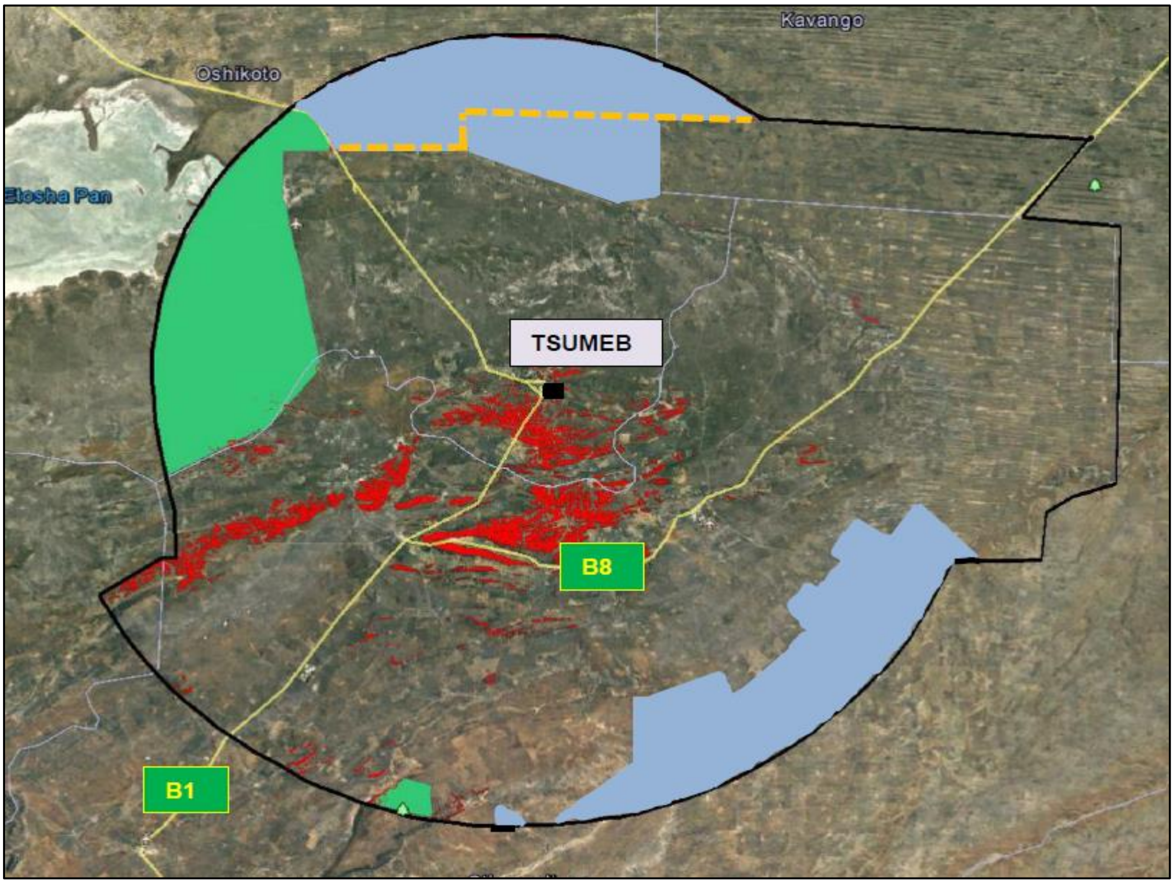
An assessment of the micro- and macroeconomic benefits of an Encroacher Bush Biomass Power Plant near Tsumeb in Namibia



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NamPower
Namibia Biomass Industry Group (N-BiG)
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Disclaimer

The opinions expressed herein are those of the authors and do not necessarily reflect the views of the funders.

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List of Acronyms

AfDB	African Development Bank
BOP	Balance of Payments
EPC	Engineering, Procurement, and Construction
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (Bush Control and Biomass Utilisation Project)
IRR	Internal Rate of Return
KfW	Kreditanstalt für Wiederaufbau ("Reconstruction Credit Institute")
$kgCO_2e$	Kilograms of carbon dioxide equivalents
LSU	Livestock unit
MIRR	Modified Internal Rate of Return
N-BiG	Namibia Biomass Industry Group
NIRP	National Integrated Resource Plan
NLFS	National Labour Force Survey
NNF	Namibia Nature Foundation
NPV	Net Present Value
PAYE	Pay-as-you-earn tax (withholding tax on income payments to employees)
SAM	Social Accounting Matrix
SAPP	Southern Africa Power Pool
SCC	Social Cost of Carbon
TCO_2e	Tons of carbon dioxide equivalents

Executive summary

Introduction

The purposes of this study are to quantify and assess the microeconomic and macroeconomic impact of:

- A 20-megawatt (MW) grate-fired biomass power plant adjacent to the Otjikoto substation, near Tsumeb, Namibia, over its 25-year lifespan.
- The fuel supply and harvesting activities for a 20 MW power plant at the aforementioned site, over a 25-year period.

The study aims to both assess the direct, indirect and induced impacts of the project on the Namibian economy, and endeavours to identify the broad beneficiaries of such.

The key findings for the study are presented below for each of the main sections of the report. The report quantifies the benefits, both in the microeconomic and macroeconomic sections, in real prices (i.e. adjusted for inflation) per kilowatt hour (kWh) of energy produced. In other words, the value of benefits or value generated by an activity are shown per kilowatt hour of electricity generated by the power plant. Unless otherwise indicated, nominal prices have been adjusted to reflect future value and ensure consistency. All prices, unless otherwise indicated, were escalated at a fixed rate of 6% per year in order to compensate for inflation. Where appropriate, nominal prices were discounted to real, 2018, values.

Assumptions

A number of assumptions were received from NamPower. The grate fired power plant has a capacity of 20 MW, at a load factor of 85%. This translates to annual generation of 148.92 gigawatt hours (GWh). The plant lifetime is given at 25 years, and depreciation is to follow the straight-line method. NamPower also provided the proposed harvesting area, the capital costs of the power plant, revenue generated by tariffs, the fuel input of 106,500 tonnes of dry biomass per annum, and the expected staffing complement for the power plant. With a demand of 106,500 tonnes of feedstock per annum, and an average yield of 12.65 tonnes per hectare, the project will be responsible for the thinning of 8,419 hectares of land annually. Three price points for biomass were provided by NamPower, as per the terms of reference. These are N$ 450/tonne, N$ 600/tonne and N$ 750/tonne (2018 prices), corrected for moisture content (on dry matter basis) and delivered to the plant gate. The construction and operational timeline of the power plant was also provided by NamPower. Generation is assumed to begin in January 2022, with construction taking place in the preceding 30 months.

Biomass demand and supply

The proposed harvesting site is a radius of approximately 100 km. The assumed sustainable harvesting yield of 12.65 tonnes of biomass per hectare, on a dry matter basis, means an estimated 46.7 million tonnes of biomass is available within the proposed harvesting area. The power plant has an annual fuel requirement of 106,500 tonnes of biomass, which equates to just 5.7% of the available encroacher bush being utilised over the full 25-year lifespan. The Ohorongo Cement factory makes use of, amongst others, woodchips to fire its kiln, and its encroacher bush harvesting area overlaps with the proposed harvesting area for the NamPower power plant. The charcoal industry is the single largest off-taker of biomass in the country and is forecast to remain so. The proposed harvesting area falls within one of the main charcoal producing areas of the country. An upper limit of 360,000 tonnes per annum of biomass for charcoal within this area is assumed, amounting to 21.4% of the current resource harvested within the proposed area over the 25-year period. Rural and informal households make use of firewood and encroacher bush as an energy source for heating and cooking. An upper limit of 137,000 tonnes per annum is anticipated, equating to 7.4% of the resource over the 25-year lifespan of the power plant. Based on these calculations, about 61% (or 28.5 million tonnes) of the biomass in the area will remain unused. Thus, the availability of biomass far exceeds total anticipated demand, and means competition for the resource itself is unlikely to be sufficiently large to jeopardise the viability of the project.

Harvesting

The assumptions relating to harvesting methods were provided by GIZ studies and consultations with the Namibia Biomass Industry Group (N-BiG). It was proposed that harvesters charge land owners an average fee of N$ 300/hectare for the bush thinning services[1]. The modelling also assumed that land owners will be responsible for aftercare treatments on the bush thinned land, at an average cost of N$ 200/hectare, incurred every three years, in order to prevent re-encroachment. Three harvesting methods were considered, namely manual, semi-mechanised and fully mechanised. The manual harvesting method is labour intensive, while the fully mechanised method is capital intensive. The semi-mechanised method is both relatively capital and labour intensive, as it makes use of more sophisticated equipment (capital) than the labour-intensive method, and also employs significantly more persons than the fully mechanised method. The price received per tonne plays a key factor in the commercial feasibility of harvesting projects. It is found that harvesters do not earn a feasible return at the lowest price point of N$ 450/tonne (marginally positive returns for manual and semi-mechanised), while at the highest price point (N$ 750/tonne), the power plant earns a low modified internal rate of return. At the middle price point (N$ 600/tonne), harvesters generate a return, on average, of 10.5%, while the plant generates an internal rate of return of 4.1% over the period. In consultation with NamPower, GIZ and N-BiG, it was decided to further model two scenarios that utilise a combination of the harvesting methods. Scenario 1 encompasses two fully mechanised harvesting units, producing a combined 96,000 tonnes of biomass per annum, with the semi-mechanised and manual harvesters sharing the remaining 10,500 tonnes per annum. Scenario 2 makes use of one fully mechanised harvesting unit, producing 48,000 tonnes of biomass per annum, with the remaining 59,000 tonnes being shared between semi-mechanised and manual harvesters. There is slight harvesting overcapacity under both scenarios, due to the fact that harvesting units are assumed not to be divisible.

Microeconomic findings

The microeconomic section of the report focuses on the benefits to gross value addition (GDP) in the country, looking particularly at the impact on agricultural output, value addition from biomass harvesting, benefits accruing to the environment and ecosystem services and employment. The power plant will directly employ 239 people during the construction phase and 62 people during its 25-year operational phase. The 62 employees will be made up of 35 operational/maintenance staff and 27 service staff. The majority of the power plant staff will be skilled and semi-skilled workers. It may be difficult to find skilled workers in the vicinity of the power plant, but these could be appointed from elsewhere in the country or abroad. Semi-skilled staff, such as administrative staff and machinery operators, and service staff will likely be available from the surrounding towns. However, the overwhelming majority of jobs created by the project will be indirect and induced. Many indirect jobs will be created on the biomass supply chain (i.e. harvesting and processing operations), while induced

[1] The payment and magnitude of this fee is not material to the findings of the study and will depend on the arrangement made between land-owners, harvesters and NamPower.

employment will be the result of the increased local consumption of goods and services as a result of the employment created by the power plant and biomass supply chain.

The two harvesting scenarios have significantly different capital, labour and skill requirements. Scenario 1 makes use of more mechanised harvesters, thereby employing fewer people at a total of 156, but a greater proportion of semi-skilled people. Scenario 2 employs significantly more people overall at a total of 603, however the majority of these employees are assumed to be at lower skill levels. Discounted from nominal to real (inflation adjusted) at 6% per annum, Scenario 1 generates a benefit of N$ 352 million in direct wages, or N$ 0.09 per kWh of electricity produced over the project's 25-year lifetime. Scenario 2, being more labour intensive, generates a total benefit of N$ 534 million in direct wages over the 25-year lifespan, or N$ 0.14 per kWh.

In the agriculture sector, the assumption is that bush thinned land will be used for cattle farming. Should land owners choose to deviate from this, the assumption is that this is because any alternative practice will generate greater returns. The model runs under the assumption that the carrying capacity of encroached land is 17 hectares per head of cattle (large stock unit), and that carrying capacity will increase to 10 hectares per head of cattle[2], four years after bush thinning. Livestock farmers will begin marketing cattle in year four, using the prior years to re-stock. Over the project lifetime, an additional 6,933 cattle will be added, based on the improved carrying capacities, with an additional 347 cattle becoming eligible for marketing each year, after year four. Cattle are valued based on the 2017 average beef producer price of N$ 35/kg (inflated at 6% per annum) and a conversion factor of 250 kg per head of cattle. The average direct value addition from livestock over the 25-year lifespan of the power plant, in 2018 terms, is N$ 61.5 million worth of gross value added in the form of operating profit in 2018 terms. This equates to N$ 0.02/kWh[3]. These values accrue to the farmers whose land is cleared.

The environmental and ecosystem services benefits were assessed, with the quantified benefits focusing on improved groundwater recharge and impact on greenhouse gas emissions. An average rate of groundwater recharge at 1% of rainfall is used as the baseline for bush encroached land, while a conservative estimate of improvement to 2% recharge on bush-controlled land was applied. Some studies suggest much higher recharge rates, however this analysis retains the conservative assumptions found in the two Namibia Nature Foundation (NNF) studies (2016 and 2017) and thus notes a possible bias to underestimate the level of the groundwater resource improvement. The extractable groundwater level increase needs to be offset by the increases water usage attributable to larger cattle herds, as well as water usage by the power plant. Once all offsets are accounted for, the extractable groundwater resource is expected to increase by 11.7 million m^3 over the 25-year project lifespan. Based on the avoided cost approach, the real net value of groundwater recharge in 2018 terms is N$ 244 million, or N$ 0.07/kWh, over the 25-year lifespan.

Burning the biomass to fire the power plant is a source of greenhouse gas emissions. However, it is assumed that these emissions will be recaptured by plant growth and is termed biogenic carbon – and therefore has a net zero emissions assumption. However, the supply chain and livestock farming will contribute to emissions. The use of fully and semi-mechanised harvesting methods, as well as the

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[2] The formal literature on this topic suggests that a minimum of a 100% increase in carrying capacity can be expected after bush thinning has taken place, however it is the view of NamPower that this figure is highly optimistic in the specific harvesting area. As a result, following consultation with farmers in the region, it was decided that a more conservative increase in carrying capacity, of 70%, would be utilized.

[3] It is worth noting that the contribution of agriculture in to GDP is highly sensitive to the increases in stocking values following bush thinning, due to the large fixed cost-component of the clearing and after care activities required for cleared land.

transport of the biomass to the power plant, contribute to emissions. Supply chain emissions will total about 130,000 TCO_2e over the 25-year period. The methane emissions by the additional cattle are converted to a CO_2 equivalent, and amount to approximately 665,000 TCO_2e over the 25-year power plant lifespan.

To produce an aggregate value for the microeconomic benefits, a price/tonne of biomass of N$ 600 is used. Of the three provided price points, the N$ 600/tonne option provides the best trade-off in terms of returns for both the harvesters and the power plant itself. In net-present-value (NPV) terms (discounted at 6%, the assumed annual inflation rate), the aggregate value of gross value addition under Scenario 1 (90% mechanised) is N$ 1.47 billion of value addition that would otherwise not take place were it not for this project, or N$ 0.40/kWh; and under Scenario 2 (45% mechanised) is N$ 1.52 billion, or N$ 0.41/kWh. The second scenario results in a marginally higher aggregate value of gross value addition due to its significantly higher employment and therefore greater total wage contributions.

Macroeconomic findings

The construction of the power plant will see the greatest short-term addition to GDP, while the operational phase will provide a lower, but longer-lived contribution. The total construction cost is estimated at N$ 941.07 million, on an assumed exchange rate of N$ 12 to the US dollar. Approximately 45% of this will be spent on direct imports (such as the boiler and steam turbine), and will therefore register as a negative contribution to GDP[4]. Only gross value addition (i.e. output less intermediate consumption) on the remaining construction activity positively contributes to GDP. Factoring in this large import component results in a net contribution of -0.16% of forecast 2018 GDP, in 2018 value terms. The construction industry has a 2.36 x multiplier, implying that for every N$ 1 spent on construction, N$ 2.36 of output is produced in the economy as a whole.

During the operational phase, the assumption is that power generated is offset against imported power from the Southern African Power Pool. In net-present-value terms, the reduced electricity imports (import substitution effect) over the plant's 25-year lifespan equate to a benefit of N$ 0.87/kWh, as the imported value of electricity over the 25-year period, in 2018 value terms, is approximately N$ 3.24 billion. The price that NamPower pays for biomass plays a large role in the GDP contribution of the power plant. In net-present-value terms over the plant's operational lifetime, a feedstock price of N$ 450/tonne returns N$ 0.18/kWh, N$ 600/tonne returns N $ 0.08/kWh and N $ 750/tonne returns -N$ 0.03/kWh. These figures represent the gross value addition from the power-plant in terms of gross operating surplus from the operation of the power-plant.

The indirect contribution to the economy will primarily come from the biomass supply chain and increased agricultural output. The contribution by the biomass sector is, once again, heavily dependent on the sales price of biomass and the harvesting method utilised. At a price point of N$ 600/tonne, the contribution to GDP per kWh increases over the 25-year project lifetime, however this is largely as a result of increasing livestock output which is independent of the feedstock price points. The livestock industry has an extensive upstream value chain, requiring inputs and therefore benefiting nearly every other sector/industry in the domestic economy. Similarly, there is also a well-developed downstream value chain for livestock. The implication is that for every N$ 1 of output generated by this industry, N$ 3.63 of output is generated in the economy as a whole, across various different up-and-downstream activities.

[4] The GDP calculation is the aggregation of consumption, investment, government spending and net exports (exports minus imports).

The contribution to personal and company income tax is, once again, heavily dependent on the price point of biomass and the harvesting mix utilised. The first scenario contributes slightly higher tax revenues, as the mechanised harvesting units are slightly more profitable than the alternatives. However, under both scenarios the harvesters only start contributing to corporate tax in their third year of operation, when they first break even. At the mid-price point of N$ 600/tonne, the net present value of income tax amounts to N$ 97.2 million under Scenario 1, and N$ 65.9 million under Scenario 2. The difference in personal income tax between the two harvesting scenarios is minimal. This is because most of the unskilled labourers fall below the tax threshold, so higher levels of employment do not result in larger tax payments per-se. With regard to social security, the contributions are minimal but vary greatly between the scenarios due to the second scenario employing significantly more workers. The net present value of these contributions to social security over 25 years amounts to N$ 1.67 million under Scenario 1 and N$ 6.05 million under Scenario 2.

Based on 2017 annual energy sales by NamPower of 4,157 GWh, this power plant will represent less than 4% of total energy sales in Namibia. According to discussions with NamPower, with the current execution philosophy the erection of this power plant will have little to no impact on the overall tariff charged to consumers. Furthermore, electricity, gas, and other fuels make up 3.86% of the inflation basket. As a result, the inflationary impact of the project will be negligible.

The impact on the balance of payments sees an initial large outflow in order to import the equipment, however this would be offset by financing obtained from foreign sources, where an initial inflow of funds would be seen, followed by a slow outflow of funds as the funding loan is repaid over the operational phase of the project. The import-substitution effect of electricity is the largest contributor to the positive balance of payments effect, resulting in N$ 314 million less leaving Namibia per annum, working out at N$ 0.87 kWh (in 2018 terms) over the full 25-year period. Increased cattle and beef exports will also contribute in some part to greater exports. The equipment for harvesting, as well as increased fuel imports for harvesting will offset some of the positive balance of payments effects.

Conclusion

The underlying assumptions of this report are based on figures and information provided by NamPower, N-BiG, as well as the referenced material. According to these, an annual feedstock requirement of 106,500 tonnes of biomass is required for the power plant. At an average sustainable yield of 12.65 tonne/ha, we calculate harvesting operations will bush thin approximately 8,419 hectares of land a year. As per the terms of reference, three different harvesting methods (being manual, semi-mechanised and fully mechanised) and three different price points (N$ 450/tonne, N$ 600/tonne and N$ 750/tonne) were analysed. In consultation with NamPower, N-BiG and GIZ, it was decided to conduct the study looking at two harvesting scenarios: one focused primarily on mechanised harvesting (90% fully mechanised, with the remaining 10% split evenly between manual and semi-mechanised), while the second was predominantly manual and semi-mechanised (55% split between these two, with the remaining 45% fully mechanised).

Despite other users of encroacher bush within the proposed harvesting area, there does not exist sufficient competition for the resource to the extent that available supply for the proposed power-plant may be threatened. In this regard available supply is far greater than total demand across all users.

The overall positive microeconomic impacts of the proposed power-plant are as a result of employment creation, salaries and wages, agricultural benefits from livestock production, improved groundwater recharge, reduced CO_2 emissions and the value addition derived from biomass harvesting. At a price of N$ 600/tonne, the first harvesting scenario generates a total microeconomic benefit of N$ 1.47 billion, or N$ 0.40/kWh, over the project lifetime in 2018 (inflation adjusted) value terms, while Scenario 2 generates a benefit of N$ 1.52 billion, or N$ 0.41/kWh. These values represent the direct, indirect and induced additional gross value addition activity (GDP) that takes place in the country because of the proposed power plant and its up-and-downstream value chains.

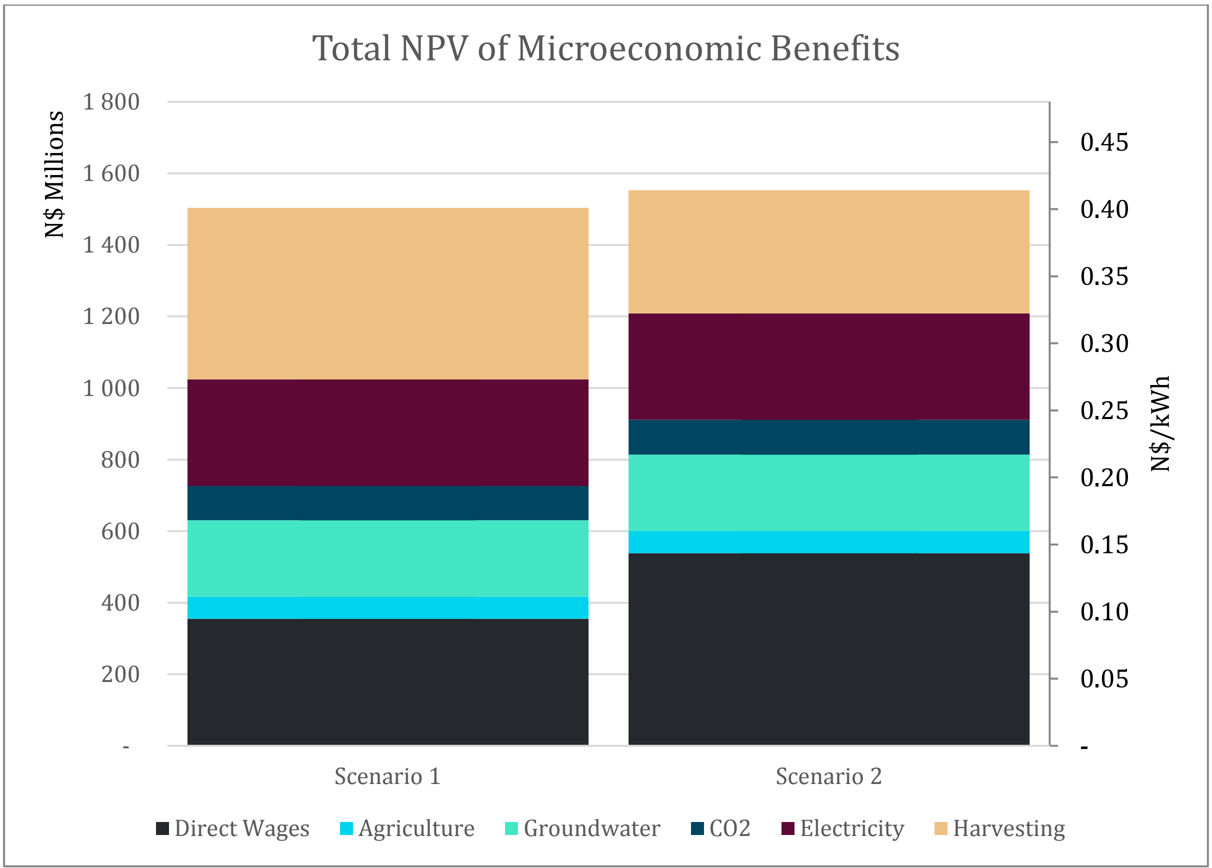

Figure 1: NPV of microeconomic benefits

On the macroeconomic impact, it was noted that while the majority of the employment is generated at the micro level, the contribution to GDP by both personal and corporate income tax is heavily dependent on the price point and harvesting method. As the mechanised harvesters are slightly more profitable, the first scenario contributes more to income tax (at N$ 600/tonne, this is N$ 92 million as opposed to N$ 76 million, in net-present-value terms over 25 years). The large import factor of the power plant construction sees an initial negative impact on GDP. However, the operational phase of the power plant has a smaller, but longer-lived contribution to GDP over its 25-year lifespan, between -0.004% and 0.019% (dependent on the biomass price). The impact on inflation is expected to be negligible, as the 20 MW power plant produces less than 4% of hourly power requirements, and electricity (and other fuels) make up less than 4% of the inflation basket. The balance of payment sees net positive effects, largely due to the import-substitution of electricity (N$ 134 million/year in 2018 value terms) as well as contributions from cattle and beef exports.

From a price/kWh perspective, the first harvesting scenario results in a total NPV per kWh of N$ 1.33 and the second harvesting scenario results in a total NPV of N$ 1.28/kWh when all value addition multipliers have been incorporated.

From a balance of payments perspective, the NPV of the project over the power plant lifetime is N$ 0.83/kWh to N$ 0.85/kWh, depending on harvesting methods used.

From a tax perspective, the NPV per kWh depends on the harvesting scenario and price/tonne of biomass. At N$ 600/tonne for biomass, the NPV of the first scenario including both the power plant and harvesting is N$ 0.06/kWh, while the second scenario is N$ 0.05/kWh.

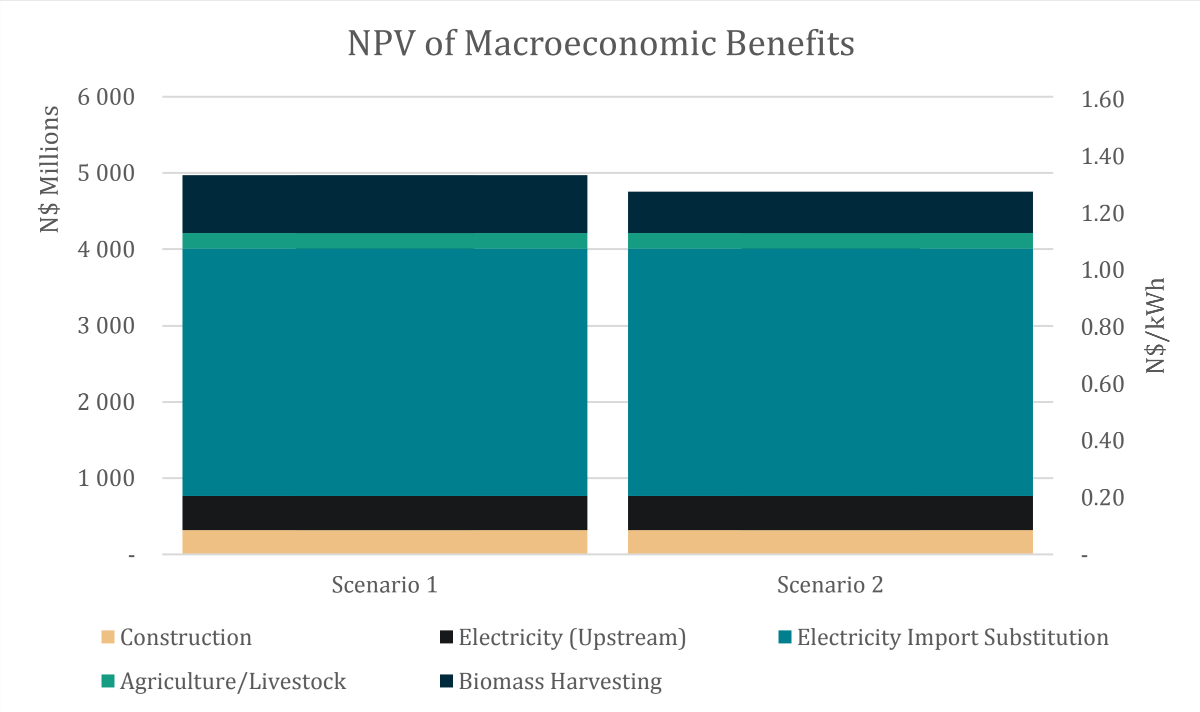

Figure 2: NPV of macroeconomic benefits

The key considerations for this project are around the harvesting methods utilised and the price paid for biomass. While mechanised harvesters are marginally more profitable, the manual and semi-mechanised methods employ more people (albeit with lower wages). Ultimately, the harvesting method decision will come down to harvesters themselves, who are likely to favour the slightly higher returns under mechanised harvesting. The price point for biomass is the other key factor, as a higher price is beneficial to harvesters, but producers a lower return for the biomass power plant. So, while a price of N$ 750/tonne is preferable for the harvesters, this jeopardises the feasibility of the power plant. On the other hand, the N$ 450/tonne price point, while preferable for the power plant, is too low for harvesters to generate profit. The N$ 600/tonne price point is the most feasible of the assessed price points for both the power plant and harvesters, and so for the purpose of this study, many calculations adopt this price point.

The two harvesting scenarios differ widely in their composition. In terms of the overall impact, Scenario 2 employs significantly more persons, especially for unskilled jobseekers. While this does provide a wide social benefit, through employment creation and the income generated by these persons, the majority of workers will fall below the lowest income tax threshold. Scenario 1, on the other hand, is more mechanised and thus employs far fewer people, although at higher wages. However, the fully mechanised harvesting methods tend to be more profitable, and so realistically are more likely to be pursued by independent harvesters. The more manual methods require more administration and supervision of workers, with fairly intensive work, possibly leading to high staff turnover. Over and above this, farmers are likely to be wary of large numbers of workers on their land and this may pose problems for harvesting. Thus, while Scenario 2 may look more appealing in terms of its wider employment impact, it may pose some problems pragmatically. Independent operators are likely to prefer the fully mechanised method as it is more profitable and poses less difficulties and uncertainties in terms of human resources, despite its higher capital costs. The encroacher bush biomass power project provides far reaching economic benefits, from biomass harvesters, to farmers, to indirect and induced employment. Making use of an abundant resource such as encroacher bush creates more employment than other sources of renewable energy. This project also serves as an alternative off-taker for the use of encroacher bush, and its successful implementation will likely lead to other similar projects, which could reap greater benefits through efficiency gains.

Although there are assumed biomass-based power generation costs associated with operating and maintaining a biomass power station, there are significant economic benefits which were quantified at approximately N$ 0.40 /kWh and N$ 1.33 /kWh for the micro-economic benefits and macro-economic benefits, respectively. These figures also vary slightly, depending on the type of harvesting arrangement (combination of fully mechanised, semi-mechanised and manual labour).

From the National Integrated Resource Plan (2016) the Unit Cost of Energy (N$/kWh) for a biomass-based dispatchable renewable plant is listed as N$ 2.25/kWh and N$ 2.07/kWh for a 5 MW and 10 MW capacity, respectively. The assumptions used in the Macroeconomic study, considering a 20 MW capacity plant operated at 85% capacity factor, uses a Unit Cost of Energy (N$/kWh) which is lower than these quoted for the 5 MW and 10 MW plants. In addition, the Unit Cost of Energy is also expected to be less for a larger 40 MW option.

Taking this into account, the quantified economic benefits on a micro and macro scale are significant when compared to the expected Unit Cost of Energy and should play a vital role in decision making.

Introduction

Background and Context

Namibia faces the challenge that its traditionally open savannah rangeland, characterized by a mixture of trees, thickets of bush and extensive grassland, is increasingly transforming into a dense, bush encroached landscape. Bush encroachment is defined as the densification and rapid spread of native shrub and tree species, resulting in an imbalance of biodiversity. This phenomenon affects over 30 million hectares of land in Namibia.

This imbalance of the woody species leads to a reduced biodiversity, a decreased carrying capacity of the rangelands, and in the medium term, a reduction of available groundwater, as a result of the increased water uptake by the encroacher bushes.

Due to bush encroachment's detrimental effect on the grazing capacity of agriculturally productive land, productivity has declined, often to such an extent that many previously productive livestock farms are now no longer economically viable. As such, bush encroachment is considered the single most important obstacle for the development of the country's meat industry. Restoring bush encroached areas by the sustainable removal (harvesting/thinning) of some of the woody plants to yield a more balanced rangeland ecosystem will result in an improvement in grass production and therefore also the grazing capacity. Many national policies, such as the National Rangeland Management Policy and Strategy (2012), the Harambee Prosperity Plan (2016) and the Fifth National Development Plan (NDP5, 2017), promote bush control/thinning towards rangeland restoration.

