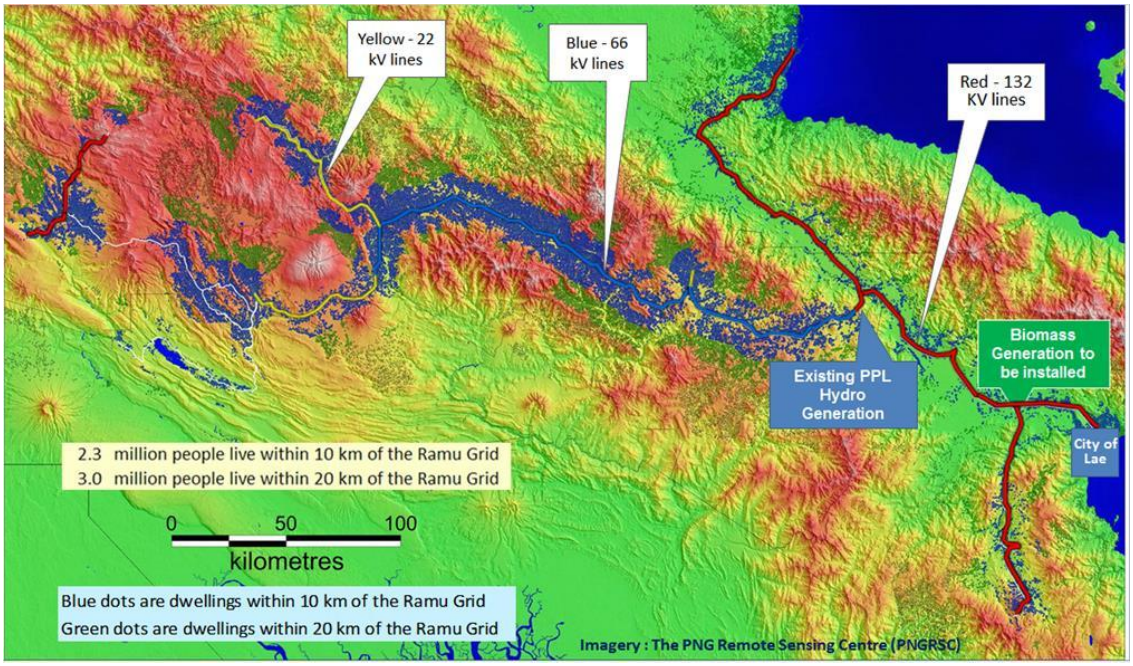
[4] PNG Electricity Industry Policy

There is currently insufficient power generated to meet the demands of the Ramu Power grid, and additional power is needed for both public and resource project supply. Many companies in Lae have installed standby generators due to the intermittent and poor quality of the power supply. The Chamber of Commerce and Industry estimates that there is over 30MW of private generation capacity in Lae.

Demand for electricity in the Lae region is strong. The population is rising rapidly as people are drawn to food processing factories, mines and supporting industry. Demand is also increasing due to greater penetration of air conditioning and refrigeration. The power grid is under stress with frequent load shedding. In addition to current demand, there is potential demand from mines and commercial buildings that currently use their own diesel generators.

The Ramu Grid services close to half of the PNG population with an estimated 3 million people living within 20 km of the main 132 kV line (Figure 5).

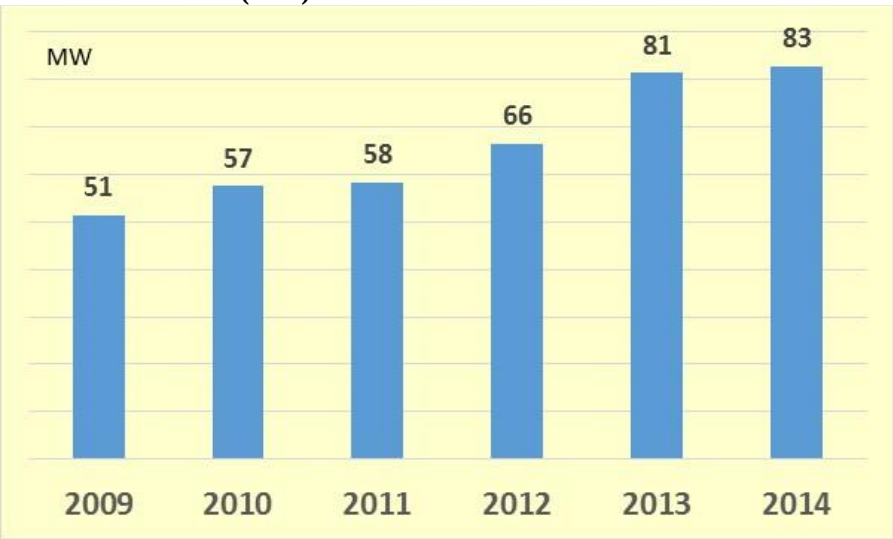
Figure 5: Ramu Grid and population



Source: The PNG Remote Sensing Centre

Power demand in the Ramu Grid has been steadily rising since 2009 to an estimated 83MW of demand in 2014 (Figure 6).

Figure 6: Ramu Grid demand (MW)



Source: www.tradingeconomics.com

Ramu Grid demand is driven principally by commercial, industrial, and mining customers (approximately 86% of sales). The low proportion of residential sales (14%) indicates the lack of penetration of household connections, which is forecast to increase and drive significant sales growth in future years.

Mining customers account for approximately 24% of total sales, although, there is significant potential for this to increase with several world class mining developments at various stages of planning and feasibility. The Wafi-Golpu mine would be one of the largest gold and copper mines in the world[5], and would have an estimated ultimate electricity demand more than 120MW[6]. Other potential projects include the Ramu Nickel and Yandera mines.

