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STELLENBOSCH BIOMASS POWER STATION
– A FEASIBILITY STUDY

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Eskom

STELLENBOSCH BIOMASS POWER STATION
– A FEASIBILITY STUDY

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A wood-fired Power Station for Stellenbosch that can produce dispatchable power on a continuous basis, irrespective of the weather conditions or time of day, makes this form of power generation an ideal component in the mix of renewable power generation solutions.

Stellenbosch is geographically well positioned to supply a 5 MW *biomass-to-energy [B2E]* Power Station with biofuel for the next 20 years and beyond, as the town is surrounded by extensive biomass resources, from *invasive and alien tree [IAT]* biomass to biomass from old fruit orchards and other unwanted woody biomass. In fact, if long-term operating and management access to the nearby state-owned plantations can be obtained, the additional waste-wood fractions of these woodlots, currently a largely abandoned resource, could provide enough biomass to supply a 10 MW (or larger) baseload power station for the next 25 years and beyond.

This study will show that the technology and expertise exist in the Western Cape to *engineer, procure, and commission [EPC]* a biomass-to-energy power plant of world-class standard, with the required efficiencies and reliability to generate power at a significantly lower *Levelized Cost of Electricity [LCOE]* than its diesel-driven or PV Solar-charged battery storage counterparts.

A full *Environmental Impact Assessment [EIA]* is not a legal requirement for renewable energy power plants up to 10 MW and with a small footprint of less than one hectare, such as the 5.0 MW pilot project proposed in this study. However, an Emission (Atmospheric) Licence must be obtained from the Cape Winelands District Municipality.

The preferred site for this project is on the same grounds as the existing *Wastewater Treatment Works [WWTW]* of *Stellenbosch Municipality [SM]* next to the main Eskom intake substation. This site is within walking distance of the municipal solid waste *Materials Recovery Facility [MRF],* garden refuse handling station, and the solid waste landfill site, off Vredenburg Rd in Stellenbosch.

This location can benefit Stellenbosch Municipality in several ways:

- Sewage sludge from the WWTW can be composted and pasteurised on the same site in aerated windrows, processing sludge, woodchips, and potassium rich wood-ash from the Power Station into a marketable organic growing medium for tree nurseries and fruit farmers in the district.
- Alternatively, the sewage sludge can be pasteurised using steam from the boiler. This Combined *Heat and Power [CHP]* approach will improve the overall thermal efficiency of the Power Station and lower the LCOE.
- Electrical power for the Biomass Power Station can then be supplied directly to SM without any wheeling agreement with Eskom.
- The neighbouring capped landfill site is ideally orientated to accommodate PV Solar panels to blend its low-cost electricity with the B2E Power Station during daytime.
- Several permanent on- and off-site job opportunities will be created. From operating and maintenance staff at the power station, to a host of harvesting personnel, truck drivers, composters, tree nursery workers and others.

- The possibility also exists to pipe raw methane gas from the neighbouring landfill sites to the B2E boiler to be flared off within the combustion chamber for additional thermal energy and efficiency.

Although the proposed 5 MW Power Station can be regarded as viable from a biomass fuel supply and available technology perspective, its total generating cost per unit electricity, measured in kWh, is still higher than what the average retail price of electricity currently is.

At an estimated LCOE of R3.64/kWh (at a conservative capacity factor of 75 %), it will be difficult to find willing customers to buy this power, without some other non-monetary incentive.

The following options could be leveraged to implement the project:

a) Obtain a sponsor/donor that will provide the estimated R336 million (VAT excluded) capital required as a grant to demonstrate the B2E-technology in the South African context. A 100% capital grant will bring the LCOE down to approximately R2.40/kWh.
b) Investigate the option to find off-takers prepared to pay R3.64/kWh for uninterrupted electricity. This will mean that Stellenbosch Municipality supports this option and is willing to wheel the power uninterrupted to these clients during periods of load shedding.
c) A combination of the above options and/or a loan at a near zero interest rate could form part of the way forward.

It should be noted that the escalation curve of the cost of electricity from the B2E Power Station will be significantly less that the average 15% p.a. from Eskom over the past 10 years. It is foreseen that a blended (PV Solar + B2E) price of circa R2.94/kWh will soon be lower than most of the other dispatchable retail power suppliers, including Eskom.

It should also be noted that Biomass Power Stations can produce electricity at substantially lower costs than its baseload power generating competition, namely PV Solar Battery Energy Storage Systems and Diesel-powered Generators.

II. ACKNOWLEDGEMENTS

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- Mr Leon le Grange, CEO of Agulhas Biomass Fuel, Napier, for the biomass detail of the Baardskeerdersbos, Elim, Napier area. Refer to **Annexure E**.
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- Prof Ben du Toit and the team of the Faculty of AgriSciences, Department of Forest and Wood Science, for their work on woodlots. Refer to **Annexure K**.
- Mr Greg Forsyth and Dr Willem Stafford of the CSIR, Stellenbosch, for updating an earlier report on invasive and alien trees in the targeted riparian zones. Refer to **Annexure A**.
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III. GLOSSARY OF TERMS

The following abbreviations, definitions and explanations are applied in this report:

- **AIS:** Alien and invasive species (Also refer to *IAT: Invasive and alien trees*, which would be a more appropriate term to use in this report)
- **B2E:** An acronym for Biomass-to-Energy. [Power or heat generation using biomass as fuel source]
- **Chippers:** General term used for disc chippers (vertical rotary disc with blades) or drum chippers (drum with blade cutters spinning horizontally and equipped with a drum screen). These chippers are generally used to cut wet wood into flakes or dimensional chips. Some drum chippers can be strengthened to chip dry hardwoods like some Namibian encroacher bush species. [Also see “Grinders”, defined below]
- **CHP:** Combined heat and power. Power plants able to generate steam (or heat) as well as electricity
- **CO_2:** Carbon dioxide
- **CV:** Calorific Value as the general term. [Also refer to “GCV” and “Heating Value” below]
- **dia:** Diameter
- **DoA:** Department of Agriculture
- **d.p.a:** Days per annum
- **EIA:** Environmental impact assessment
- **GCV:** Gross Calorific Value, typically measured in kcal/kg, or in the SI system referred to as *Higher Heating Value [HHV],* measured in kJ/kg. Both GCV or HHV refer to the amount of thermal energy available in dry combustible material [*1 calorie = 4.187 Joule*; *1 Joule is equal to the amount of energy required to raise the temperature of 1 cm^3 of pure water from 14.5°C to 15.5°C]*
- **GJ/m^3:** Giga Joules per cubic meter; the term generally used to refer to the *Volumetric Energy Density* of a combustible material [The bulk density of hardwood chips is approximately 4.5 GJ/m^3 versus Power Station (lignite) coal of 21 GJ/m^3]
- **GJ/metric ton or GJ/t:** The units generally used to express the calorific energy available per metric ton of combustible material. Lignite coal has a typical calorific value of 24 - 26 GJ/t vs Eucalyptus (red river gum) of 15 - 16 GJ/t at 20% moisture content
- **Grinders:** The term is generally used for larger chipping or biomass grinding equipment. The preferred grinder type for abrasive dry alien trees or encroacher bush would be a horizontal infeed drum type grinder/chipper with an adjustable anvil (or walking floor anvil) and drum screen. In most cases, grinders are also called chippers

- **GWh:** Giga Watt hours [Equal to one million kWh [Also see “kWh”, defined below]
- **ha:** Hectare [100 m x 100 m = 10 000 m^2]
- **Heating value:** The heating value [or energy value or calorific value] of a substance such as wood, is the amount of heat released during the combustion of a measured amount of the substance. The heating value is typical for each substance. It is measured in units of energy per unit of the substance, such as mass, using parameters such as kJ/kg, MJ/kg, GJ/t or even kJ/mol, kcal/kg or Btu/lb
- **Hogfuel:** The general term used for ground or milled woody biomass used in boilers
- **hp:** Horsepower [1 hp = 0.746 kW] referring to *power* in the Imperial System
- **h.p.:** Horsepower
- **h.p.a:** Hours per annum
- **HPSS:** Hydro Pumped Storage System
- **HV:** High Voltage
- **IAT:** Invasive and alien trees [E.g. Eucalyptus, Pine, Blackwattle, Hakea, etc.]
- **IDC:** Interest During Construction
- **IWMP:** Integrated waste management plan
- **IPP:** Independent power producer
- **J:** Joule
- **km:** Kilometre [1.0 km = 1 000 m]
- **kV:** kilo Volt
- **kWh:** The unit of energy consumption; one kW energy consumed for one hour
- **kWp:** Kilo Watt peak
- **ℓ:** Liter
- **LCOE:** Levelized cost of energy [Normally given in R/kWh]
- **m^2:** Square meter
- **m^3:** Cubic meter
- **MC:** Moisture content, generally expressed as the percentage of water contained in a material
- **MTS:** Main Transmission Station
- **MVA:** Mega Volt-Ampère
- **MW_t:** Megawatt thermal [Heat output measured in Mega (10^6) Watt]
- **MW_e:** Megawatt electrical output [Electrical output measured in Mega (10^6) Watt]
- **MWh*:*** Mega watt hours
- **p.a.:** Per annum

- **p.m.:** Per month
- **PPA:** Power purchasing agreement
- **PSD:** Particle size distribution
- **p.u.:** per unit
- **RVC:** Rapid Voltage Change
- **R/GJ:** Rand per Giga Joule
- **R/kWh:** Rand per kilowatt hour
- **RH:** Relative humidity
- **Riparian Zones:** The area between water surface level and the 100-year flood lines of a river
- **t/m^3:** Tonnes per cubic meter [Bulk density]
- **t.p.a.:** Tonnes per annum
- **t.p.h.:** Tonne per hour
- **t.p.d.:** Tonnes per day
- **t.p.m.:** Tonnes per month
- **t.p.w.:** Tonnes per week
- **t/ha:** Tonnes per hectare
- **ton/tons:** Short ton = 2 000 lbf
- **tonne/tonnes:** Metric or “long tonne” of 2 240 lb or 1 000 kg [Unit of mass used in this report]
- **W:** Watt. Unit of power. Rate of energy transfer over a unit of time. 1W = 1 Joule/second
- **Wp:** Watt peak
- **yrs:** Years
- **Woodlot:** State-owned, local government, and privately owned plantations

1. BACKGROUND TO THE PROJECT

1.1 Introduction to the need for dispatchable power

The average daily energy demand of Stellenbosch Municipality, excluding Franschhoek and Klapmuts, is roughly 45 MW, with morning and early evening peaks of up to 55 MW. A daily 4.5 MW to 5.5 MW dispatchable power input from a nearby baseload power source would lessen the town's dependence on Eskom by approximately 10%. Such an input would be seen as a reasonable step towards better addressing the town's peak demand and periods of loadshedding. [It is estimated that if approximately 21 MW of in-house dispatchable power can be added to the local municipal grid, the effects of loadshedding can be eliminated.]

A wood-fired Power Station that can produce dispatchable power on a continuous or on-demand basis, by day and by night, irrespective of the weather conditions, would make this form of power generation an ideal component in the mix of renewable power generating solutions. A power generating option of 5.0 MW from a PV Solar installation producing energy from roughly 09:00 till 15:00 per average fair-weather day and *biomass-to-energy [B2E]* for the rest of the day, could be an ideal addition to this solution.