Bush thinning of Namibia's affected rangelands will lead to more productive, ecologically diverse, and balanced state. The abundance of undesirable woody biomass, coupled with the need for local electricity generation creates an opportunity to utilize this encroacher bush resource for electricity generation.

Electricity generation utilizing encroacher bush also falls in line with national and local development priorities, serving to provide employment opportunities, skills development, local economic growth and, importantly, an improved agricultural carrying capacity of the farmland where encroacher bush has been harvested. The economic benefits of improved carrying capacities of land is likely to yield a more robust local economy, as well as to increase the capacity and resilience of local communities to manage with environmental variability, exacerbated by climate change.

In June 2013, NamPower finalised a pre-feasibility study for a biomass power plant. The pre-feasibility study assessed the technical, environmental, socio-economic and financial aspects of this project. The use of commercially proven combustion technologies for the conversion of biomass to heat energy for generating electricity was recommended.

Methodology

The purposes of this study are to quantify and assess the microeconomic and macroeconomic impact of:

- A 20 MW biomass power plant adjacent to the Otjikoto substation, near Tsumeb, Namibia, over its 25-year lifespan.
- The fuel supply and harvesting activities for a 20 MW power plant at the aforementioned site, over a 25-year period.

The economic modelling for this project is based on the 20 MW encroacher bush power plant as well as the supply chain that produces the primary fuel for the power plant. For the purpose of the study, three different harvesting methods are considered, which were further blended into two harvesting scenarios. These two scenarios are used to analyse the economic costs and benefits on both the micro- and macro-economic levels.

Timeline

The project timeline is assumed as provided by NamPower as follows:

1. Construction is planned to commence mid-2019, for completion end of 2021.
2. Commissioning starts Q4 2021 and full operation is achieved in Q1 2022.
3. The plant's operational lifespan is 25 years, from Q1 2022 to end of 2046.

Prices

Unless otherwise indicated, nominal prices have been adjusted to reflect future value and ensure consistency. All prices, unless otherwise indicated, were escalated at a fixed rate of 6% per year in order to compensate for inflation. Where appropriate, nominal prices were discounted to real, 2018, values.

Harvesting methods

Three harvesting methods were considered for the purpose of the study, namely:

1. Fully mechanised harvesting, whereby heavy machinery, semi-skilled and highly skilled labour are combined to harvest land and produce biomass feedstock.
2. Semi-mechanised harvesting, whereby semi-skilled teams utilise primarily operator driven power tools to harvest land and produce biomass feedstock.
3. Manual harvesting, whereby teams of unskilled labourers utilise primarily hand tools to harvest land and produce biomass feedstock.

The harvesting value addition and employment estimates were generated through the construction of a micro-level financial model for each of the scenarios discussed within the Harvesting Scenarios section of this document. Conventional financial models were built utilising inputs from the Namibia Biomass Industry Group.

All of the harvesting methods assume the same transport requirements from the points of harvest to the power plant gate. The different methods assumed different processing requirements, with the fully-mechanised operations requiring fewer, larger units than the manual operations. A number of assumptions surrounding the biomass harvesting scenarios are provided in the Harvesting Scenarios section of this document.

Biomass Price Points

Three distinct price points for the purchase of biomass were provided by NamPower, namely N$ 450/tonne, N$ 600/tonne and N$ 750/tonne (2018 prices), delivered to the power plant gate. These prices were given as 2018 prices and escalated by 6% per year to the first operational year of the plant in 2022.

Power plant

The core assumptions provided by NamPower included the construction costs of the power plant, the power plant capacity and capacity factor, energy charge and capacity charge, exchange rates, operational expenditure estimates, financing sources, rates and currencies and the price of biomass. As with the biomass harvesters, a detailed financial model was constructed to assess gross value addition of the power plant.

Ecosystem

The groundwater valuation methodology is adapted from Birch and Middleton (2017). Assumptions for infiltration rates from rainfall for bush encroached and bushed thinned land, the average amount of rainfall, and the expected amount of land to be thinned, net of any regrowth, lead to an estimate for total groundwater increase from harvesting. A proportion of this stock increase is estimated as being extractable via existing water supply infrastructure, with no value assigned to the stocks that would require new infrastructure for extraction. Calculations for water consumption from incremental cattle and power station usage are then deducted from the extractable stock increase. This net remaining stock increase is valued using a price for water, which is implied from a water supply project, using an avoided cost approach.

Environment

The greenhouse gas emissions valuation methodology is also adapted from Birch and Middleton (2017). It assumes net zero emissions from biogenic carbon (CO_2 absorbed during growth and emitted during burning), and focuses on the calculation of supply chain emissions from harvesting, transport and conversion, due to diesel and electricity usage. Emissions from land-use change are also considered and calculated for reduced soil organic carbon, and increased methane from incremental cattle stocks. These combined sources of increased emissions are then offset by displaced emissions from the generation of electricity. The relevant figure for the default value is calculated using the Namibian grid emissions factor, which is derived from the supply mix as referenced from previous studies and validated by recent NamPower figures. Net emissions are then valued using a price for carbon, which is based on the figure used by the Namibian National Integrated Resource Plan.

Agriculture

It is assumed that bush thinned agricultural land will be used for livestock farming, particularly cattle, as this is the dominant type of livestock farming within the region. With the power plant requiring an annual feedstock of 106,500 tonnes and the average yield of 12.65 tonnes/hectare, 8,419 hectares will be harvested every year. Based on interviews with local farmers, NamPower has suggested an initial carrying capacity of 17 hectares per head of cattle, gradually improving to 10 hectares per head of cattle (70% improvement) four years after the land has been bush thinned. Birch and Middleton (2017) suggest that the carrying capacity will increase by 100% after four years, but the anecdotal evidence provided by NamPower suggests this increase as very optimistic, and so the 70% improvement is used in the model. It is implicitly assumed that current carrying capacity is fully utilised, as well as that sustainable rangeland practices and harvesting aftercare will be adopted, once land has been bush thinned.

The revenue generated by farmers from the additional livestock is calculated using the average beef producer price for 2017 (available from the Meat Board of Namibia), inflated at 6% per annum, along with a conversion factor of 250kg per head of cattle. It is assumed that the volume of cattle marketed per hectare will also increase by the same ratio as the increase in carrying capacity.

In order to calculate gross value addition, a conversion factor of 35% is assumed from gross output to gross value addition, implying a fixed intermediate consumption ratio of 65%. In layman's terms, this is to say that profit for the farmer is assumed to be 35% of total revenue, with costs being the remaining 65%. This is in line with long term norms in the Namibian National Accounts.

Macroeconomic multipliers

GDP and Growth

Further to the specific micro-economic implications of the project, broad-level macroeconomic multipliers were utilised to determine the cumulative micro-impacts on the economy as a whole.

GDP multipliers were extracted from the Namibian Social Accounting Matrix (SAM) of 2013 (Schade, 2016; Lange and Schade, 2008) and applied to the output of the microeconomic modelling exercises. The multipliers were split into and applied on four micro-level components of the study as follows:

1. The macroeconomic multiplier effects of the 30-month construction phase of the project.
2. The upstream value addition for energy generation (downstream was assumed as constant due to local generation only substituting for imports, not increasing energy available).
3. The macroeconomic multiplier effects of biomass harvesting activities.
4. The macroeconomic multiplier effects of increased agricultural/livestock output.

Multipliers from the SAM were adjusted as necessary to avoid double counting of the upstream components of electricity production (i.e. to avoid double counting the biomass harvesting value addition).

The potential contribution to GDP was estimated using 2016 GDP figures, with nominal growth assumed at 5% in 2017, 5.5% in 2018, 7% in 2019, 7.5% in 2020 and 8% per year from 2021 onward.

Employment

Direct contributions to employment from the power plant construction and operation were provided by NamPower, and expected salaries were determined with input from NamPower. Biomass harvesting employment figures and wages were estimated with the input of the Namibia Biomass Industry Group.

Indirect and induced employment figures were estimated using macroeconomic value addition multipliers from the SAM and known value addition from the agriculture, electricity, biomass harvesting and construction sectors, coupled with the employed-to-value-addition ratios implicit in the 2016 National Accounts and the 2016 Namibia Labour Force Survey.

Average wages per sector from the Namibia Labour Force Survey, 2016, were used to estimate wages in the various industries in which indirect and induced employment would be created. Wages were inflated by 6% per year across the lifetime of the power plant.

Balance of Payments

The balance of payments impact of the power plant was only estimated from the direct (electricity production substituting for imports, construction imports, external loan funding inflows and outflows of interest and principle during loan repayment) and indirect activities (harvesting imports of machinery and fuel, exports of livestock and similar) relating to the power plant. Induced impacts on the balance of payments were not considered.

The flow of merchandise goods into the country for the power plant's construction, the flow of machinery and fuel into the country for biomass harvesting, the flow of agricultural output out of the country from increased livestock production, the reduction in electricity imports and the inflow of capital and outflow of interest and capital for funding activities were all calculated in the various micro-scenario models, and captured in the balance of payments estimates.

Inflation

Due to the negligible nature of the output from the power plant (less than 4% of total demand), and the small weighting of electricity in the Namibia Consumer Price Index basket (3.84%), it was assumed that this plant would have little impact on Namibian inflation.

Microeconomic Impact of the Project

Supply and Demand

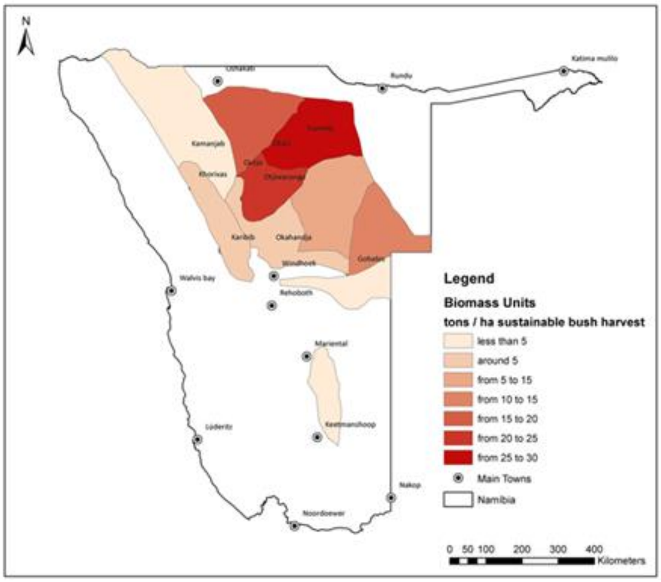

Figure 3: Biomass harvesting density

Over 30 million hectares of land in Namibia is affected by bush encroachment. According to Petrick and Katali (2017), there is sufficient encroacher bush biomass to supply 10 power plants of 20 MW each for more than 180 years, which does not consider any potential regrowth. It is thus apparent that this resource is abundant, and that production is largely constrained by uses driving demand for the resource.

The chosen site, near Tsumeb, is located in the most encroached area in Namibia, as seen in Figure 3. This area is classified as Karstveld and contains moderate densities of 3,000–4,000 bushes per hectare in the west and very high densities of 10,000 bushes per hectare in the east. More than 75% of sampled plots in Karstveld areas fall in either the “very high” or “high” density category (De Klerk, 2004). The main encroacher species in these areas is *Dichrostachys cinerea* (or Sickle Bush), which occurs in densities up to 10,000 bushes per hectare. The area is also subject to relatively high rainfall, on average 550 mm per annum, which also contributes to the high density of encroacher bush.

The proposed harvesting area is defined as a radius of approximately 100 km (approximately 3.7 million hectares), which is extended to include the similar bioclimatic envelope beyond this boundary as shown in Figure 4, around the power plant, with “no-go” areas marked off for areas north of the veterinary cordon fence, steep sloping areas, national parks and communal farmland.

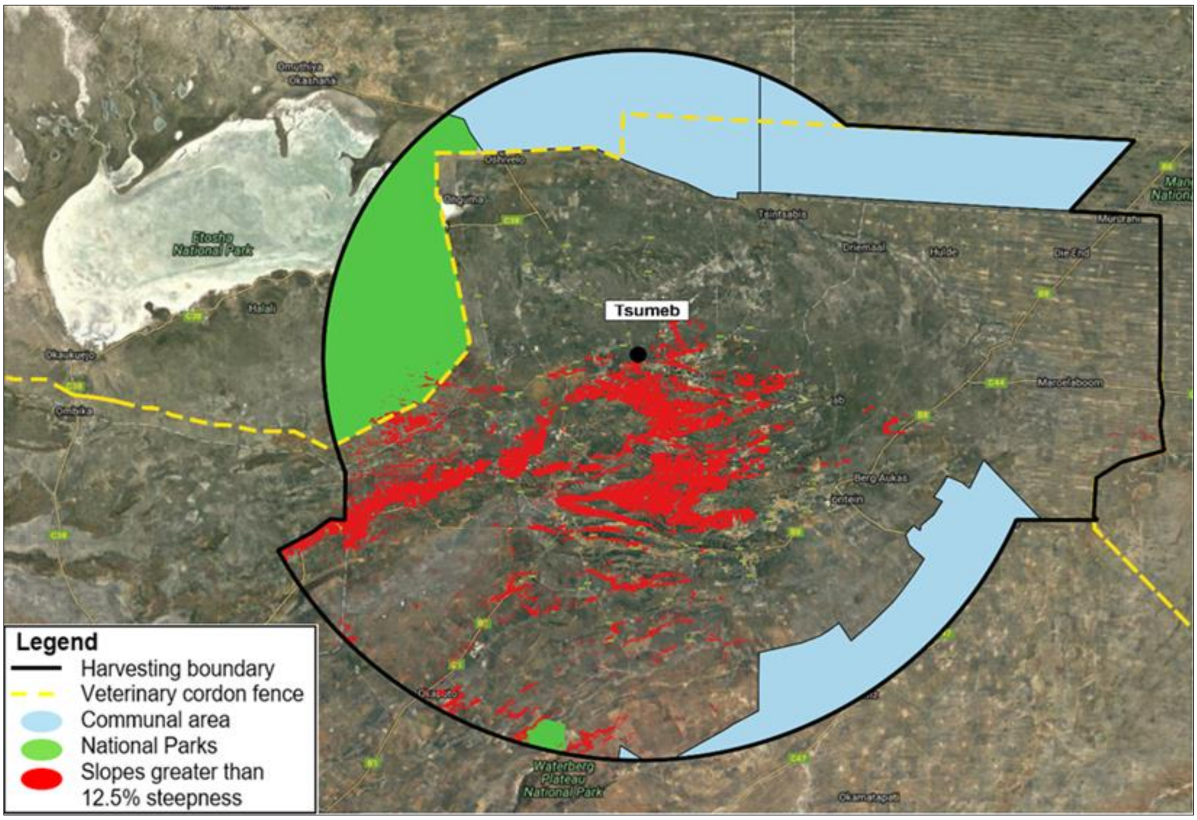

Figure 4: Proposed harvesting area

Seeing as many farmers are motivated to increase the carrying capacity of their rangeland, it is expected that harvesting can take place close to the delivery point. Based on an average harvesting density of 12.65 tonnes per hectare (Smit *et al.*, 2015), on a dry matter basis, it is estimated that 46.7 million tonnes of biomass can be harvested from within the demarcated harvesting area. Based on an annual fuel requirement of 106,500 tonnes per annum, only 5.7% of the initial resource will be utilised over the lifetime of the project.

Aftercare will be essential to increase and maintain the livestock carrying capacity of agricultural land[5]. If left untreated, encroacher bush can proliferate after first-time harvesting, re-coppicing from the rootstocks and remaining stumps, while some species of encroacher bush, such as Sickle Bush, are particularly prolific, and tend to regrow over a short time period, and can result in land that is even more encroached than before the initial harvest. Additionally, saplings do not present sufficient wood yield to attract large scale biomass harvesters. This thinner woody material, typical of recent re-growth, is also less suitable for conversion into woodchips for fuel purposes.

[5] Figures provided by N-BiG suggest this aftercare will cost approximately N$200 per hectare every three years.

Competition for Resource

At present, there are a number of players in the immediate value chain for biomass, including farmers whose land is to be thinned of encroacher bush, harvesters, who thin the encroached land and produce woodchips and other biomass products, and the consumers of the biomass products including charcoal producers, firewood producers or potential biomass power plants and heating plants. The interaction between these players depends heavily on price, including the cost to the farmers for restoring the land, the cost to harvesters of harvesting the land and producing woodchips or similar, and the cost to charcoal, firewood or electricity producers incurred in purchasing the biomass input products. In this regard, the biomass suppliers who are able to harvest most efficiently at low cost are at a distinct advantage.

With regards to chipped biomass, the most likely direct competition in the region will be from the Ohorongo Cement factory. This facility is within the 100 km radius of the proposed Otjikoto power plant (Figure 4) and currently purchases woodchips directly from biomass harvesters, requiring up to 85,000 tonnes of dry wood chips per annum for its multi-fuel kiln at the plant (IDFC, 2017). The facility uses both biomass and refuse-derived fuels (specifically waste with high calorific values), in an effort to reduce reliance on imported coal. Producers are paid to deliver woodchips to the factory gate, subject to quality control, while most of the refuse-derived fuel is provided by Rent-A-Drum.

Most of Ohorongo's woodchips are harvested within a 75 km radius of the cement factory which overlaps with the Otjikoto power plant's proposed harvesting area. However, the fact that only 5.7% of the total encroacher bush resource within the proposed harvesting area is expected to be harvested over the project lifespan of 25 years means that competition will likely be minimal, and the combined demand from Ohorongo Cement and the NamPower biomass power plant may well provide desirable economies of scale for harvesters. Demand for bush thinning services in the region is expected to remain high for the foreseeable future due to the agricultural benefits and relatively low all-in costs, when compared to other bush control alternatives such as arboricides.

Rural and informal households in the Otjikoto region are also large users of biomass, specifically as an energy source in the form of firewood for heating and cooking (Birch and Middleton, 2017). However, this is not limited to encroacher bush, but also deadwood and non-encroacher species. Current estimated usage of biomass as firewood currently amounts to 550,000 tonnes per annum (Development Consultants for Southern Africa, 2015). Approximately 160,000 households nationally rely on firewood as an energy source, such as for cooking. Given that 40,000 private households are situated in the Otjikoto region, an upper limit of 137,000 tonnes per annum, or 7.4% of the local resource will be harvested over the 25-year project lifespan of the power plant in the Otjikoto region. Care must thus be taken not to remove all sources of firewood close to informal settlements or households' dependent on firewood as an energy source.

Charcoal harvesting areas in Namibia

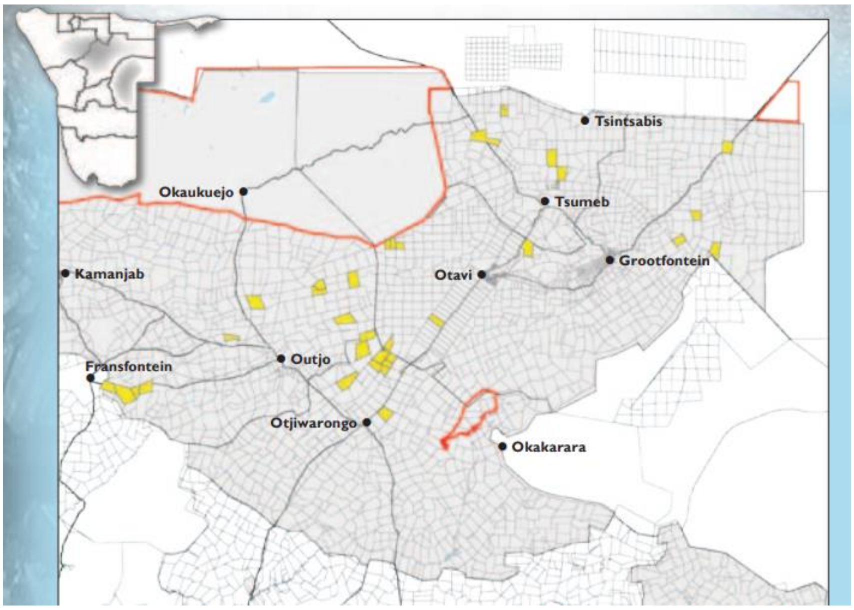

Figure 5: Charcoal harvesting areas in Namibia

Another large user of encroacher bush is the charcoal industry. According to Dieckman & Muduva (2010), 490 producers are registered members of the Namibia Charcoal Association. WSP (2012) indicate there are an estimated 4,800 charcoal workers operating in Namibia. The charcoal industry has been operating for more than 30 years and is currently the largest off-taker of biomass in the country. The Tsumeb, Otavi and Grootfontein area is one of the main charcoal producing areas in the country. Upwards of 72,000 tonnes, of the 121,000 tonnes of the national output, are produced in this area. The abundance and density of encroacher bush, and unskilled labour (mostly from the Kavango region), has made harvesting in this area relatively attractive. It is estimated that charcoal production requires about five times the weight of raw wood to produce the final product, using the traditional conversion technology, which would imply that around 360,000 tonnes of biomass is required for this industry in the proposed harvesting area for the power plant. This equates to approximately 21.4% of the current resource in the proposed harvesting area over the 25-year lifetime of the power plant. The GIZ Bush Control and Biomass Utilisation (BCBU) project notes that output is expected to increase to 400,000 tonnes nationally, if production is modernised. The charcoal industry will likely remain the largest biomass off-taker in Namibia. Charcoal production releases greenhouse gases, both in its production and end-use, and so has a considerable impact on emissions.

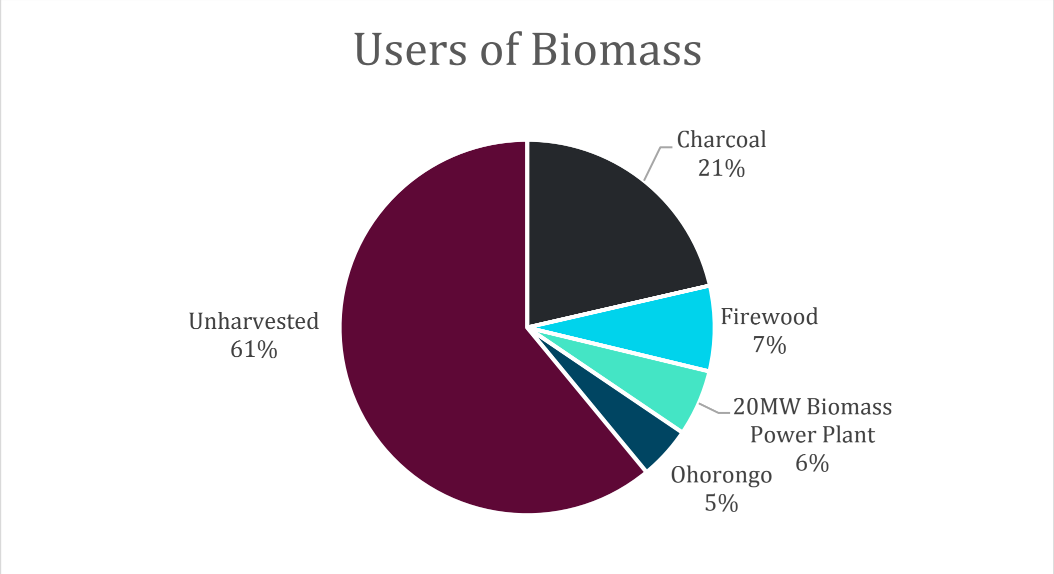

Figure 6: Users of biomass in the harvesting area over a 25-year period

Based on the conservative estimates outlined above, around 61% of the resource will remain unused despite the harvesting for the power plant. This assumption also considers no resource regrowth. Thus, the supply of the resource will far exceed the demand for the resource, meaning that competition will revolve around optimal harvesting locations (based on density and proximity to the resource off-takers), rather than for the resource itself. Competition for the resource will likely be limited and would only arise in securing off-takers of the product, as commercial harvesters would need to ensure they have a reliable market for their product.

In conclusion, the current and anticipated demand for biomass in the area surrounding the proposed power plant is expected to remain substantially below the potential biomass available in the area, despite highly conservative (i.e. 100% over-lap of harvesting zones and above current offtake levels[6]) assumptions pertaining to potential competitors for the resource.

[6] This assumption is the most conservative assumption that can be made, and implies that there is the greatest possible competition for the region's biomass resource. Despite this, there is still ample supply of biomass for all users in the area.

Market Structure

Long-term supply contracts with independent harvesters or a harvesting association will be required for security of supply of material to the power plant. A secure supply would be essential to the operations of the power plant, seeing as it will be a baseload producer.[7] Thus, reliance on a spot market would not be recommended due to the risk of fuel shortages. However, opening a spot market for independent producers to supplement stockpiles may be considered when harvesting conditions are favourable, or stockpiles of fuel start to run low. The possibility of supplementing this supply with a spot delivery market may, however, exist. This spot market need not necessarily exist at the plant gate but may make use of an offsite depot or farmgate pickup operators, who act as intermediaries between harvesters and the power plant. It is advised that long-term contracts should include an escalation clause in line with inflation to compensate the increasing costs of labour, pump price of diesel and maintenance.

The Environmental Investment Fund has indicated that a reliable business model and a dedicated off-taker is imperative to securing concessional financing, which is sourced from the French Development Agency and made available to harvesters via the commercial banks. This type of financing is generally provided at rates below those available from commercial banks and other commercial financiers. That being said, commercial financiers would also require a similar model in order to offer financing.

Multi-year supply contracts are likely to be critical for suppliers as they will enable harvesters to secure financing for equipment off the back of the offtake commitment for the product. As indicated under the methodology, the upper price point will likely be the only one attractive enough to attract commercial harvesters. However, business models will vary widely from harvester to harvester and it is entirely plausible that harvesters will be willing to accept lower price points.

[7] For the purpose of this study a baseload capability factor of 85% is assumed, but will likely be utilised as mid merit to baseload.

Harvesting Scenarios

Broad Scenarios

Based on a 12.65 tonnes/hectare sustainable harvesting yield, it is estimated that the harvesters will thin 8,419 ha of farmland per annum. Over the full 25-year period, this totals 210,474 hectares of bush thinned land. It is assumed that aftercare will be applied to bush-thinned areas every three years in order to ensure that land that has been thinned remains thinned. It is further assumed that despite these efforts, after 20 years and despite on-going aftercare, some regrowth of bush will recommence 20 years after initial harvesting.

It is assumed that harvesters earn revenue from two sources. The first is the price per tonne received for all biomass delivered to the plant gate, paid by NamPower. The second is a bush thinning fee, estimated at N$ 300/ha, in 2018 value terms, for their value adding activities, which is paid by the land owner[8]. The objective of this exercise is to increase the carrying capacity of agricultural land and so it is expected that the land owner will be responsible for aftercare. Aftercare will most likely consist of manual application of arboricides to the stumps of harvested bush to prevent regrowth and is assumed to cost the land owner N$ 200/ha, in 2018 value terms, every three years, following the initial harvest. This is best practice according to Southern African Institute for Environmental Assessment (2015) and discussions with N-BiG members currently operating. The harvesting methodology is based on three different types of harvesting methods, namely: fully mechanised, semi mechanised and fully manual. These three methods were translated into three harvesting units, roughly based on the harvesting technologies research paper published by GIZ (2016). The biomass delivered to the power plant is to be of particle size P100. This means that the bulk of the biomass particles (minimum 75%) are to have dimensions between 3.15 mm and 100 mm, with a maximum of 10% of particles allowed to be oversized (between 125 mm and 350 mm).

Fully Mechanised

The fully mechanised unit is made up of the following equipment:

Harvesting Equipment	Units	Cost per unit (N$)	Useful Life (years)
Shear attachment, for harvesting excavator	8	500,000	3
Grapple attachment, for feeding excavator	2	300,000	3
Harvesting Excavator- 20 Tonne (Harvesting)	8	1,800,000	7
Loading Excavator- 20 Tonne (Feeding)	2	1,800,000	7
Front end loader	1	1,000,000	7
Mobile Grinder (700-1000 horsepower)	1	10,435,100	9
Haulage Tractor	4	700,000	9
Hydraulic Tipper Trailer- for Tractor	4	500,000	9
Bins - (12 Tonne capacity)	17	100,000	9

Table 1: Capital outlay of a fully mechanised harvesting unit

This production unit is estimated to be able to produce 48,000 tonnes of chipped biomass per annum and requires a crew of 20 to operate. The current fuel assumption, is to produce wood chips at P100 specification[9]. The diesel consumption for this type of machinery is expected to be in the region of 2,200 litres per day. The crew consists of excavator operators, tractor drivers, a front-end loader

[8] See footnote 1.

[9] P100 refers according to the ISO/EN 17225: Solid biofuels -- Fuel specifications and classes.

operator, a dedicated mechanic, a manager and a site supervisor. Although very capital intensive, this harvesting unit is by far the most efficient and requires very little manpower to harvest a large amount of biomass.

For each of the scenarios it has been assumed that machinery and equipment have fixed useful lives. Machinery is purchased new and depreciated fully over their useful lives. A zero-salvage value has been assumed for machinery as there will likely be no or very low scrap values.