This study assumes that there is 20 to 30MW of latent and currently diesel-based self-generating industrial (baseload) power requirement in Lae that can be met by a biomass project power station. The study assumes that the first unit will be operating in late 2019 and the second unit in 2023. The second unit could be available earlier if there was a demand for this.

The Ramu Grid will require 30MW of baseload and shoulder capacity in 2024, which the Biomass Units are ideally place to fill, with diesel or fuel oil generation retained purely for backup of the system.

The proposed power plant will have a high level of reliability with approximately 25MW of back-up diesel generating capacity. This is required to insure reliability when biomass boilers are serviced. The impact of this additional diesel capacity is included in the analysis.

[5] Newcrest Mining, various presentations
[6] By analogy with other gold mining operations

Chapter 3

3. The Project

3.1 Project summary

Markham Valley Biomass Limited plans to construct 30MW of generation capacity in two stages to supply electricity into the Ramu grid. The primary fuel source will be plantation biomass grown in the Markham River Valley.

Provisional agreements are in place with landowners covering 22,000 ha of land. The land is mostly grassland or timbered with invasive species and is not being used for subsistence agriculture or other productive purposes. The first plantings have been made and the first harvest timber is expected to be available in 2021 - two years after the first power station commences operating.

Current plans are to harvest exotic and invasive Rain Trees in the planned plantation areas to cover the fuel supply until the plantation timber can meet the fuel demand. Rain Trees will be harvested during land clearing on the plantation areas with additional logs from third party suppliers near the project area. Some additional wood and fibre may be purchased from other locations in PNG.

The power plant will have two 15MW output units and planned plant availability of 93% after allowance for maintenance downtime. PNG power is installing 30MW of low sulphur fuel oil (diesel) standby generation in the grid which will provide system backup.

3.2 Timeline

A critical factor in the timeline is a commitment to deliver electricity under a contract in October 2019. This study assumes a timeline that meets this date. However, it is important to note that the timeline will change as the project is more fully investigated. Some stages such as the time taken to obtain government approvals are hard to predict.

MVBL announced the pre-construction stage known as Front-End Engineering and Design (FEED) in September 2016. Power station construction is expected to start within two months of MVBL making a Financial Investment Decision (FID) to proceed.

This study assumes the following timeline:

- Approvals - 8 months (some completed and most underway)
- Plantations and FEED - 12 months (underway)
- Power Station 1 engineering, equipment supply and construction - 26 months
- Power Station 2 equipment supply and construction – 22 months

3.3 The establishment and construction phases

3.3.1 Plantation establishment

To supply the initial 15MW power station, an estimated 87,500 tonnes a year of bone dry (BDMT) wood chips will be required or approximately 200,000 tonnes of wet harvested wood. This will require around 2,000 hectares (ha) of timber harvest each year. At the full 30MW of capacity, the harvested area will double to 4,000 ha per year.

Following the first cutting (harvest cycle), the coppiced trees will regrow. Depending on the yield and recovery time, the trees may be coppiced a second or third time, or new seedlings planted to replace them.

Trial results indicate promising yields and early maturity and hence the latest plan (December 2016) is to plant nearly 15,000 ha (Table 2).

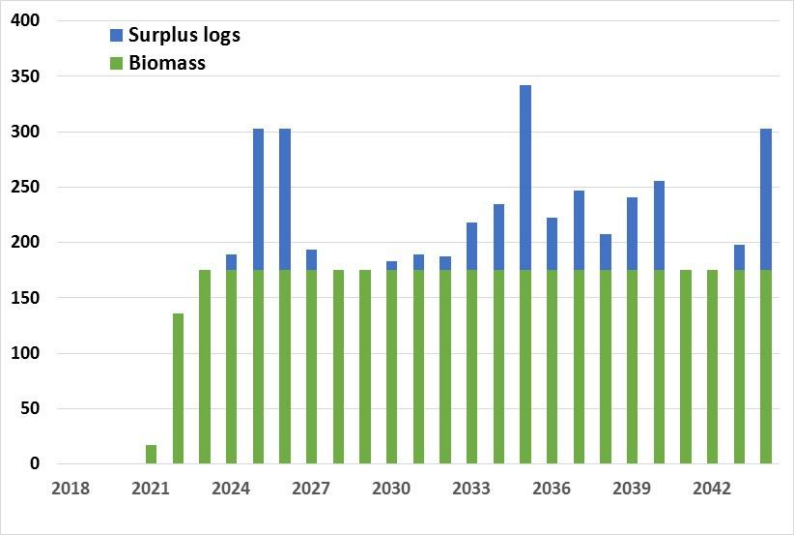
Table 2: Plantation establishment

Year	Hectares
To 2016	340
2017	1,600
2018	3,400
2019	4,500
2020	1,160
2021	1,160
2022	1,197
2023	1,230
Total	**14,587**

Based on five years to maturity, the first trees will be cut in 2021 or 2022.

The planted areas will provide surplus logs in most years after 2026 and veneer sales are budgeted to increase income and create diversity (Figure 7). This scenario is based on a planted area of 15,000 ha and a 25-year project life although it is likely that the project will exceed this duration.

Figure 7: Plantation wood production (bone dry thousand tonnes)



The plantation will require a propagation and seedling nursery with the capacity to produce 8 million seedlings a year in the peak planting year of 2019. Nursery requirements beyond 2023 will depend on coppice yields and the need to replant trees.

Establishment costs cover the costs of land preparation, spraying, planting, seedlings, fertilising, releasing, and survival survey. Tending costs from age two onwards include weed control, fertiliser, and quality control.

Plantation establishment costs (excluding land acquisition) are estimated at close to K6,000 a hectare (Table 3). Fertilizer costs are about 30% of the planting cost with weed control at 25%.