Even if loadshedding is eventually phased out, a near continuous input of 4.5 MW to 5.5 MW of dispatchable power, at a lower cost than its diesel-driven or PV Solar-charged battery system equivalents, would be regarded as a valuable renewable energy generating asset for the local grid. Such a hybrid (biomass blended with solar) renewable energy Power Station would be seen as a fundamentally positive contributor to baseload power and to supply those local industries currently using mainly diesel generators for uninterrupted power supply during loadshedding.

Since an *Environmental Impact Assessment [EIA]* is not required for power generating plants of less than 10 MW on footprints of less than 1.0 hectare, it would be tempting to plan a B2E Power Station of 10 MW right from the beginning. However, this study endeavours to determine the sustainability and long-term viability of a wood-fired Power Station with a gross energy output of > 5 MW_e as its primary goal, and to save on biofuel by introducing PV Solar where practical as a secondary goal.

1.2 Why biomass as fuel for power generation?

The following few paragraphs will show the advantages, with a few limitations, of woody biomass as an available, renewable, and sustainable biofuel for the proposed project:

1.2.1 Availability

Stellenbosch is geographically well positioned near to (unwanted) alien invasive tree biomass resources of the Western Cape. Despite many trials conducted by South African government departments and others to add value by using these unwanted trees, no real long-term cost-effective solution has yet been found to warrant the costs of removing aliens from invaded areas. In most cases, felled aliens are left to rot in situ, or where this poses a fire hazard, disposal thereof is by means of controlled burning. In some cases, mulch for agricultural use is produced but this cannot be offered economically to farmers unless felling is subsidised by either the *Working for Water* or *Working on Fire*, state-funded programmes. This funding from the *National Department for the Environment, Agriculture, Fisheries and Forestry*

[DEAFF] Division: Natural Resources Management Programme is currently being reduced and is already only a fraction of its original value. {Now named the *Department of Fisheries, Forestry and Environment [DFFE]*}.

Invasive and alien trees are often converted into biomass billets, chips or hogfuel[1] (with bulk densities of 280 to 330 kg/m^3) to make it more transportable and easier to handle. However, with a stationary 50 t/h grinder, with electrical power pack, planned to be located at the Power Station site, biomass payloads can be reached by loading felled tree trunks on flatbed trucks to be chipped at the Power Station.

Billets, chips and hogfuel prepared from a mixture of alien invasive tree species can be regarded as an economical biofuel with a typical calorific value of 12.5 to 15.5 GJ/t at moisture levels of approximately 20% - 25%. For more biomass details and general specifications refer to **Annexure C.**

Sufficient biomass is available within a radius of 160 km from Stellenbosch/Klapmuts[2] to power at least a 10 MW Power Station, requiring ± 100 000 tonnes of biofuel per annum.

Although a 10 MW gross output power plant will feature strongly in this study as a possible high road scenario, it is proposed to investigate a more practical and more modest output Power Station of approximately 5.0 MW$_e$ requiring approximately 50 000 t.p.a of biofuel when operating at full load at 90 % capacity factor.

The biomass supply mass can be further reduced to roughly 38 000 t.p.a. when the proposed 5.0 MW B2E Power Station is linked to a PV Solar input of say 5.0 MW for circa 27% of the average day (with the sun peaking from 08:45 to 15:15, or 6.5 hours per day).

This study will show that the supply of > 60 000 t.p.a. of biomass is sustainable, achievable, and available for the next 20 years (and beyond), to feed the 5.0 MW$_e$ net output B2E Power Station. When connected to an expandable and nearby PV Solar farm, the Solar Farm initially only has to cater for the parasitic load of the B2E Power Station, whereafter it can be enlarged to an optimum B2E and PV Solar hybrid power plant. Solar power from a Renewable Energy Trader (such as Energy Exchange or EnPower) can be combined with this B2E project as part of a negotiated *power purchasing agreement [PPA].*

Chapter 6 will deal with the long-term *security of biomass supply* in the Western Cape in more detail.

1.2.2 Calorific value and costs

Biomass specifically prepared for wood-fired boilers (moisture content < 25%) has an average calorific value of close to 13.5 GJ/t and could cost between R700 and R1 000/t (VAT excluded) delivered to the proposed B2E Power Station near Stellenbosch. This translates to an upper

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[1] *"Hogfuel"* is the name given to the fibrous substance formed when trees are milled, chipped or grinded down by a heavy-duty mobile chipper/grinder, equipped with a horizontal grinding drum and built-in screening system. Due to their size, these machines, weighing up to 30 tonnes and more, are self-propelled and are used at the biomass harvesting sites. Billets, on the other hand, are larger than chips, have bulk densities of > 250 kg/m^3 and can be produced from trunks/branches < 180 mm in diameter at a much lower cost than chips.

[2] Klapmuts (part of Stellenbosch Municipality) is situated next to the road infrastructure of the N1 highway and the R44 regional road, as well as near a large Eskom substation; this easily accessible region could well be selected as a future Power Station site.

cost of energy of R1 000/13.5 GJ/t = R74/GJ. See Table 2: Energy cost per baseload fuel type in R/GJ [December 2023]Table 2 for more detail.

It is interesting to note that so-called low ash content coal delivered from the Mpumalanga coal fields by road to the Cape is currently costing > R109/GJ, making coal nearly 35% more expensive than wood from an energy value perspective. It is, therefore, safe to say that a modern wood-fired boiler in the Western Cape can produce thermal energy at a significantly lower cost than its local coal fired counterpart.

1.2.3 Further advantages of biomass as boiler fuel

Further advantages of biomass fuel are:

- Lower ash content of 2 - 3% vs coal @ 15 - 22%
- Lower sulphur content of < 0.05% vs coal @ 2.5%
- Wood-ash is considered an organic and environmentally friendly soil ameliorant, while coal-ash is toxic to soil and must be disposed of at a registered landfill site or equivalent.
- Biomass is cleaner to handle.
- Available from all six major river systems[3] of the Western Cape.

1.2.4 Disadvantage of biomass

The most significant disadvantage of woody biomass is its low *energy density*. Table 1 shows the approximate energy densities of fuel used to generate dispatchable power.

Table 1: Energy densities of some comparable baseload fuels

Fuel type	Energy Density [GJ/m^3] = CV [GJ/t] x Average Bulk Density [t/m^3]
Diesel	44.5 x 0.85 = 37.83
Coal	23.0 x 1.10 = 25.30
Wood (Mixture of alien invasives @ < 25% moisture content in chipping/hogfuel format)	13.5 x 0.30 = 4.05
Biomass pellets (from the same mixture of alien invasives) @ 8% moisture content	18.0 x 0.65 = 11.70

This low energy density characteristic of chipped woody biomass makes the necessary materials handling and stockpiling large and bulky compared to other fuels. However, this study proves that the cost of hogfuel generated energy is so reasonable that the capital cost of large biomass storage and the more complex infeed facilities can be warranted. [Biomass

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[3] The Berg, Breede, Hex, Bot, Zonderend and Olifants river systems.

pellets are not considered viable at the large volumes required by this project, as Table 2 shows.]

1.2.5 Biofuel supply volumes applicable

The invasive and alien trees supply base of the Western Cape (based on a previous study conducted by the CSIR, see **Annexure A**) can sustainably produce 180 000 t.p.a. of biomass from selected riparian zones within an 80 km radius from Worcester for > 20 years. The results of the above study are expected to be similar when the centre of the supply base is shifted to either Klapmuts or Stellenbosch. It is proposed that the maximum volumes required for this project not exceed 50 000 - 60 000 t.p.a. from the river systems for the first approximately 10 years. For years 10 to 20 it is proposed that replanted *woodlots*, dedicated or formally linked to this project, become the primary biofuel source to the B2E Power Station.

An important factor in the biofuel supply chain is the re-establishment of selected woodlots in the targeted supply base of the Power Station into high-density/high yielding biofuel producing, well-managed entities dedicated to supplying the Power Station. This approach will ensure biomass availability to the Power Station for the long term and will make up a substantial part of the future biofuel supply strategy of the proposed project. Refer to **Annexure J** for more details of the *Woodlot Revival Plan* by the SU Faculty of Forestry.

It is further proposed to make the general biomass supply base not further than a radius of approximately 100 km by road from the wood-fired Power Station.

Chapter 6 will go into more detail regarding the actual areas and biomass volumes applicable to this study and will show that enough biofuel exists within the targeted areas to later supply an up to 10 MW_e gross output wood-fired Power Station. It is, however, proposed to start with a more conservative B2E power plant of 5.0 MW_e – to be optimised once the final equipment supply team can be formally appointed to do the detailed design, based on the available biofuel volumes and specifications.

1.2.6 Positive environmental impact

Finding a useful and cost-effective purpose for unwanted biomass will accelerate the restoration processes of catchment areas of rivers and bulk storage dams. Refer to *Chapter 4* for further detail in this regard.

A monetary value for biofuel produced from labour intensive woodlots will create sustainable income for the necessary care and maintenance thereof. The Power Station is a long-term investment requiring a long-term biofuel supply. Woodlot plantations are complex business ventures requiring long-term off-take agreements to survive financially. Most of these woodlot areas, which are currently lying fallow and in a general state of disrepair, are attracting informal harvesters, beekeepers, and illegal squatters, and are, amongst other things, becoming a wildfire hazard.

1.2.7 Biomass from alien invasives for the long-term

Although not the only source of biomass, there are enough alien invasives available as the primary component of biofuel for this project for at least 10 to 15 years at a harvesting tempo of ± 100 000 t.p.a., and much longer at a harvesting tempo of ± 50 000 t.p.a. A virtually unlimited seedbed of these trees is entrenched in the Western Cape's river systems and catchment areas, waiting to germinate. The fight against these high water-consuming alien trees needs a long-term and focused project that gives value to this (unwanted) renewable resource, to ensure better control and be financially sustainable. The wood-fired Power Station is poised to do just that and give sufficient value to this wood for it to fund the management and control thereof. In fact, this project can be the incubator to provide off-take agreements to re-establish woodlots in selected areas of the province, to supply biofuel to more than one of these wood-fired Power Stations.

1.3 Methodology applied to gain data for this study

The following local *champions of industry* were invited to assist the CRSES and NRGen team with actual data pertaining to, and needed for, an accurate assessment of the sustainability of this project:

- Messrs Willem van der Merwe (CEO) and Cobus du Plessis (Commercial Manager) of Africa Biomass Company, Worcester – A large biomass handling company.
- Mr Gerhardus Neethling (CEO) Vallei Organies, Worcester – A large biomass transporting organisation.
- Mr Dave Lello (CEO) Ekasi Energy, Stellenbosch – Biomass pelletising and torrefied wood specialist.
- Mr Darryl Phipps Pr Eng (MD) Adsorb Technologies, Johannesburg – Gasification, pyrolysis, biochar, and activated carbon specialist.
- Mr Leon le Grange (CEO) Agulhas Biomass Fuel, Napier – A biomass harvesting and value-adding company.
- Messrs Dana Snyman, Edward Ehlers, Richard Ehlers, Casper Steenkamp of TFDesign, Stellenbosch – A design and project implementation company with many years' experience in this field.
- Mr Etienne de Villiers (Executive Technical Manager) of Actom - John Thompson Boilers, Cape Town – A steam boiler manufacturing company.
- Mr Matthys du Toit, (CEO) Steamhouse Western Cape, Cape Town, and Vyncke represantative – A steam boiler repair and installation group.
- Dr William Stafford, author of the CSIR biomass audit report of 2019 – Refer to **Annexure A.**
- Prof Wikus van Niekerk (Dean: SU Faculty of Engineering) and his team at the Centre for Renewable and Sustainable Energy Studies.
- Prof Bruce Talbot, Prof Ben du Toit, and their team at the Department of Forest and Wood Science, SU Faculty of AgriSciences – Refer to **Annexure K**.