Staff	Number	Monthly Remuneration (N$)
Mechanic	1	40,000
Manager	1	50,000
Site Supervisor	1	20,000
Administrator	1	15,000
Harvesting Excavator- 20 Tonne (Harvesting)	8	9,600
Mobile Chipper- CBI 6400T	1	12,000
Loading Excavator- 20 Tonne (Feeding)	2	9,600
Haulage Tractor	4	5,000
Front end loader	1	9,600

Table 2: Staff compliment of a fully mechanised harvester

Based on three harvesting units and eight delivery vehicles (the minimum amount to supply and deliver the required biomass), the fully mechanised method yielded the following net profits for the three price points provided:

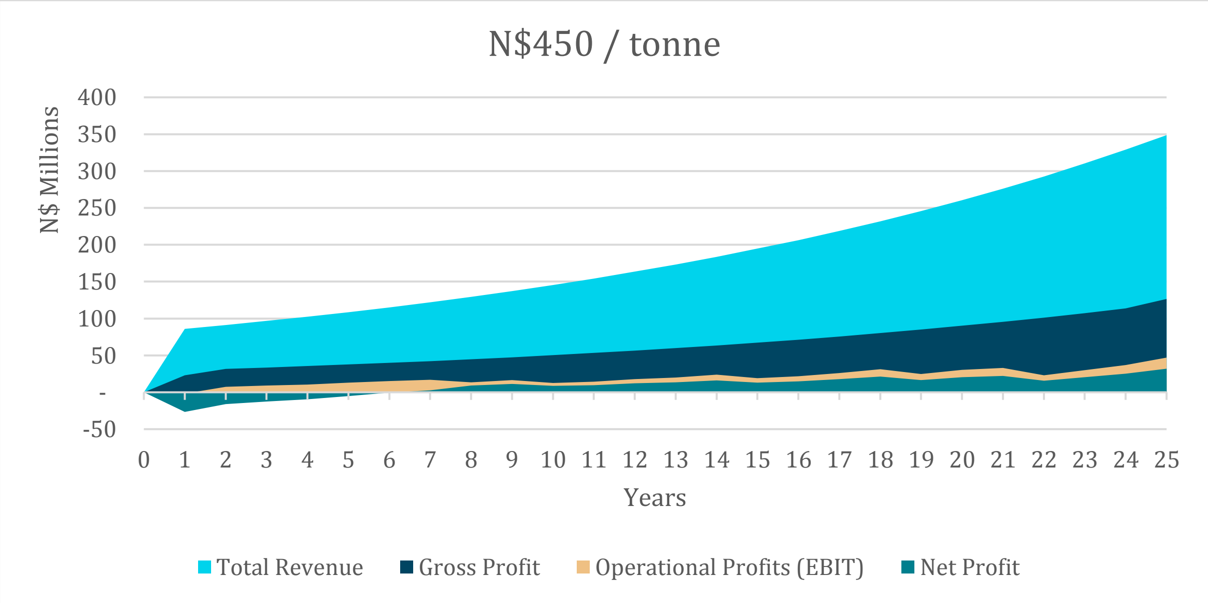

Figure 7: Income statement of a fully mechanised harvesting operations at the N$ 450/tonne price point

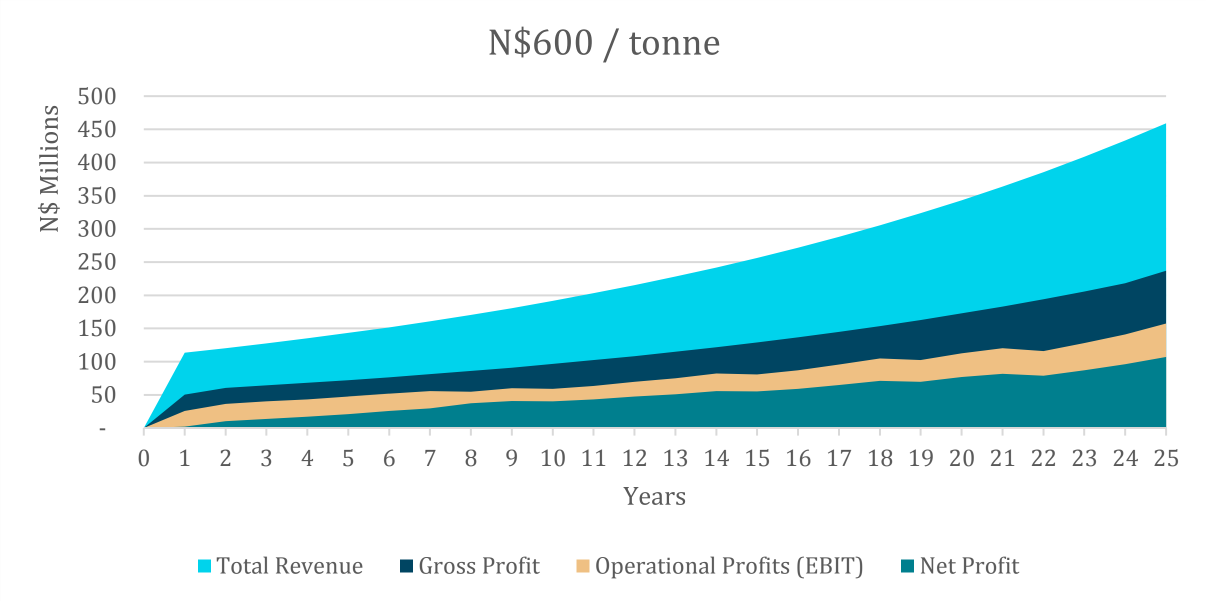

Figure 8: Income statement of a fully mechanised harvesting operations at the N$ 600/tonne price point

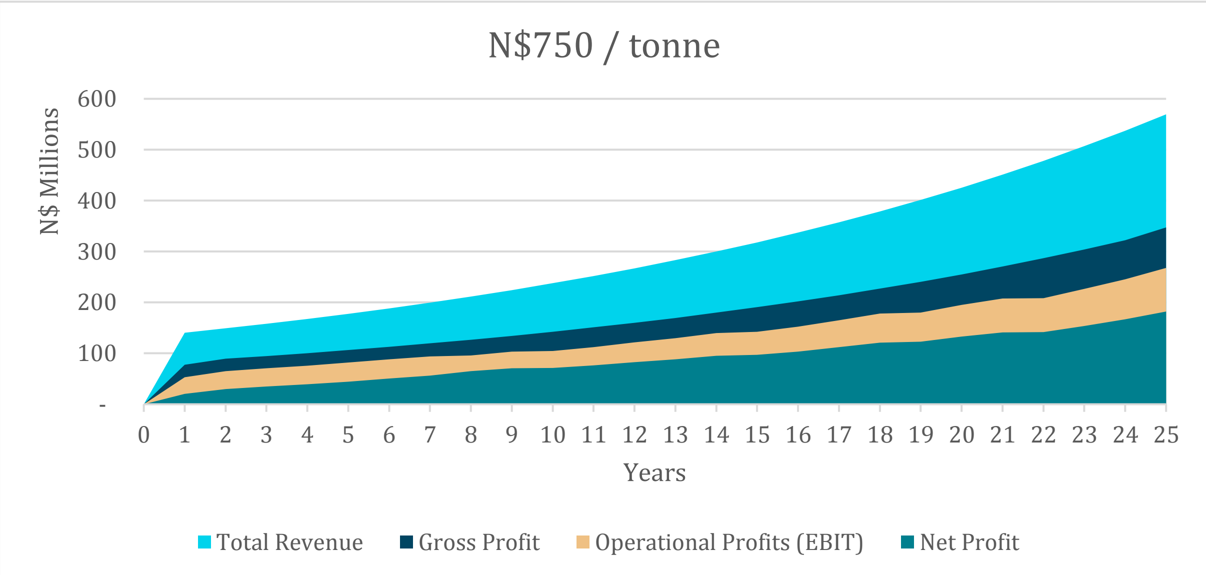

Figure 9: Income statement of a fully mechanised harvesting operations at the N$ 750/tonne price point

Semi-Mechanised

The semi-mechanised harvesting method is based on the second harvesting unit contained in GIZ's compendium of harvesting technologies for encroacher bush in Namibia (2016). It was assumed that this harvesting method could produce 1,400 tonnes of biomass per annum. One semi-mechanised unit is made up of the following equipment:

Harvesting Equipment	Units	Cost per unit (N$)	Useful Life (years)
Hand operated 13 hp trolley saw	2	25,000	7
Vertical saw trolley (13 hp)	1	22,000	7
35 hp chipper	1	300,000	7
Bulk bags	100	500	7
Trailers	2	50,000	7
Air hoists, compressor I-beam and crawls	1	120,000	9
40 hp Tractor	2	330,000	9

Table 3: Capital Outlay of a semi-mechanised harvesting unit

Two horizontal trolley saw cutters and one vertical saw cutter trolley are proposed for the above felling and operation. The diesel consumption for this type the above-mentioned machinery is expected to be approximately 45 litres per day. The staff compliment of a unit is made up of ten people, namely a supervisor/chipper operator, two tractor operators, four stackers/feeders and three trolley saw operators.

Staff	Number	Monthly Remuneration (N$)
Supervisor/Handyman/Chipper operator	1	10,000
Bulk bag trailer/tractor operators	2	8,000
Stack/pruners/feeders	4	2,000
Trolley saw operators	3	4,000

Table 4: Staff compliment of a semi-mechanised harvesting unit

Based on 77 operational units and eight delivery vehicles (enough to supply and deliver the required biomass) the semi-mechanised harvesting method yielded the following net profits for the three price points provided:

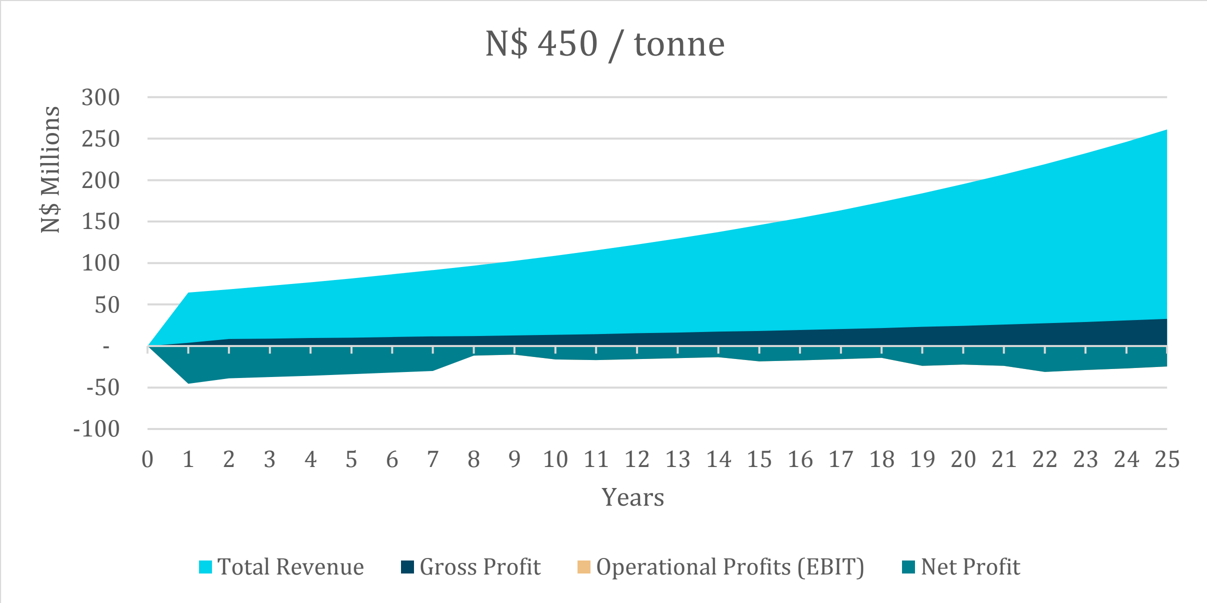

Figure 10: Income statement of a semi-mechanised harvesting operations at the N$ 450/tonne price point

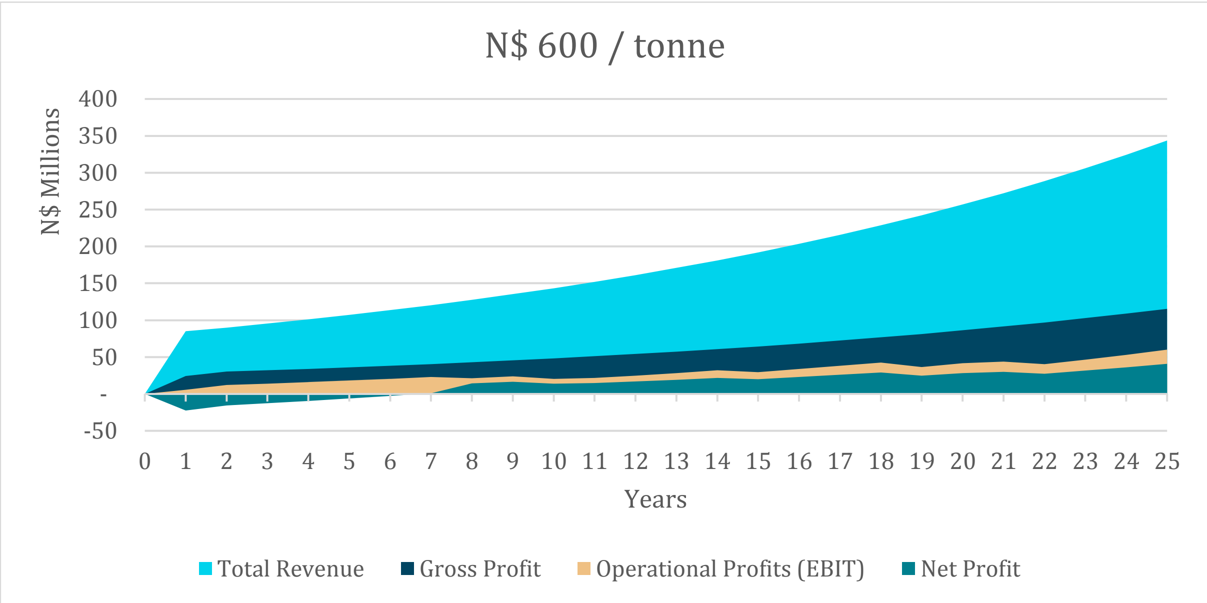

Figure 11: Income statement of a semi-mechanised harvesting operations at the N$ 600/tonne price point

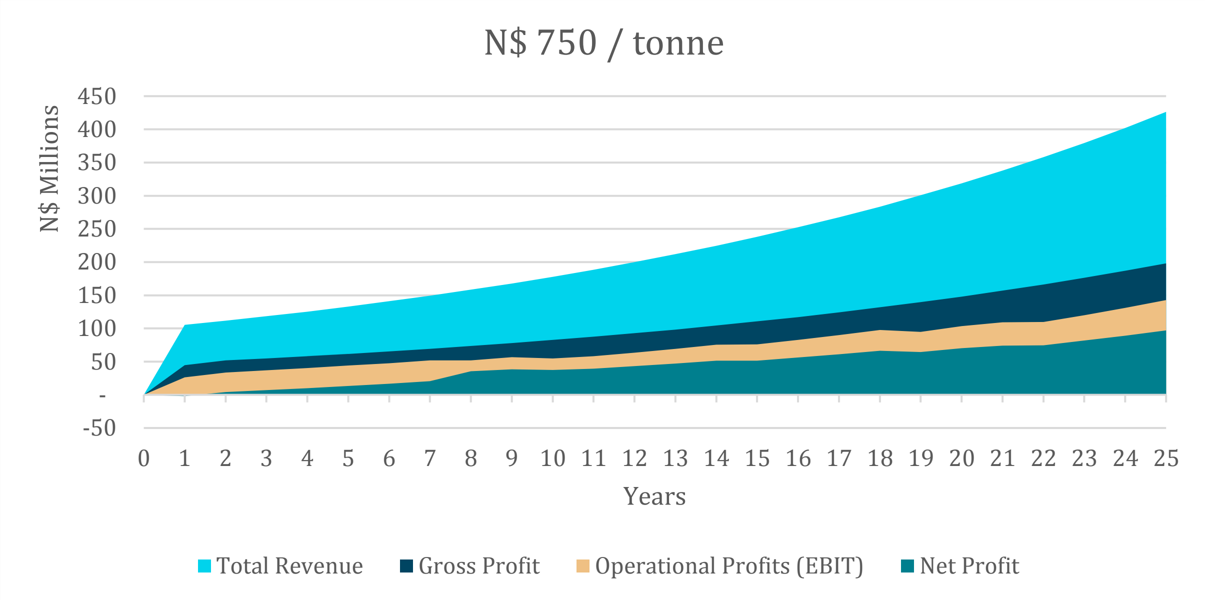

Figure 12: Income statement of a semi-mechanised harvesting operations at the N$750/tonne price point

Manual

The final method of harvesting considered was the fully manual method. This operation consists of manual felling, stacking and feeding actions. Only the chipping and in-field haulage operations would need to be mechanised. It was assumed that a team of manual harvesters would consist of ten persons and could produce 800 tonnes of biomass per annum. One of these production units is made up of the following equipment:

Harvesting Equipment	Units	Cost per unit (N$)	Useful Life
Hand Tools	1	5,000.00	1
20 hp chipper	1	250,000.00	9
Light weight off road trailers	2	40,000.00	9
Air hoist, compressor, I-beam and crawl	1	65,000.00	9
Haulage Tractor	1	120,000.00	9

Table 5: Capital Outlay of a manual harvesting unit

The diesel consumption for the above-mentioned machinery is expected to be approximately 16 litres per day. Ten people are required to man such a unit. The staffs required for this operation consists of a supervisor/chipper operator, four tree fellers, four stackers/ trimmers/ chipper feeders and tractor driver/chipper operators.

Staff	Number	Monthly Remuneration (N$)
Supervisor	1	7,000
Fellers	4	3,600
Stackers, trimmers, chipper feeders	4	2,000
Tractor driver	1	4,000

Table 6: Staff compliment of a manual harvesting unit

Based on 134 operational units and eight delivery vehicles (enough to supply and deliver the required biomass) the manual method yielded the following net profits for the three price points provided:

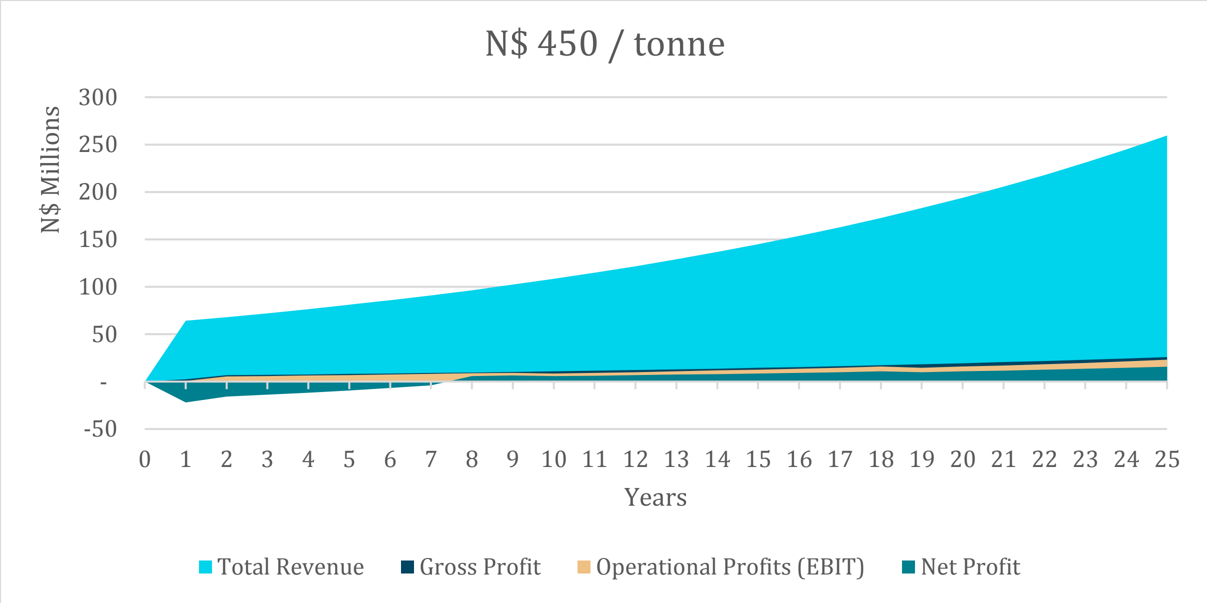

Figure 13: Income statement of a manual harvesting operations at the N$ 450/tonne price point

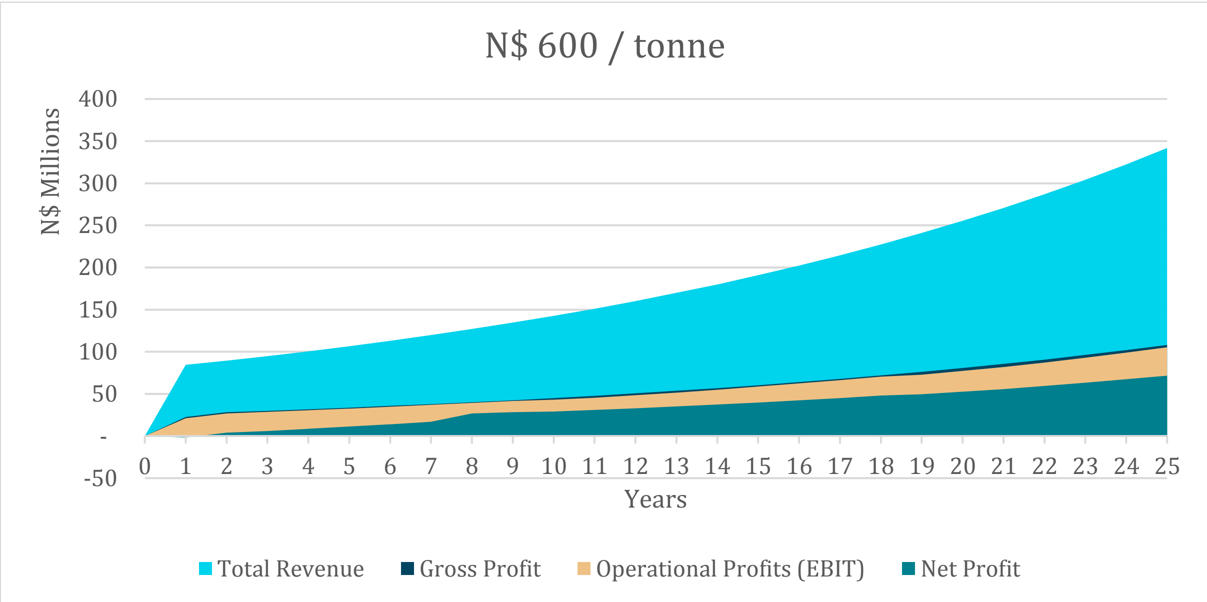

Figure 14: Income statement of a manual harvesting operations at the N$ 600/tonne price point

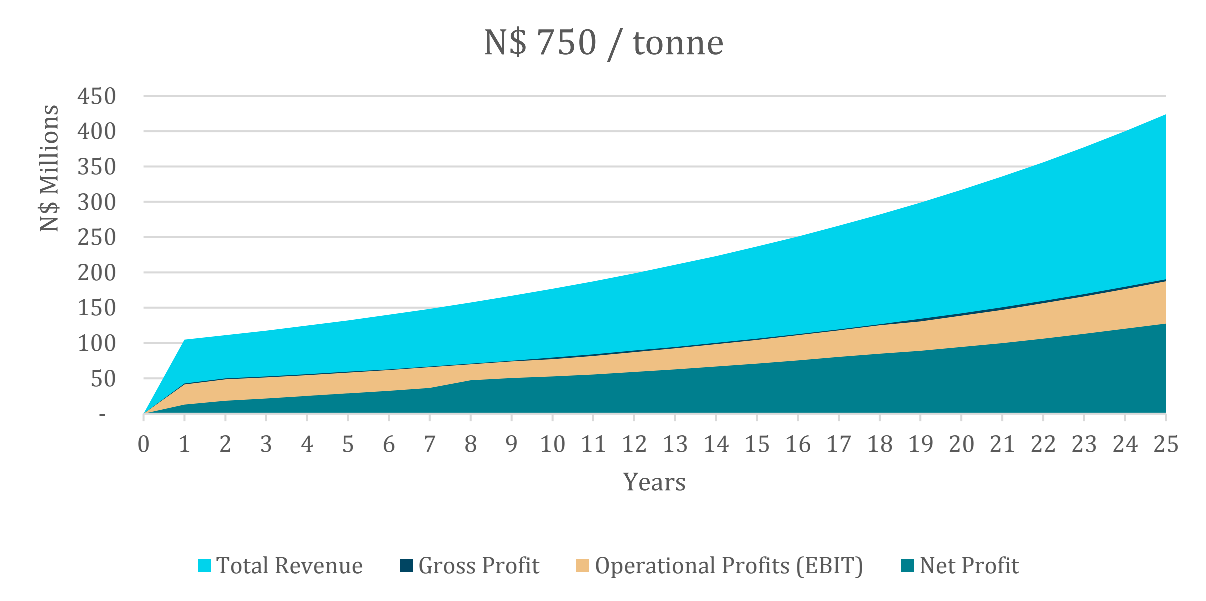

Figure 15: Income statement of a manual harvesting operations at the N$ 750/tonne price point

Transport

For each scenario it was assumed that the production unit is able to transport the biomass to the farm gate, where a dedicated delivery unit of eight delivery trucks will collect the biomass. Each truck is equipped with a trailer and hydraulic arm for pickup of the biomass at the farm gate and delivery to the power plant. In each of the broad scenarios it is assumed the costs are shared equally between units.

Return

Based on the initial scenario analysis of the three different harvesting methods and the three distinct price points, the following modified internal rates of returns (MIRR) are observed. It is assumed that excess cash flows can be reinvested at 7.75% (prime minus 3%) while shortfalls can be borrowed at 10.75%, (the current prime rate). Based on these assumptions the returns for the harvesters are as follows:

MIRR		Price point		
		N$ 450	**N$ 600**	**N$ 750**
Harvesting Method	**Fully Mechanised**	8.4%	12.1%	14.8%
	Semi Mechanised	0.2%	9.7%	12.7%
	Manual	2.1%	9.9%	12.9%
Power plant		6.3%	4.1%	0.2%

Table 7: MIRRs of different harvesting methods

To make a harvesting project commercially viable, the price received per tonne is a key factor. At the N$ 450 price point, the internal rates of return for the semi-mechanised and manual options are marginally positive, while the fully mechanised option earns a return of only 8.4%. At the higher price point of N$ 750, the two manual options earn returns in excess of 12% while the fully mechanised option delivers 14.8%.

It is possible that harvesters could become more efficient over time, and thus reduce their expenses. Reducing cash operating costs (which include labour, fuel expenses, administrative and insurance costs) would improve overall project/activity IRR. The sensitivity of MIRR to efficiency gains at the three price points is presented below:

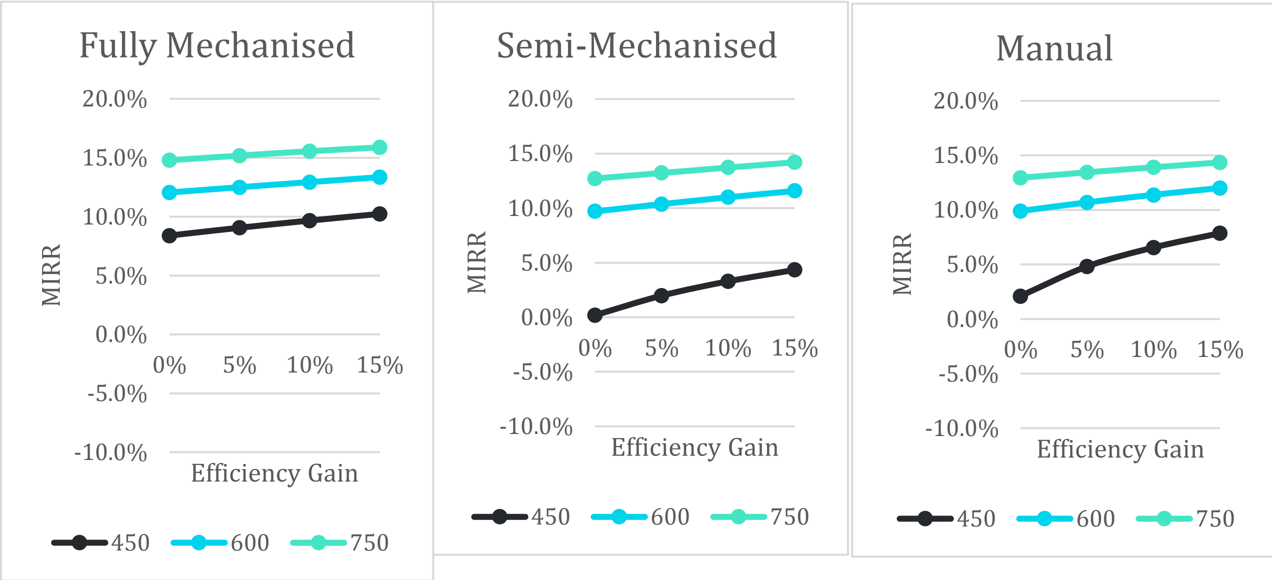

Figure 16: Sensitivity of harvesting MIRRs to input costs

Blended Supplier Scenarios

NamPower indicated that the ultimate supply mix that will materialise will be a combination of the aforementioned scenarios. Thus, the expected scenarios are further refined as follows:

1. Two fully mechanised harvesters producing 96,000 tonnes per annum combined (90% of the total annual feedstock requirement), with the remaining 10,500 tonnes (10%) being split equally between semi-mechanised and manual harvesting methods; *and*

2. One fully mechanised harvester producing 48,000 tonnes per annum (45% of the total annual feedstock requirement), with an additional 59,000 tonnes (55%) being split between semi-mechanised (29,400 tonnes per annum) and manual (29,600 tonnes per annum) harvesting methods.

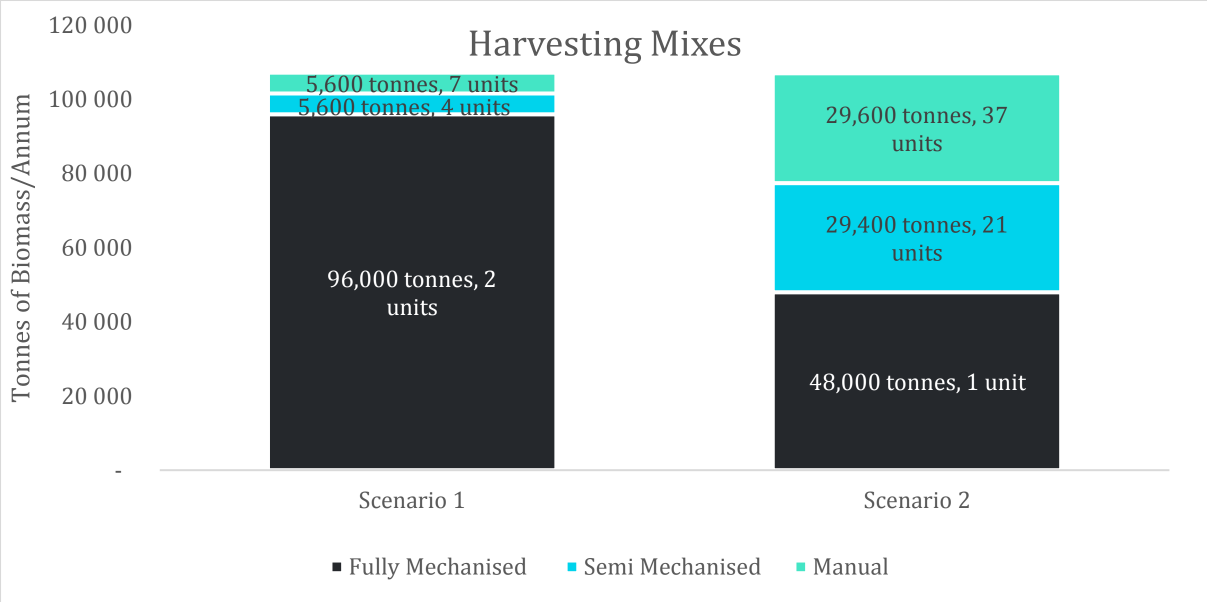

Figure 17: Harvesting mixes

The first scenario ("Scenario 1") represents a market in which large mechanised operators produce the majority of the chipped biomass, with the manual operators picking up the shortfall. This makes use of two of the mechanised units, four semi mechanised units and seven manual units. The second scenario ("Scenario 2") represents a more equal distribution of the production between the various harvesting methods. This scenario assumes one mechanised unit, 21 semi mechanised units and 37 manual units. The total number of people employed will be the product of the number of people employed per unit multiplied by the number of units used, and is detailed in the section concerning employment.

The weighted average modified internal rates of returns of these two scenarios are presented below and are calculated using the weightings as per the harvesting mixes presented above:

MIRR	Price point		
	N$ 450	**N$ 600**	**N$ 750**
Scenario 1	7.6%	11.8%	14.6%
Scenario 2	4.4%	10.8%	13.7%

Table 8: MIRRs of different harvesting mixes

The micro- and macro-economic impacts of the chosen supply mixes will be based on these two scenarios. Based on the aforementioned assumptions, we will quantify the direct and indirect benefits and costs of the project in annual monetary terms and per kWh produced.

Employment

Direct

The biomass power plant will directly employ up to 239 people during the construction phase of the project, and 62 people during the operational phase of the project. Of the 62 individuals, 35 will be operational/maintenance staff and the remaining 27 will be service staff. The majority are therefore skilled and semi-skilled workers. Skilled labour may be difficult to hire from the immediate surrounding areas, meaning engineers, chemists and technicians may have to be appointed from elsewhere in the country or abroad, while semi-skilled individuals such as administrative and accounting staff, machinery operators and weighbridge officers will likely be available in the surrounding towns.

Indirect

The majority of the employment that will be created in the country and the region as a result of the power plant will be indirect and induced employment, the former on the biomass supply chain side, and the latter as a result of increased local consumption of goods and services relating to the employment generated in the power plant and related value chain. The indirect employment, however, will largely depend on the supply-side scenarios mentioned above. The greater the mechanised component of production, the lower the employment creation.

The mix of labour and capital based on the two scenarios differ widely, as do the skills required for each category. The fully mechanised harvesting method requires more skilled and semi-skilled individuals to operate trucks and machinery, while the manual operations generally only have small chippers and tractors as machinery, which requires fewer semi-skilled operators. Making use of more mechanised harvesters, under Scenario 1, employs fewer people, but a greater proportion of semi-skilled people. The second scenario is assumed to employ more people but at lower wage levels due to lower skill requirements.

Number of people employed:

	Power plant	**Scenario 1**	**Scenario 2**
Skilled	15	4	2
Semi	22	53	79
Unskilled	25	99	522
TOTAL	**62**	**156**	**603**

Table 9: Labour requirements of power plant and harvesting scenarios

The manual and semi-mechanised categories of harvesters are based on the manual and semi-mechanised examples of harvesting units presented in GIZ's Harvesting of Encroacher Bush (2016) compendium of harvesting technologies, while the mechanised harvesting units are based on adjusted business models presented by N-BiG. Due to the fact that harvesting units are assumed not to be divisible, there is slight overcapacity in the two scenarios.

The estimated total wages for the two scenarios and the power plant are illustrated below.