Table 3: Establishment costs excluding land acquisition

Category	Kina/Ha
Clear	550
Plough	450
Spray	230
Plant	100
Fertilise	2,652
Weed control	1,995
Total	**5,977**

3.3.2 Power Station construction

The proposed power plant site is close to the Highlands Highway and to a PPL switching station and approximately 4km from the Markham River.

Each 15MW unit will have a boiler, steam turbine generator and associated operating plant. The net output of each unit will be 15MWe, after parasitic loads for plant operation and wood chipping are deducted. The wood chips will be conveyed to a day bin then into the furnace for combustion.

The capital cost for a single 15MW unit is estimated at K174m. The final cost will include an additional K25m in owner costs (Table 4). The full cost for both stations is estimated at K344m.

Table 4: 15MW Power station costs (million Kina)

Category	Million Kina
Construction contract	158
Water supply	7
Fuel handling	16
Transmission line	3
Contingency cost	12
Total	**196**

3.3.3 Capital investment in construction phase

Close to K63m is expected in expenditure prior to any decision to proceed with the project (Table 5). To date, K47m has been spent on the project mostly on plantation operations.

Table 5: Early establishment costs – pre-FEED (Km)

Category	Km
Management and advisors	3.3
Business Services	1.9
Power Plant Engineering	4.9
Forestry Operations	12.1
Forestry Technical	13.2
Government and Community Affairs	6.6
Health, safety, security and environment	5.8
Plantation	4.7
Project Financing and finance costs	3.8
Long Lead Time Items	6.3
Total	**63**

The total investment to 2022 with the two power station units is estimated at K582m (Table 6). The power station is 66% of the total and the plantation 32%.

Construction is expected to commence within two months of the company deciding to proceed (FID) which is targeted for the third quarter in 2017. First power will be delivered 26 months later. Further capital investment occurs for construction of the second power station.

Table 6: Establishment costs timing (Km)

Category	2016	2017	2018	2019	2020	2021	2022	Total*
FEED	3.0	10.8						**14**
Power stations			73.0	122.5	12.6	73.0	97.5	**344**
Plantation	16.6	24.4	29.4	47.0	32.6	36.2		**186**
Working capital			12.7	12.7		6.3	6.3	**38**
Total	**19.6**	**35.1**	**115.3**	**160.2**	**45.5**	**116.0**	**91.0**	**582**

3.3.4 Establishment and Construction Employment

The plantation establishment phase is assumed to last for the seven years from 2017 to 2023 inclusive. The average PNG workforce is 507 people with 5 expatriates (Table 7).

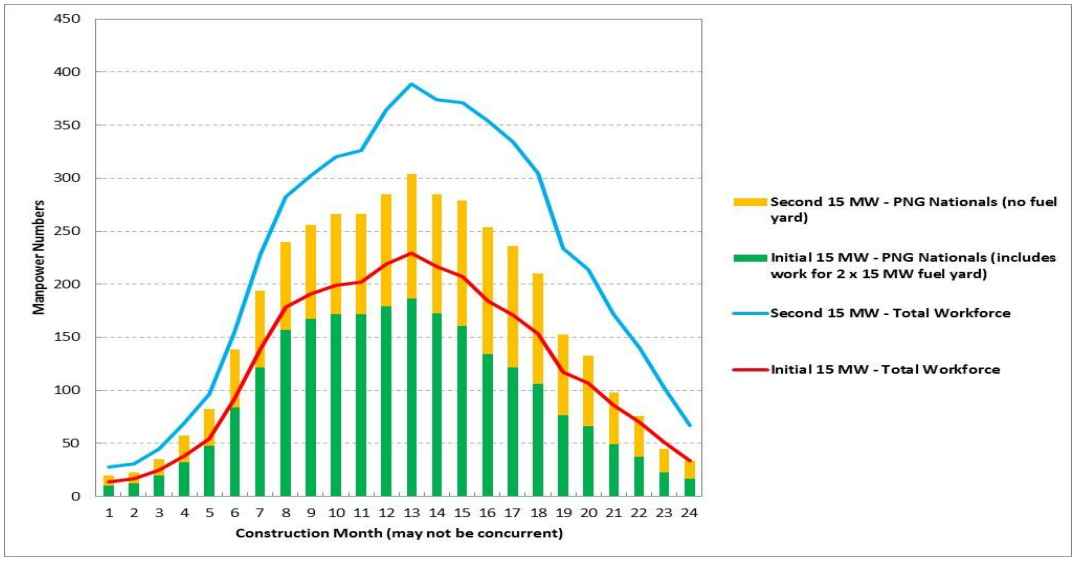
Table 7: Establishment phase employment in the plantation sector (person years)

Category	Average annual
Management/professional	24
PNG clerical / support	25
PNG skilled - trade	42
PNG skilled - horticultural	6
Local semi-skilled	410
Total	**507**

Sources: Company data, ECS estimates including head office / project management

The power station construction is labour intensive with a duration of 24-26 months of work although the months may not be concurrent. To estimate power plant construction numbers and assist in estimating local wages and payments, MVBL has considered two cases (smaller workforce and larger workforce cases. The base (smaller workforce) case has been developed from public domain sources and EPC tenders. For the two power station units, this has a peak workforce of 390 people (for concurrent construction of the two 15MW units) and an average of 220 over 24 months. The average workforce of 220 persons provides 442 person years of work (Figure 8). An alternative option uses a larger workforce peaking at 726 people for concurrent construction of the two 15MW units) and averaging 335 people. This study uses the lower workforce base case to ensure that the impacts of the project are not overstated.

Figure 8: Power station construction workforce



There will be an average of 165 PNG workers out of the average of 220 workers for 2 x 15MW Units (75%) and a combined plantation/power station workforce of 3,830 person years of work (Table 8).