Several work sessions were held with the above people to compile the submissions contained as Annexures within this study and report.

The professional team is confident that the data and figures used in this study-report are recent and sufficiently accurate for the purposes of this report.

Work sessions were also held with engineers at the Faculty of Engineering of the University of Stellenbosch and its *Centre for Renewable and Sustainable Energy Studies* to debate and refine the work contained in this feasibility study.

2. AIMS AND OBJECTIVES

2.1 The need for dispatchable power

A power-on-demand generating system at a continuous net output of 5.0 MW_e would make the energy generation mix with PV Solar (and wind) more ideal for the needs of the Stellenbosch Municipality. Better management of early morning and late afternoon energy demand peaks can then be enabled.

Loadshedding is currently addressed by Stellenbosch University, local industries, and businesses using diesel generators mainly, at costs of more than R 8.00/kWh depending on the hours in use. Middle-class households are progressively adding inverters and battery systems to their homes, and some of the more affluent communities have included PV Solar panels to charge the batteries of their household installations, at typical energy costs exceeding R 5.00/kWh.

It is therefore an aim of this study to show that electricity can be generated at significantly lower costs by using woody biofuel as an energy source, rather than its diesel and PV Solar-charged battery system [BESS] equivalents.

2.2 Finding a useful purpose for unwanted and redundant biomass

The second aim of this B2E project is to find a sustainable use for invasive and alien trees, other waste woods, and unwanted biomass like the woody parts of garden refuse and the biomass of old orchards and vineyards in the surrounding local fruit- and wine-producing agricultural sector.

In fact, this project should aim to create a steady biomass off-take from the surrounding fruit and wine farms currently disposing of old orchards and vineyards by dozing them into windrows for drying and disposing of these through burning.

A financially sound solution for using biomass from invasive and alien trees would lead to the sustainable and labour-based control of this infestation, leading to job creation, and a better natural environment. It would lead to long-term local economic development programmes focussing on the felling and chipping of alien vegetation to sell to the Power Station as fuel for the duration of the techno-economical lifespan of said Power Station, which could be longer than 20 years. Typically, wood-fired boilers have working lifespans exceeding 40 years.

Felled trees and tree trunks can also be delivered to the on-site chipper/grinder, which is a more cost-effective option for most tree-harvesting contractors. (For more detail in this regard, refer to §6.3).

An area of particular interest is the basin above the Idas Valley dams, which belongs to the *Stellenbosch Municipality [SM].* SM has the duty of care in the area - to remove the large invasive trees, mainly thirsty Eucalyptus species, which will not only restore this area to a more natural state but will also increase the water run-off to the two dams, making more water available for the town.

2.3 Biomass-to-energy: Beating other fuel options for dispatchable power

Table 2 *illustrates the cost of energy per fuel type currently being used for small to medium-sized power generators:*

Table 2: Energy cost per baseload fuel type in R/GJ [December 2023]

Baseload fuels **Variable and CV**	**Fuel Type**				
	Low ash pea-coal for boilers [For reference purposes only]	**Industrial diesel used in generators**	**Mixture of alien invasive tree biomass chips/hogfuel**	**Mixture of alien invasive biomass pellets**	**Mixture of IAT and fruit orchards in billet format**
Cost of fuel delivered to the Stellenbosch area [R/t]	2 500 - 3 000	19 270[4]	± 1 000	1 900 - 2 100	± 700
Approximate calorific value [GJ/t]	23 - 25	45.5	13 - 14	18	13
Cost of energy [R/GJ] (rounded)	109 - 120	424	71	106 - 117	54

From Table 2, a mixture of biomass from IAT, such as Eucalyptus and Black Wattle trees, has a lower energy cost than coal. It is approximately 30% lower than coal delivered to the Western Cape.

- In billet format, the biofuel costs can be further reduced – but is not recommended for this application, because of boiler combustion chamber limitations.
- Diesel applications are popular because a *genset* can be purchased at short notice, and diesel, although expensive as a fuel, is readily available with a high energy density, making it easy to handle.
- For this project, the use of biomass pellets is not viable. Biomass pellets are better suited to smaller B2E applications.

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[4] Diesel for agri-industrial use @ ± R23/liter (Dec 2023); Density of diesel = 0.838 kg/liter
∴ The cost of industrial diesel = 23.00 x 0.838
= R19.27/kg
Or = R19 270/t

2.4 The main objective

The main objective of this Feasibility Study was to prove to potential buyers of the B2E-generated power that electricity can be produced at costs as low as R2.50/kWh, VAT and escalations excluded (Dec 2023). In addition to demonstrate to current users requiring uninterrupted power, employing PV Solar BESS and diesel-driven equivalents, that a Biomass Power Station can be more economical.

To enable the Biomass Power Station to reduce its LCOE from R 3.64/kWh to say R 2.50/kWh, will however require further optimisation (such as PV Solar blending, better plant utilisation/Capacity Factor, etc.) which was not part of the *Terms of Reference* for this study. [*Further research in possible ways to improve the above LCOE is however continuing as part of an MEng (Industrial Engineering) research project at the SU Faculty of Engineering and should be available by the end of 2024*].

3. DEFINING THE VIABILITY OF THE PROJECT FROM A *LOCAL ECONOMIC DEVELOPMENT* PERSPECTIVE

3.1 Financially

The project should be regarded as (technically) viable when the cost per unit of useable electrical energy generated, measured in R/kWh, is found to be lower than other practical dispatchable (baseload) power generating options like:

- Electricity generated by diesel-driven applications.
- Electricity from PV Solar-charged battery systems.

An aim of this project was to be at least 15% to 20% more cost-effective than battery power and 25% to 30% more cost-effective than power from an equivalent diesel-driven generator when measured over a utilisation period of say 8 000 hours per annum or running at circa 90% capacity factor. However, after a work session with the *Energy Exchange (Remgro),* it was suggested to strive for a much lower selling price of approximately R2.20/kWh to R2.50/kWh to be able to better compete with baseload B2E power generation from the sugar industry in KZN. (Refer to § 14.2.4 for a more detailed explanation.)

3.2 Environmentally

The B2E Power Station will have these more environmentally friendly aspects than comparable diesel and natural gas generators:

- Cleaner emissions with virtually zero SO_2
- Lower noise levels
- Renewable fuels are used
- An overall lower carbon footprint
- Working towards becoming an integral part of other renewable energy projects, including PV Solar and a possible future *hydro pumped storage system [HPSS].*

3.3 Socially

The B2E project aims to provide several permanent and sustainable job opportunities to do the following:

- Harvesting and preparing invasive and alien trees into useable biofuel/hogfuel – providing an opportunity for the *Working on Fire* and *Working for Water* contractors to sell their biomass harvest to the Power Station instead of burning it.
- Operating and maintaining the B2E Power Station.
- Composting the wood-ash, fly-ash, twigs, buds, leaves, and other green waste together with sewage sludge from the Wastewater Treatment Works of the Municipality, into a *growing medium* for trees and fynbos as part of an on-site nursery unit for woodlot trees and fynbos-area restoration.
- Creating a better and safer environment for beekeepers and honey farmers, by lowering the fire risk inherent to alien species. Further, the proposed new woodlots could be planned by the specialist team of Stellenbosch University's Department of

Forestry and Wood Science to incorporate hives and beekeeping, in close collaboration with the local authorities and established and emerging beekeepers.

4. THE POTENTIAL BENEFITS OF AN INTEGRATED APPROACH TO BIOMASS POWER GENERATION

4.1 Utilising and controlling invasive and alien trees

As seen from the preceding chapters, biomass boiler fuel produced from invasive and alien trees will give this redundant, unwanted yet pervasive commodity a better and long-term value. A valued biofuel from harvested biomass would lead to a more sustainable way to manage and control these trees and will provide a definite purpose for the pro-active restoration of catchment areas, riverbanks, and other invaded areas.

Over the past nearly 20 years, approximately 80% to 90% of alien invasives removed from riverbanks and catchments were burned to dispose thereof. In a few instances, some of the wood was chipped and sold as mulch to the agricultural sector. However, it is estimated that when the *Working for Water* programme was running at its peak (2015 - 2017), more than 180 000 tonnes per year of alien biomass was burned for disposal in the Western Cape. Rather, seeing this biomass instead as a useful biofuel for power generation (or *Combined heat and power* generation) could make clearing of alien invasives not only self-funded and therefore sustainable, but also more environment friendly.

Working for Water contractors, during the past 2023 winter rainy season, reported that felled and stockpiled trees waiting to be burned were, on a few occasions, washed down bordering riverbanks into rivers, causing bridges to be blocked. This, in turn, led to the partial washing away of these bridges and causing other stormwater damage. It is therefore essential that biomass be harvested and processed on a more continuous basis and in a less environmentally damaging way than burning it in the open.

4.2 Managing and absorbing other unwanted and redundant waste woods

An opportunity is proposed to better absorb the following waste woods:

- The woody components of garden refuse are often found in large stockpiles at municipal landfill sites, and garden refuse transfer sites throughout the Cape Metro and larger municipalities of the Western Cape. Refer to **Annexure J** for more detail. These large volumes of garden refuse are being reduced by chipping contractors at several of the above garden drop-off sites to produce low grade, and often not sufficiently pasteurised, compost. This compost could be used as cover material at landfill sites as it generally does not qualify for use in agriculture, mainly because of the presence of glass fines, small pieces of plastic, and other impurities. Microplastic infestation of agricultural land to produce food must be prevented at all costs.
- Trees infested by the *polyphagous shot hole borer beetle* need to be felled, chipped, and incinerated – a function which the proposed wood-fired boiler system of this project can do. In this case, incineration is essential to prevent further spreading of the damaging pest.
- Any industrial wood waste from furniture, chipboard, pallets, and other factories using wood as raw material.

4.3 Establishment of labour-based productive woodlots

This B2E project could provide the opportunity to better utilise the existing licenced woodlots of municipalities, Cape Nature and DFFE. Harvesting and re-planting of these woodlots – for future use as biofuel – could be the answer to re-establish neglected woodlots urgently in need of a formula to operate and manage them in a sustainable way for the long-term. A labour-based, high-quality composting unit – utilising ash, leaves and twigs from harvested biomass and sewage sludge from Wastewater Treatment Works – could provide growing medium to off-site clients and an on-site nursery producing carefully selected tree species for future biofuel production.

These woodlots will be scientifically established and managed like a productive forestry project. Beekeeping by qualified beekeepers should be allowed at these woodlots as part of an integrated local economic sub-section of the Power Station project. To reduce wildfire risks, beekeepers should be better trained in the use of smokers for their beehives.