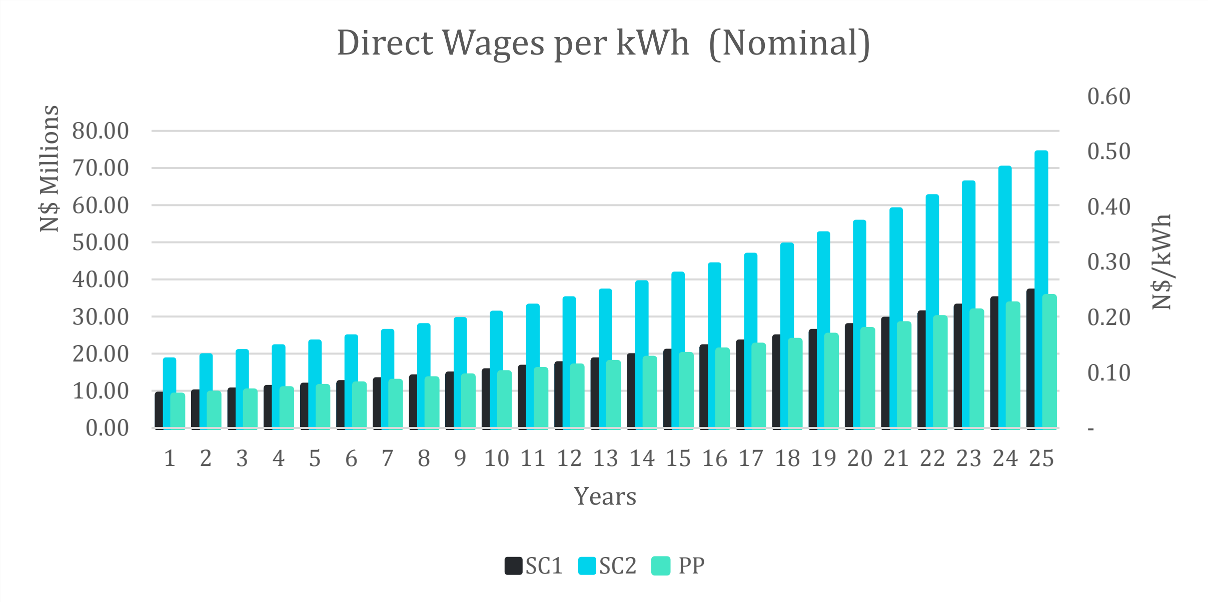

Figure 18: Direct wages to harvesters and power plant staff in nominal terms

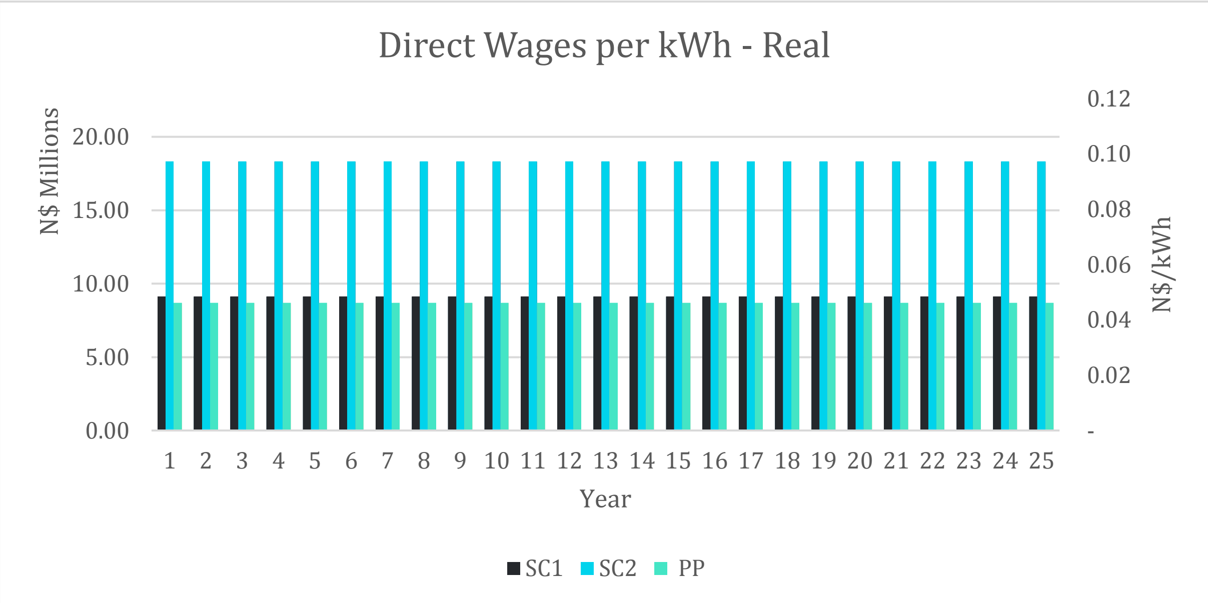

Figure 19: Direct wages to harvesters and power plant staff in real terms

Ample suitable labour is assumed to be available in both scenarios. According to the Namibia Statistics Agency (2017), unemployment in Namibia increased to 34% of the working population in 2016. Based on the 2011 Population and Housing Census data (NSA, 2012) there are 3,472 unemployed people (broad definition) in Tsumeb alone, of whom 2,245 were actively seeking employment. Overall, unskilled labour in the northern parts of Namibia is plentiful according to the same reports. The Omuthiyagwiipundi Constituency in Oshikoto Region is the sixth most employment-deprived constituency in the country and this partially falls within the 100 km radius of the proposed harvesting area for the biomass power plant.

Evidence from the charcoal industry (Dieckmann & Muduva, 2010) indicates that, in the process of bush thinning and producing charcoal, local farmers were capable of employing half of the available workers – depending on the number of kilns available and the size of the area to be harvested. This suggests that there are surplus workers available, particularly for manual harvesting. In 2010, it was estimated that the charcoal industry employed approximately 4,800 unskilled workers, implying that there is likely to be sufficient unskilled labour in the surrounding area for manual operations to take place. The history of mining, smelting and other industrial activity also suggests that there should also be suitable semi-skilled labour available in the region, if not the broader country.

Labour intensive harvesting concerns

Previous studies (such as Birch et al., 2016, and WSP, 2012) have raised concern around the desirability of having a large number of migrant workers moving through the area, as farmers have experienced challenges with regards to game poaching, crime and an increased spread of HIV. Some farmers have indicated that they prefer methods such as the use of aerial arboricides as opposed to manual bush control due to the abovementioned problems. However, first time treatment with aerial arboricides is highly expensive, environmentally unfriendly and due to its lack of selectiveness, illegal (SAIEA, 2015). As a result, it is expected that farmers will likely prefer to procure their bush control services from mechanised operators. The organisational structure of using a large number of labourers will also have to be considered. In our modelling the chipper operator also acts in a supervisory role, however, a more suitable supervisory hierarchy may be needed.

Anecdotal evidence, supported by Trede and Patt (2015), further suggests that the labour-intensive unskilled harvesting, while potentially lucrative for labourers, is challenging and physically demanding work. As such, employee turnover may be high, putting security of supply at risk, while also increasing administration costs.

Local and Cluster development

Development and value addition activities, inclusive of indirect and induced impacts, will be focused in and around the Tsumeb area. This is due to the power plant being situated just 6 km from the town, with the operational staff assumed to be living in Tsumeb. Similarly, the harvesting operations are expected to occur in close proximity to the power plant, moving outwards over time.

The employment impact will see relatively more low-wage earners, who are more likely to consume locally-produced goods. Increased employment across all skill levels will see retailers, as well other goods and service providers, in Tsumeb benefitting.

Running on the assumption that harvested land will be used for livestock farming, the increased livestock carrying capacity of land will result in greater demand for agricultural inputs, such as animal feeds, nutritional supplements, and livestock medications and inoculations. Greater livestock numbers will also see a marginal increase in employment for farmworkers. Downstream activities will also benefit, with increased livestock production providing more opportunities for meat processing. This could see the expansion of capacity at existing abattoirs in order to manage the new output levels, thereby creating some additional employment as well.

In terms of industrial spin-off effects, increased harvesting in the area will lead to increased local support services. These would likely be in the form of increased equipment repair and maintenance services for smaller harvesting tools such as chainsaws and trolley saws. In a similar fashion the successful rollout of mechanised harvesting technologies will allow replication in other encroached areas. Should this be the case, greater demand for parts and repair for mechanised harvesters will spur the development of these specific support services, likely to be centralised close to the majority of operations.

As this project is the first of this nature and scope, significant benefits will be the spin-off in knowledge, business opportunities and transfer of skills generated. Seeing as the area already being utilised for charcoal production, the opportunity for knowledge sharing is quite high. Workers with experience in the harvesting industry will be able to drive efficiencies and increase productivity, especially using the manual and semi-mechanised methods of harvesting.

Microeconomic Impact on Agricultural Sector, Ecosystem and Environment

Agricultural Sector

Livestock farming is one of the primary land uses in the harvesting area. As a result, it is an existing source of employment and income generation in the area and region. Agricultural land in the proposed harvesting area that has been bush thinned will most likely be used for livestock farming, as land for crop farming needs to be cleared in its entirety. The primary benefits derived by the agriculture sector will therefore come from increased livestock farming, as it is the most likely use of the bush thinned land. As such, it is taken that the majority of upstream benefits will come from an increase in livestock carrying capacity as a result of bush control, ultimately manifesting in increased beef production.

Several steps (outlined below) were taken to determine the benefit to agriculture, particularly livestock farming, from bush thinning. The annual hectares thinned (attributable to this project) were estimated based on the annual demand in tonnes for the power plant (106,500 tonnes) and the average yield per hectare (12.65 tonnes/ha). This amounts to annual thinning of 8,419 hectares. Over the full 25-year period, this totals 210,474 hectares of bush thinned land.

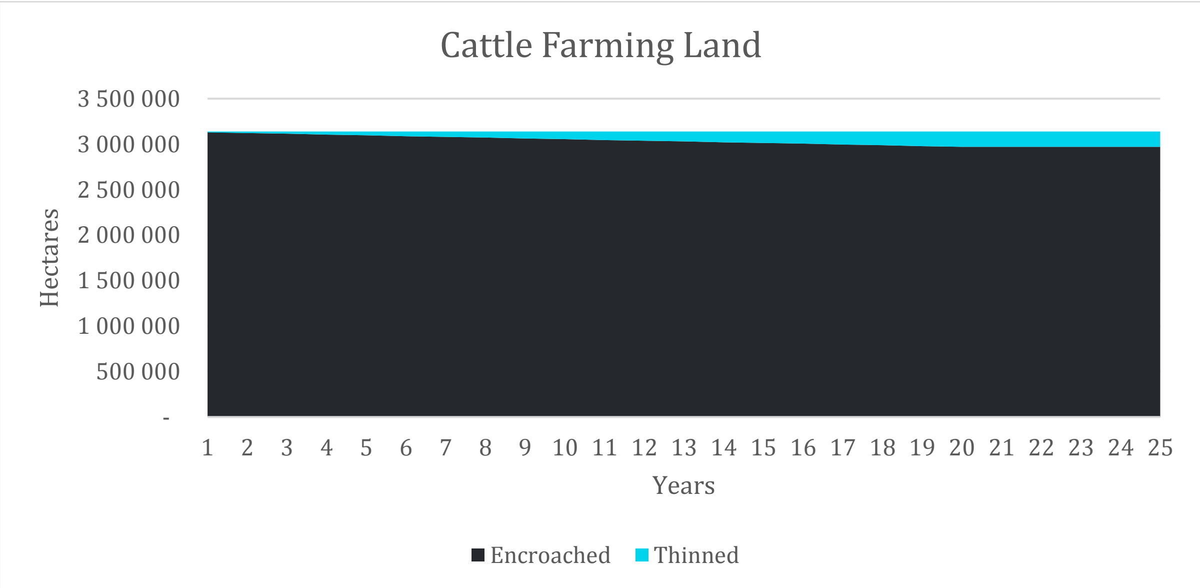

Figure 20: Cattle farming land

Based on consultations with farmers in the area, an initial carrying of 17 hectares per livestock unit is used. Using this carrying capacity, the current heard size within the proposed harvesting area is estimated at about 185,000 heads of cattle, and is used as the 'business-as-usual' case. The formal literature on the subject (Birch and Middleton, 2017) indicates that once land has been bush thinned, carrying capacity will increase by a minimum of 100% after a period of four years. However, based on NamPower's consultation with farmers, it was suggested that this increase is very optimistic for the Tsumeb area. As such, it was suggested that an increase of 70% (i.e. from 17 to 10 hectares per head of cattle) is more realistic, and so is used as the base case in the model. The delay in reaching the increased carrying capacity is split over the preceding years in the project model. Full utilization of current carrying capacity is implicitly assumed. It is assumed that farmers are charged N$300/ha[10] by harvesters for the thinning of bush, and it is furthermore assumed, based on the expert judgement of N-BiG that the bush thinned land is subject to aftercare (at N$200/ha every three years), with

[10] See footnote 1

regrowth only occurring in year 20. While the aftercare regime should prevent any regrowth from occurring, the model incorporates regrowth from year 20 as a precaution. This is however, an expensive activity and as a result not all farmers will be in a financial position to be able to pay the upfront and recurring costs. As a result, some farmers may only clear small portions of their land at a time to ensure affordability.

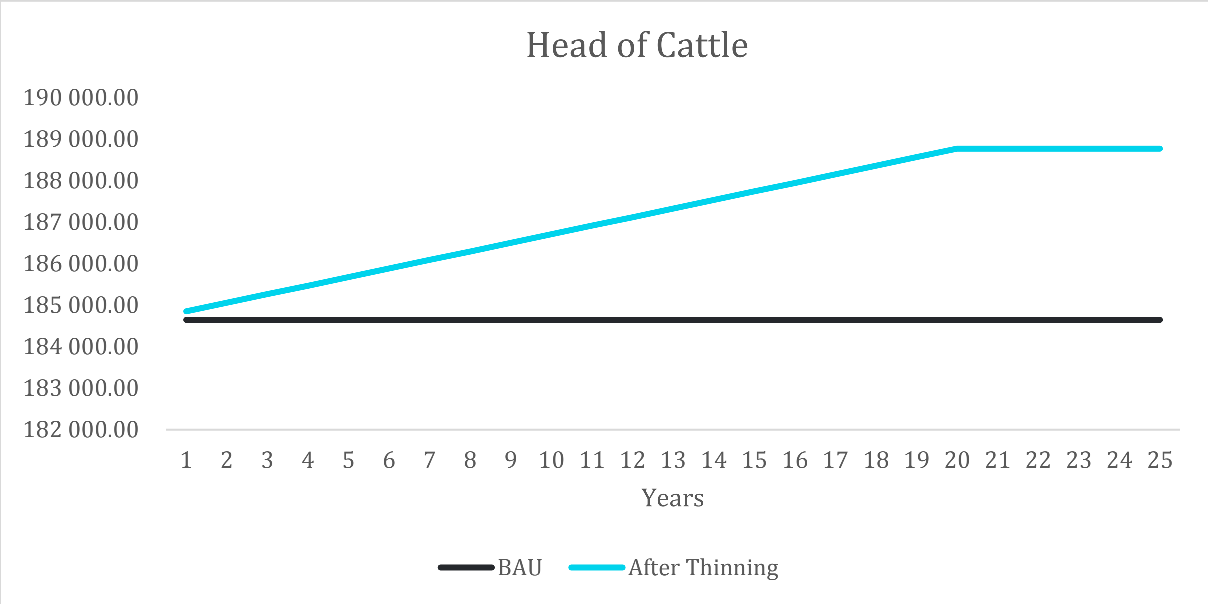

Figure 21: Head of cattle

With 8,419 hectares being bush thinned annually, as well as the carrying capacity of bush thinned land increasing by 70% over four years, the increase in livestock numbers attributable to the bush control practices amounts to additional carrying capacity of 6,933 cattle over the 25-year period, assuming regrowth commences in year 20, despite on-going aftercare.

Livestock farmers will earn revenue through the increased carrying capacity, as greater volumes of cattle can be expected to be marketed. It is assumed that marketing will only begin in year 4, allowing for stock levels to rise and young animals to reach maturity. It is assumed that farmers will not market all of the new livestock, but that 60% will be marketed, with the majority of the remainder being retained as breeding stock. Of the additional cattle available for marketing, trends within the market suggest that 75% of these are to be exported (either live or through export butcheries), boosting foreign exchange earnings (detailed in the macroeconomic section of this report).

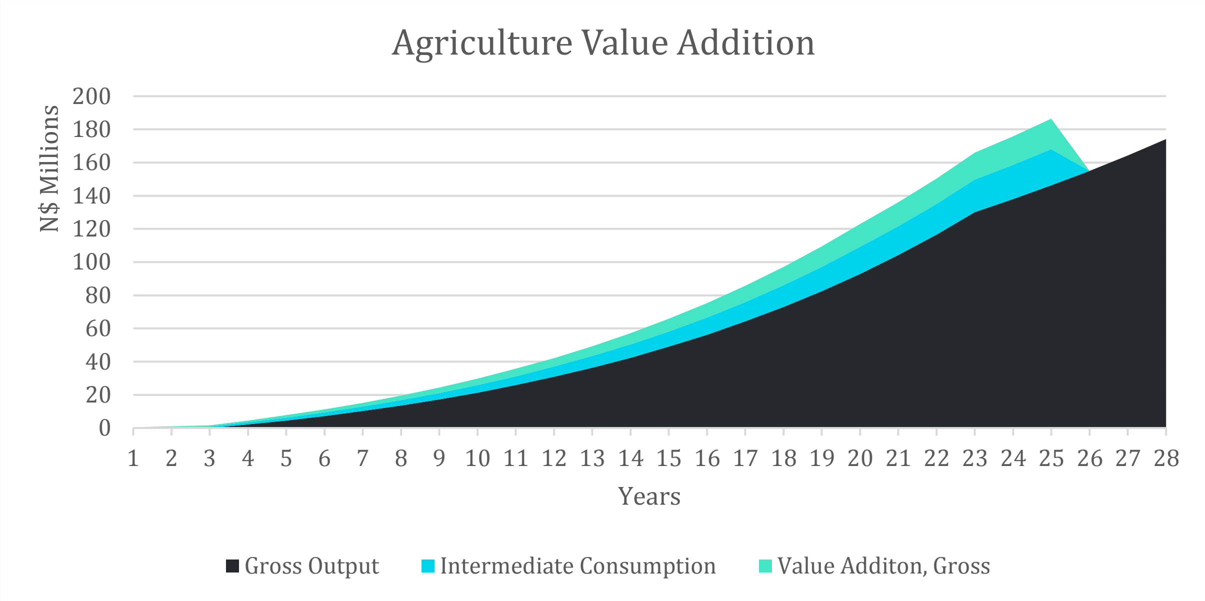

Figure 22: Net agricultural value generated

The revenue for farmers, attributable to the cattle marketed, was calculated by using the 2017 average beef producer price of N$35/kg (inflated at 6% p.a.), a conversion factor of 250kg per head of cattle, and the number of additional cattle from the bush thinned land and increased carrying capacity.

The initial benefit generated in N$/kWh terms is negative, as input costs are greater than output during the harvesting and re-stocking period. However, from year seven onward, sales from the increased carrying capacity start to outstrip costs, and the aggregate profits of farmers whose land has been bush thinned expands over the project lifespan.

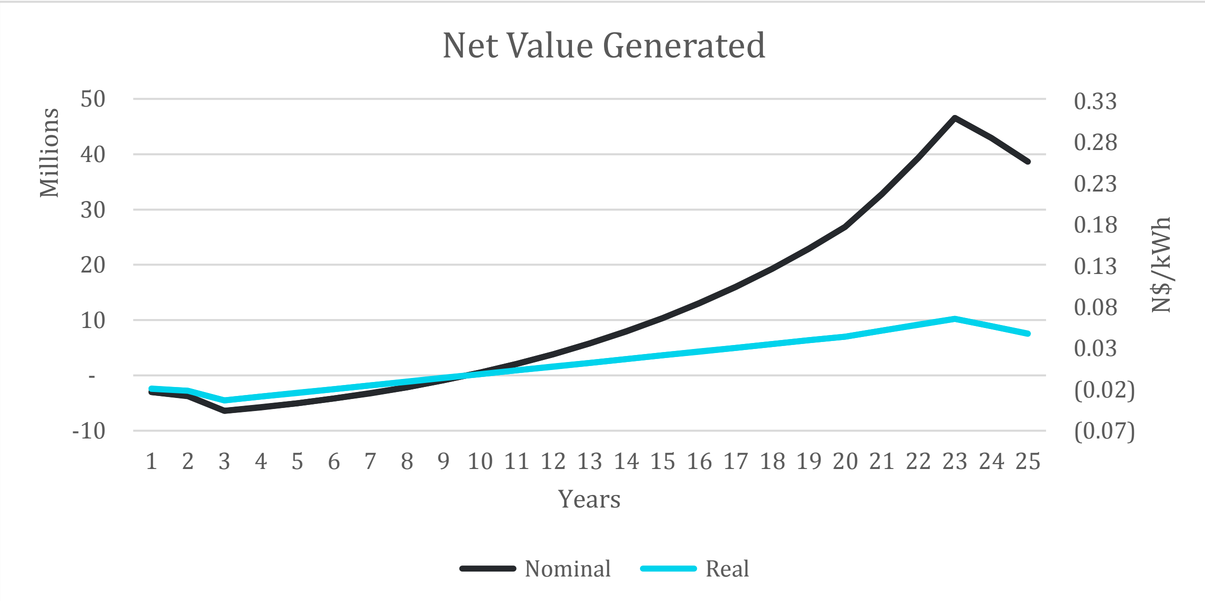

Figure 23: Net agricultural value generated

On a net basis, the benefit in year one amounts to a loss of N$ 3 million, as the marginal additional value of the cattle on bush thinned land does not offset the costs of harvesting and aftercare, as well as the input costs for the increased number of livestock. However, over time, the carrying capacity of the land increases, so does the additional value to farmers. Thus, by year ten, farmers are expected to see a net benefit of approximately N$ 2.1 million. The total net benefit to famers over the 25 years, once discounted (at 6% p.a.) is N$ 62 million. This value accounts for the cost to farmers for bush control and aftercare, under the assumption that farmers pay N$ 300/ha and N$ 200/ha for these services, respectively[11].

The average direct value addition from livestock per kWh over the 25-year lifespan of the power plant, in 2018 terms, is N$ 0.02/kWh, which accrues to farmers. The further benefits are to the upstream and downstream activities, such as input industries for farming (cattle feed, veterinarians) and downstream activities (such as abattoirs), increased exports, and additional workers hired as a result of larger herd sizes.

Harvesting Scenarios Impact on Value Addition

The two harvesting scenarios achieve different direct contributions, in real terms, to local value addition, with the first scenario displaying a NPV of N$ 0.15/kWh, compared to a N$ 0.11/kWh NPV for Scenario 2.

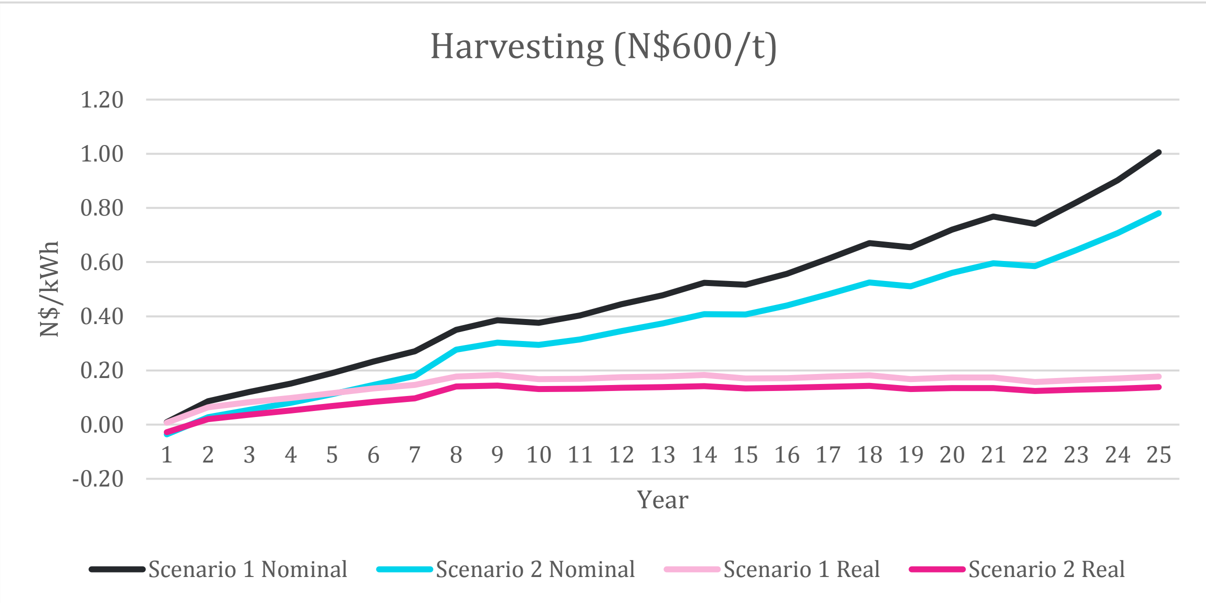

Figure 24: Net harvesting value generated

Harvesting Value Added (N$ 600/tonne)	NPV (N$/kWh)
Scenario 1	0.15
Scenario 2	0.11

Table 10: Harvesting value added per kWh

[11] See footnote 1

Ecosystem Services

Bush encroachment impacts a range of ecosystem services. A review in Birch *et al*. (2016), taking into account the Common International Classification of Ecosystem Services (CICES) classification, recognised three categories of services: provisioning, regulation and maintenance, and cultural. The point is made that for many of the services "there is little data or research on how they might be impacted by de-bushing". Below is a summary of the services which are expected to be highly impacted by a harvesting programme:

Category	Ecosystem Service Class	Example	Estimated direction of impact from bush control
Provisioning	Reared animals and their outputs	Beef production	positive
	Groundwater for drinking and non-drinking uses	Drinking water, non-drinking water	positive
	Plant-based resources	Charcoal and firewood production, electricity generation	positive
	Wild animals and their outputs	Game meat, skins	mixed
	Fibres and other materials for direct use processing	Materials for construction	positive
	Materials for agricultural use	Animal feed supplement	mixed
Regulation & Maintenance	Global climate regulation by reduction of greenhouse gas concentrations	Carbon sequestration	negative
	Mass stabilisation and control of erosion rates	Control of soil erosion	positive
	Hydrological cycle and water flow maintenance	Groundwater recharge	positive
	Maintaining nursery populations and habitats	Habitats for species	mixed
	Weathering Processes	Restoration of soils	positive
	Decomposition and fixing processes	Nitrogen fixing and nutrient replenishment	mixed
Cultural	Experiential use of plants, animals and landscapes	Wildlife viewing	positive
Cultural	Physical use	Trophy hunting	positive

Adapted from Birch *et al*. (2016)

Table 11: Environmental impacts of bush control

For the purposes of this project, valuations are undertaken for beef production (see previous section), groundwater recharge (see next section), and climate regulation, via greenhouse gas emissions. Tourism is also discussed, although only a transfer valuation is estimated. Other areas are harder to assess, and also less relevant in some cases given that the biomass is allocated for a single use i.e. electricity generation. However, there are potential spin-off effects from the establishment of major bush thinning and offtake programmes, that could help accelerate the development of other services listed above.

Groundwater

The objective to increase groundwater resources is one of the main motivations behind bush control. Bush-encroached land places more demand on these resources than bush thinned land, due to a higher rate of evapotranspiration (Christian *et al*., 2010). Previous studies (Birch *et al*., 2016; Birch and Middleton, 2017) by the NNF found that the evidence was limited on groundwater recharge rates both for bush-encroached and bush thinned land. Therefore, they adopted an average recharge rate of 1% of rainfall across the country (Christelis and Struckmeier 2011) as the baseline for bush-encroached land. Studies on the impact of bush control suggested increases to between 4-8%, however a conservative estimate of 2% was applied. A more recently completed 9-year controlled study in Okahandja (Groengroeft *et al*. in press) suggests that recharge rates for both bush-encroached (15%) and bush thinned (42%) land are much higher, however we retain the NNF assumptions for this analysis, and note the likely bias to underestimate the level of groundwater resource improvement. It must be noted that the use of herbicides on agricultural land will have a negative impact on the quality of available groundwater resources, as herbicides biodegrade over a prolonged period (with a half-life of anywhere between 2-15 months for commonly used arboricides such as Bromacil or Tebuthiuron) and could leak into groundwater, thereby causing contamination.

Also noted from the NNF studies were two different approaches to valuation, in respect of the extent of increased stocks that could be valued. In the national study (Birch *et al*., 2016), the total increase in stocks were valued, whereas in the regional study (Birch and Middleton, 2017), only the increase in stocks that could be extracted by existing infrastructure were valued. The latter approach is more realistic as it implicitly assumes non-negligible investment costs to realise the value of increased groundwater stocks. It is therefore also more conservative. In place of current information regarding the existing water extraction infrastructure in the project region, we apply an accessibility ratio derived from the NNF regional study, of 10%.

The total direct groundwater increase from bush control can be calculated using the area bush thinned (8,419 hectares/annum), and the average rainfall for the region (550 mm/annum), based on climate data from Grootfontein (Petrick and Katali, 2018). Assuming no bush regrowth, and applying the accessibility ratio, the increase in extractable groundwater stocks would be 879 783 m^3 per annum after 25 years, or 13.6 million m^3 in total over the time period. Before placing a value on these stock increases, there are various offsetting factors to consider.

A co-objective of bush control is to improve the carrying capacity of land, in particular with regard to cattle. For this analysis, it is assumed that all harvesting takes place on cattle farms, and that the improved carrying capacity would be utilised. This results in an increasing number of cattle, as detailed previously, and a consequent increase in demand for water by cattle. Figures provided by NamPower indicate a value of 9.13 m^3 of groundwater consumed per head of cattle per annum. This results in additional water consumption over the period of 981 155 m^3.

The biomass power plant would also use water in the production of steam to drive the turbine. The amount required has been estimated as 5 m^3 per hour, which assuming 85% capacity equates to 37,230 m^3 per annum, and 930,750 m^3 over the period.

A large potential offset comes from bush regrowth. This can be avoided by the deployment of an aftercare regime. The assumptions for this study are that such a regime is followed until the 20th year, ensuring zero regrowth over this time, after which bush regrowth occurs to the extent that it offsets the impact of harvesting i.e. there is no net increase in bush thinned land during the last five years. Regrowth therefore reduces extractable groundwater stocks by 833,000 m^3 over the period.

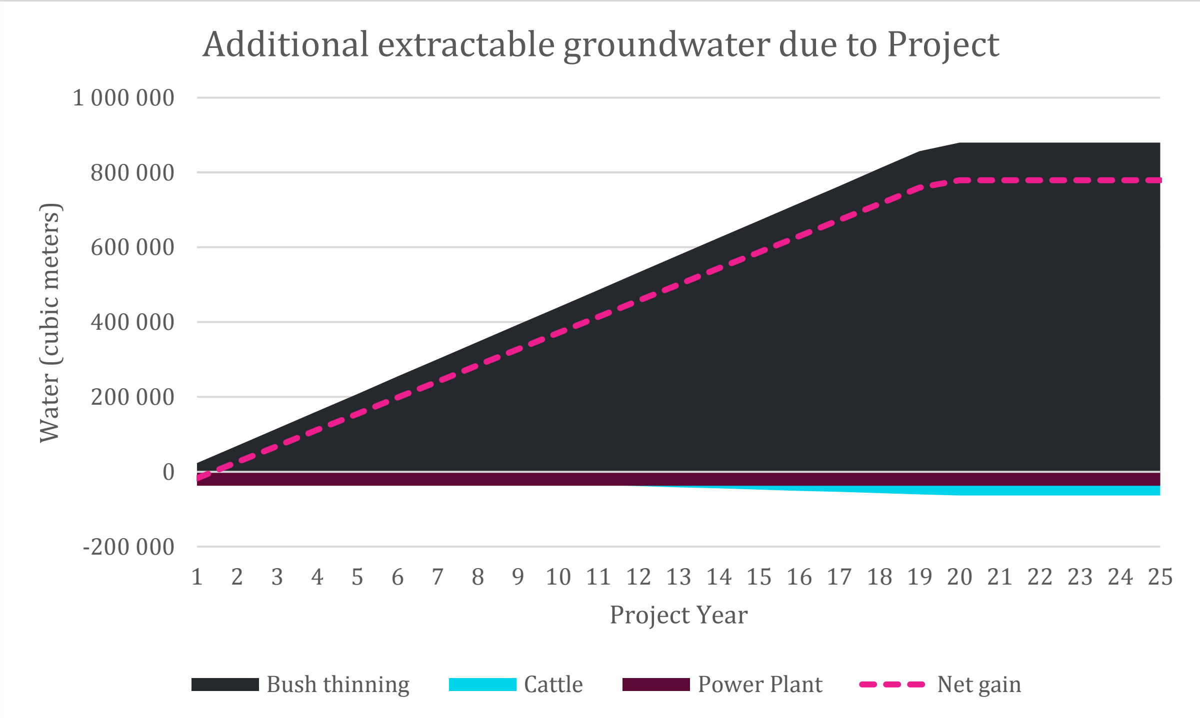

Figure 25: Additional extractable groundwater

Net of all offsets, extractable groundwater stocks are projected to increase by 11.7 million m^3 over the 25-year period. In order to value these stocks, we observe that the NNF studies took an avoided cost approach, obtaining an implied price for water from the Kalkfeld supply project, of N$ 14.7 million per million m^3 of water, at 2015 prices. Assuming 6% inflation to the start of the operational period in 2022, and valuing cash flows in real terms from then on, results in a net valuation of N$ 244 million (N$ 0.07/kWh) for the increase in extractable groundwater stocks.