Table 8: Construction phase jobs (annual average jobs)

Category	Plantation	Biomass Power Plant
All jobs	507	220
PNG jobs	502	165

The estimated PNG wages and payments to landowner companies during the power plant construction range from K25.4m to K32.3m for the two stations (Table 9). This includes wages, payments made to Landowner Businesses and the profit margin on those payments (which is assumed to flow to landowners as dividends). The high workforce case assumes less machinery in civil works and less power station prefabrication meaning more lower-skilled labouring jobs for civils and earthworks.

Table 9: Wages paid to PNG nationals (total Km)

	Base case	High workforce case
Station 1	14.9	19.8
Station 2	10.5	12.5
Total	**25.4**	**32.3**

3.3.5 Plantation establishment and construction household income

An estimated K13.5m in household income will be received in PNG for each of the seven years of plantation establishment. This includes direct wages, an estimated share of the payment made to Landowner Businesses (60%) and payments for land rental and royalties.

The estimated wages and salaries for PNG workers on the power stations is K25.4m over the two-year construction period, representing around K12.7m a year.

Total PNG payments over the seven years of plantation establishment is estimated at K94.5m and power station construction at K25.4m for a total of K120m.

Table 10: Average annual household income during construction (Km/year)

	Plantation	Power station	Total
Average household income	13.5	12.7	
Total from 2017 to 2023	94.5	25.4	120*

***rounded**

Establishment of the plantations and power stations involves a total investment of K582m. The average plantation workforce alone will be 570 jobs with 550 expected to be PNG workers. Household income over the seven years to establish the plantation and 24 months of work it takes to construct two power stations is estimated at K120m.

3.4 Operating phase

While the plantation is essentially a continuous project from first planting to harvesting and then replanting in cycles, this study uses the first seven years as the basis for an establishment phase, and the operations phase as a single year with the project operating at the full 30MW capacity (post 2022). The steady sustainable plantation production level for 30MW is not reached until 2024 but then lasts until at least 2049.

Plantation harvesting is expected to commence in 2021 with the harvested area increasing to a steady rate of about 4,000 ha for the full 30MW capacity. The area harvested will generally include a mix of plantation trees in their first growth cycle and subsequent coppice cycles.

The plantations will be mechanically harvested using specialised equipment operating two shifts a day on a six to seven-day week. Replanting will occur between 5 and 18 years depending on the productivity of the coppice cycles.

All wood will be trucked to the power plant where it will be stored prior to chipping. The trucks used to transport the logs will have a capacity of 20 to 30 wet tonnes and the 30MW plant will require 40 to 50 deliveries a day.

In the first few years of operations, Rain Trees will be harvested to supplement the wood supply. This is an exotic species that is invasive and local landowner groups and the PNG Forest Association are seeking to remove them from the Markham Valley. It

is estimated that this species can provide 200,000 to 300,000 BDMT of wood in the first four or five years. The project will also contract for third party biomass and this may contribute up to 10% of supplies over time.

3.4.1 Operating costs

Annual project operating costs for the full project are estimated to average K47.8m over the 25-year period from 2023 to 2047 (Table 11). This is in 2016 currency terms with no inflation. Costs are dominated by harvesting and transport of the logs (60%).

Table 11: Average annual plantation operating costs by nature of expenditure (Km/year)

Category	Km	Share (%)
Tree tending	7.4	15%
Roads	0.5	1%
Harvesting	19.9	42%
Transport	8.8	18%
Management	6.0	13%
Land lease and royalties	5.2	11%
Total	**47.8**	**100%**

The operating cost of the power stations excludes the fuel price paid to the plantations. Biomass power stations are specialised plants requiring constant staff attendance and the costs are dominated by external service companies and expatriate professional power station operators (Table 12). Over time, it is intended that the operating and management staff will become PNG nationals.

Table 12: Average annual operating costs of 30MW power station (Km/year)

Category	Km	Share (%)
Maintenance – local services	0.9	5%
Maintenance – overseas contracts	1.5	8%
PNG labour	6.3	35%
Expatriate labour	9.3	52%
Total	**18**	**100%**

The power station expenditure in PNG is estimated at K7.2m a year.

3.4.2 Operating employment

During an average year of full operation, the plantation workforce will be 423 and the power station 49 for a total of 472 jobs (Table 13). Of these, 462 will be PNG nationals.

About 175 of the plantation workforce are expected to be direct employees and the balance will work through landowner companies.

Table 13: Operating phase employment (annual jobs)

Category	Plantation	Power station	Total
Expatriate	5	5	10
PNG management/professional	20	7	27
PNG clerical / support	30	5	35
PNG skilled - trade	74	8	82
PNG skilled - horticultural	6		6
Local semi-skilled	288	24	312
Total	**423**	**49**	**472**

3.4.3 Operating household income

An estimated K29.6m of household income will be spent in PNG during an average year of operation (Table 14). This includes direct wages for employees, a share of the payments to Landowner Businesses (estimated at 60%) and land rentals, wood royalties and operation of the power station.

Over 25 years, this becomes K585m for the plantation and K155m for the power station for a total of K740m.

Table 14: PNG household income in operations phase (million Kina)

	Plantation	Power station	Total
Average household income	23.4	6.2	29.6
Total over 25 years	585	155	740

PNG expenditure is estimated at K45.3m a year for the 25 years of operations making the total K1,132m.

The project will create 472 jobs in the operating years of which 462 are expected to be PNG employees.

Household income is estimated at K29.6m a year during operations providing a total of K740m over 25 years.