An *Integrated Masterplan* is proposed to re-establish existing municipal and DFFE woodlots in the targeted supply base area. An opportunity, therefore, exists for the SU Faculties of AgriSciences and Engineering to facilitate this prospect with the Provincial Government, Cape Metro, surrounding Local or District Municipalities and DFFE. The proposed Power Station near Stellenbosch should be seen as an *Incubator Project* to demonstrate the economic generation of baseload renewable electricity, and if found to be running well, can be duplicated near areas with large woodlots, like Grabouw. It is important to note that the expected life of a wood-fired Power Station can be 40 years or longer. Long-term cyclic biofuel utilisation from re-established and well-managed woodlots could be an ideal opportunity for the Western Cape Provincial Government and DFFE to revive this industry into a job-creating gem. For the first time in many decades, a long-term use for wood of alien invasives can be established, even providing a reasonable and constant financial income.

See **Annexure K** for a more detailed description of the proposed new approach to the master planning, ownership/custodianship, and re-establishment of existing licenced woodlots. It is proposed that the Faculty of AgriSciences compile this masterplan under the guidance of that faculty's Dean, Prof Danie Brink, and his team.

The following assumptions can be made for the woodlot master planning process:

i. The proposed 5 MW - 10 MW wood-fired Power Station would require between 50 000 and 100 000 t.p.a. of biomass at an average moisture content of 25 % delivered to the Power Station in log format.

ii. The above biofuel volumes per annum are estimated to remain more or less constant for 20 years and beyond.

iii. The *Independent Power Producer [IPP]* and owner of the Power Station will pay between R 250 and R 350 per tonne (excluding VAT) for whole logs arriving on site; the price depends on the calorific value and moisture content.

iv. The proposed Power Station will be equipped with an on-site weighbridge, laboratory, a large 50 t/h 400 kW horizontal grinder for trees and logs up to 1.2 m diameter. Refer to **Annexure G** for cost calculations of the proposed on-site grinding plant.

v. The IPP will negotiate medium-term contracts (5 years, renewable for a further 5 years) with biomass suppliers willing to pre-prepare felled unwanted trees or vines into transportable logs (or billets in the case of old orchards and vineyards) to be grinded into hogfuel at the Power Station site in Stellenbosch.

4.4 Integrating the B2E Power Station into the grid and with other alternative energy sources

The proposed *B2E Power Station* near Stellenbosch should form an integral part of the local electricity distribution network of Stellenbosch Municipality to better address peak demand periods and periods of loadshedding.

The new Power Station should ideally form part of a larger renewable and alternative energy supply masterplan and/or the *Integrated Waste Management Plan [IWMP]* of the Stellenbosch Municipality.

The energy supply options will include a mixture of large-scale PV Solar and a possible future hydro pumped storage scheme with water from the Idas Valley dams. A masterplan in this regard can be compiled at a later stage.

4.5 Grid study for B2E Power Station

Stellenbosch Municipality currently receives electricity from Eskom at Stellenbosch substation at 66 kV, at the Cloetesville substation at 66 kV, at the Franschhoek substation at 66 kV, and at the Kylemore substation at 11 kV. Figure 1 shows the Eskom *high voltage [HV]* network which supplies these four substations. The transmission source for this network is at Muldersvlei MTS which in turn supplies Stellenbosch and Safariland substations via the 132 kV reticulation network. Cloetesville and Kylemore substations are supplied from Stellenbosch substation at 66 kV and Franschhoek substation is supplied from Safariland substation via Wemmershoek at 66 kV.

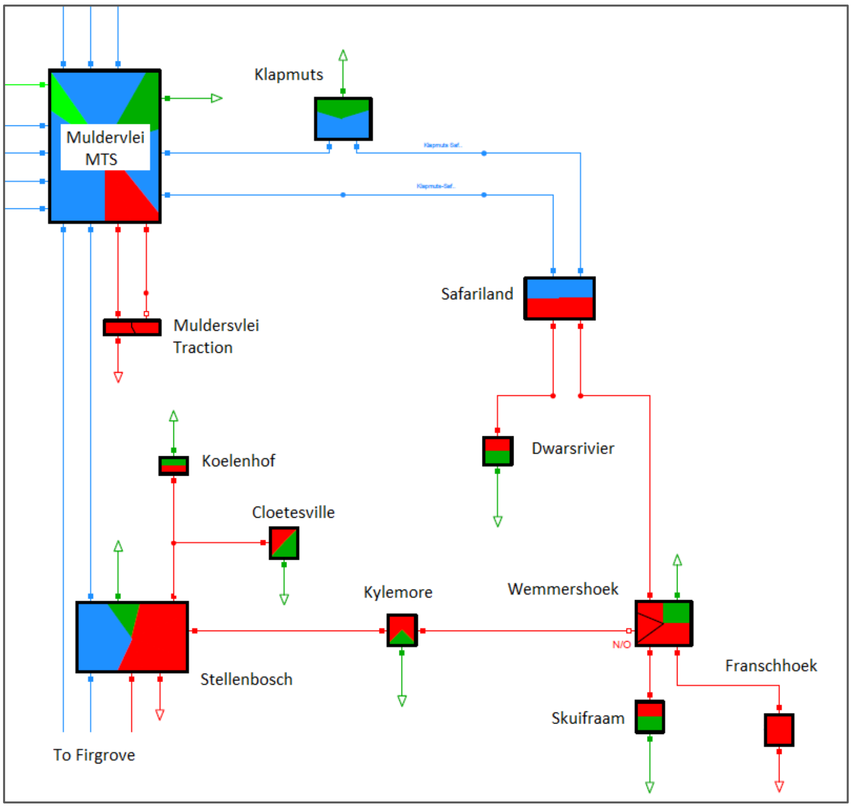

Figure 1: Eskom Polkadraai HV network, showing the main supply points to Stellenbosch Municipality

Due to the proposed biomass plant being near the Stellenbosch substation, this substation was considered as the most feasible grid connection point for the plant. Grid integration studies were performed to determine whether it is technically feasible to connect a 5 MW biomass plant at this substation and what the high-level cost of the grid connection would be.

The grid integration studies were performed using *Digsilent Powerfactory* software and the latest network data as obtained from Eskom and Stellenbosch Municipality. For each connection option, the following steady-state simulation studies were performed, and the following technical limits were considered:

A. Power flow analysis under various operating scenarios (loading and generation) at the point of connection. The following scenarios were studied:

    i. High load, high generation

    ii. Low load, high generation

B. For each scenario, the following limits and system impacts were studied:

    i. Equipment thermal loadings

    ii. Busbar voltage levels at the *Point of Connection [PoC]*

C. *Rapid Voltage Change [RVC]* test

The technical criteria that were studied and the limits that need to be adhered to are as follows [according to the South African Grid Code, Version 10.0, National Energy Regulator of South Africa, August 2019]:

- Thermal limits: 80% of equipment rating
- Busbar voltage levels at the PoC: 0.95 p.u. – 1.05 p.u.
- RVC limit: 5%

The study results and costing are given below for the two possible connection options available at the substation.

OPTION 1: 66 kV connection at Stellenbosch substation

Stellenbosch substation has 2 x 132/66 kV 80 MVA transformers and a third 132/66 kV 45 MVA transformer that is on standby; Stellenbosch Municipality takes supply at 66 kV at Stellenbosch substation, shown in Figure 2. For this option, it is proposed to connect the 5.0 MW plant to the 66 kV busbar at Stellenbosch substation.

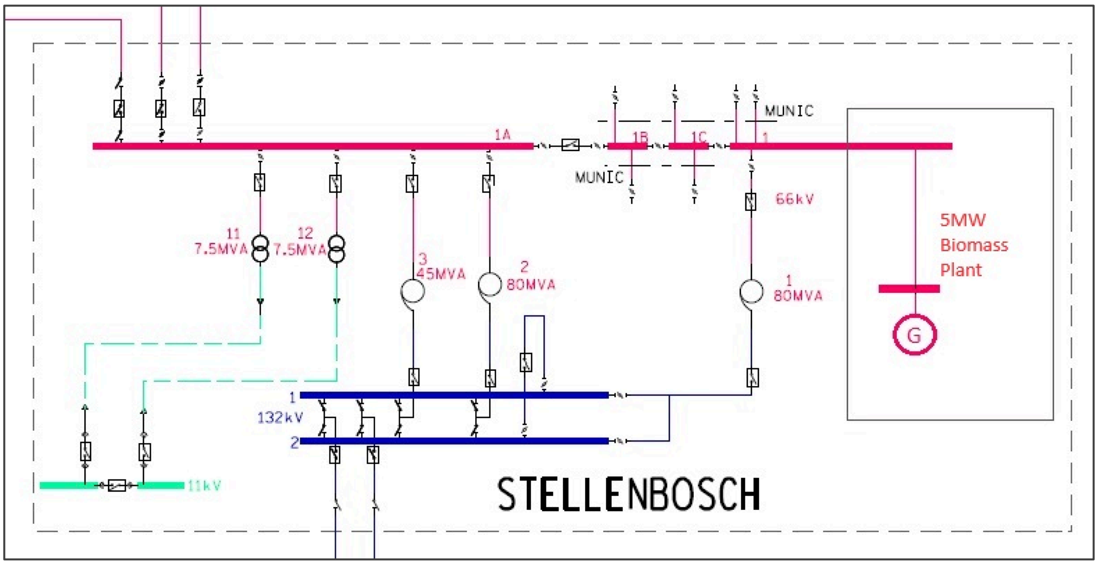

Figure 2: Stellenbosch substation diagram, Option 1
[Distribution System Diagram, Eskom WCOU, 2012]

Simulations were done taking this arrangement into account. For this option all the technical limits are maintained, and the simulation results are given in Table 1Table 3.

Table 3: Grid study: 66 kV results

		Low Load		High Load	
	Voltage Level	*Voltage at PoC BB*	*RVC %*	*Voltage at PoC BB*	*RVC %*
Stellenbosch SS	66 kV	1.03 p.u.	1.01%	0.98 p.u.	1.04%

Even though this connection option is technically feasible, and all the technical limits are maintained, the cost of the connection is high due to the connection at 66 kV. A high-level indicative cost estimate for the connection of the biomass plant at 66 kV is given below in **Table 4**.