Applying individual shifts to key variables gives an indication of the model sensitivity. As previously mentioned, conservative assumptions have been applied in respect of the recharge rate, and accessibility ratio. Their equivalence is shown for shifts which would effectively double or half the amount of groundwater to be valued. An increase in the recharge rate could easily be justified by evidence from recent studies. Increasing the accessibility ratio, assuming a fixed water supply infrastructure, would be equivalent to applying a non-zero valuation to the remaining groundwater stocks, and could also be justified on this basis.

Sensitivity Analysis for groundwater recharge			
Base Case		244,486,673	0.07
Variable	**Shift**	**NPV (N$)**	**N$/kWh**
Rainfall (550 mm/year)	-20%	187,615,840	0.050
	+20%	301,357,507	0.081

Water Price (N$ 14.7)	-20%	195,589,339	0.053
	+20%	293,384,008	0.079
Aftercare Rate (100%)	75%	162,665,499	0.044
	50%	105,503,975	0.029
Accessibility (10%)	5%	65,773,618	0.018
	20%	601,912,783	0.162
Bushed Thinned Land Recharge Rate (2%)	1.5%	102,309,589	0.027
	3%	528,840,840	0.142

Table 12: Sensitivity Analysis for groundwater recharge

Tourism

The tourism industry is an increasingly important sector in Namibia's economy. It is based on a rich resource of landscapes and wildlife, both of which can be impacted by bush encroachment. For those with aesthetic objectives, dense bush can make it difficult to see animals, and changes the nature of the landscape. Other tourists with consumptive objectives may find reduced success, when hunting for example. There is a lack of research on quantifying the impacts of bush encroachment on tourism. The NNF regional study (Birch and Middleton, 2017) made a preliminary attempt, a summary of which follows.

The study considered both non-consumptive (wildlife viewing) and consumptive (trophy hunting and game products) aspects of tourism in Otjozondjupa. Revenues from wildlife viewing were hard to isolate, with only anecdotal evidence available to suggest increased tourist satisfaction, and willingness to pay higher prices for viewing animals on bush thinned land. An estimate was made that an additional N$ 19.9 per hectare of revenue could be due to bush control. Based on 9,150 hectares per annum of private game farms being bush thinned, as per the NNF study, this resulted in a net discounted benefit of N$ 22.7 million over 25 years. Increased costs were not estimated, but were expected to increase in line with the expectation of more visitors.

Trophy hunting and game products provide larger baseline amounts of revenue to conservancies and private game farms. The perception within conservancies was that bush encroachment did not have a significant impact on hunting or game stocks, therefore the analysis focused on private farms. Assuming a 50% carrying capacity increase (from a 30-80% evidential range) due to bush thinning, an attempt to model the sustainable stock increase was made. Based on 1.25 million hectares of existing farms, additional revenue of N$ 135.2 million per annum was estimated. Adding new farms, based on a 10% capacity expansion, led to an estimated N$ 33 million per annum, for a total discounted benefit of N$ 1.1 billion over 25 years. Such a benefit requires significant investment to realize, and the associated costs were estimated at N$ 882 million, for a net benefit of N$ 202 million.

The study area assumed a bush thinning rate of 316,000 hectares per annum, with a weighted density reduction of 38.5%, so effectively 121,500 hectares per annum of bushed thinned land. This is ~15 x the area to be bushed thinned per annum in this project, so a naive calculation, assuming all conditions are equivalent, suggests potential tourism benefits in the project region of N$ 15 million (N$ 0.004/kWh) over the 25-year period. Given the assumed utilization of all harvested land for cattle farming elsewhere in this analysis, this figure should only be considered for comparison, rather than as an addition to the value of the project.

Environmental Impact

The environmental impact of the project is to be analysed in various impact assessments over the coming months. Therefore, a complete microeconomic assessment is not possible at this stage, however some baselines and key considerations are briefly outlined, which may give rise to arguments for further costs and/or benefits to be evaluated. Greenhouse gas emissions are evaluated in the subsequent section.

The following sections are based on the Draft EIA Scoping Report (Petrick and Katali, 2017), commissioned for the project.

Biodiversity

The harvesting area has high levels of plant endemism, and high diversity levels for plants, birds, amphibians and mammals. Five identified bird species are on the Red Data list, and two are Globally Threatened. In total, eight bird species are regarded as being at potential risk from the project development, with breeding birds deemed especially vulnerable. Assessments of the potential for disturbance or destruction could form the basis for existence value calculations. The area is suitable as a Black Rhino habitat, although for security reasons, no numbers are available. Regardless, the economic impact of any disturbance, or increase in poaching, both in terms of existence value and tourism impact, could be significant. Potential improvements in biodiversity from bush thinning, and rangeland improvement are explicitly valued in the groundwater and agriculture sections.

Water

Contamination potential exists for both surface and groundwater from hydrocarbons at plant and from transport, chemicals spillages, ash, and water treatment activities. Any such occurrence would have direct and indirect economic impacts. Run-off is likely to increase to farms, dams, rivers, which is positive in a Namibian context, but could also increase erosion impacts on steeper ground. The positive impacts likely due to recharge rate increase are evaluated in the previous section.

Air quality and third-party health

Baseline pollution sources in the region include: Namibia Custom Smelter (in Tsumeb), cattle farming, crop farming, and dust from unpaved roads. Potential exists for early morning pollution impacts at Tsumeb from night-time westerly winds. Evaluation should be made as to whether any increases in pollution from the power plant cause acceptable pollution levels to be breached.

Noise

Baseline noise levels were measured at two farms, both within 2 km of the proposed site, and deemed to be relatively high due to traffic and farm noise. Levels are likely to increase from plant and harvesting activities, but with limited impacts on the local population.

Visual

The project site area is covered in medium to tall bush, and there are mining and quarrying activities in the surrounding area. The visual value has been assessed as moderate. No residential or tourist sites occur within the study area, so the aesthetic impact of the plant is likely to be minimal, although harvesting and transport activity may be more exposed.

Traffic

The site is situated adjacent to the Trans-Kunene Highway Corridor, and would require some geometric upgrades. The increased traffic, particularly large, bulky vehicles will likely cause safety issues. Road surface conditions are likely to be impacted from the heavy vehicle flow transporting woodchips. These factors add up to some potentially significant economic impacts that will need to be addressed.

Greenhouse Gas Emissions

Burning biomass to produce electricity, impacts greenhouse gas emissions in several ways, with varying degrees of clarity. Different accounting procedures for these emissions can fundamentally change the outcome, so we set out our assumptions with regard to the most important aspect first. On burning, the carbon that was stored in the woody biomass over the growth period is released as carbon dioxide. At that point in time the emissions factor per unit of energy can be similar to that of coal, and perhaps even larger due to higher water content. However established procedure, adopted for instance by the EU Renewables Directive 2009, assumes that the carbon dioxide emitted will be compensated by that captured during plant regrowth (EC, 2016). As mentioned in WSP (2012), "The carbon dioxide released during this process is termed biogenic carbon, and as it forms part of the short carbon cycle, is not considered to have a significant impact on long term carbon stocks". This can be controversial when considering biomass derived from forests with long growth cycles. However, given that encroacher bush is typically fast growing, particularly in the case of Sickle Bush, which dominates in the project area, this approach can be justified. It should also be recognised that the amount of biomass required for this project will likely not prevent net growth in stocks of encroacher bush nationally, or even regionally, and the sequestration capacity that this entails. With this net zero emissions assumption from biogenic carbon, the focus therefore is on emissions from the supply chain and land use change.

Supply chain emissions include harvesting, transport and conversion processes. Emission factors measured in Tonnes of Carbon Dioxide equivalent (TCO_2e) per megawatt hour (MWh) were estimated for a project of this type in WSP (2012).

GHG emissions ($kgCO_2e$) per kWh of electricity generated		
Harvesting	9	17
Infield Transport	1	
Handling	2	
Road Transport	5	
Conversion	15	15

WSP (2012)

Table 13: GHG emissions ($kgCO_2e$) per kWh of electricity generated

Using data provided for the project, the fuel expended for transport is in line with these estimates, however for harvesting, the partial use of mechanised methods will incur an emissions factor, 1.5-2 times higher than those estimated. For conversion, which essentially is power used to run the plant, we adopt the estimate provided. These factors produce supply chain emissions of ~130,000 TCO_2e over the 25-year period.

Land-use change can be considered in two ways. The first concerns soil organic carbon, and the impact of transitioning from encroacher bush to savannah. To date, studies have rather focused on the transition from savannah to encroacher bush, as this the typical direction of change. We are therefore limited to adopting the assumption that taking the negative value of observed effects is a valid approach. A paper by Blaser *et al*. (2014) found a range of results from 15 studies across 21 locations, mostly in the US, with a mean value of 21 gC/m^2 for the impact of transition to encroacher bush, although with a wide range between -80 gC/m^2 and 239 gC/m^2. The authors also conducted their own study on Sickle Bush encroached areas in Zambia and found a range of 12-16 gC/m^2. This is the same species type as present in most of the project area, so it gives some reassurance that adopting the mean study value has some validity. Namibia has very low levels of soil organic carbon, so the NNF studies made the assumption that "the capacity of the soil to sequester carbon is only reduced in the first year of de-bushing, rather than annually". Applying the negative sequestration figure to annual bush thinning volumes, net of regrowth, results in ~123,000 TCO_2e over the 25-year period.

The second consideration for land-use change is the impact of improved carrying capacity and the utilisation of it by increasing numbers of cattle. The effects can be significant given that cattle emit methane, which has a GHG potential ~30 x greater than CO_2. Following the sources included in the NNF studies, provides an estimate of emissions per additional head of cattle per annum:

Estimate of CO_2e emissions / Head / Annum from additional livestock	
Average liveweight (kg)	297
Emissions per kg liveweight ($kgCO_2e$)	11.93
Additional emissions ($kgCO_2e$) per Head	3543.21

NNF (2015)

Table 14: Estimate of CO_2e emissions / Head / Annum from additional livestock

Applying this figure to the cumulative increase in cattle as modelled for this project, results in additional emissions of ~380,000 TCO_2e over the 25-year period.

Alternative land use scenarios could be considered, for example switching to a mixed model with game and tourism, as well as cattle farming. This would likely be much less directly emissions intensive, however the secondary effects of increased tourism, with associated air miles, could offset or outweigh, on a macro scale, the reduced emissions from cattle.

To summarise the supply chain and land-use change emissions, we have the following:

Activity	**$kgCO_2e$ over 25 Years**	**$kgCO_2e$ / kWh**
Harvesting*	69,160 (1) / 55,083 (2)	19 (1) / 15 (2)
Transport	12,529	3
Conversion	55,845	15
Soil Carbon	123,330	33
Livestock	380,771	102
Total	**641,635 (1) / 627,558 (2)**	**172 (1) / 168 (2)**

*1 & 2 relate to the different harvesting scenarios

Table 15: Supply chain and land-use change emissions

One of the motivations behind the project is for Namibia to become more self-sufficient in electricity. Current domestic generation satisfies less than half of demand, with the remainder being imported from neighbouring countries, predominantly South Africa. Namibia produces electricity with a very low emission factor of around 50 $kgCO_2e$/kWh, due to the large proportion coming from the Ruacana hydroelectric plant. However, on a grid-level basis, including imports, the emission factor is around 10 times higher, due to the reliance of South Africa on coal powered generation. WSP's Prefeasibility Study (WSP, 2012), used the grid level factor of 489.8 $kgCO_2e$/kWh. Analysis of current energy sources as stated in the NamPower 2017 Annual Report (NamPower, 2017) suggests a figure of around 500 $kgCO_2e$ is still relevant today. Applied to the project parameters, this result in 1.82 million TCO_2e of displaced emissions, which would more than offset the emissions generated by the project, for a net value of -1.2 million TCO_2e emitted. Furthermore, a reasonable case can be made that any new generation capacity would be expected to specifically displace imported power. A UNFCCC (2013) baseline study for projects within the Southern Africa Power Pool (SAPP) acknowledges this approach, and establishes a grid emission factor of 964.4 $kgCO_2e/kWh$, for any new generation capacity to be measured against. Recalculating with this factor gives displaced emissions of 3.59 million TCO_2e over the 25-year period, and a net saving of 2.96 million TCO_2e:

	$kgCO_2e$ over 25 Years			
Grid Emission Factor	**Emitted***	**Displaced**	**Project Net**	**Per kWh**
Namibian Grid = 489.8 (WSP)	634,596,318	-1,823,525,400	-1,188,929,082	-319.3
SAPP = 964.4 (UNFCCC)		-3,590,461,200	-2,955,864,882	-794.4

*This is an average of the two scenarios considered, which are variable by only 0.78%

Table 16: Kilograms of carbon dioxide emissions over 25 years

A note of caution with regard to applying the SAPP grid emission factor over the whole period is that it largely assumes South Africa will remain almost entirely dependent on coal power generation over the next 25 years. It is more likely that renewables will increasingly come online, leading to a decline in the factor over time. It is therefore prudent to use the Namibian Grid factor, although this will decline commensurately, as a basis for emissions value calculations.

Converting these emissions into an economic value requires a carbon price. There are various emissions trading schemes for both mandatory and voluntary offsets, around the world. The current price in the European Trading Scheme (EU ETS) is ~€ 10 per TCO_2e, (N$ 145), having doubled over the past year. Voluntary offsets are typically cheaper. Neither is thought to be high enough to motivate serious action, and an alternative measure, the Social Cost of Carbon (SCC) has been devised as an estimate of the economic damages associated with increases in CO_2e (US EPA, 2015). For 2017, this was set at US $39 (N$ 457). Within Namibia a much lower value of N$ 60 per TCO_2e was being used for the National Integrated Resource Plan review in 2015 (NIRP, 2016). As this aligns reasonably well with voluntary carbon markets, it can be applied as a conservative figure, although we have assumed 6% inflation to the start of the operational period.

	Value of Net Emissions at beginning of operational period		
Carbon Price	**NIRP N$ 85**	**EU ETS N$ 145**	**SCC N$ 457**
NPV N$	101,058,880	172,394,560	543,340,096
N$/kWh	0.028	0.046	0.146

Table 17: Value of Net Emissions at beginning of operational period

The value of net displaced emissions resulting from the project is calculated to be N$101 million (N$ 0.028/kWh). Valuations based on the other carbon prices discussed are shown for comparison.

Summary of microeconomic benefits

The aggregate microeconomic impact of the proposed power plant is made up of direct payment of wages and salaries, agricultural benefits in the form of livestock production, improve groundwater recharge from thinning bush-encroached areas, reduced CO_2 emissions, increased domestic electricity production and value addition derived from biomass harvesting.

Assuming a price per tonne of N$ 600 for biomass, the point at which both biomass harvesters and the power plant are profitable, the two harvesting scenarios (detailed in the Blended Supplier Scenarios portion of this document) yield similar returns. The greatest value addition in terms of Namibia Dollars per kWh of electricity generated can be seen in the direct wages and biomass harvesting operations.

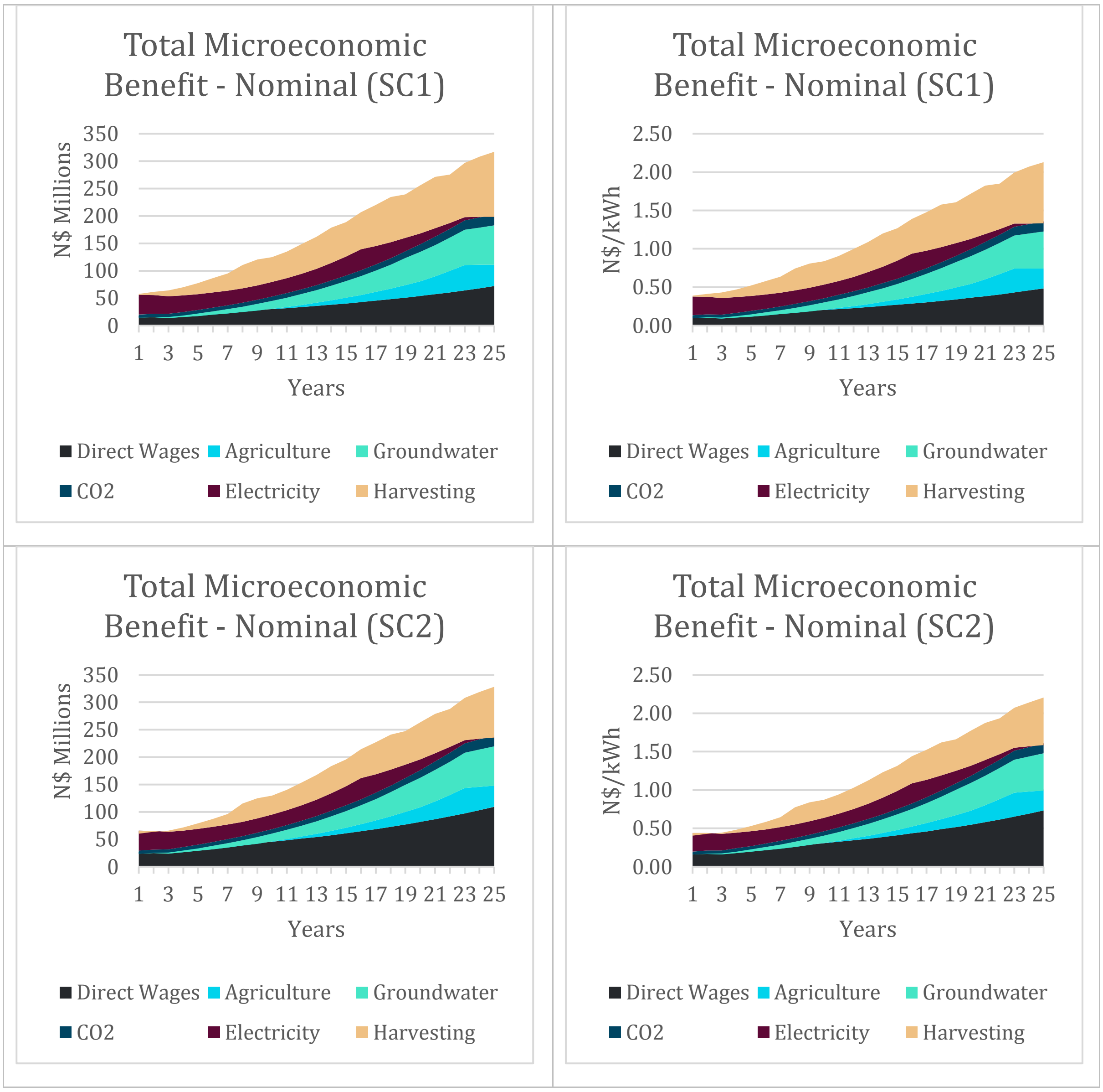

Figure 26: Total microeconomic benefit

In net-present-value terms (discounted at 6%, the assumed annual inflation rate), the aggregate value of gross value addition under Scenario 1 (90% mechanised) is N$ 1.47 billion of value addition that would otherwise not take place were it not for this project, or N$ 0.40/kWh.

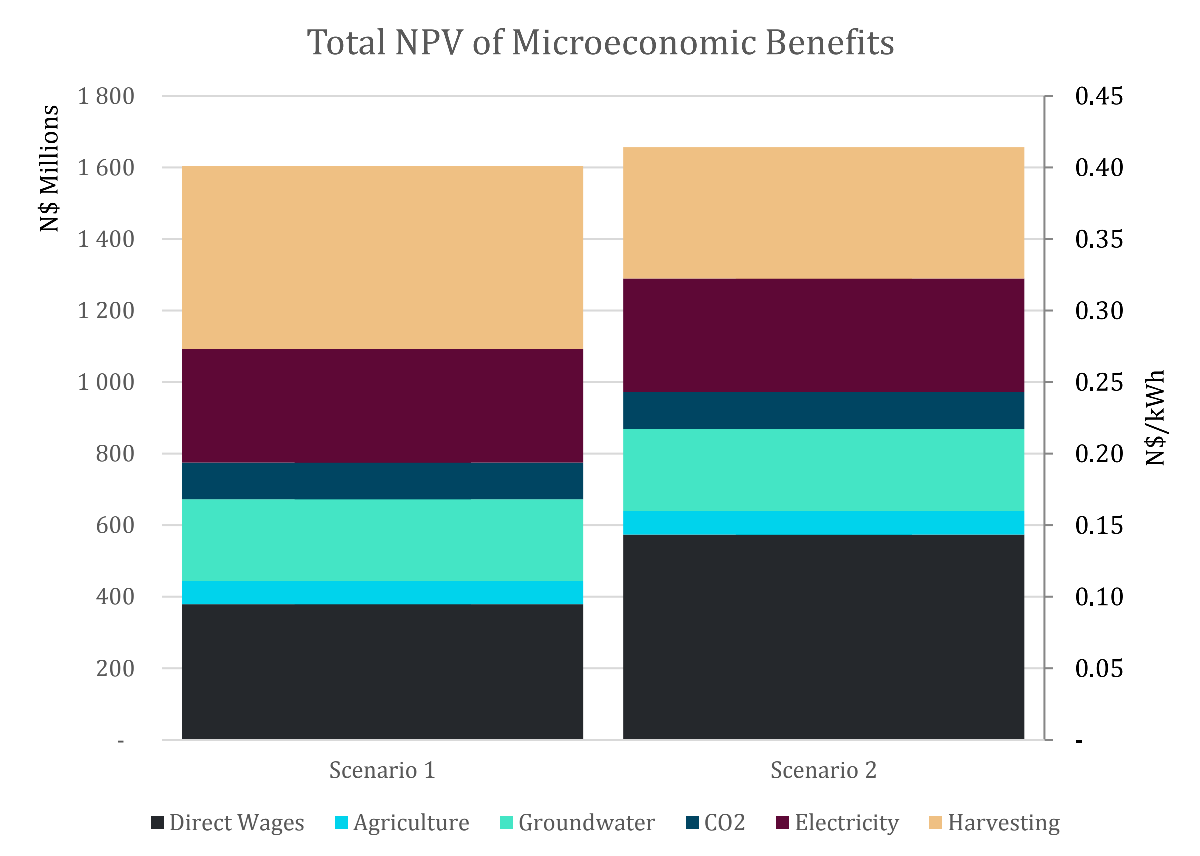

Figure 27: NPV of microeconomic benefits

In net-present-value terms (discounted at 6%, the assumed annual inflation rate), the aggregate per kWh value of gross value addition in the more manual (45% mechanised) Scenario 2 is N$ 1.52 billion, or N$ 0.41/kWh. The second scenario provides for a slightly better NPV in terms of N$/kWh due to the relatively higher aggregate wages that the more manual form of harvesting generates.

Harvesting method and price-point sensitivity

The aforementioned NPV calculations assume a fixed breakdown of mechanized vs. semi-mechanized vs. manual harvesting, as well as a price point of N$ 600/tonne for biomass. These assumptions may deviate from those that will materialize in practice. The impact of a change in harvesting approach, as well as price, can be inferred from the below charts.

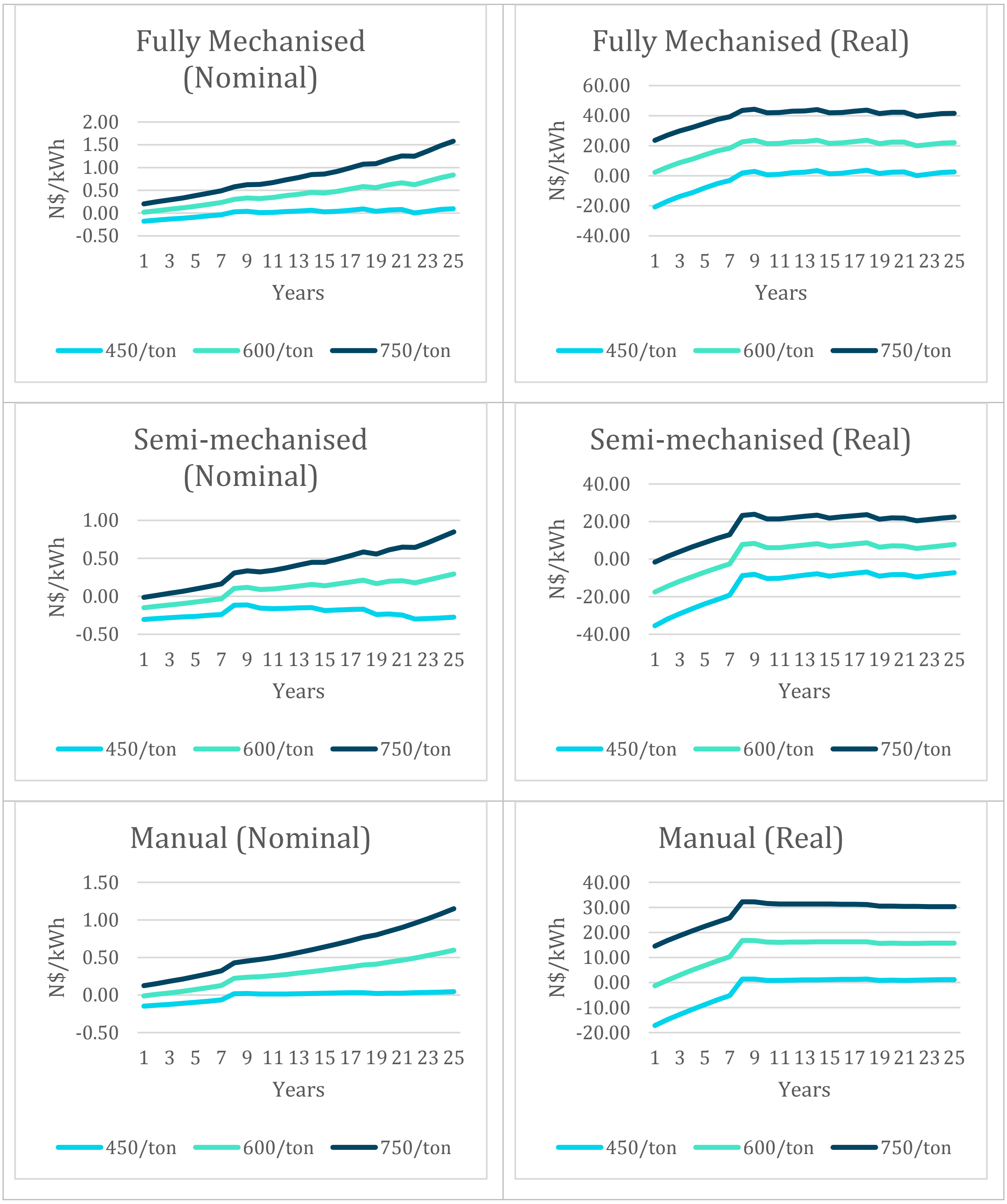

Figure 28: Harvesting method and price-point sensitivity

	NPV (N$) 2018	NPV/kWh
Fully Mechanized: 450/tonne	(43.12)	(0.01)
Fully Mechanized: 600/tonne	475.09	0.13
Fully Mechanized: 750/tonne	984.99	0.26
Semi-Mechanized: 450/tonne	(341.46)	(0.09)
Semi-Mechanized: 600/tonne	61.52	0.02
Semi-Mechanized: 750/tonne	443.24	0.12
Manual: 450/tonne	(57.06)	(0.02)
Manual: 600/tonne	322.53	0.09
Manual: 750/tonne	702.12	0.19

Table 18: Harvesting method and price-point sensitivity

Similar to the price assumptions for harvesters, the contribution of the power plant to the economy will depend on the price of the main fuel, namely biomass. The below charts and table illustrate the sensitivity of the contribution to the economy made by electricity at the three price points.

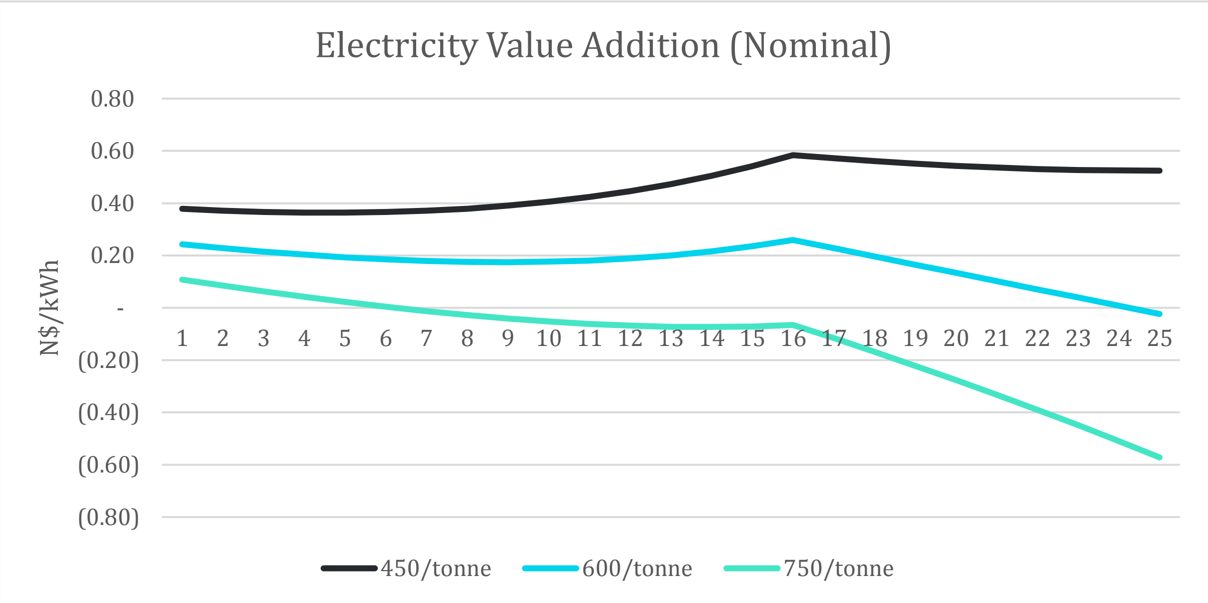

Figure 29: Electricity value addition - Nominal

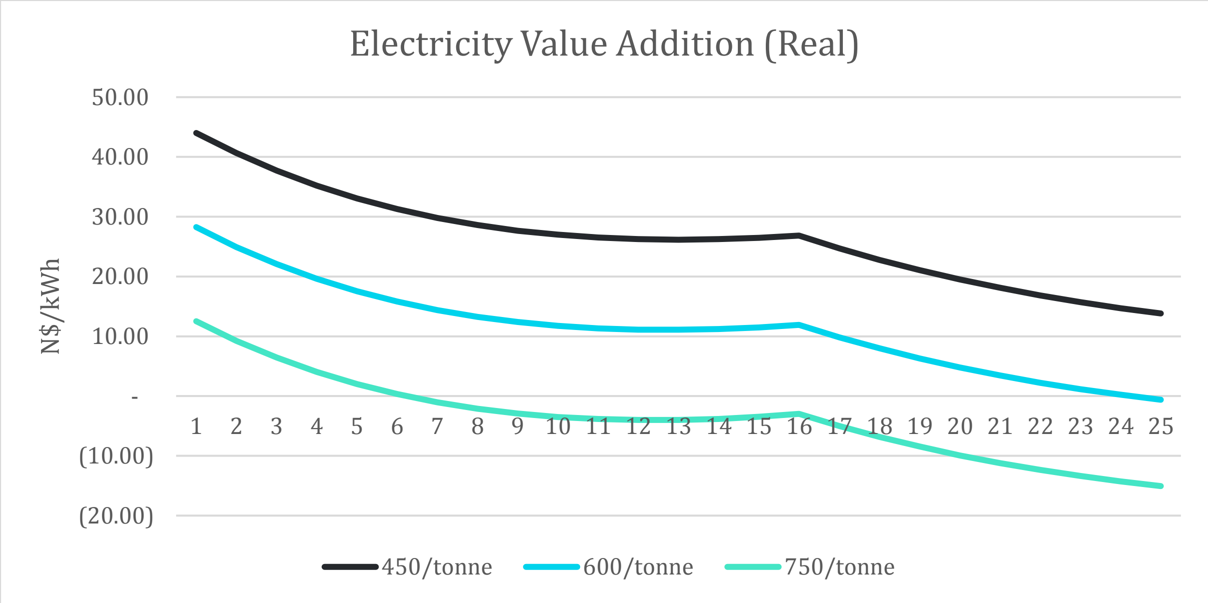

Figure 30: Electricity value addition – Real

Electricity Value Addition	NPV of Benefits (N$) 2018 Dollars	NPV / Total kWh
450/tonne	660.50	0.18
600/tonne	283.39	0.08
750/tonne	-93.72	(0.03)

Table 19: Harvesting method and price-point sensitivity

Macroeconomic Impact of the Project

Contribution to GDP

Direct

The direct contributions to GDP from the project will be seen both during the construction phase and the operational phases of the project. The construction phase will see the greatest short-term addition to GDP, while operations will provide a smaller but longer-lived contribution.