3.4.4 Operating revenue

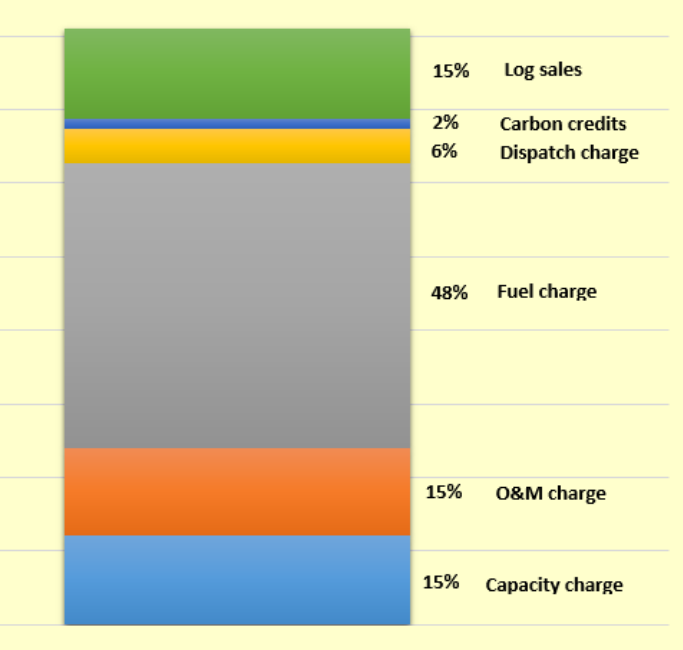
Project revenue will include power sales, log sales, carbon credits, dispatch charges, Operations and Management revenue and capacity charges. Revenue from the boiler residual ash is not included although it can be used in concrete and for road base.

Aligned Energy has signed a 25-year supply agreement with PPL that has four components:

- Capacity charge to ensure cost recovery for the power station
- Operations and maintenance charge (fixed)
- Transmission charge to cover the connection line
- Fuel charge to cover all biomass production costs

Operating revenue comes mostly from the charges paid by PPL with the largest being the fuel charge (48%) followed by the capacity charge, operations and maintenance charge and log sales all at 15% (Figure 9). As a broad indication of scale, annual fuel revenue for 30MW of power at full dispatch is estimated at around K70m in 2016 real terms. This is approximately K40m a year less than the equivalent fuel cost for diesel or fuel oil

Figure 9: Average annual operating revenue



Chapter 4

4. Economic Impacts

4.1 The underlying philosophy

The impact of a new project will be determined by the scale of the project and the size of the economy in which it is located. A large project will create substantial flow-on effects for other industries and wage and salary earners in a small economy. Purchases from suppliers create employment and investment opportunities in these businesses while wages and salaries allow employees to acquire living needs such as food, clothing and accommodation, as well as other services and tools for their homes and work.

The size of the flow-on benefits depends on the economic linkages between it and the local economy and the extent to which demands for labour, materials and services for the project can be supplied from this economy. Hence, the size of the economic benefits depends on the capacity of the local economy to provide the goods and services rather than imports from outside of the region.

The most comprehensive approach to measuring linkages in an economy involves the use of a financial transaction or input-output table of the economy. Such a table is not available for the Morobe Province or the PNG economy in the relevant economic sectors and the work in building one is beyond the scope of this study.

Input output models have been developed by the OECD for member countries which include Argentina (1997 data), Brazil (2000 data), and India (1999 data) – see OECD Input-Output Database 2006 Edition. However, the model which is considered to have most direct similarities with PNG is one for Northern Queensland, a regional model developed by the Government of Queensland. This model is used in the current analysis, but modified using the Aligned Energy information on imports to estimate the leakage from the PNG economy. More detail on multipliers is included as Appendix 1.

The impacts are described in three measures – economic output, employment and household incomes.

4.2 Economic output

To ensure that the economic impacts of the project are not overstated, this study uses an estimate of PNG expenditure as the starting point for the estimation of output changes. The estimation of PNG expenditure is based on an understanding of company capacity in the different service sectors. The high cost of the power station equipment and the specialised nature of installation and infrastructure means than in a

cost weighted breakdown, PNG expenditure is only 21% of the establishment/construction phase (Table 15). Plantation expenditure is a high 85% with the power station at 10%.

Table 15: Local business involvement – construction / establishment phase

Category (Capital costs)	Local business involvement (by value)	Cost* (Km)	PNG spend (Km)
FEED	15%	14	2
Plantation	85%	186	158
Biomass Power Plant	21%	344	70
Working capital	0%	38	
Total (weighted average)		**582**	**230**

***Numbers rounded**

When operating, the local project expenditure share is much higher at 64% (Table 16).

Table 16: Local business involvement – operating phase, per year

Category	Output Local %
Plantation wood Harvest	100%
Plantation wood Haul	100%
Diesel	10%
Landowner & community benefits	100%
Maintenance	100%
G and A	50%
Fertiliser	10%
Biomass Power Plant	20%
Total (weighted average)	**64%**

Expenditure in PNG in the establishment phase is estimated at K194m. The multiplier effect increases this impact in the PNG economy to K437m (Table 17).

The annual project operating cost of K45.3m spent in PNG will multiply through the economy to an annual total of K88m. Over the full 25 years this represents an increase from K1,132m to K2,190m.

Table 17: Output generated by the Project (million kina)

Expenditure Component	Construction Phase			Operations Phase		
	Direct	Multiplier	Total	Direct	Multiplier	Total
FEED	2	2.2	4			
Plantation Operations	158	2.2	348	952	1.9	1,810
Biomass plant	34	2.5	85	180	2.1	380
Total	**194**		**437**	**1,132**		**2,190**

4.3 Employment

Using multipliers (Appendix 1), the full impact of the project in PNG can be estimated. The construction of the power station generates 1,000 jobs for the two years of construction while the plantation generates 3,000 in each of the seven years of establishment (Table 18). This is a total of 23,000 job years of employment.

When operating, the project generates a total of 2,560 jobs a year for 25 years.