Table 4: Option 1 grid cost [Excluding overheads and IDC]

HV PLANT ITEM	COST
10 MVA Transformer	R14 m
Single Busbar	R5 m
Transformer Bay	R3 m
Feeder Bay	R4.7 m
Control Building	R1.6 m
Transformer Platform	R2.6 m
66 kV O/H Line	R1 m
TOTAL COST	**R32 m**

OPTION 2: 11 kV connection at Stellenbosch substation

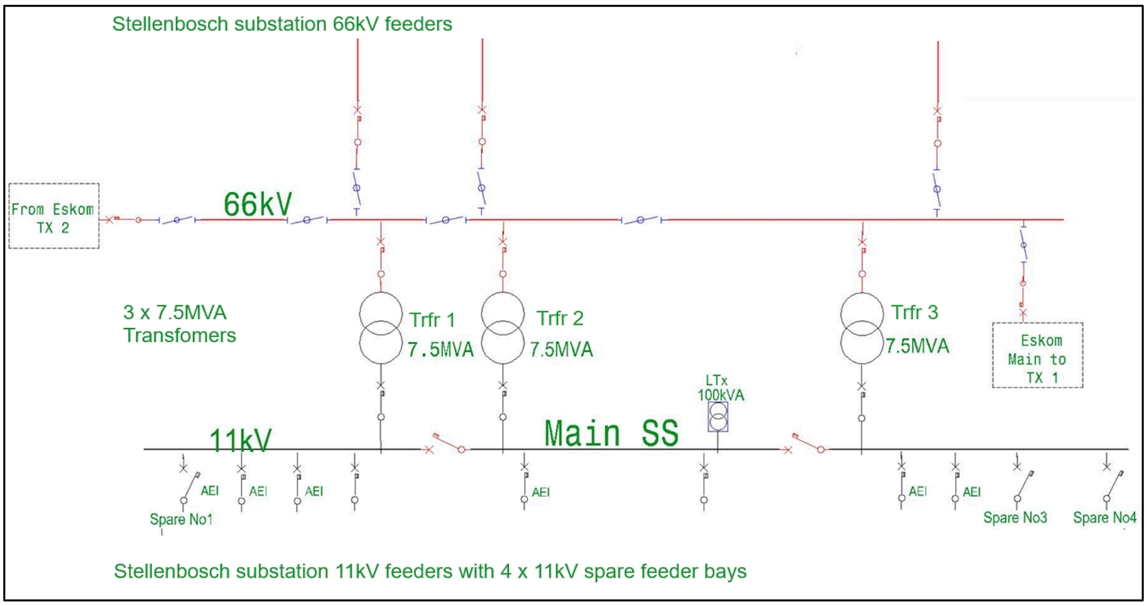

Figure 3: Stellenbosch substation diagram, Option 2
[Adapted from Stellenbosch Municipality Single Line Diagram, SM, 2024]

Simulation studies were done considering the integration of a 5 MW biomass plant on the 22 kV busbar at Stellenbosch substation. The 22 kV busbar is supplied via 3 x 66/22 kV 7.5 MVA transformers. The three transformers are not run in parallel and normally open points are operated between the three transformers. The diagrams that were supplied by SM indicate that there are four spare 11 kV bays and, for the purpose of this study, it was assumed that one of the spare bays can be used for the connection of the biomass plant.

Detailed load information was not provided by SM and assumptions were made regarding the splitting of the load across the three transformers. This should not have a material impact on the study results. Information that was obtained from Eskom shows that the three transformers are possibly operated at a higher tap position by the municipality to assist with voltage control on the 11 kV busbar and 11kV feeders. If this is the case in practice, the connection of the biomass plant at 11 kV might not be feasible due to high voltage levels on the 11 kV busbar (1.065 p.u.) as well as a RVC above 5% (6.9%) with the addition of the biomass plant.

The operation of the transformers on neutral tap would need to be approved by SM as it could cause voltage control problems on their network and the 11kV feeders which are supplied from the same busbar as the biomass plant could experience low voltage conditions towards the end of the feeder. If SM approves the operation of the transformers on neutral tap, the technical limits on the 11kV busbar are maintained with the addition of the biomass plant and the study results for this option are given in Table 5.

The grid cost associated with a connection at 11 kV is significantly lower than for the 66 kV connection. For an 11 kV connection, only 1 x 11 kV feeder bay is needed, at a cost of approximately R2 million.

Table 5: Grid integration study results

		Low Load		**High Load**	
	Voltage Level	***Voltage at PoC BB***	***RVC %***	***Voltage at PoC BB***	***RVC %***
Stellenbosch SS	22 kV	1.00 p.u.	1.22%	1.04 p.u.	1.5%

From the grid study for the B2E power station it was shown that there are two feasible options available to connect the power station to the municipal network. The first connection option is a 66kV connection at Stellenbosch substation which has a high capital cost due to the need for a 66/11kV transformer and associated connection works. A second option was investigated to connect the power station at 11kV at Stellenbosch substation. This option will be significantly cheaper to implement compared to the 66kV option but consideration would need to be given regarding the operation of the 66/11kV transformers at Stellenbosch substation to ensure that the technical limits of the local network are maintained. It is recommended that the 11kV connection option should be pursued together with Stellenbosch Municipality.

5. WORKING TOWARDS CARBON NEUTRALITY

5.1 Establishment of productive woodlots for future biofuel

As referred to in §4.3, the idea is to eventually produce a fair percentage of the required biofuel for the Power Station in selected woodlots with carefully selected Eucalyptus tree species or equivalent. High-density dryland forests or plantations are proposed, which could yield mature biomass on a nine-to-twelve-year cycle. These woodlots should form part of the formal biofuel supply network of the IPP, based on long-term agreements with the relevant authorities currently responsible for this resource. Unfortunately, very few of the licenced woodlots are currently being managed because of the uneconomical nature of such long-term crops for which no structured off-take agreements are in place.

The carbon footprint of the IPP and its biofuel supply contractors could, therefore, be reduced by the large-scale replanting of carefully selected trees to produce biofuel under contract for the Power Station. This arrangement should be developed in such a way that the carbon footprint continues to reduce as more and more fossil fuels energies and diesel generators are phased out by the downstream benefits of installing a wood-fired Power Station.

5.2 Fynbos restoration

Rehabilitation of the Idas Valley dams and the 430 hectares of Krom River catchment area, especially along the steep Simonsberg mountain slopes, can be accelerated by introducing different species in different areas of this region, as is considered most viable. For example, slower growing fynbos planted against the steeper slopes to repopulate natural vegetation to grow in areas that are inaccessible for harvesting planted biofuel species and planting productive woodlands for biofuel in the harvestable areas. These plants can all be generated in the on-site nursery of the Power Station. fynbos plants from the proposed on-site nursery of the Power Station. The intention being to restore the gentler base slopes with trees for future biofuel. Fynbos species are generally slow to re-establish and will have to get a head start in the more inaccessible areas where aliens are initially harvested to be used as biofuels. Aliens and fynbos cannot be planted in the same areas otherwise the quicker germinating and faster growing young alien vegetation will overshadow and suppress the new fynbos efforts. It is proposed that the Stellenbosch University Department of Forestry and Wood Science (virtually neighbouring this area) plays a formal and long-term master planning and research role in the reforestation and how best to restore the Krom River catchment area. As soon as the above replanting model proves successful, it can be duplicated at selected other biomass harvesting areas.

5.3 Improving the water catchment area of the Idas Valley dams

The 430-hectare Helshoogte Valley and Botmaskop conservancy area is zoned *Agriculture Zone I* and can be cleared of its current Eucalyptus, Blackwattle, and other aliens within a few years of the commissioning of the proposed B2E Power Station. During this period, a full-blown effort should be launched to restore the area into a well-run woodlot with specific focus on an improved run-off to the two municipal dams. Part of the SU Department of Forestry and Wood Science's master plan will include a carefully drawn-up plan to manage the harvesting of this area, so as not to cause erosion and mudslides during the rainy season from overharvesting.

The increased water run-off into the Idas Valley dams could extend the service lifespan of said dams, improving their water-holding capacity and thereby increasing the town's resistance to drought as well as extending service period of the current sized dams, delaying their need to be enlarged.

5.4 Improving the riparian zones of the central river systems within a 90 to 180 km radius[5]

The following riparian zones are the primary supply areas of biomass fuel to the proposed Power Station for the first 10 to 12 years of its lifespan. Approximately 50 to 60% (or approximately 50 000 to 60 000 t.p.a.) of the biofuel is expected to come from the riparian zones of the following four river systems during years 1 to 12:

- Berg River
- Breede River and Hex River system
- Zonderend River
- Bot River

See **Annexure A:** A preliminary assessment to estimate the woody alien invasive plant biomass in the riparian areas of the Breede, Berg, Hex, and Zonderend rivers conducted by the CSIR in 2019.

The preliminary results of the above survey indicate that in the riparian area of approximately 150 000 ha, approximately 180 000 t.p.a. of biomass (22% moisture) is available over a constant harvesting period of 20 years.

The average dry biomass yield from the banks of these river systems is 80 - 90 t/ha (See **Annexure A**; CSIR Report). At 80 t/ha and a biofuel requirement of c. 55 000 t.p.a. it can be calculated that up to 700 hectares of alien-infected areas along these rivers will be cleared per annum, to supply fuel to the proposed wood-fired Power Station. This clearing is estimated to lead to an improved run-off of more than 8.0 million cubic meters of water p.a. into these rivers. That is equivalent to ± 1 000 hectares of additional irrigated farmland (@ 8 000 m^3/ha p.a.) for food production.

5.5 Sequestrating wood-ash from the boiler

It is estimated that 2 500 to 3 500 t.p.a. of wood-ash would need to be removed from the boiler house (10 MW Station scenario) and 1 300 to 1 700 t.p.a. from the proposed 5 MW Power Station, once operational. This ash will be rich in potassium [K] and could become a significant component in the proposed on-site composting plant of the Power Station.

The proposed on-site nursery would require volumes of compost to produce growing medium for the new fynbos plants and biofuel trees. It is proposed that the young trees selected to produce biofuel should be produced by the Power Station site nursery, to

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[5] For the 5.0 MW B2E Scenario the supply base need not be larger than ± 90 km radius from the Power Station. [A 5.0 MW B2E Power Station requires ± 50 000 t.p.a. of biomass when running on 100% biofuel only].

demonstrate the cyclical nature of this renewable energy project, producing its own fuel and sequestrating its own ash.

The wood-ash from the Power Station will therefore find its way back into the soil as part of an organic compost.

5.6 Addressing fly-ash

The fly-ash from the boiler will be removed from the *particulate matter portion* of the boiler emissions using purposely built scrubbers. Analyses of fly-ash of similar wood-fired boilers indicate that it can be regarded as a medium-quality *biochar.* The biochar volumes are however too small (< 300 t.p.a. from the proposed 5.0 MW Power Station) for commercial use and will be mixed in with the proposed on-site composting operation.

5.7 An on-site electrical wood billeting and chipping system

A stationary electrical chipper and billeting plant is proposed to accommodate whole trees, tree trunks, large logs, and branches at the infeed-end of the Power Station. Initial indications are that between 45 000 and 55 000 t.p.a. can be chipped on site. The aim is to prepare approximately 50 - 60% of the Power Station's biofuel through this on-site chipper for the eventual 10 MW Power Station scenario and > 90 % of the biofuel required by the proposed initial 5.0 MW scenario.

5.8 PV Solar production of on-site power

Approximately 500 - 600 kW of on-site power would be required for the initial 5.0 MW Power Station, including supplying full load energy to the 400-kW on-site wood-chipper capable of grinding between 45 and 55 t/h of tree trunks into hogfuel. This chipper/grinder will initially, for the 5 MW scenario, only run during daytime. PV Solar power generation is being considered to power most of the daily on-site auxiliary operations for the initial 5.0 MW Power Station. This will improve the net output of the power plant from 4.5 MW_e to nearly 5.0 MW_e.

6. SECURITY OF BIOMASS SUPPLY

6.1 Defining the volumes of biomass required

The estimated mass of biomass required is a function of a few parameters:

- Type of wood species: Eucalyptus and Blackwattle have higher calorific values than most Pines at the same moisture content
- Moisture content of the wood
- Particle size distribution [PSD] of the chips, hogfuel or billets
- Bulk density, typically measured in kg/m^3
- Age of the wood

The proposed 5.0 MW wood-fired Power Station will burn a variety of tree species, with wood at a wide range of moisture levels. Later, when the security of biomass supply has been proven to be stable and sustainable, a second 5MW steam turbine can be considered to increase the output of the Power Station to 10MW.

A benchmark biomass specification is contained in **Annexure C** as reference.