Construction

From the total construction cost of the project, an approximate 45% will be direct imports, including the boiler, steam turbine, feedwater heaters, condenser and other specialised equipment. From a GDP perspective, these imports register as a negative in the value-addition calculation, while only gross value addition (output less intermediate consumption) on the remainder of the construction activity forms a direct positive contribution to GDP.

In the construction sector, the ratio of gross value addition to total output varies from 28% to 32%, as illustrated below. Over the past 10 years, the ratio has averaged approximately 30%, which is the assumed ratio for this project. As a result, the direct construction phase value addition from this project is assumed to be N$ 152.04 million.

N$ Million (2018 dollars)	**Value addition as % of Output**		
	28%	**30%**	**32%**
Output	506.79	506.79	506.79
Intermediate consumption	364.89	354.76	344.62
Value added, gross	141.90	**152.03**	162.17

Table 20: Direct construction phase value addition

However, when the large import component of the project's costs are factored into the equation, the direct net contribution to GDP during the construction phase falls, to -N$ 282.23 million, a net contribution of -0.16% of forecast 2018 GDP, in 2018 values.

Operation

During the operating phase, the direct contribution of the power plant will be two-fold when compared to the status-quo, assuming that the power generated is offset against what would otherwise be power imported from the region. In this regard, power generation would constitute one portion of the direct contribution to GDP, while the reduction in imports would be a second contribution.

The price paid by NamPower for biomass will be a large determinant of intermediate consumption cost for the contribution to GDP of the power plant, and thus the GDP contribution of the plant. The higher the input (biomass) cost, the lower will be the direct contribution to GDP, although the inverse is true when it comes to biomass producers and their contribution to GDP. The contribution to GDP also varies from year to year over the 25-year life expectancy of the plant. As a result, depending on the year, and depending on price paid for biomass, the plant will generate electricity worth between -0.041% and 0.088% of GDP per year.

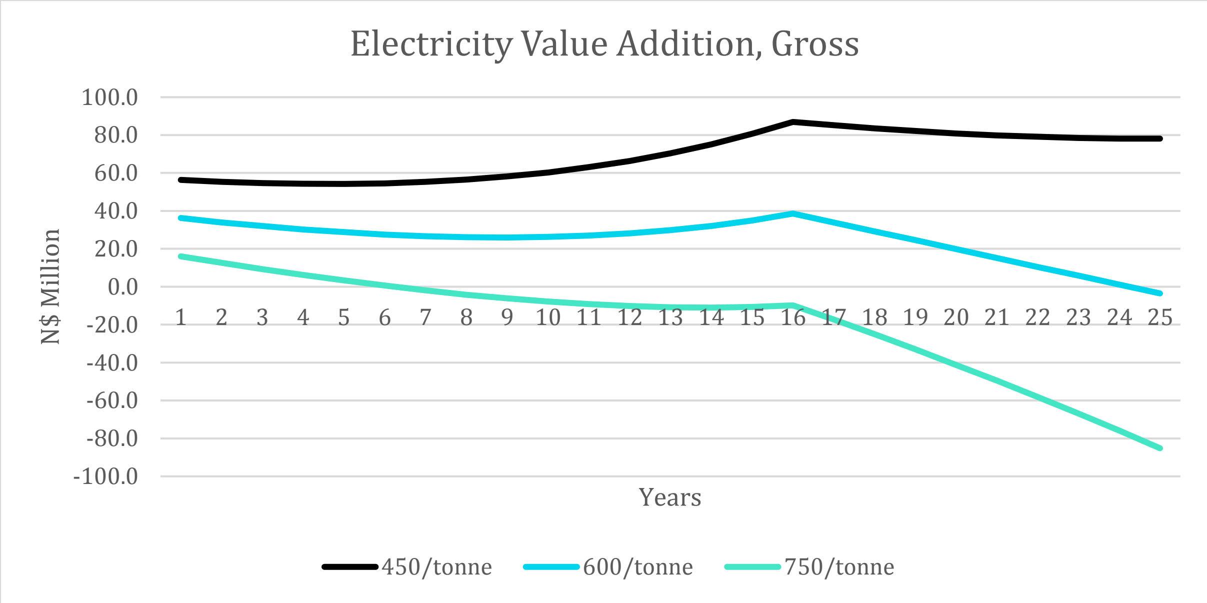

Figure 31: Electricity Value Addition, Gross

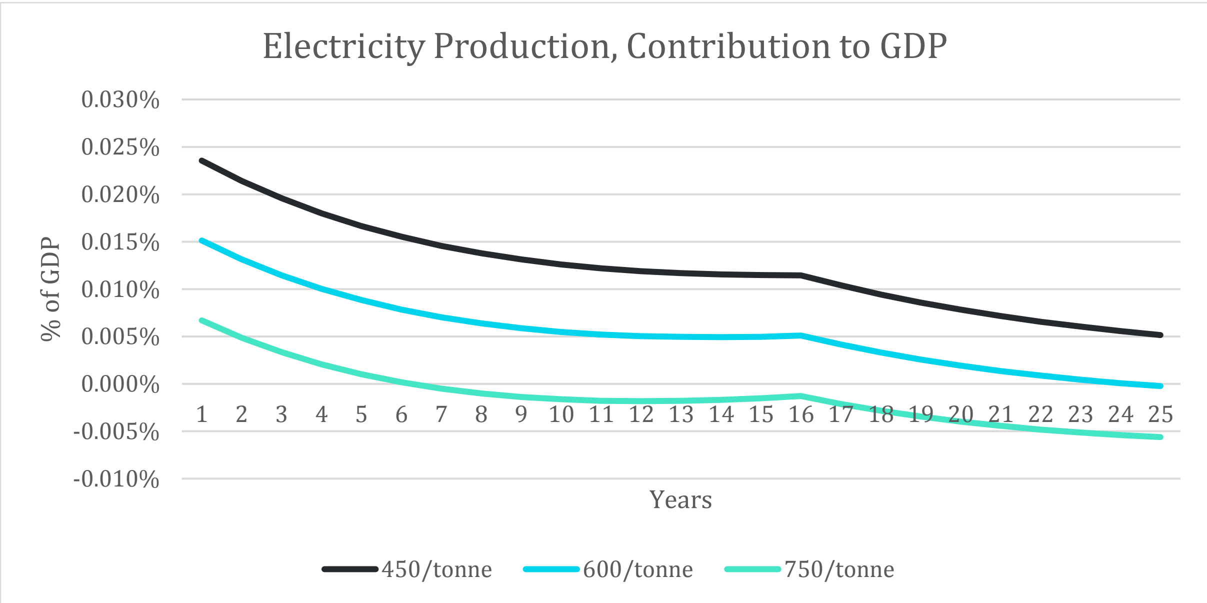

Figure 32: Electricity Production, Contribution to GDP

In inflation adjusted terms, the power plant value addition per kWh varies from -N$ 0.07 and N$ 0.24 depending on the price of biomass and the year of operation. The negative contribution implies that the cost of power production is greater than the revenue that is generated there-from, meaning that the net effect on GDP would be negative.

Additionally, the reduction in imported electricity will contribute between 0.036% and 0.056% of GDP over the 25-year life expectancy of the power plant.

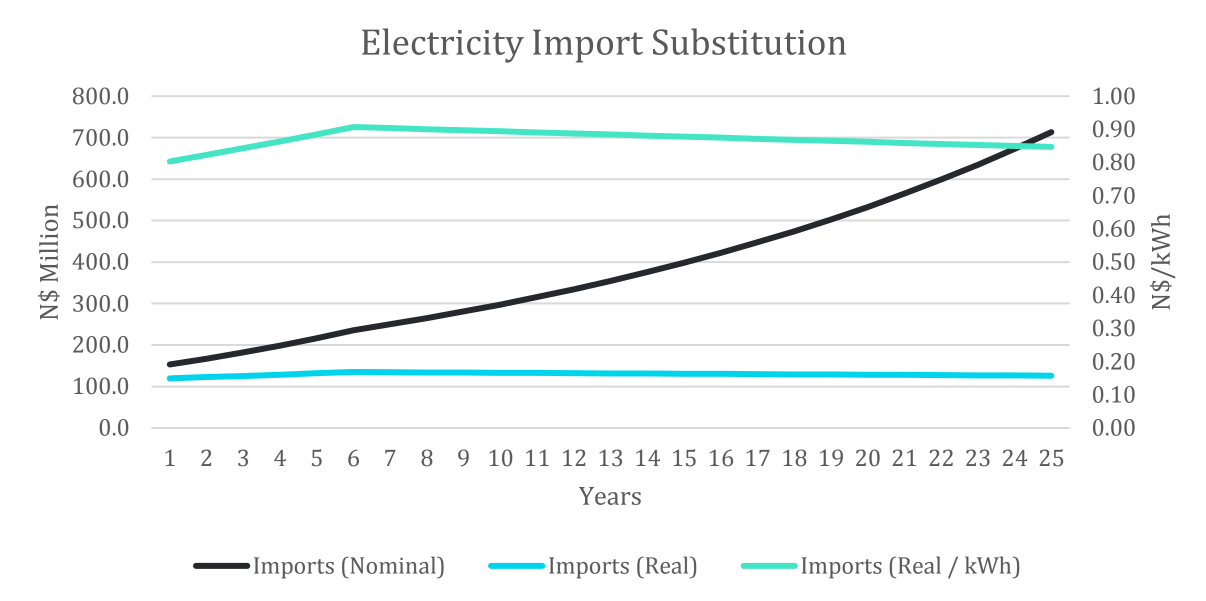

Figure 33: Electricity Import Substitution

In net-present-value terms, the electricity value addition over the project lifetime is illustrated in the table below at each of the respective price points, as well as the impact of reduced electricity imports.

Electricity Value Addition	NPV of Benefits (N$) 2018 Dollars	NPV / Total kWh
450/tonne	660.50	0.18
600/tonne	283.39	0.08
750/tonne	-93.72	-0.03
Import Substitution	3,238.85	0.87

Table 21: Net present value of electricity value addition

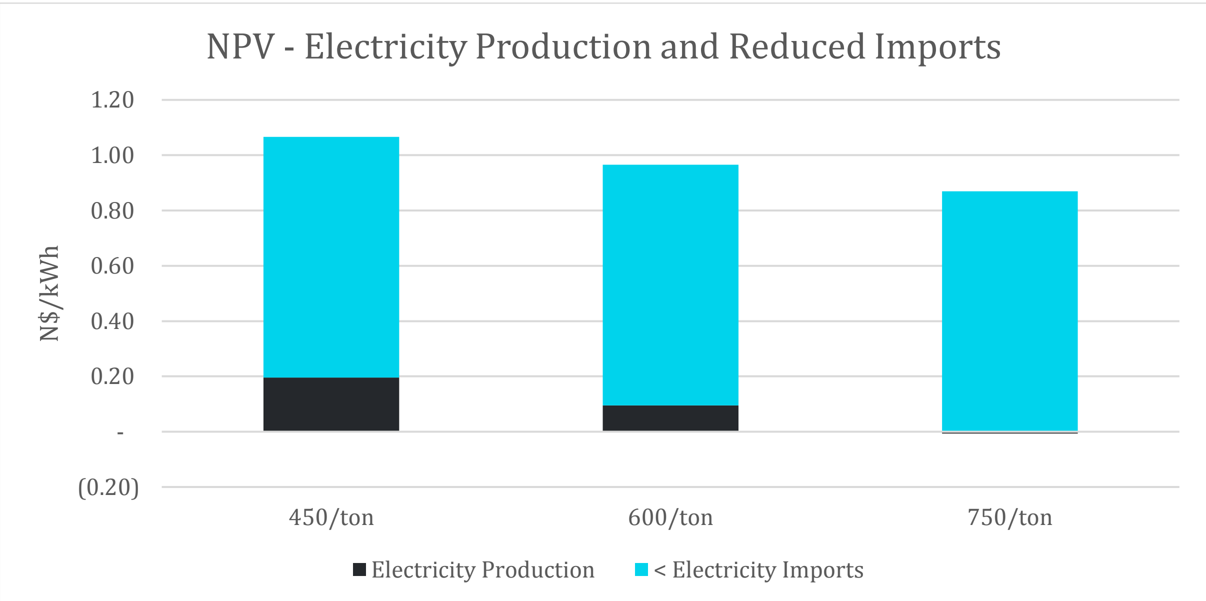

Figure 34: Net present value of electricity value addition at different price points

The total NPV of reduced electricity imports and local production in N$ per kWh varies from N$ 0.87/kWh (biomass purchased at N$ 750/tonne) to N$ 1.07/kWh (biomass purchased at N$ 450/tonne).

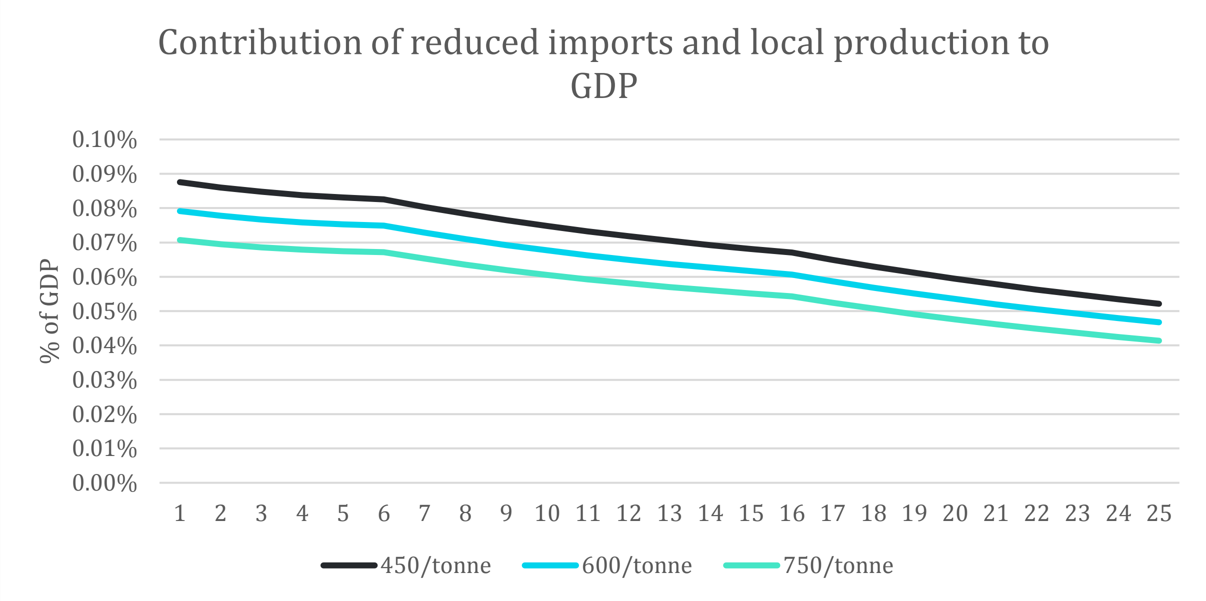

Figure 35: Contribution of reduced imports and local production to GDP

As a result, the direct contribution to GDP from the power plant during the project's operational phase will vary between 0.041% and 0.088%, largely depending on the input cost of biomass.

Indirect

The indirect contribution to the economy is viewed, primarily, to come from two sources. These are the biomass industry, as well as the increase in agricultural output expected from the bush thinned land and improved rangeland management (as outlined earlier) associated with biomass harvesting. The downstream benefits of the energy production are assumed to be net-neutral on the Namibian economy, as the locally produced power is merely a substitute for imported power, not power that would otherwise not exist. Therefore, apart from the upstream benefits, no direct downstream benefits are assumed.

Biomass

The direct contribution of biomass to GDP depends on the sales price of biomass to NamPower, as well as the harvesting method used by harvesters. In this regard, the greatest direct contribution to GDP is seen from fully-mechanized harvesting, although the indirect and induced contributions to GDP may be smaller than some of the more labour-intensive harvesting options. The lowest direct contribution to GDP is from partially mechanized harvesting, while fully manual harvesting sees a direct contribution between the two.

The greatest contribution to GDP from harvesting is seen when fully mechanized harvesting is utilized and the price per tonne of biomass is set at N$ 750. In this scenario, the contribution to GDP from the biomass supply chain varies from 0.0126% to 0.0210% over the 25-year lifespan of the plant. At N$ 600/tonne, fully mechanized, the contribution to GDP varies from 0.0012% to 0.0112%.

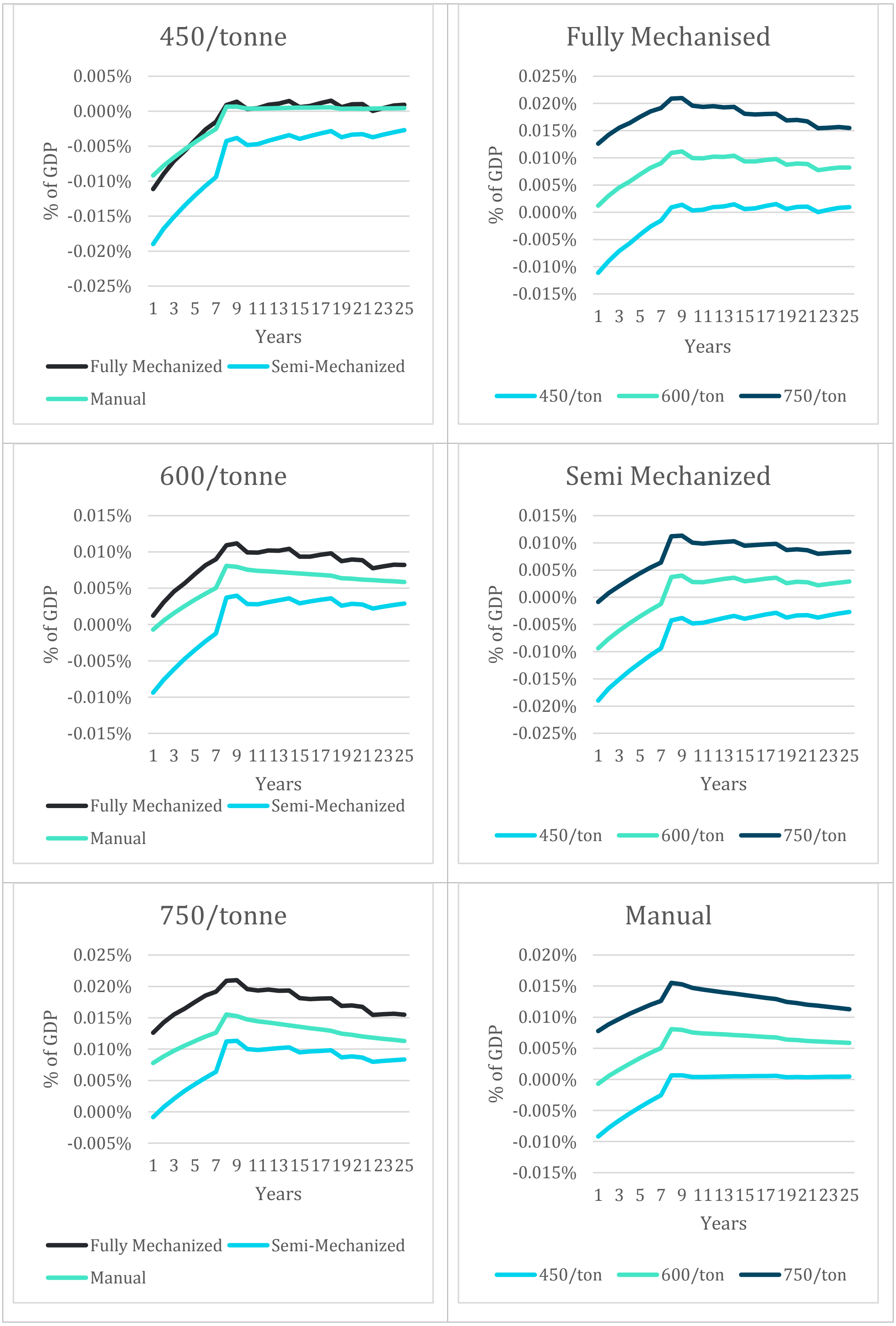

Figure 36: GDP- Harvesting method and price-point sensitivity

The value addition profiles, and thus the contribution to GDP vary across the scenarios due to a) the revenue generated by the harvesters, which is dependent on the price per tonne of biomass (as the volumes are fixed); and b) the costs associated with the harvesting approach. Manual harvesting requires less reinvestment in harvesting equipment over the power plant lifetime, whereas fully mechanized harvesting requires extensive and costly reinvestment. On the manual side, labour and equipment costs are thus fairly constant across years, whereas on the mechanized harvesting side, they are less so, hence the smoother profile seen in the manual harvesting figures, when compared to the more staggered profiles for the more capital intensive semi-mechanised and fully mechanised figures.

Further details on the N$/kWh and NPV of harvesting activities can be found in the Harvesting method and price-point sensitivity section of this report.

Agriculture

One of the single largest benefits to GDP as a result of the proposed power plant is the impact that bush-thinned land will have on increased agricultural carrying capacity. For the purpose of this study, it is assumed that all thinned land will be used for agricultural purposes - particularly livestock farming - and all alternative land-uses are not considered in this study. The reason for this is that it is assumed that the base-case scenario for farmers in the area is to increase livestock numbers as carrying capacity on the land increases. In the event that farmers undertake activities other than livestock farming, it is assumed that this will be done only because the potential returns from such activities are greater than would be the return from livestock farming. This is to say that the base-case for value addition is captured in the assumptions made, and any deviation away from such can be expected to yield greater long-term return for farmers and thus the local economy.

Assuming a sustainable yield of 12.65 tonnes of dry biomass per hectare, and 106,500 tonnes of biomass to be consumed by the plant a year, a total of approximately 8,419 hectares of land will be harvested per year. This is expected to allow for a 70% increase in carrying capacity of livestock on this land, from one animal every 17 hectares, to one animal every 10 hectares. This ultimately implies that every year, a total of 347 new head of livestock will be able to be carried by the bush-thinned land. However, it is likely to take some time to achieve this level of stocking.

Over the 25-year lifespan of the plant, the increased contribution of agriculture to GDP is expected to peak out at approximately 0.004%. This is the point at which agricultural output peaks and is based on the assumption of aftercare being applied every three years.

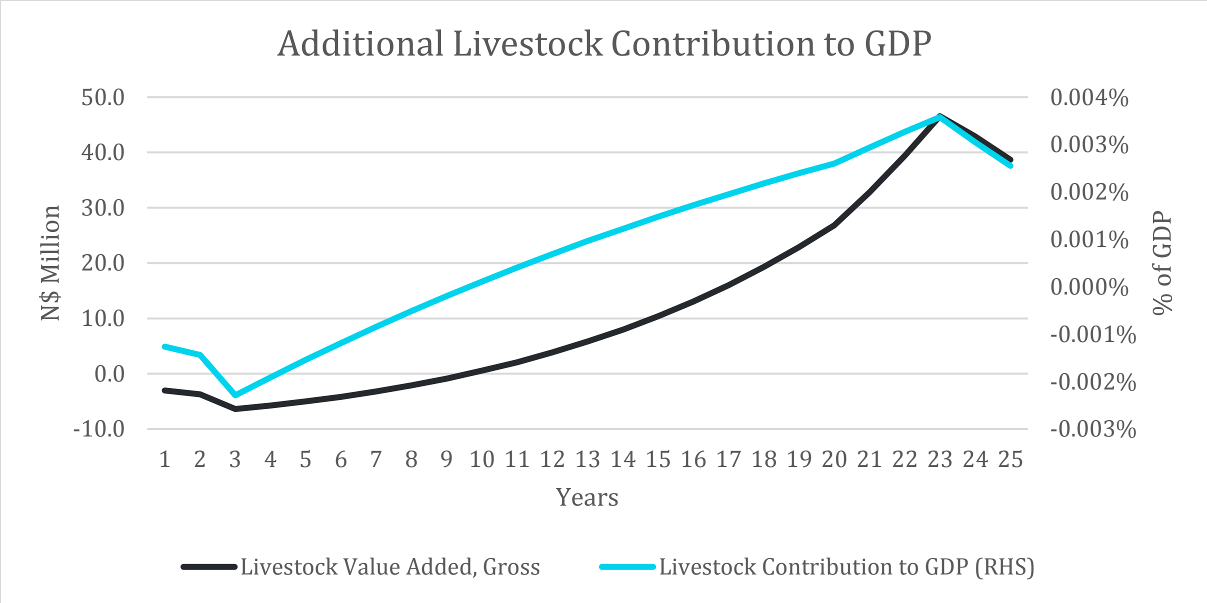

Figure 37: Additional Livestock Contribution to GDP

Further details on the N$/kWh and NPV of agriculture/livestock value addition can be found in the Agricultural Sector section of this report.

Multiplier effect

GDP multipliers were extracted from the Namibian Social Accounting Matrix (SAM) of 2013 (Schade, 2016; Lange and Schade, 2008) and applied to the output of the microeconomic modelling exercises. Multipliers from the SAM were adjusted as necessary to avoid double counting of the upstream components of electricity production (i.e. to avoid double counting the biomass harvesting value addition). The 2013 SAM remains relevant, as these models are only updated to adjust for major changes within an economy.

Livestock

UPSTREAM

The livestock (commercial animal product) industry has an extensive upstream value chain, with output from the sector requiring inputs from almost every other sector and/or industry in the economy. From a commodity consumption perspective, the largest first round industry inputs are from the fabricated metals, machinery and equipment sector (21.8%) and the petroleum products sector (18.1%). From the services and production side, the industry consumes primarily from the wholesale and retail trade industry, as well as from the finance and insurance (13.1%) and transport (7.1%) industries.

DOWNSTREAM

Similarly, there is a well-developed downstream value chain for livestock in Namibia. The largest downstream consumer of commercial animal agriculture is the meat processing industry, which captures approximately 48% of the output value of the livestock industry, followed by leather production which captures approximately 20%. The wood and furniture industry captures approximately 12.5%, with hotels and tourism at 4.8% and 3.5%, respectively.

As a result, the industry multiplier effect is approximately 3.63 x, implying that for every N$ 1 of output generated by the industry, N$ 3.63 of output is generated in the economy as a whole through up and downstream activities.

Construction

UPSTREAM

The construction industry also has substantial multiplier effects through the economy. The first-round upstream multiplier of the sector is approximately 2.09 x, driven primarily by input consumption from the wholesale and retail trade space (25.5%), the real estate and business services sector (16.8%) and the transport industry (9.5%).

DOWNSTREAM

From a downstream perspective, the construction industry has a notably lower first-round multiplier effect, totalling just 1.13 x. The small multiplier is created through various inter-sectoral linkages, however none are individually larger than 2.0%. In total, the construction industry has a 2.36 x multiplier effect on the economy, implying that for every N$ 1 dollar spent in this industry, a total of N$ 2.36 of output is created in the economy.

Electricity

UPSTREAM

The upstream value chain of the electricity sector is substantial, with a first-round multiplier effect of 1.59 x. The main contributors to this is the consumption of petroleum products (23.2%) and fabricated metals, machinery and equipment (20.2%).

DOWNSTREAM

While there are sizable downstream multiplier effects from the electricity sector, it would be inaccurate to apply these multiplier effects to the output calculation, as no additional electricity will be available in the country as a result of this power plant. Rather, locally produced electricity will replace imported electricity, but the downstream impact of the change will be negligible.

Because of the exclusion of downstream multipliers, for the purpose of this study, the multiplier effect derived from the introduction of the power plant is exclusively upstream, at 1.59 x.

Biomass

The biomass industry does not have a specific line in the Social Accounting Matrix, and it is thus assumed that the industry will have similar multiplier characteristics to those of the commercial cereal crop sector.

The commercial cereal crops sector has a 1.71 x multiplier effect on the economy. This implies that N$ 1 of output from the sector adds N$ 1.71 to the local economy.

Overall, indirect and multiplier contribution to GDP

The overall contribution to GDP contribution of the power plant varies from year to year, as well as on the harvesting mechanism used and the price paid by NamPower to the biomass harvesting industry.

N$ Million	Multiplier	Year		
		-2	-1	0
Construction Value Addition, Gross		45.61	60.82	45.61
- Downstream	0.21	9.63	12.84	9.63
- Upstream	2.15	97.96	130.62	97.96
Total (Multiplied Value Addition)	2.36	107.59	143.46	107.59
Construction Value Addition to GDP		**0.024%**	**0.030%**	**0.021%**
Multiplied Value Addition to GDP		**0.056%**	**0.070%**	**0.049%**
Value addition/kWh		0.03	0.04	0.03
Value addition/kWh (real)		0.03	0.03	0.02

Table 22: Overall, indirect and multiplier contribution to GDP during construction phase of power plant

During the construction phase of the project, the direct and indirect contribution to GDP increases from 0.056% in the first year to 0.070% of GDP in the second year and reduces to 0.049% of GDP in the third year. The value addition/kWh of the construction phase of the project is estimated based on the total number of kWh's produced by the plant over its operational lifetime. As a result, the N$/kWh value addition for the project construction is relatively low, at N$ 0.03 in years one and two of construction, and N$ 0.02 in year three.

Following the construction phase of the project, the indirect and multiplier impact on GDP drops initially, as both gross value addition in the biomass and electricity sectors drops in the early years of operation. Further to this, the benefits from increased carrying capacity on bush thinned land and the harvesting of livestock therefrom takes some years to develop as the re-stocking of this land is expected to be a gradual process over four years. Thereafter, the cumulative increases in harvested land, resultant increases in carrying capacity and increased livestock production, see the total value addition increasing over the full 25-year lifespan of the project (after which it would be assumed to flat-line for so long as the land is kept clear of excess bush). The contribution to GDP sees a similar trend, however the assumption that encroachment resumes once again 20 years after land was first harvested results in GDP growth expanding faster than the marginal value addition, ultimately resulting in a slow reduction in the ratio of value addition to GDP.

The overall gross value addition and percent contribution to GDP hinges on the harvesting scenarios mentioned earlier in this report as well as the price paid to harvester by NamPower for one tonne of biomass.

As demonstrated in the following charts, the first scenario (96,000 tonnes of biomass harvested by fully mechanized operations and 5,600 tonnes harvested by manual and semi-mechanized operations, respectively), shows greater addition to GDP than does Scenario 2 (48,000 tonnes of biomass harvested by fully mechanized operations and 29,600 tonnes harvested by manual and 29,400 by semi-mechanized operations, respectively). In addition, the greatest gross value addition from a price-point perspective can be seen at the highest price point sampled – N$ 750/tonne. The reason for this is that the multiplier effects from biomass value addition are greater than those from the additional electricity value addition, as the latter is simply substitution for already available, but imported, electricity. Nevertheless, the overall impact is marginal between the price points.