Table 18: PNG employment generated by the Project (annual average*)

Jobs Component	Construction Phase (job years)			Operations Phase (jobs per year)		
	Direct	Multiplier	Total Generated	Direct	Multiplier	Total Generated
Power station	165	6.1	1,000	44	6.0	260
Plantation	500	6.1	3,000	418	5.5	2,300

*** rounded**

4.4 Household income

An estimated K13.5m of household income will be contributed by the project for each of the seven years of plantation establishment and K6.2m a year for power station workers (Table 19). Total PNG payments are thus estimated at K120m over the seven years of plantation establishment and power station construction.

Table 19: Annual PNG household income (Km/year)

	Plantation	Power station
Construction phase	13.5	12.7
Operations phase	23.4	6.2

The wage and salaries will flow through the PNG economy. The first round of impacts will be the expenditure by the income earners. The Household Income and Expenditure Survey provides data on the categories of goods and services that will be purchased. There will be leakages from the expenditure impacts as some of it will go to imports, some will be repatriated as profits to overseas owners, and some will go to government. The expenditure on imports can be estimated directly.

It is estimated that over the seven-year establishment period the project will provide K120m in household incomes and that this will generate a total of K364m of household income in the PNG economy (Table 20). The multipliers are higher than apply for most economies as the levels of leakage from the PNG economy are lower. This is due to a lower proportion of household expenditure on imported goods and services such as household equipment and foodstuffs, motor vehicles and overseas travel.

Table 20: Household income generated by the project (Km*)

Income Component	Construction Phase			Operations Phase		
	Direct	Multiplier	Total	Direct	Multiplier	Total
Plantation	94.5	2.8	265	585	2.9	1,696
Power station	25.4	3.9	99	29.6	4.8	142
Total			**364**	**610**		**1,838**

Source: ECS, * rounded

The operations phase of the project has a higher annual PNG expenditure and a far longer duration. The operations phase is estimated to provide direct household incomes of K29.6m per year and to generate a total of K740m over the 25 years of operating life. The multiplier for operations incomes is higher than for construction phase incomes because in the operations phase there is a higher proportion of local income in the total and smaller leakage of expatriate earnings.

Chapter 5

5. Energy Supply Alternatives

5.1 Introduction

An alternative way of looking at the project impacts is to examine the energy supply alternatives. This approach assumes that the government has elected to enhance the electricity supply and the key issue is then to compare the impacts of the alternative supply options. The focus is on the most likely alterative and hence a comparison of the impacts of biomass generation versus diesel or heavy fuel oil option.

In comparison with a diesel fuelled power station, the biomass project involves a far higher investment in PNG, greater employment and much higher household income (Table 20). The key difference is that the biomass plant has the plantation as the local fuel source rather than imported diesel. The large workforce involved in the timber plantation operations means vastly greater local expenditure and employment. This is not surprising as MVBL selected biomass as the fuel source that would provide the greatest local impacts.

In round terms, the biomass project involves a K346M higher investment, has 452 more jobs during each of the 25 years of operations and K23.4m more household income each year (Table 21).

Table 21: Biomass project and diesel fuelled power station

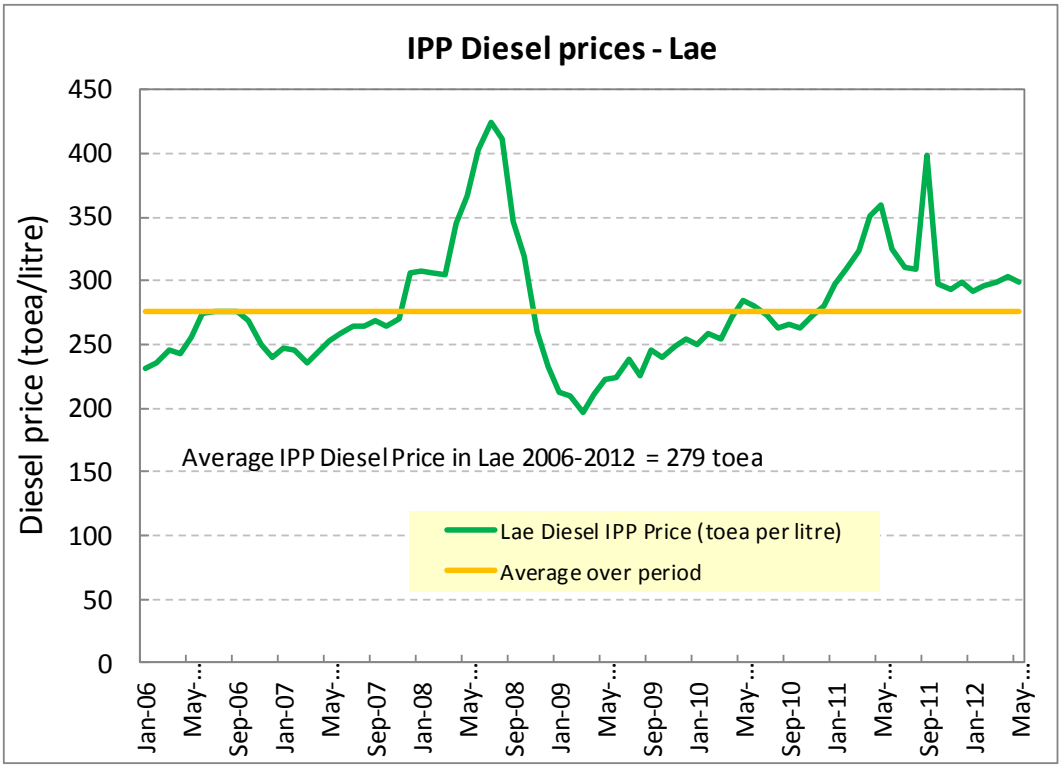
Category	Total Biomass project	Diesel-only Power	Difference
Establishment/construction investment	K582m	K236m	K346m
Operating phase PNG employees	462 jobs	6 jobs	456 jobs
Household income in operations year	K29.6m	K6.2m	K23.4m

5.2 Diesel fuel use

Development of the wood chip plantations and its use as a fuel source for power generation will help curb reliance on high priced diesel for electricity generation. Current levels of diesel consumption for electricity generation either require use of domestically produced diesel from export markets or for diesel to be imported into PNG every year. This leaves the cost of electricity in the country highly susceptible to both oil price and exchange rate fluctuations.