For this study, it was planned for a larger-than-calculated required volume of biomass:

- For a continuous net output of say 9.0 MW$_e$ from the eventual 10 MW gross output plant, the mass of biomass required would be approximately 90 000 t.p.a. [It is proposed to plan for a mass of nearly 100 000 t.p.a., consisting of a mixture of biomass types].
- For a continuous net output of say 4.5 MW$_e$ from the initial 5 MW gross output plant, the mass of biomass would be approximately 45 000 t.p.a, rounded upwards to 50 000 t.p.a.

  The proposed mixture of biomass sources can include:

  - Invasive and alien trees from riparian zones and catchments as the ***Primary Source*** of supply to the Power Station initially. It is estimated that after approximately 10 to 14 years (worst case to best case) this source will become too far away from the Power Station, and the effect of transport will impact negatively on the delivered cost of the biofuel. It is hoped that by years 10 - 12, biomass from re-established woodlots can be phased in to replace the by-now dwindling volumes of biomass harvested from the riparian areas. Woodlots will from year 15 onwards become the primary source of biomass to the Power Station. [It is further hoped that by then, the more considerable woodlot potential of the Theewaterskloof Municipality, with specific reference to the Grabouw area, will have sufficient biomass to warrant a second 5 to 10 MW wood-fired Power Station].
  - Old orchards of the surrounding agricultural sector (See §6.2.2) as the ***Secondary Source*** of biomass supply. [Also refer to **Annexure B:** Fruit Orchard Survey of the Department of Agriculture, Western Cape Provincial Government].

- Tree trunks dumped at municipal garden refuse sites and industrial wood waste as the ***Tertiary Source*** of biomass supply to the Power Station. [Refer to **Annexure J** for a survey of the wood wastes from surrounding *Garden Refuse Transfer Sites*].

6.2 Defining the supply base and its volumetric yield potential

6.2.1 Riparian zones as primary biomass source

To ensure a biomass supply from these zones of approximately 50 000 t.p.a., a supply base with a radius of 160 km (or 180 km by road) from Stellenbosch[6] is proposed. That will include the riverbank riparian zones of the following perennial river systems:

- Berg River, from the Berg River dam downstream to Gouda and beyond.
- The Breede River, from its origin near Wolseley to where the N2 crosses the river near Swellendam.
- The Hex River from its origin to where it flows into the Breede River.
- The Zonderend River from the Theewaterskloof dam wall to beyond the town of Riviersonderend to Stormsvlei.
- The entire Bot River system.

However, for the proposed proof of concept 5.0 MW Power Station, the supply base can be much smaller, with a radius of 100 km maximum distance by road, bringing down the average transport costs of the biofuel.

6.2.2 Fruit orchards as secondary source

The Western Cape has > 135 000 hectares (2017 survey) of harvestable orchards consisting of nectarines, olives, citrus, guavas, peaches, pears, plums, table grapes, wine grapes, pecan nuts, and pomegranates, according to a 2019 study by NRGen. [A Report for Remgro Limited, Fusion Energy and Africa Biomass Company based on data obtained from the Department of Agriculture, Elsenburg. Refer to **Annexure B**].

Approximately 3.5 to 4.0% of these orchards are cleared annually to make room for new varieties.

- Lately, approximately 30% of the old orchards are extracted, chipped, and recycled by the farmer as mulch.
- Approximately 50% is burned.
- The remaining ± 20% is disposed of either way (for mulch or being burned) depending on the state of the economy at that stage.

It is probably safe to say that if fruit farmers can receive some form of compensation for the biomass of these orchards, instead of burning it on site, ± 50% would agree to part with the biomass material. The following calculation can thus be made:

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[6] The 160 km radius from Stellenbosch represents a 180 km road distance to, for example, places like Stormsvlei along the banks of the Zonderend River, downstream of Riviersonderend, places like Napier, Elim, Baardskeerdersbos in the so-called Strandveld, and Nuwejaars Wetland.

3.5% (average conservative renewal rate p.a.) x 50% (number of farmers) x 135 000 hectares @ ± 25 t/ha (average dry biomass yield) = ± 60 000 t.p.a.

The authors are of the opinion that if fruit farmers can receive some form of compensation to the clearing and disposing of their old orchards, the biomass available within a reasonable radius (Say 50 km) of the proposed B2E Power Station can probably exceed 30 000 t.p.a. by the time the proposed B2E Power Station is in operation. See Table 6.

6.2.3 Tree trunks from garden refuse sites

Surveys conducted by NRGen of tree trunk volumes currently being stockpiled (for chipping and disposal approximately once every 6 - 8 weeks) indicate that this figure could be as high as 12 000 t.p.a. for Stellenbosch Municipality alone.

6.2.4 Estimated biomass yields from logical sources

Table 6 *indicates the potential sources for the Power Station biomass*:

Table 6: Summary of likely biomass sources and resources for this project

Name of area/Biomass resource **(Figures obtained during Aug to Dec 2023)**	**Biomass from this source Yrs 1 - 10** **[t.p.a.]**	**Biomass from this source Yrs 11 - 20** **[t.p.a.]**	**Estimated lifespan of resource** **[yrs]**
Riparian zones up to 160 km radius	45 000 - 55 000	± 20 000	11 - 13
Idas Valley dams and Krom River catchment area [430 ha x 60% @ 80t/ha = 20 640 t]	2 000 - 3 000	-	4 -7
Agricultural orchards within an 80 km radius [70 000 ha x 3.5% @ 25 t/ha x 50% participation by fruit farmers = 30 000 t.p.a.]	5 000 - 10 000	± 20 000	> 20
Existing woodlots in selected areas within a 90 km radius [Years 1 - 10]	40 000 - 50 000	-	> 10
Re-established woodlots west of Stellenbosch) [Years 11 - 20]	-	50 000 – 55 000	20
Stellenbosch Municipal woody biomass from parks, gardens (excluding Cape Town Metro)	5 000 - 6 000	± 10 000	> 20
Stellenbosch industrial wood waste and others (excluding Cape Town Metro)	2 000 - 3 000	± 3 000	> 20
Total	**99 000 - 127 000**	**103 000 - 108 000**	**> 20**

6.3 Preferred harvesting methodology with the future in mind

Alien trees in catchment areas and against steep mountain slopes where fynbos needs to be restored will be harvested so that re-growth thereof is curtailed. Advice in this regard will be obtained from forestry specialists.

Woodlot areas where high-yielding tree species can be established and managed for future re-harvesting in a cyclical and sustainable way will be identified. Care will be taken not to disturb run-off or available water sources negatively. Again, the knowledge of forestry experts will be applied and harvesting manuals will be drawn up to form part of the *Special Conditions of Contract* when future biomass farming and harvesting contracts are awarded. It is thus intended that the proposed wood-fired Power Station will become the pilot or incubator project for a new and viable biomass-to-energy industry.

6.4 Biofuel/Hogfuel specifications

Refer to **Annexure C**.

6.5 The value of biofuel

From **Annexures D and E**, a delivered price for correctly prepared biofuel could range from R960/t to R1 300/t (VAT and escalation excluded, based on August 2023 figures).

With a much-reduced supply base area of a maximum 100 km radius, and with processing most of the wood into biofuel at the Power Station site, this cost can be reduced to R550/t (VAT excluded, Dec 2023). Refer to **Annexure G**.

Annexure F, a literature survey of biomass data from the Eastern Cape provided purely for comparison, shows that biomass providing 13 GJ/t can obtain prices as high as R650/t, and biomass chips providing 16 GJ/t (< 15% moisture) obtain prices as high as R850/t (VAT excluded, June 2023).

Annexure H refers to producing billets from woody trunks and poles with diameters smaller than 180 mm. When considering all the capital and operational costs applicable to a full-scale billet production unit, the assumptions and calculations illustrate that billets can be produced at R440/t. However, the billeting approach is not recommended for this project.

6.6 Securing the biomass supply

The most likely way to ensure biomass supply to the Power Station is through medium- to long-term supply contracts. Five-to-ten-year supply agreements would be drawn up, with attention given to escalation clauses pertaining to impactful variables, such as diesel prices, the ZAR/US$ exchange rate fluctuations, labour costs, etc.

It will be up to the *Independent Power Producer [IPP]* and owner of the Power Station and its biofuel supply contractors – who would need to be established and experienced biomass handlers, with the necessary felling, chipping and or billeting plant – to secure their biomass harvesting areas for the awarded contract period. These areas may include riparian zones, old fruit orchards, municipal garden refuse transfer stations, and others.

Hopefully, by the time the riparian zones begin to dwindle, the effect of the proposed new woodlot sites will come into play. It is of cardinal importance to the biofuel supply future of this project that the systematic re-establishment of woodlots takes place.

The delivery of tree trunks and other useable, unchipped woody biomass can be directed from the chosen sourcing sites to the Power Station site, where it will be chipped by the on-site stationary horizontal grinder. The chips will then be conveyed to the biomass storage bunker, where it will be kept dry before feeding it to the boiler. This is illustrated in the conceptual site layout in Figure 5.

6.7 Audit of the applicable riparian zones by the CSIR

Refer to **Annexure A** for a detailed survey, conducted in 2019, of the riparian zones of the Berg, Bot, Zonderend, Breede and Hex rivers by the CSIR and updated again for this study in 2023.

This survey states that approximately 180 000 t.p.a. of biomass can be harvested from these areas without depleting the resource in 20 years. Latest figures, however, indicate that more and more projects are being directed to these biomass resources (e.g., Toronto Charcoal Factory, Wellington), and it would be wise to see the proposed re-establishment of woodlots as a *Key Success Factor* to the new B2E project.

In conclusion, the proposed B2E Power Station would have sufficient areas from where biofuel can be obtained to feed the wood-fired boiler for the first 10 to 12 years, whereafter biofuel from woodlots will have to be included in the supply formula. This applies to the fuel consumption scenario of 100 000 t.p.a. at 25% moisture content, representing a gross continuous baseload power output of 10.0 MW_e, or a net output of approximately 9.0 MW_e of dispatchable energy. For a more realistic approach, however, a 5.0 MW_e proof of concept Power Station is proposed, ensuring a biofuel supply of 20 years, without the woodlots as part of the supply base.

6.8 The proposed biomass supply strategy

It is important to note that if the above approach to re-establish woodlots is successful, or even partly successful, the opportunity to implement more than one B2E Power Station in the Western Cape can be considered.

The generation of baseload electricity from licenced and sustainable re-established woodlot resources will not only improve water run-off, create long-term jobs, and improve the environment, but could also supplement other renewable energy projects (wind and solar) with dispatchable power. It is, therefore, crucial that a strategy is formulated to obtain management care over the 7 000 ha of woodlots in the Boland. The future sustainability of these woodlots can hopefully be secured with the necessary biofuel off-take agreements with the owners of the proposed B2E Power Station(s).

6.9 Traffic and delivery route impacts

6.9.1 Traffic impact

Approximately 100 000 t.p.a. or 500 to 600 t.p.d. of biomass is required at a 10 MW Power Station. At an average payload of 30 tonnes per truck, 20 large superlink trucks (worst case) could be expected on the roads to the Power Station daily. However, it is expected that the average number of trucks on the road for this project will more likely be between 14 and 16 per day when the total number of “working days p.a.” is taken at 200.

The more likely 5 MW Power Station will only require approximately 8 x 30 t trucks daily for tree trunk deliveries to the site.

6.9.2 Site option: ‘Stellenbosch WWTW’

The main high-voltage substation of Stellenbosch Municipality is neighbouring the *Wastewater Treatment Works [WWTW]* on the western fringe of the town at the corner of Adam Tas (R310) and Vredenburg Road.