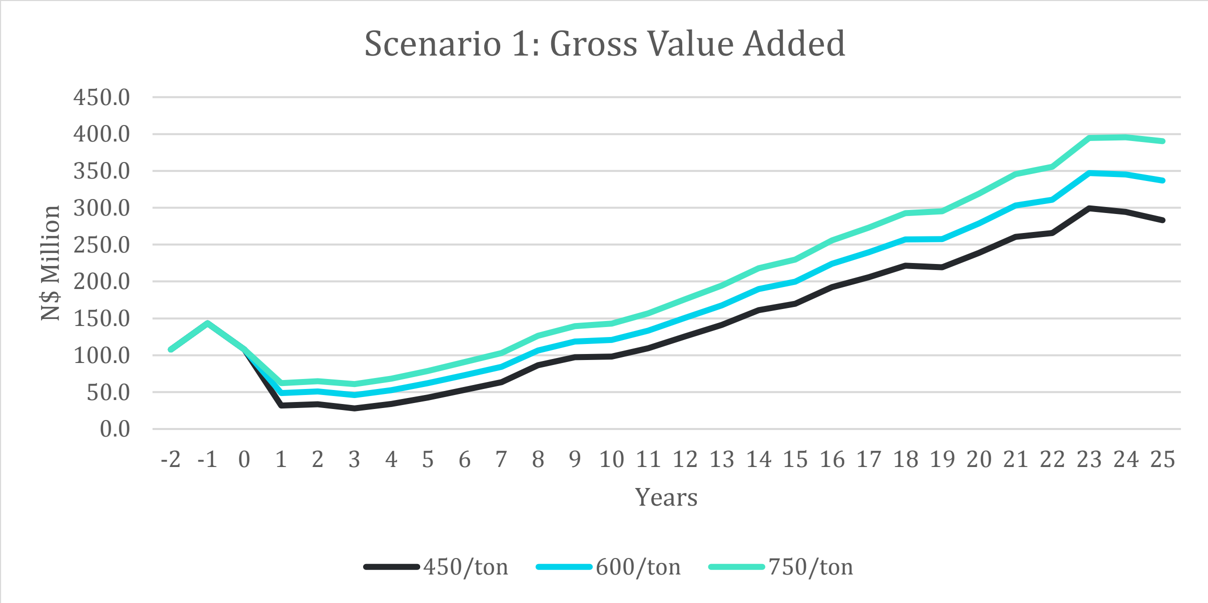

Figure 38: Scenario 1 – Gross value added

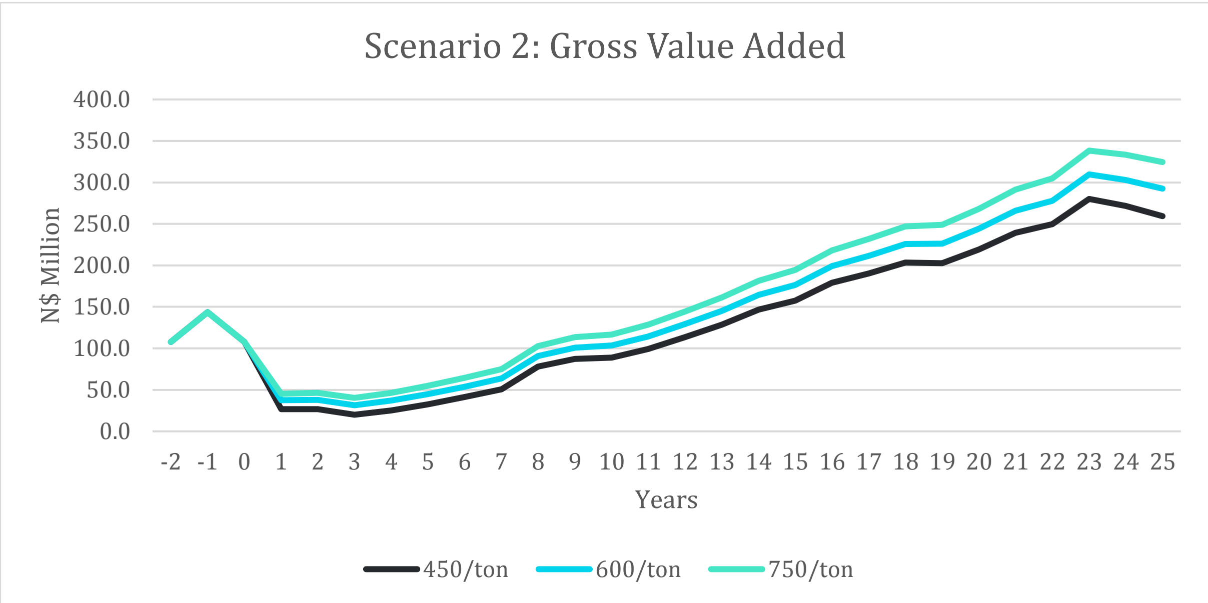

Figure 39: Scenario 2 – Gross value added

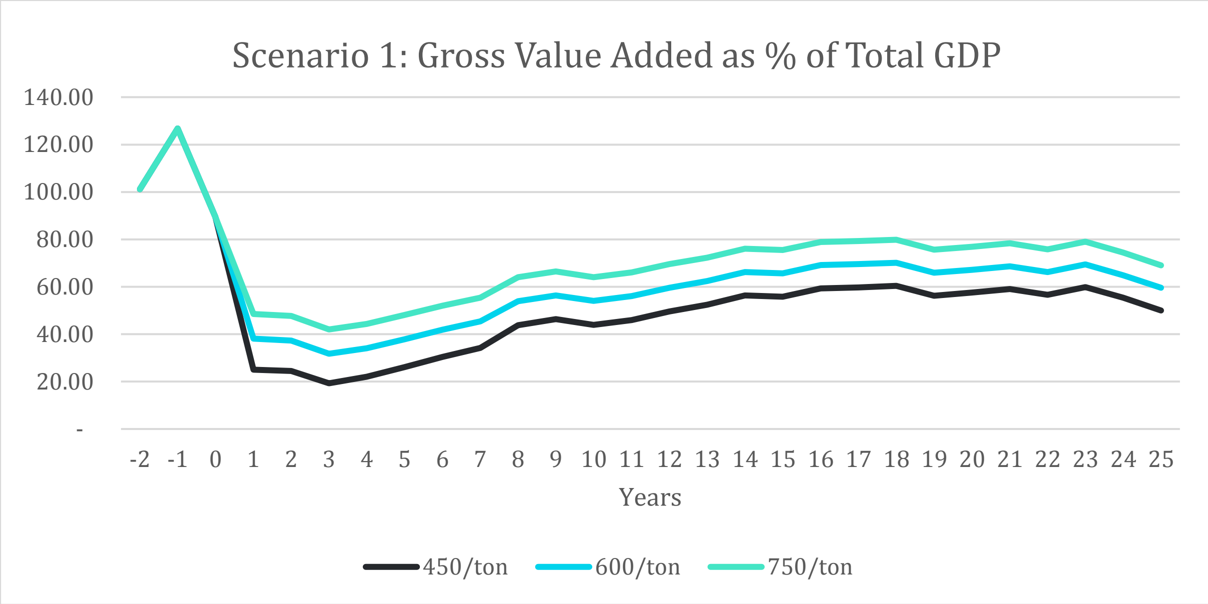

Figure 40: Scenario 1 – Gross value added as % of Total GDP

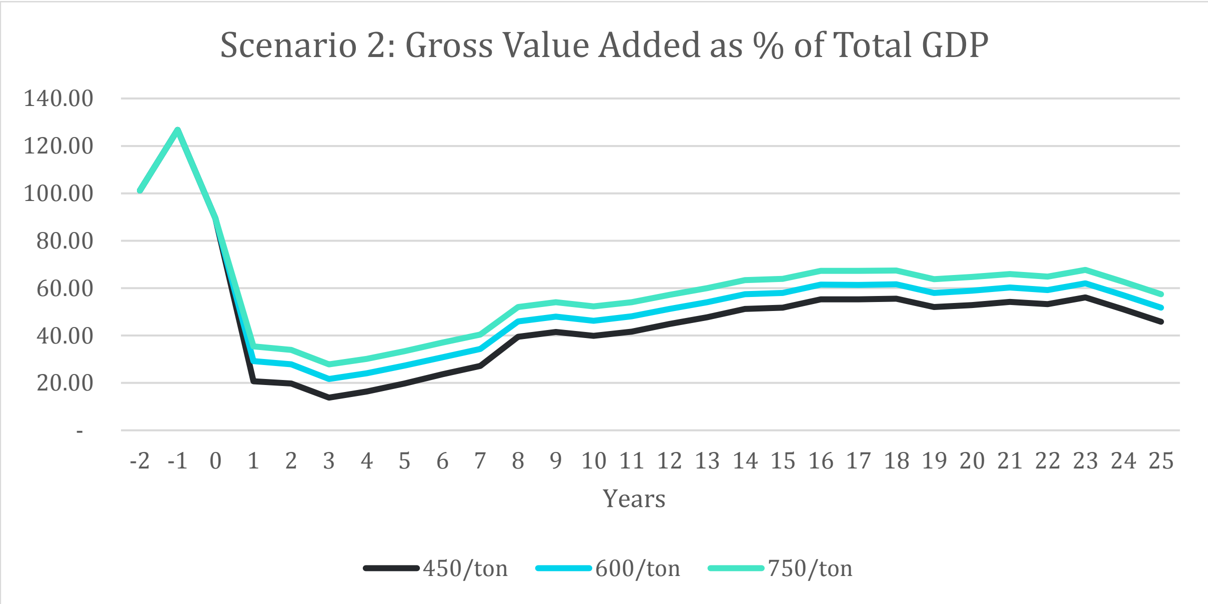

Figure 41: Scenario 2 – Gross value added as % of Total GDP

On a per-kWh value addition basis, the more mechanised harvesting scenario outperforms the more manual approach, however the difference is marginal. The first scenario shows an overall macroeconomic benefit to the economy of N$ 4.97 billion in 2018 terms, equitable to real value addition/kWh of N$ 1.33. The largest contributors to this value addition are reductions in imported electricity and biomass harvesting.

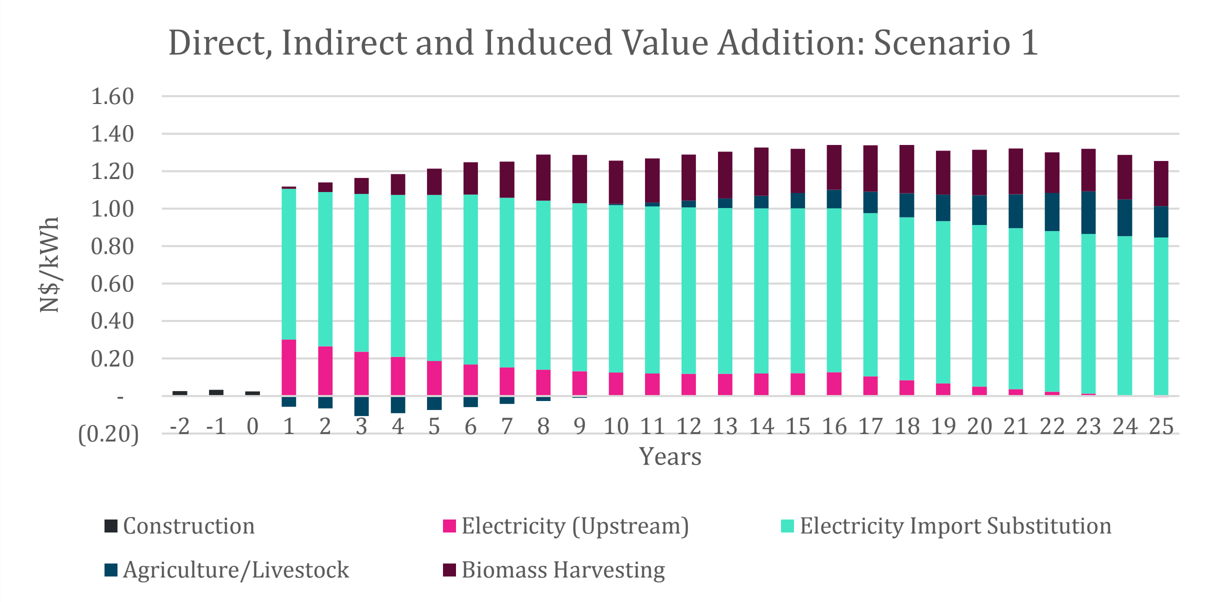

Figure 42: Direct, Indirect and Induced Value Addition: Harvesting Scenario 1

Scenario 1	NPV of Benefits (N$) 2018 Dollars	NPV / Total kWh
Construction	317.26	0.09
Electricity (Upstream)	450.60	0.12
Electricity Import Substitution	3,238.85	0.87
Agriculture/Livestock	200.88	0.05
Biomass Harvesting	760.14	0.20
Total	4,967.72	**1.33**

Table 23: Net present value of Direct, Indirect and Induced Value Addition: Scenario 1

The second scenario shows an overall macroeconomic benefit to the economy of N$ 4.75 billion in 2018 terms, equitable to real value addition/kWh of N$ 1.28. The largest contributors to this value addition are reductions in imported electricity and biomass harvesting.

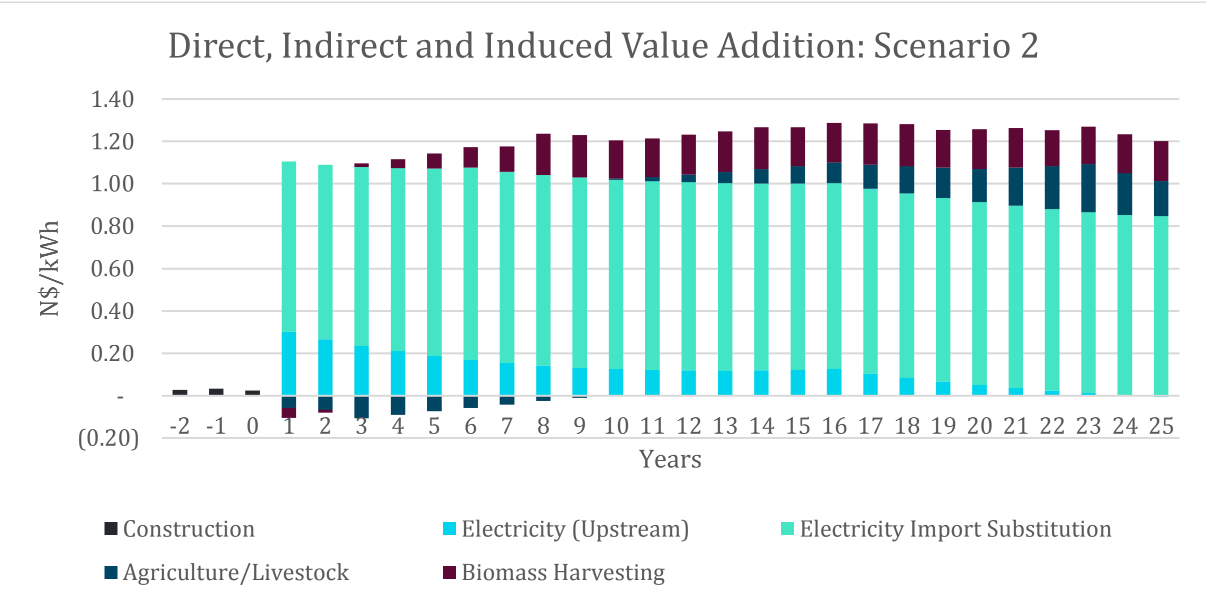

Figure 43: Direct, Indirect and Induced Value Addition: Harvesting Scenario 2

Scenario 2	NPV of Benefits (N$) 2018 Dollars	NPV / Total kWh
Construction	317.26	0.09
Electricity (Upstream)	450.60	0.12
Electricity Import Substitution	3,238.85	0.87
Agriculture/Livestock	200.88	0.05
Biomass Harvesting	543.89	0.15
Total	4,751.46	**1.28**

Table 24: Net present value of Direct, Indirect and Induced Value Addition: Scenario 2

Direct, Indirect and Induced Employment

Direct

The direct employment generated by the power plant is covered in the microeconomic section of this report.

Indirect

The indirect employment created through harvesting activities are covered in the microeconomic section of this report.

Induced

In order to estimate induced employment as a result of upstream and downstream activities, an output-weighted ratio of employees per million Namibia Dollars' worth of value addition was estimated using the 2016 national accounts and 2016 Namibia Labour Force Survey (NLFS). The output-weighted ratio was then multiplied with the gross value addition (discounted to 2016 levels) for the various sectors that were derived from the social accounting matrix.

	NLFS 2016	Value Addition 2016 (N$ Million)	Employees/ Million N$ Value Addition
Agriculture, forestry and fishing	135,832	10,130	13.41
Accommodation and food service activities	47,840	3,600	13.29
Construction	63,005	6,509	9.68
Real estate and other service activities	107,129	11,590	9.24
Human health and social work activities	19,058	4,729	4.03
Wholesale and retail trade	65,492	18,792	3.49
Transport and storage	22,175	7,202	3.08
Education	41,422	15,733	2.63
Manufacturing	44,419	17,711	2.51
Electricity and Water and related industries	9,530	3,858	2.47
Financial and insurance activities	15,525	9,085	1.71
Public administration and Defence; compulsory social security	30,260	18,065	1.68
Mining and quarrying	14,825	18,178	0.82

Table 25: Direct, Indirect and Induced Employment

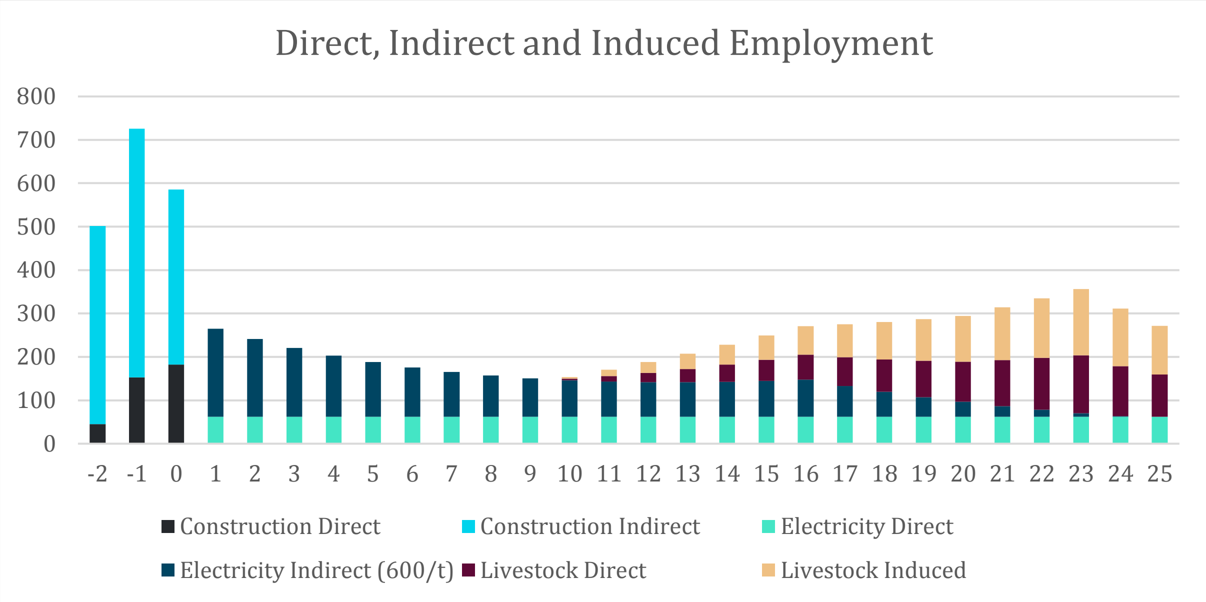

Figure 44: Direct, Indirect and Induced Employment

In total, the livestock sector creates a large number of direct and induced employment opportunities over the lifespan of the power plant, which jobs may well be sustained thereafter should the increased carrying capacity of the land be maintained through aftercare activities.

Similarly, harvesting activities create a number of induced job opportunities, however the magnitude thereof depends heavily on the price/tonne paid by NamPower to harvesting entities.

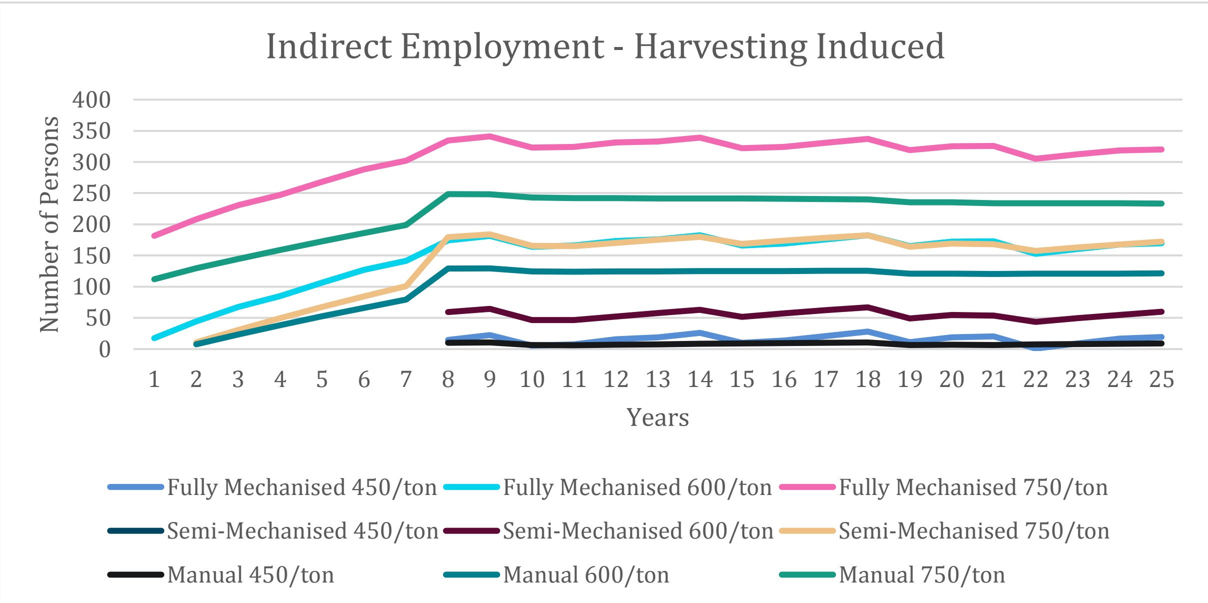

Figure 45: Indirect Employment - Harvesting Induced

Contribution to Corporate and Personal Income Tax in nominal and real terms are presented below.

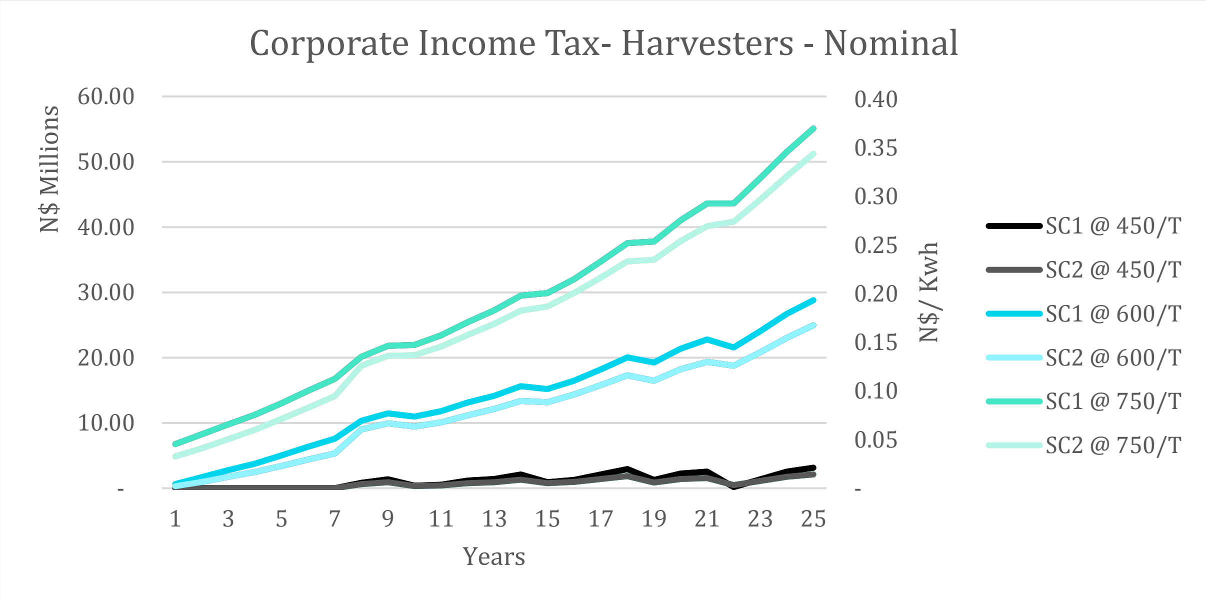

Figure 46: Corporate Income Tax- Harvesters - Nominal

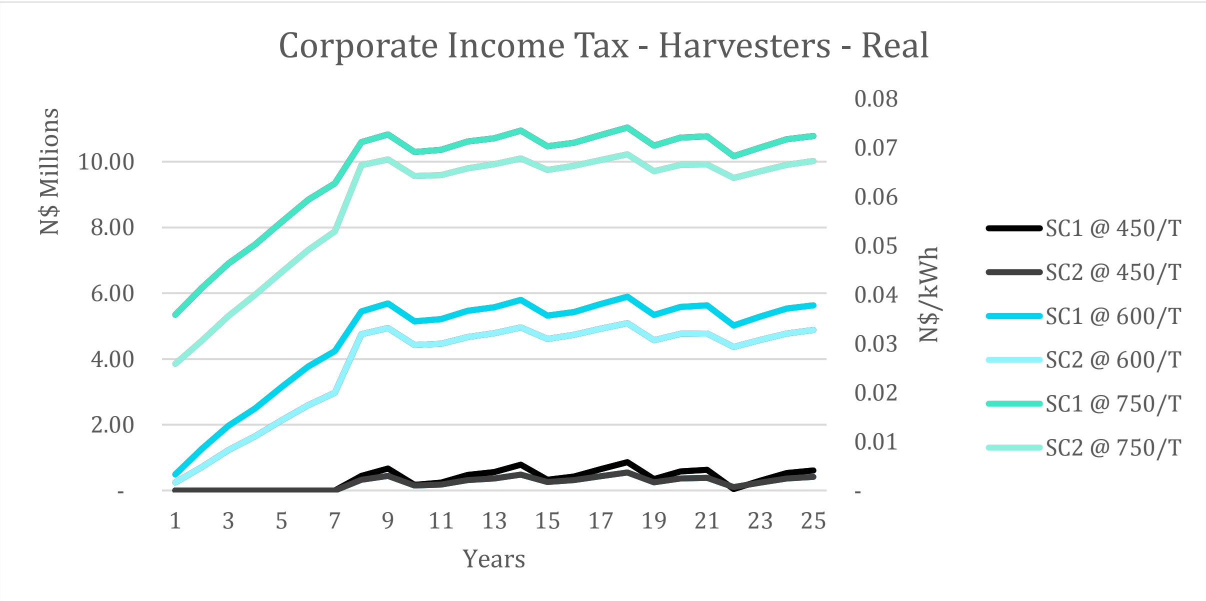

Figure 47: Corporate Income Tax- Harvesters – Real

Generally, the first harvesting scenario produces higher tax revenues relative to the second scenario, as the mechanised harvesters are more profitable. At the N$ 450/tonne price level most harvesters make little profit and as a result pay little corporate income tax, while at the higher price points, higher profitability leads to higher corporate taxes.

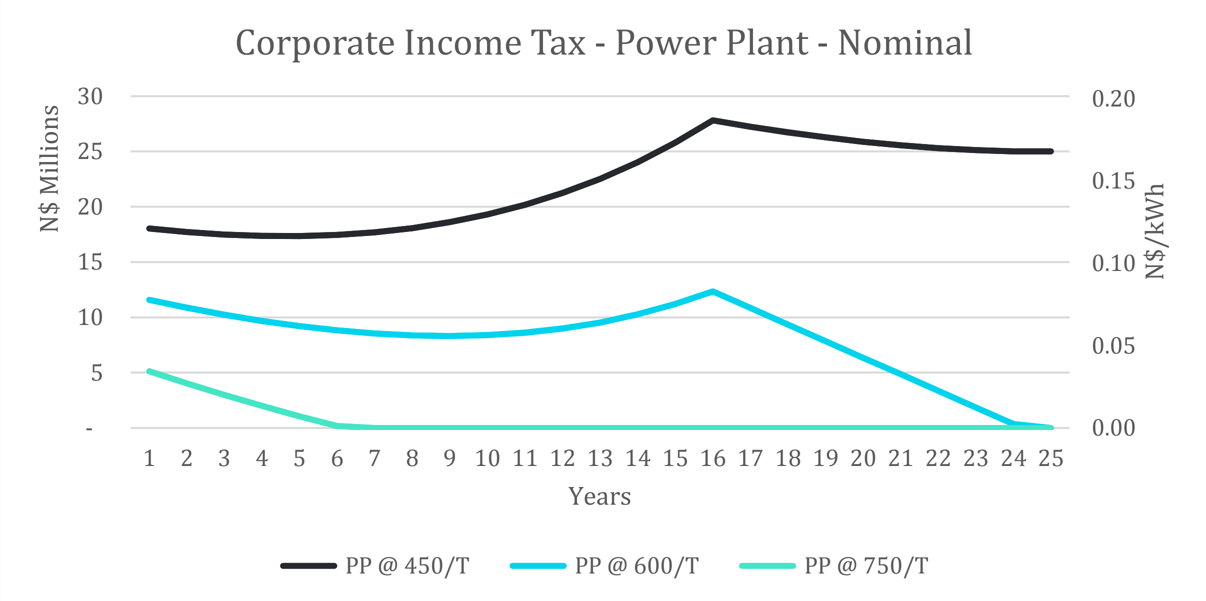

Figure 48: Corporate Income Tax - Power plant - Nominal

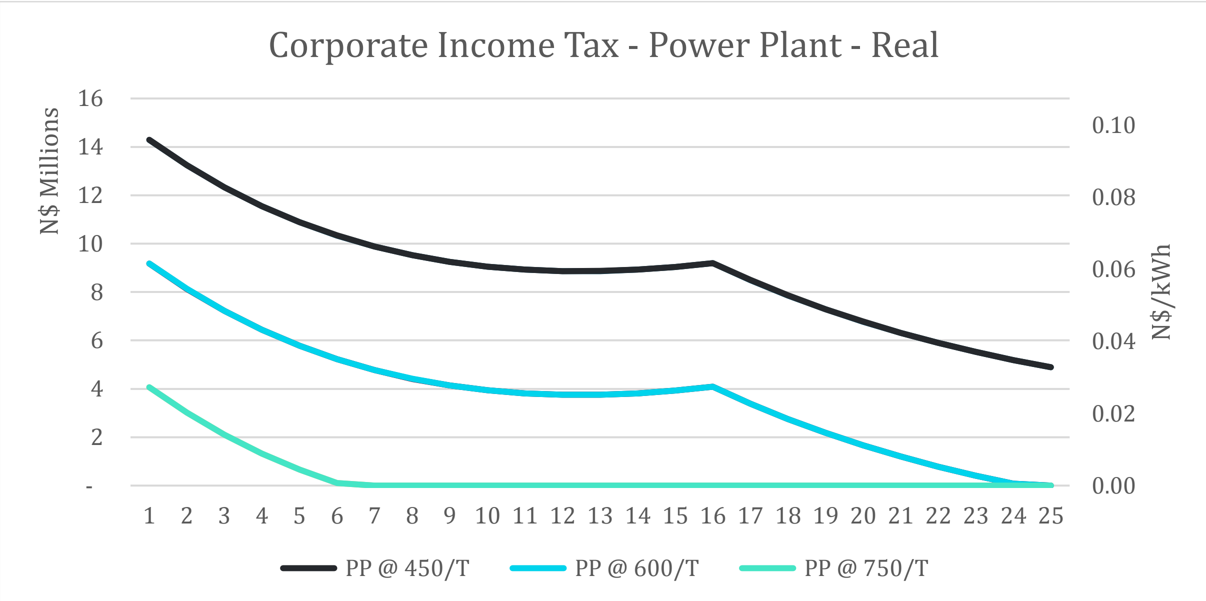

Figure 49: Corporate Income Tax - Power plant – Real

In the case of the power plant, the higher the price paid for fuel, the lower the corporate income tax paid by the power plant. At the higher price point, the power plant runs into losses from year 6, after which it does not contribute to income tax at all. The net present value of income taxes received in presented below.