The IPP diesel price in Lae has varied from 150 toea/litre to 425 toea with an average over the last decade of approximately 280 toea Figure 10).

Figure 10: Diesel price (IPP, Lae, toea/litre)



Source: PNG IPP Price Records

Savings in annual fuel oil purchases are estimated at K39m in a typical operating year at the current oil price of US$52 per bbl (Table 22). This saving will increase if oil prices rise.

The effective impact of the Biomass project is conservatively estimated to result in a reduction over a 25-year period of 1,340 million litres of heavy fuel oil or diesel.

The cost of diesel generation is substantial, and is responsible for high electricity supply costs on the Ramu grid. A lower cost alternative would mean significant cost savings. At the current average price to PNG power of diesel or fuel oil, a comparison of 30MW of dispatch indicates a lower annual fuel cost with biomass of K40m compared to biomass.

Table 22: Fuel savings

Parameter	Diesel/LFSO
Annual US$ million benefit (fuel prices)	12.5
Annual K million benefit (fuel prices)	39
$US million (10-year benefit)	125
Km (10-year benefit)	393
Fuel used (litres in 10 years)	536
Fuel used (litres in 25 years)	**1,340**

Chapter 6

6. Other project benefits

6.1 Introduction

Benefits of the biomass project can be described in more specific local terms. The project also provides some environmental benefits.

6.2 Landowner Businesses

Land owners will be paid a rental for the use of their land in plantation areas. They will also receive a royalty based on the quantity of harvested wood.

Landowner Businesses will be set up to represent the local clan groups and to provide a business entity for contracts. Contracts will be awarded for most plantation operations and hence the community will receive benefits in four ways:

- Landowner land rents
- Royalties on timber harvested (thinning and mature harvest)
- Wages for employment in the Landowner business
- Profit distribution from Landowner Business contracts

The benefits have been estimated by assessing the share of each expenditure category to be passed on in the form of rents, royalties, wages and Landowner Business contracts

Using this approach, 26% of the annual operating costs flow through the Landowner businesses with 23% flowing to both wages and consumable items (Table 23). These payments do not include the power stations.

Table 23: Average annual operating costs by recipient (Km)

Category	Km	Share (%)
Landowner company payments	12.5	26%
PNG wages	11.0	23%
Land rental and royalties	5.2	11%
Foreign labour	4.2	9%
Consumables	10.9	23%
Other	4.0	8%
Total	**47.8**	**100%**

6.3 Company taxation

The Project will be subject to the PNG tax system and the proponents will seek to negotiate a Project (Implementation) Agreement with the PNG government. This will include any fiscal incentives or concessions like those negotiated for other significant resource and industrial projects. Defined concessions and incentives are available under PNG law for agriculture and primary production with eligibility subject to a review process by Government.

A taxation estimate has been made for this project to provide an order of magnitude to the project impact. This estimate is intended as an indication only and will not be the final amount. The estimate is K740m over the project life for a 30 MW development at full dispatch.

6.4 Infrastructure Improvement

Improved road access will be developed during construction to facilitate movement of materials and people. Development of roads to improve access for construction, and for the ongoing transport of raw materials and machinery, has the potential to provide additional benefit through improving access to the region. This is particularly relevant given the reduction in carrier services in the region due to poor road infrastructure.

6.5 Reduced Carbon Dioxide Emissions

Reduced reliance on diesel based electricity generation will also reduce the carbon dioxide emissions caused by diesel generation. It has been estimated for PNG that diesel generation produces 0.750 tonnes of carbon emissions per MWh. At this level of abatement, the biomass fired power station will reduce CO2 by 200,000 tonnes a year.

6.6 Agriculture

It is anticipated that horticulture crops will be grown by landowners between the trees in the plantations providing real potential for market sales in the Markham Valley. Early plantings have been seen good sales from the trial tree areas.

Appendix 1: Multiplier analysis

The impact of a new or existing project or economic activity will be determined by the scale of the project and the size of the regional economy. A large project or group of smaller projects will create substantial flow-on effects for other industries and wage and salary earners. Purchases from suppliers will create employment and investment opportunities in these businesses while wages and salaries allow employees to acquire basic living needs such as food, clothing and accommodation, as well as other services and tools for their homes and work

The size of the flow-on benefits from a project depends on the economic linkages between it and the local economy and the extent to which demands for labour, materials and services for the project can be supplied from the local economy. Hence, the size of the economic benefits depends on the capacity of the local economy to provide the goods and services rather than imports from outside of the region.

The most comprehensive approach to measuring these linkages involves the use of a financial transaction or input-output (I-O) table of the economy. Such a transaction table is not available for PNG at this stage and the work involved is beyond the scope of this study.

An alternative approach is to use an input output model for a similar economy as a proxy for the PNG economy. A Fiji model has been applied to PNG but the date in this model is now outdated (1971) and the development of the economy since that time will have seen an increased diversification in the economy.

This study uses a hybrid approach following the logic of the input output model but with separate estimation of specific components. First it makes a direct calculation of what is termed the "first round" effect. Expenditures on the project flow to employees, goods and service providers and government agencies. Aligned Energy have identified these costs for both the establishment and then for the operations of the project. There will be some leakage of this first round effect because some of the expenditure will be on imported goods and services.