An initial total area of 2 to 2.5 hectares could be considered at the WWTW to accommodate the proposed B2E Power Station. The WWTW is also bordering the municipal solid waste MRF and clay-capped old landfill sites, where additional space could be made available for stockpiling biofuel. The new landfill site entrance, equipped with weighbridge, and the garden refuse handing area is also within walking distance from the WWTW.

From a biomass supply perspective, this site is less ideal if trucks need to drive through the town of Stellenbosch. Specifically, biomass from the Berg, Breede and Hex Rivers, as well as the Northern Woodlots, will have difficulty reaching this site unless they drive through Stellenbosch. However, the proposed Western Bypass skirting west around Stellenbosch could change this situation.

The main substation of Stellenbosch Municipality borders the above site, making it convenient from an in-house switching point of view. Therefore, this site would be a more convenient site for the smaller, 5 MW Power Station. This scenario would require a maximum of 60 000 t.p.a. of biofuel, which can be translated over a (shorter) working year of 180 days to 333 t.p.a., or approximately 10 x 32 t trucks per day. Refer to **Annexure P** (Environmental Approvals) for further background.

6.9.3 Site option: ‘Klapmuts’

Eskom has a large high-voltage substation to the northwest of Klapmuts. Several hectares of municipal land on the northwestern fringe of Klapmuts appear to be vacant land bordering this substation and could be considered as a suitable site. For more detail in this regard, refer to **Annexure P.**

Biomass access from the Berg, Breede, Hex Rivers and the Northern Woodlots would be easy, using the N1 and a small section on the R44 from the N1 to Klapmuts.

Biomass access from the Bot, Zonderend and Nuwejaars Wetlands, Elim, and the Grabouw Woodlots, would be along the N2, R300, N1, to Klapmuts.

Klapmuts is, therefore, a more ideal site from a biomass supply perspective, but not from an electrical connection perspective.

7. SELECTING THE OPTIMUM BIOMASS-TO-ENERGY [B2E] BOILER SYSTEM

This chapter will deal with selecting the most appropriate wood-fired boiler system for generating high-pressure superheated steam to turn a steam turbine. Previous *Biomass-to-Energy [B2E]* studies have indicated that the classic steam turbine is an appropriate and cost-effective way to generate power for applications larger than 1.0 MW_e. [The *Combined Heat and Power [CHP]* option, with power as a byproduct, or the *Pyrolysis Process* with biochar as a byproduct, are also options to generate power from biomass, but a separate study would be needed to determine those merits compared to the simple wood-fired approach used in this study].

7.1 Medium pressure and temperature boilers

This category of boilers is straightforward to operate and needs less complex metallurgical alloys for its hot sections than the high-pressure high-temperature counterparts. While these boilers are generally less efficient and will use more biofuel, the most expensive part of the operational expenses to generate power, they are, however, less costly to build and maintain, and are proposed for the system by *TFDesign* (Refer to **Annexure M**).

7.2 **H**igh pressure and temperature boilers

This category of boilers is generally more complex, has higher metallurgical specifications for its hot sections and is more capital-intensive to build and maintain. Required water treatment specifications are also at a higher level than the lower pressure lower temperature applications. They are, however, thermally more efficient and will therefore use less biomass.

These boilers are proposed by both *John Thompson* and *Steamhouse Western Cape – Vyncke companies. (*Refer to **Annexures N** and **O**).

7.3 Selecting the optimum boiler for this application

Although the professional team had work sessions with the three top boiler companies of the Western Cape and they have submitted preliminary quotations for use in this study, no final boiler selection can be made at this stage. The above proposals were compiled to get a clearer indication of the electricity generating cost – using the B2E method. These costs, ranking from R2.20/kWh to R3.00/kWh, before escalation and project contingencies, give a clear enough indication that whichever supplier is used, the B2E generation of electricity outperforms the other methods of baseload power generation. For a preliminary comparison in this regard, please refer to Table 7.

From Table 7, it can be ascertained that the B2E steam-driven system can generate electricity at a significantly lower cost than its PV Solar-charged battery storage systems and diesel-driven generator equivalents.

Since both the *medium-pressure-and-temperature* and the *high-pressure-and-temperature* biomass boilers can generate electricity at a lower cost than the other dispatchable power systems, the professional team would propose that a final boiler plant selection only be made once the project is approved and comprehensive tender or *Request for Proposal [RfP]* documents are drawn up for this purpose.

Table 7: Cost comparison of baseload power generation [summary of data from Chapter 10]

Item	**Description of plant in the 10 MW_e output category @ 91% capacity factor**	**Generating costs (excluding VAT, contingencies and escalation, Sept 2023) @ 8 000 h.p.a. utilisation and 20-year service lifespan [R/kWh]**
1.	Biomass-to-energy steam driven system	2.50 to 3.00
2.	PV Solar charged battery systems (estimates)	4.50 to 5.00
3.	Diesel-driven generating sets	5.50 to 6.00

7.4 Materials handling and boiler infeed system

Basic biofuel handling systems were included in all three capital estimates by John Thompson, TFDesign and Steamhouse WC-Vyncke.

An on-site weighbridge, horizontal grinder, and related materials handling equipment, at a total capital cost of approximately R33 million, should be added to the Power Station complex to ensure a more sustainable biomass receiving set-up. Refer to **Annexure G** for more detail of the on-site biomass preparation facilities. These facilities will be capable of feeding the boiler at a rate of nearly 300 t.p.d. (or approximately 12 to 15 t.p.h.) over 24 hours. In total, the biofuel required to generate 10 MW_e gross output on a near-continuous basis (approximately 8 000 to 8 200 h.p.a.) is calculated at between 90 000 and 110 000 t.p.a. The same facilities would be running a single shift for the proposed initial 5.0 MW power plant.

7.5 Keeping the biofuel dry

The *Calorific Value [CV]* of biomass is higher when it is dryer. See Figure 4 for more insight into this for the proposed mixture of tree species. It is thus important to specify that the biomass that arrives at the Power Station is as dry as possible. Storage areas for large pieces of wood (trunks, logs, and larger branches) will be available for the wood to dry out further in the open. Rain does not affect this process as much as the relative humidity of the surrounding air. A felled Eucalyptus tree trunk, cut into 2.5 m lengths, takes approximately 90 days in summer and 120 days in winter in the Worcester area to dry from ± 45% *Moisture Content [MC]* when felled to ± 25% MC, naturally in the open.

		Pinaster Pine	Myrtle	Blue gum	Spider gum	Port Jackson	Port Jackson	Black wattle	Hakea
Nett CV - 25% moisture	MJ/kg	14.8	13.8	13.2	13.1	13.0	13.0	12.9	12.8
Nett CV - 30% moisture	MJ/kg	13.7	12.7	12.2	12.1	12.0	12.0	11.9	11.8
Nett CV - 35% moisture	MJ/kg	12.5	11.6	11.1	11.1	11.0	11.0	10.9	10.8
Nett CV - 40% moisture	MJ/kg	11.4	10.5	10.1	10.0	10.0	9.9	9.8	9.8
Nett CV - 45% moisture	MJ/kg	10.2	9.5	9.0	9.0	8.9	8.9	8.8	8.8

Figure 4: CV per tree species at various moisture contents

Biofuel requirements to supply the Power Station for two to three months should be stored on- site on a compacted platform in the raw wood open area, prior to being billeted or coarse ground into hogfuel or smaller billets by the on-site wood processor. Processed wood will be stockpiled on a dry, heated concrete floor in the covered intermediate storage area. This intermediate storage bunker will have a dry internal climate obtained by the heated floor and dry air blown into this store to create a small positive internal pressure. The energy to heat the under-floor hot water reticulation system and the hot-air roof ventilators will be obtained from the waste heat of the boiler during the rainy (high relative humidity) season.

From the intermediate biofuel store, the biomass is fed into the boiler. The infeed storage area can hold ± 7 days of biofuel reserves at an MC < 25%. A specialised rake (or equivalent) biomass infeed system is planned for this enclosed storage area.

7.6 Water treatment and cooling systems

7.6.1 Water treatment

The higher the boiler pressure and temperature, the higher the specifications necessary to soften the water. It is, therefore, more expensive to soften water for the high-pressure, more fuel-efficient boilers and this cost can be a fair percentage of the electricity generating cost of a steam-driven plant.

- Water treatment costs for a 16 bar and 290 °C Firetube boiler = R3.40/t steam
- Water treatment costs for a 67 bar and 485°C Microgen boiler = R6.50/t steam.

7.6.2 Cooling system

Evaporative cooling in cooling towers is used to condense steam into water in water-rich countries. Modern steam-driven power stations in South Africa use the more expensive closed-loop water condenser ("radiator") design to save water. This *Air-Cooled Condenser [ACC]* uses no water to condense the turbine exhaust steam.

Evaporative cooling towers or wet cooling systems for the 5.0 MW B2E application will consume up to 400 000 m^3 of water p.a., which is enough water to irrigate more than 50 ha of fruit orchards. Therefore, the Stellenbosch B2E Power Station is proposed to be equipped with a dry-air cooling system making use of an A-r-Cooled Condenser (CC) unit.

7.7 Emissions

Wood-fired boilers have emissions virtually free of SO_2. Coal-fired boilers are infamous for high volumes of SO_2 emissions, often leading to respiratory problems in humans and animals in its vicinity. The SO_2 gasses also chemically bind with water vapour in the atmosphere to form H_2SO_4 (sulfuric acid), also known as acid rain which is highly corrosive.

The emissions of a wood-fired boiler consist mainly of CO_2 and H_2O-vapour and are regarded as much cleaner than its diesel-driven and natural-gas-driven counterparts. The proposed Power Station would require an atmospheric licence as part of its licencing process.

7.8 Ash and other by-products

7.8.1 Ash

Approximately 3.0 - 4.5% of the 50 000 t.p.a. biomass will be burned to ash by the boiler of the 5.0 MW Power Station. This translates to between 1 500 and 2 300 t.p.a. of wood-ash[7]. Unlike coal-ash, wood-ash is not toxic and is rich in potassium – a sought-after element in the agricultural sector. For this reason, the wood-ash will be passed on to a composting works to produce a balanced compost product. [A separate Viability Study will be compiled for the proposed composting operation, and even though the Power Station owner will remain responsible for the safe and correct disposal of the wood-ash, the composting unit can become a profit centre in its own right and could be run by a separate or subsidiary operating company].

The value of the potassium present in the ash will contribute to its open market value.

7.8.2 Biochar

Small quantities (< 450 kg p.a. in the 5.0 MW application) of medium-grade biochar must be removed from the grit and fly-ash collector before reaching the smokestack. This high-value item can also be sold to the fertilizer sector. The primary function of the grit collector is however, to clean the particulate matter (mainly fly-ash) out of the emission stream to adhere to the atmospheric licence requirements.

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[7] The ash volumes will be approximately 1 500 to 2 200 t.p.a. for the 5.0 MW Power Station.

7.9 Operating staff and job opportunities (for 5.0 MW Power Station)

There are between 25 and 30 permanent (on-site) job opportunities for skilled and unskilled personnel envisaged in the proposed 5.0 MW Power Station scenario.

The biofuel value chain (felling, chipping, transporting) and the related handling facilities would lead to a further 40 to 60 permanent jobs in the Boland.

The composting and growing medium production unit and biofuel tree nursery could add a further 25 to 30 permanent jobs, directly related to the 5.0 MW Power Station.