	NPV of Taxes	NPV/kWh
Power Plant		
N$ 450/tonne	222,368,463	0.06
N$ 600/tonne	94,788,808	0.03
N$ 750/tonne	11,279,279	0.00

Scenario 1		
N$ 450/tonne	8,617,980	0.00
N$ 600/tonne	116,092,140	0.03
N$ 750/tonne	243,593,913	0.07
Scenario 2		
N$ 450/tonne	5,969,002	0.00
N$ 600/tonne	96,631,948	0.03
N$ 750/tonne	219,055,455	0.06

Table 26: Net Present value of corporate income taxes

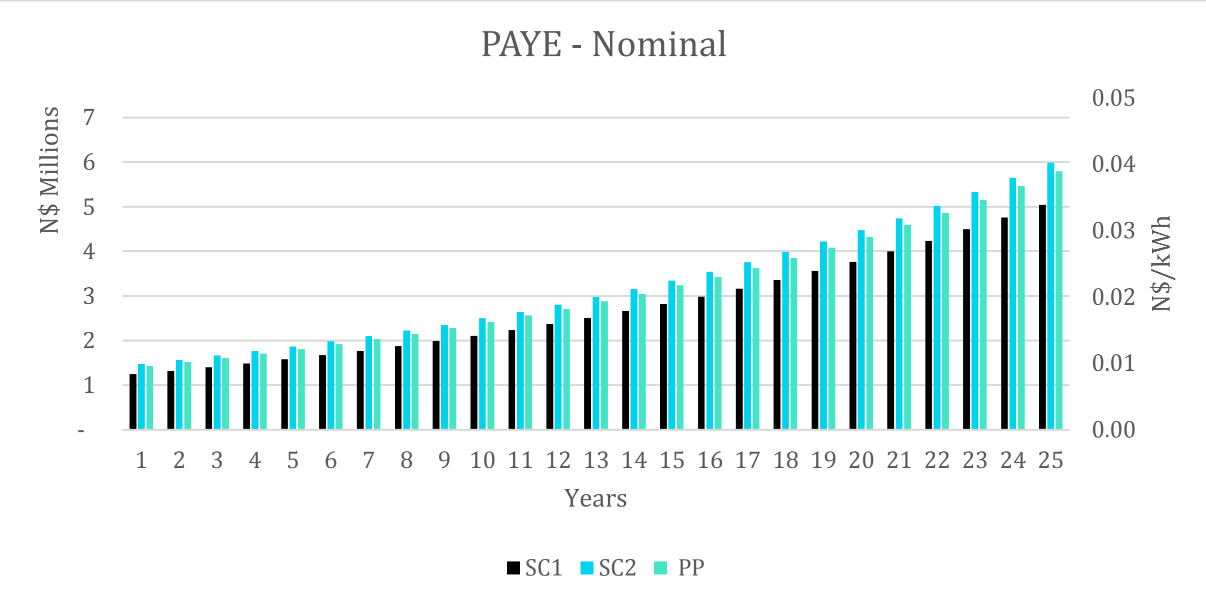

Figure 50: PAYE contributions - Nominal

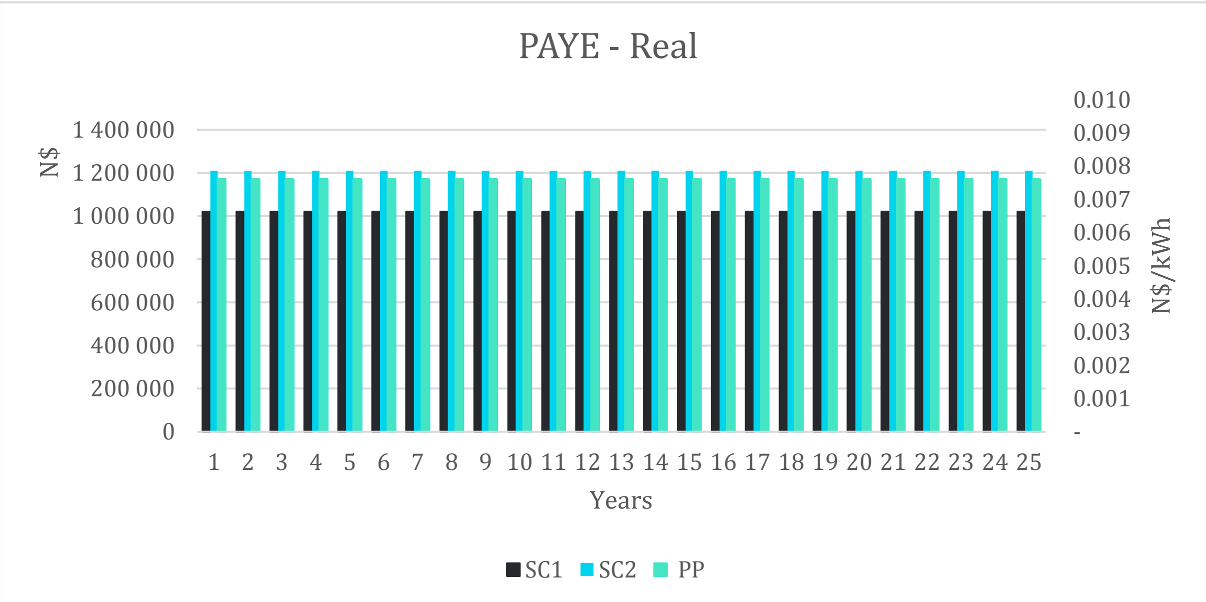

Figure 51: PAYE contributions - Real

In terms of personal income tax (in the form of pay-as-you-earn), the two harvesting scenarios provide similar benefits. This is due to the fact that most of the unskilled labourers fall below the tax threshold, and do not pay personal income tax. On a per kWh basis, the effect is less than 1 Namibian cent per annum, in real terms.

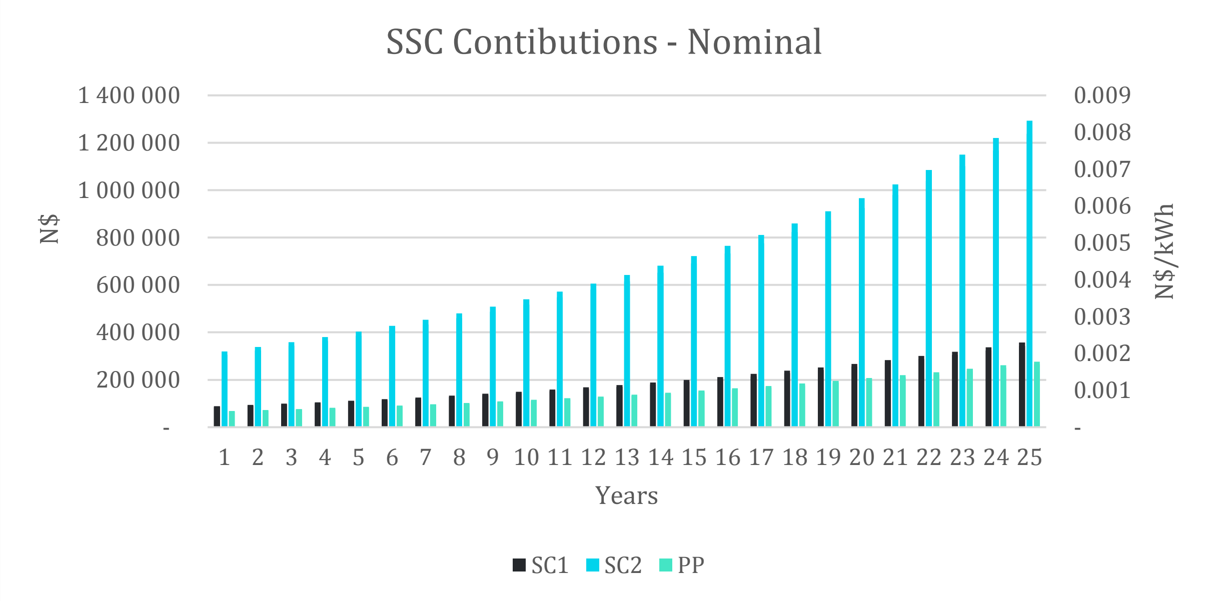

Figure 52: Social security contributions - Nominal

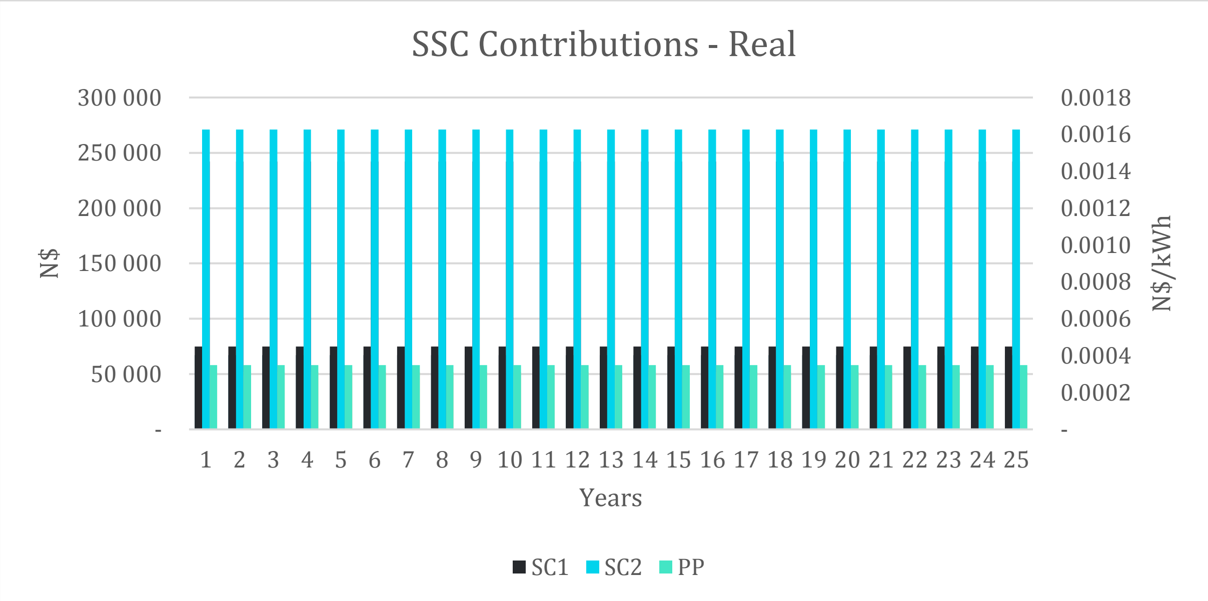

Figure 53: Social security contributions - Real

Contributions to social security will be minimal but vary widely between the two scenarios. Based on Scenario 1, the harvesters will contribute N$ 71,000 to the Social Security Commission in the first year. The net present value of these contributions amounts to N$ 1.67 million over the period. The second harvesting scenario, which employs far more people, will contribute around N$ 256,651 to the Social Security Commission in year 1, which equates to a net present value of N$ 6.05 million. The power plant will contribute roughly N$ 36,000 in social security in the first year, or N$ 1.30 million in net present value terms.

Inflation/ Deflation

Based on 2017 annual energy sales by NamPower of 4,157 GWh, this power plant will represent less than 4% of total energy sales. According to discussions with NamPower, with the current execution philosophy the erection of this power plant will have little to no impact on the overall tariff charged to consumers.

Furthermore, electricity gas and other fuels make up 3.86% of the inflation basket and is generally not a direct input into manufacturing for locally consumed products. As a result, we expect the inflationary impact to be negligible.

Balance of Payments

The effect of the power plant and harvesting on the balance of payments are the net effect of:

- Inflows of financial capital
- Outflows of repayment on debt and interest
- Outflows from capital expenditure for the power plant
- Import substitution effect of electricity
- Outflows from capital expenditure for harvesting equipment, tools and spare parts, and subsequent replacements
- Increased diesel imports for harvesting equipment
- Increased exports of live cattle

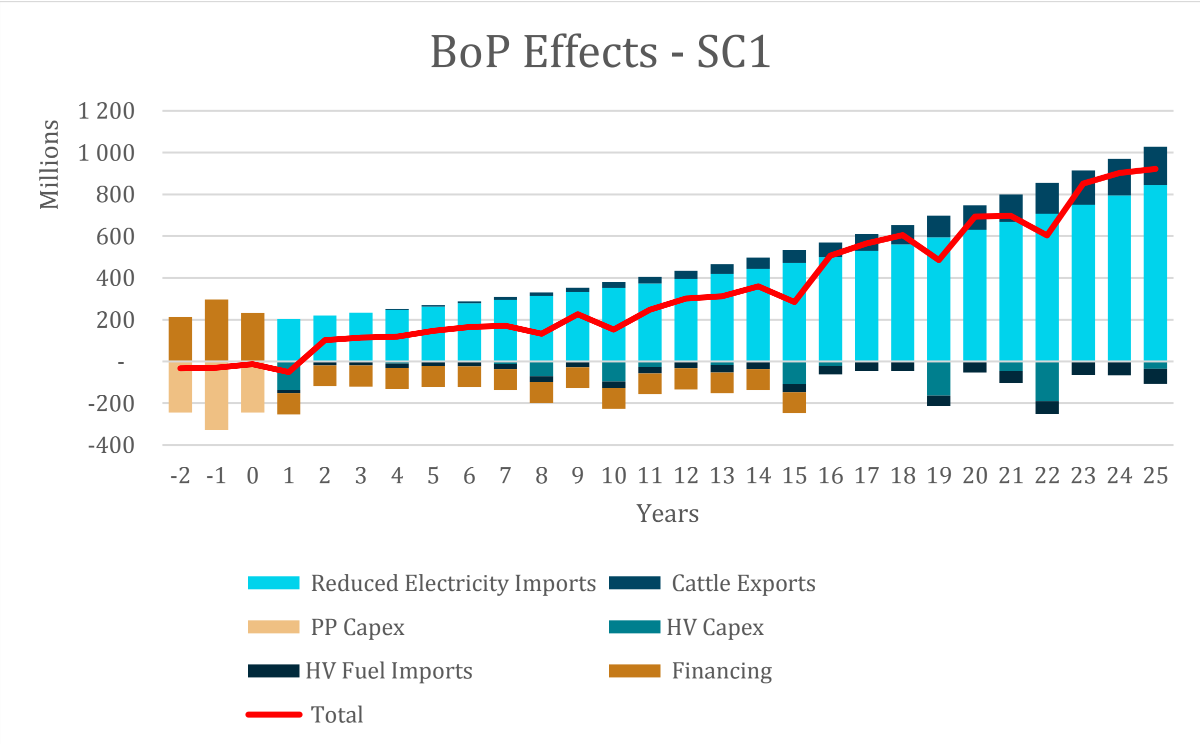

Figure 54: Balance of payments effects – Scenario 1

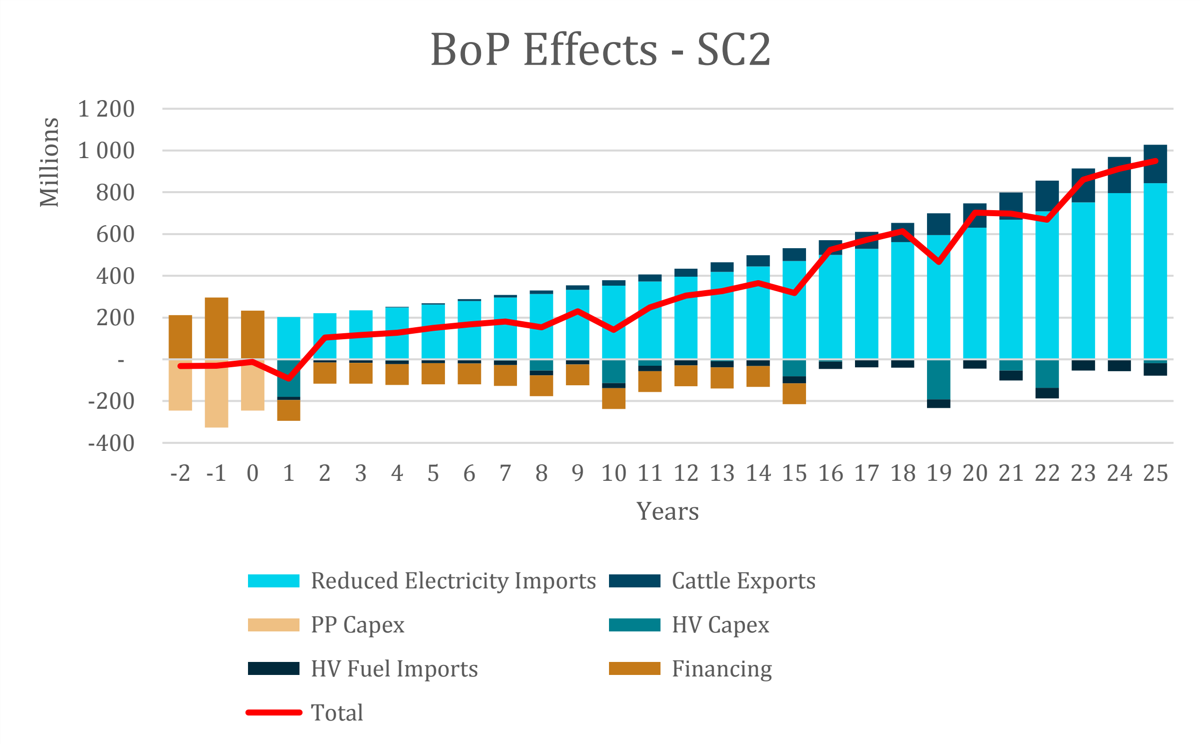

Figure 55: Balance of payments effects - Scenario 2

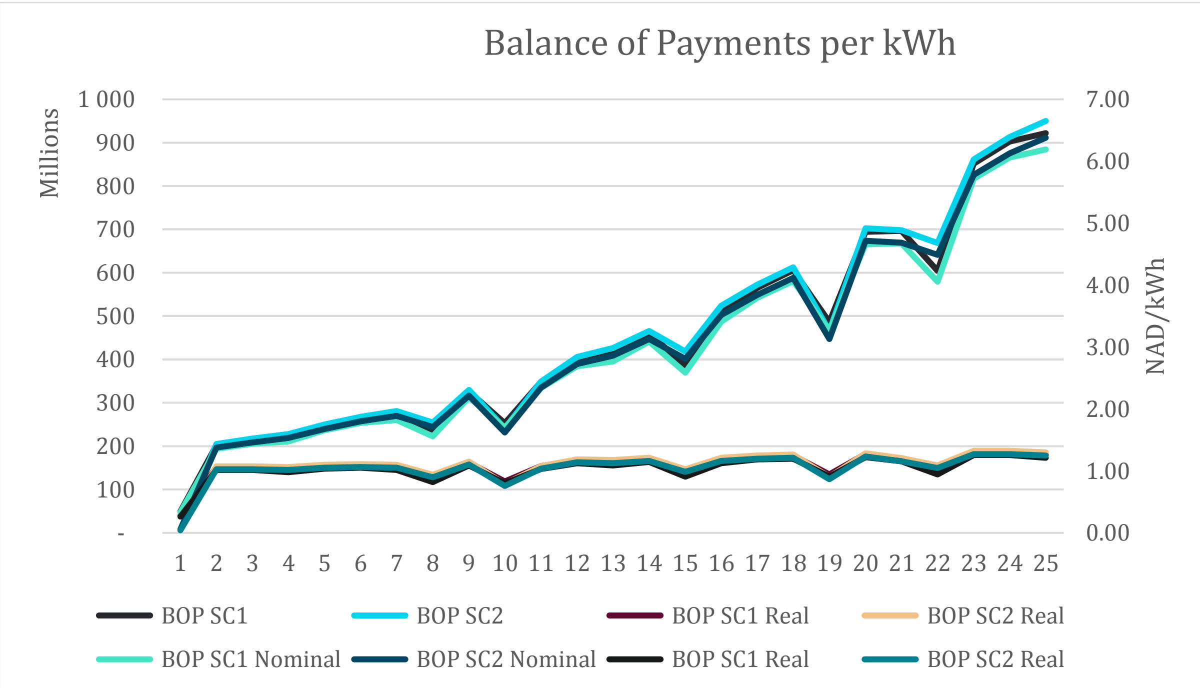

Figure 56: Balance of payments effects - per kWh

The initial impact of construction would be a relatively large outflow to import the equipment for the 20 MW plant. However, this would be offset by financing obtained from foreign sources, such as development finance institutions (DFIs) (e.g. KfW, EIB, Afd etc.). These inflows will be followed by the outflows in the form of payments of interest and principle over a 15-year period.

Harvesting, especially fully mechanised harvesting, is extremely capital intensive. That being said, even the manual harvesting tools such as pangas and axes are imported from South Africa. Additionally, the machinery, specifically the chippers, also require a large amount of (imported) diesel to operate. We estimate that harvesting Scenario 1 will require 1.1 million litres of diesel per annum, while the second harvesting scenario will require around 900,000 litres.

Cattle exports also make a moderate contribution to net-export gains for Namibia, with exports starting from year four. In 2018 value terms, total cattle exports due to the increased carrying capacity of land as a result of bush thinning will total N$ 450.50 million over the project lifetime, or some N$ 0.12/kWh. These sales are a key part of the revenue generated by farmers from cattle sales but are not net-of-operational-costs, meaning they are not comparable to gross value addition. Nevertheless, they contribute to the country's hard currency earnings more than to national GDP.

In total, the net effect on the balance of payments will be N$ 3.12 billion under Scenario 1, and N$ 3.17 billion under Scenario 2, in 2018 values. This is to say that in 2018 terms, the project will have a net-positive impact on Namibia's foreign exchange reserves of between N$ 3.12 and N$ 3.17 billion. This equates to a value/kWh of N$ 0.84 under Scenario 1, and N$ 0.85 under Scenario 2.

	NPV of BOP (2018 N$ values)	**NPV/kWh**
BOP SC1 Real	3,121,125,288	0.838
BOP SC2 Real	3,168,798,696	0.851

Table 27: Net Present value of the balance of payments impact

Security of electricity supply

The security of supply benefits of the project are twofold. Firstly, the power plant falls in a portfolio of renewable energy sources set by our National Integrated Resource Plan (NIRP) 2016. Seeing as wind and solar sources are often intermittent this power plant represents an important source of dispatchable baseload supply. Having a baseload producer on 24-hour notice adds desperately needed flexibility to the current renewable offerings.

Adding the fact that the fuel supply is in abundance in the surrounding area also means that the fuel supply is secure. It is imperative that the inventory of fuel is sufficient to minimise the possibility of downtime due to insufficient fuel stock. This will likely require the plant to store 20,000 tonnes (or two months) of fuel at the minimum.

However, as the power plant is relatively small, it is assumed that the contribution to local security of supply is limited.

Conclusion

The underlying assumptions of this report are based on figures and information provided by NamPower, N-BiG, as well as the referenced material. According to these, an annual feedstock requirement of 106,500 tonnes of biomass is required for the power plant. At an average yield of 12.65 tonne/ha, we calculate harvester will bush thin approximately 8,419 hectares of land a year. As per the terms of reference, three different harvesting methods (being manual, semi-mechanised and fully mechanised) and three different price points (N$ 450/tonne, N$ 600/tonne and N$ 750/tonne) were analysed. In consultation with NamPower, N-BiG and GIZ, it was decided to conduct the study looking at two harvesting scenarios: one focused primarily on mechanised harvesting (90% fully mechanised, with the remaining 10% split evenly between manual and semi-mechanised), while the second was predominantly manual and semi-mechanised (55% split between these two, with the remaining 45% fully mechanised).

Despite other users of encroacher bush within the proposed harvesting area, there does not exist sufficient competition for the resource to the extent that available supply for the proposed power-plant may be threatened. In this regard available supply is far greater than total demand across all users.

The overall microeconomic effect is as a result of the employment creation, salaries and wages, agricultural benefits from livestock production, improved groundwater recharge, reduced CO_2 emissions and the value addition derived from biomass harvesting. At a price of N$ 600/tonne, the first harvesting scenario generates an aggregate gross value addition benefit of N$ 0.40/kWh (discounted at 6% per annum), while under the second harvesting scenario this comes to N$ 0.41/kWh (discounted at 6% per annum).

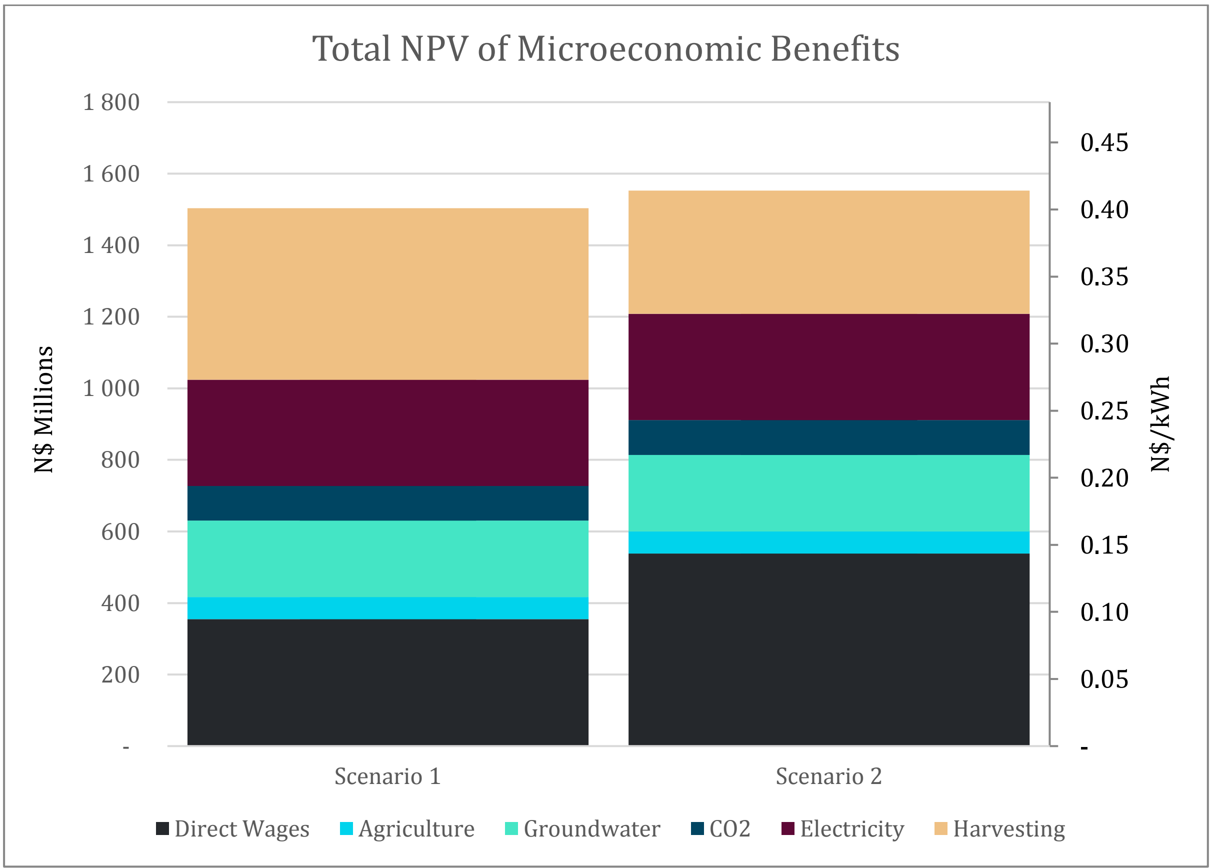

Figure 57: NPV of microeconomic benefits

On the macroeconomic impact, it was noted that while the majority of the employment is generated at the micro level, the contribution to GDP by both personal and corporate income tax is heavily dependent on the price point and harvesting method. As the mechanised harvesters are slightly more profitable, the first scenario contributes more to income tax (at N$ 600/tonne, this is N$ 92 million as opposed to N$ 76 million, in net-present-value terms over 25 years). The large import factor of the power plant construction sees an initial negative impact on GDP. However, the operational phase of the power plant has a smaller, but longer-lived contribution to GDP over its 25-year lifespan, between -0.004% and 0.019% (dependent on the biomass price). The impact on inflation is expected to be negligible, as the 20 MW power plant produces less than 4% of hourly power requirements, and electricity (and other fuels) make up less than 4% of the inflation basket. The balance of payment sees net positive effects, largely due to the import-substitution of electricity (N$ 134 million) and some contribution from cattle and beef exports.

From a price/kWh perspective, the first scenario results in a NPV per kWh of N$ 1.33 and the second scenario results in a NPV/kWh of N$ 1.28 when all value addition multipliers have been incorporated.

From a balance of payments perspective, the NPV of the projects over the power plant lifetime is between N$ 0.84/kWh and N$ 0.85/kWh, depending on the harvesting method/scenario used.

From a tax perspective, the NPV per kWh depends on the harvesting scenario and price/tonne of biomass. At N$ 600/tonne for biomass, the NPV of the first scenario including both the power plant and harvesting is N$ 0.07/kWh, while the second scenario is N$ 0.06/kWh.

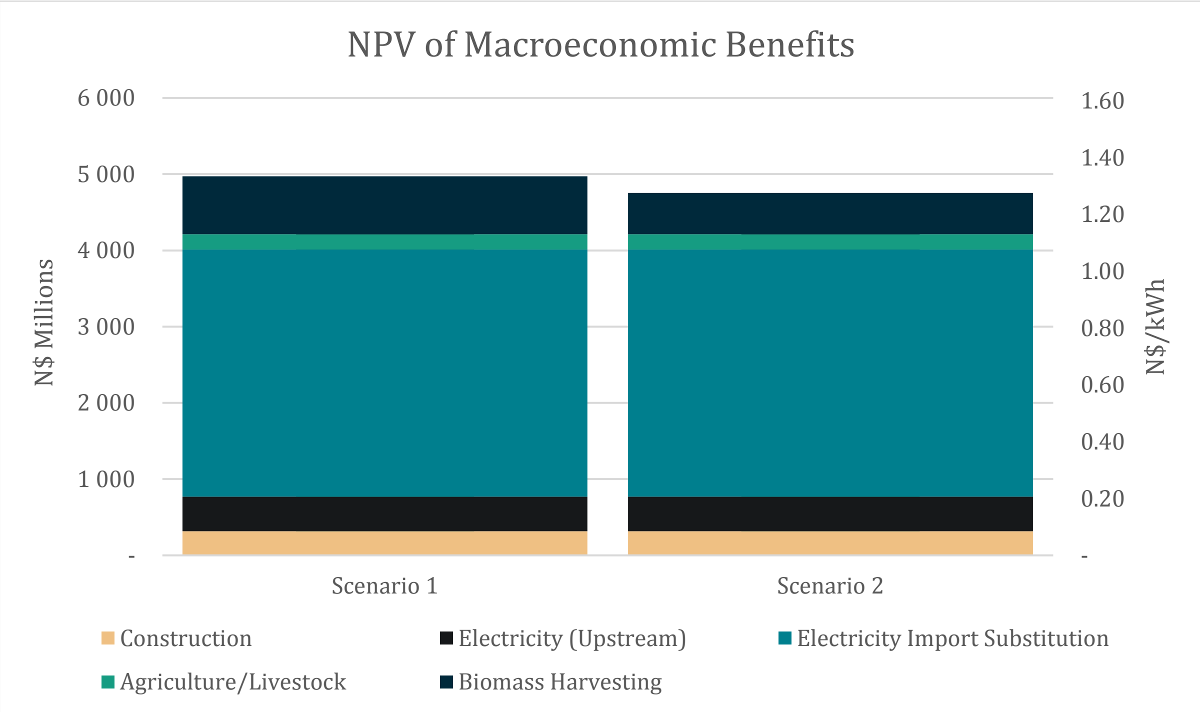

Figure 58: NPV of macroeconomic benefits

The key considerations for this project are around the harvesting methods utilised and the price paid for biomass. While mechanised harvesters are marginally more profitable, the manual and semi-mechanised methods employ more people (albeit at lower wages). Ultimately, the decision will come down to harvesters themselves, who are likely to favour the slightly higher returns under mechanised harvesting. The price point for biomass is the other key factor, as a higher price is beneficial to harvesters, but producers a lower return for the biomass power plant. So, while a price of

N$ 750/tonne is preferable for the harvesters, this jeopardises the feasibility of the power plant. On the other hand, the N$ 450/tonne price point, while preferable for the power plant, is too low for harvesters to generate profit. The N$ 600/tonne price point is the most feasible of the assessed price points for both the power plant and harvesters, and so, many calculations within this study adopt this price point.

The two harvesting scenarios differ widely in their composition. In terms of the overall impact, Scenario 2 employs significantly more persons, especially for unskilled jobseekers. While this does provide a wide social benefit, through employment creation and the income generated by these persons, the majority of workers will fall below the lowest income tax threshold. Scenario 1, on the other hand, is more mechanised and thus employs far fewer people, although at higher wages. However, the fully mechanised harvesting methods tend to be more profitable, and so realistically are more likely to be pursued by independent harvesters. The more manual methods require more administration and supervision of workers, with fairly intensive work possibly leading to high staff turnover. Over and above this, farmers are likely to be wary of large numbers of workers on their land and this may pose problems for harvesting. Thus, while Scenario 2 may look more appealing in terms of its wider employment impact, it may pose some problems pragmatically. Independent operators are likely to prefer the fully mechanised method as it is more profitable and poses less difficulties and uncertainties in terms of human resources, despite its higher capital costs. The biomass power plant project provides far reaching economic benefits, from biomass harvesters, to farmers, to indirect and induced employment. Making use of an abundant resource such as encroacher bush creates more employment than other sources of renewable energy. This project also serves as an alternative offtaker for the use of encroacher bush, and its successful implementation will likely lead to other similar projects, which could reap greater benefits through efficiency gains.

Although there are assumed biomass-based power generation costs associated with operating and maintaining a biomass power station, there are significant economic benefits which were quantified at approximately N$ 0.40 /kWh and N$ 1.33 /kWh for the micro-economic benefits and macro-economic benefits, respectively. These figures also vary slightly, depending on the type of harvesting arrangement (combination of fully mechanised, semi-mechanised and manual labour).

From the National Integrated Resource Plan (2016) the Unit Cost of Energy (N$/kWh) for a biomass-based dispatchable renewable plant is listed as N$ 2.25/kWh and N$ 2.07/kWh for a 5 MW and 10 MW capacity, respectively. The assumptions used in the Macroeconomic study, considering a 20 MW capacity plant operated at 85% capacity factor, uses a Unit Cost of Energy (N$/kWh) which is lower than these quoted for the 5 MW and 10 MW plants. In addition, the Unit Cost of Energy is also expected to be less for a larger 40 MW option.

Taking this into account, the quantified economic benefits on a micro and macro scale are significant when compared to the expected Unit Cost of Energy and should play a vital role in decision making.

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