The expenditure in PNG on local providers of goods and services forms the direct impacts. These suppliers in turn purchase the goods and services they need to operate thus creating a second-round impact (the indirect effect). Similarly, when the local residents spend their income in the region it will create a further round of income and employment generation (the induced effect). The extent to which the expenditure remains in the PNG economy and does not leak out to imported goods and services will determine the size of the economic multiplier.

The estimates of local expenditures provided by Aligned Energy allow Economics Consulting Services to estimate expenditure on imports and locally sourced materials. This means that the full first round effect can be directly estimated.

The next rounds of economic impact cannot be measured directly and this is the second stage of the hybrid model. It uses the input output information from similar economies as a proxy for the PNG economy.

Input output models have been developed by the OECD for member countries which include Argentina (1997 data), Brazil (2000 data), and India (1999 data) – see OECD Input-Output Database 2006 Edition. However, the model which is considered to

have most direct similarities with PNG is one for Northern Queensland, a regional model developed by the Government of Queensland. This model is used in the current analysis, but modified using the Aligned Energy information on imports to estimate the leakage from the PNG economy.

The extent of the imports is estimated using data from the National Statistical Office of Papua New Guinea for different industries. Expenditure data for this project was aggregated into 10 categories and the average proportion of imports calculated for each category. Then the input-output table for Northern Queensland was adjusted using the PNG import proportions.

A third part of the hybrid involved the calculation of multipliers for personal consumption expenditure. Personal expenditure in the PNG economy is expected to have a large multiplier because import leakages are likely to be small.

Effectively, the economic impact of personal expenditure is estimated by directly following the path of successive waves of expenditure.

The National Statistical Office of PNG completed a Household Income and Expenditure Survey in 2008 which provides the primary data on the ways in which employees and service providers spend their income.

The first round of impacts is the expenditure by the income earners. A core objective of the project is to use local people so almost all project expenditure for labour and services will be paid to local residents. The Household Income and Expenditure Survey provides data on the categories of goods and services that will be purchased. As discussed above, there will be leakages from the expenditure impacts as some of it will go to imports, some will be repatriated as profits to overseas owners, and some will go to government. The expenditure on imports can be estimated directly, as discussed above. Repatriation of profits overseas will be minor from this form of expenditure and a notional provision of 5% has been made. Except for personal income tax payments, leakages in the form of payments to Government are hard to estimate and a notional provision of 5% has been made in those cases. It has been estimated in a study of the Kiribati economy that about 50% of Government expenditure is leaked from the local economy (Milne, S. 1988: The Economic Impact of International Tourism on the National Economy of Kiribati, United Nations Development Program.) The significance of this leakage is reduced because payments to Government start their own rounds of economic impacts, and these need to be added back into the analysis.

The economic impact of wages has been calculated from the estimated employees and their wage levels. It is assumed for expatriate workers that personal income tax of 37% is paid to the PNG Government and that 75% of after tax earnings are repatriated to their homeland, leaving 25% to be spent in Papua New Guinea. The high incomes of the expatriate workers mean this 25% has a strong local impact.

The analysis of wages expenditure has been given special attention because it is a significant and ongoing expenditure item. However, the expenditure of wages is especially significant because a relatively high proportion of it is spent in PNG and is retained with a low leakage of expenditure out of the economy.

4.2 Flow-on household income

As well as the wages paid directly to the construction workforce, there are wages paid to employees and incomes earned by the owners of the firms that supply materials and services to the project.

The multipliers are higher than apply for most economies as the levels of leakage from the PNG economy are lower. This is due to a lower proportion of household expenditure on imported goods and services such as household equipment and foodstuffs, motor vehicles and overseas travel.

The operations phase of the project has a smaller annual impact but over a far longer duration. The multiplier for operations incomes is higher than for construction phase incomes because in the operations phase there is a higher proportion of local income in the total and smaller leakage of expatriate earnings (Table 24).

Table 24: Household income multipliers

	Construction Phase	Operations Phase
Plantation	2.8	2.9
Power station	3.9	4.8

4.3 Flow-on economic output

Expenditure on wages and materials generates increases in output by other industries in PNG. The expenditure by these other sectors leads to further increases in output and even more expenditure (Table 25).

Table 25: Economic output multipliers

	Construction Phase	Operations Phase
Plantation	2.2	2.0
Power station	2.5	2.1

The output multipliers are smaller than those for household income because of the larger share of expenditures that are to overseas companies.

4.4 Job creation

The absence of any PNG multipliers for employment was overcome by using Australian economy estimates and then modifying these for this study. The construction sector estimate of 16.0 compared with 7.9 for the power station operations phase and 17.3 for the plantation operations (Table 26).

Table 26: Job multipliers in Australia

	Establishment Phase	Operations phase
Plantation	17.3	17.3
Power station	16.0	7.9

PNG does not have the same depth of technical expertise as the Australian economy and the project will require expatriate workers in the establishment and early years of operations. Scaled down multipliers were calculated in an earlier study in 2012 by taking the flow-on estimate of household income and dividing by the average PNG wage of close to 27,800k (Table 27).

Table 27: PNG wages

Education / skill level	Proportion	Annual wage (kina)
University degree	5%	130,000
High school	10%	72,000
Some schooling	25%	47,300
Basic wage	55%	4,200
Average		**27,800**

Sources: Proportion-ECS estimate, annual wage - PNG Statistical Digest rounded

The employment multipliers used in this study are very conservative to ensure that the economic impact is not overstated (Table 28).

Table 28: Job multipliers

	Construction Phase	Operations Phase
Plantation	6.1	5.5
Power station	6.1	6.0