The proposed future re-establishment of the woodlots of the DFFEA in the Boland could also create many jobs. It is roughly estimated that the proposed 10 MW Power Station would create at least 140 to 210 new and permanent job opportunities directly related to the longer-term project scenario. Refer to **Annexure K** by the SU Faculty of AgriSciences, Department of Forest and Wood Science.

7.10 Expected techno-economical lifespan of the Power Station

The proposed Power Station mainly consists of mechanical and electrical gear (which can be overhauled at pre-determined intervals) and could have an economical service life of up to 40 years.

8. THE CAPITAL COST OF THE PROPOSED POWER STATION COMPLEX

This chapter will deal with the total capital required to design, build, construct, and commission the proposed Power Station. The complex will consist of several components, each with its own footprint and spatial needs which would impact the eventual layout of the Power Station site.

8.1 Conceptual layout of the site

See Figure 5 for a conceptual layout of a 10 MW Power Station Complex. The Power Station itself only takes up approximately 4 000 to 5 000 m^2 of the site. More than half the area is required for raw biomass storage for trunks, logs, and poles.

Biomass storage is essential for allowing the wood to dry to moisture levels of < 25% and to cater for the annual rainy season when access into riparian zones for infield harvesting of trees is more problematic.

Ideally, the site should also allow for areas where, for example, poles and firewood SMMEs can be accommodated to optimise the raw material supplied to the site. Theoretically, only wood that is not fit for higher-value items like poles should be used for biofuel.

The overall size of the 10 MW Power Station site is estimated between 8 and 10 hectares and should be able to accommodate a future PV Solar panel site for at least the on-site parasitic electrical load during daytime.

The 5 MW Power Station site can be made more compact and could have an overall surface area of between 2.0 and 2,5 hectares.

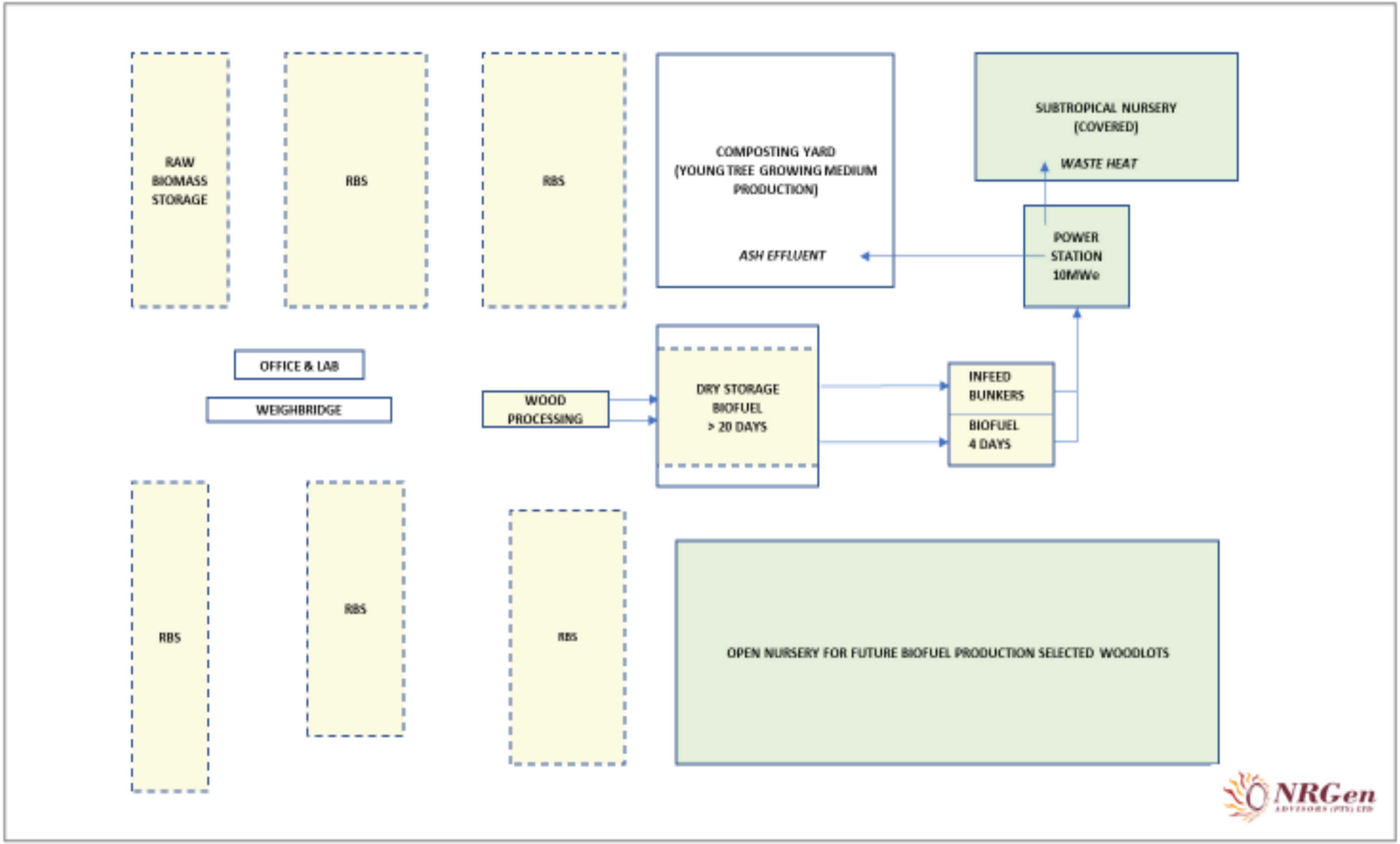

Figure 5: Conceptual layout of a 10 MW B2E Power Station and related storage and downstream facilities on a greenfield site

8.2 Spatial requirements

A future 10 MW Power Station site will consist of primary and secondary components, each with its own spatial needs. Refer to Table 8 and Table 9.

Table 8: List of primary site components and estimated spatial requirements [10 MW scenario]

Item	Description	Area [m^2]
1.	Weighbridge with control office, approach, departure ramps and related access roads	800 - 1 000
2.	Laboratory, offices, and workshop	800 - 1 000
3.	Raw biomass storage areas, truck circulation, fire breaks, roads, and truck parking. Open area	5 000 - 10 000
4.	On-site wood processing plant and processed wood receiving and manoeuvring area	1 500 - 2 000
5.	Dry processed wood storage for more than 20 days (with heated floor and circulated dry air using waste heat from the boiler stack). Covered and enclosed	2 800 - 3 000
6.	Biofuel infeed bunkers and conveyor space with 4 - 7 days storage	800 - 1 200
7.	Power Station complex with boiler and turbine houses and air-cooled condenser	4 000 - 5 000
8.	Area for future extensions/open areas	4 300 - 6 800
	Total area for primary components ①	**20 000 - 30 000**

An area zoned *'Industrial'* or *'Agriculture Zone 2'* of approximately 8 to 10 hectares is proposed for the larger 10 MW wood-fired Power Station scenario. The bulk of the area would be needed to stockpile felled trees, trunks, and logs for future on-site processing – the so-called *Raw Biomass Storage [RBS]* areas.

The logistics of how these yards will be managed is still open for debate, but the authors believe that areas can be allocated to the individual biomass harvesting contractors to store their felled trees until it has reached 25% MC for optimum pricing and payment by the Power Station owner or IPP group.

Areas are proposed for producing a growing medium for young trees, using the ash from the boiler, sewage sludge from the municipality, and wood chips. The composting plant can also produce growing medium for other nurseries to enable this business to become an independent entity.

The professional team is of the opinion that the site should be large enough to accommodate the proposed *primary components* listed above, as well as the in-house production of trees for future biofuel. For the 5 MW Power Station, the site can be reduced to 2.0 to 2.5 hectares initially until the B2E concept has proven itself.

Table 9: List of secondary components and spatial area required [10 MW scenario]

Item	Description	Area [m^2]
1.	Ash handling and composting area. Production of growing medium for the proposed biofuel tree nursery. Open area	15 000 - 18 000
2.	Young tree nursery (Area covered with netting, heated overhead irrigation system, using waste heat from the boiler)[8]	15 000 - 16 000
3.	Open tree nursery to harden young trees for future biofuel woodlots	20 000 - 22 000
4.	Circulation space and area for future extensions	10 000 - 14 000
	Total area for secondary components (e.g. PV Solar panels) ②	**60 000 - 70 000**
	① + ②	**80 000 - 100 000**

8.3 Detailed capital requirements budget of the project

Table 10 *below indicates the capital goods required by the IPP and owner of the Power Station complex:*

Table 10: Summary of capital budget to design, produce, commission, and implement the proposed 10 MW or 5 MW alternative wood-fired Power Station near Stellenbosch

Item	Description of capital item	Estimated capital cost (Dec 2023) [R million]	
		10 MW	5 MW
1.	Serviced plot with paved road access, zoned *Industrial/ Agricultural 2* of approximately 10 ha, near highways and a high voltage substation. The plot is to be selected in close collaboration with the Stellenbosch Municipality. This plot can be rented or leased from the Municipality.	To be rented/ leased	To be rented/ leased
2.	*Preliminary design work and facilitation by the professional team (CRSES, NRGen, Aubrey Withers and others in close collaboration with the selected IPP) to perform the following tasks:*		

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[8] Much more optimisation is planned for the huge amount of 'waste-heat' generated by the boiler. More time will be invested into identifying better use of this energy in the condensing circuit once the primary objectives of this study has been reached.

	(i) Concept EIA, atmospheric licence application and related approvals (ii) Biomass Supply Agreements. [RfQ facilitation, selection of biomass suppliers] (iii) Site master planning (iv) Financial and funding matters (v) Power Station RfP, selection and appointment of the primary Power Station Plant EPC supplier (vi) Finalising the PPAs (vii) Finalising the legal agreements with/on behalf of the IPP and biomass suppliers, the Woodlot Management Group and others (viii) Obtaining the necessary operating licences and approvals (ix) Finalise appointments of biomass suppliers, woodlot operators and all other biofuel handlers and on-site biofuel operator (x) Finalise ash handling, composting plant and on-site nursery operations and environmental management responsibilities		
	Allow for the above @ ± 1.5% of R450 million/R300 million	7.00	4.50
3.	*Detail design stage:* (i) On-site biomass stockpiling, preparation and dry storage by winning contractor and the professional team (ii) The Power Station with final biofuel infeed, dry condensing, ash handling, emission, and grit collector system, etc. (iii) Site works for the above, including access, civils for weighbridge, laboratory, wood processor, enclosed biofuel dry storage with related materials handling equipment (iv) Coordination and integrated masterplan of the above		
	Allow for the above @ ± 3.5% of R450 million/R300 million	16.00	10.50
4.	**Subtotal a) [in R million]**	**23.00**	**15.00**

Item	Description of capital item	Estimated capital cost (Dec 2023) [R million]	
		10 MW	5 MW
5.	*Physical site preparation:* (i) Earthworks, civils for primary plant (ii) Bulk services and site infrastructure (iii) Access and fencing (iv) Allow for site establishment of both the power plant supplier and the biomass handling, processing, and storage contractors	12.00	6.00
	Site establishment, earth, and civil works, allow for		
6.	*Biofuel handling, processing, and storage plant installation:* (i) Weighbridge, laboratory (+ equipment), offices (ii) Wood processing plant, including horizontal grinder, conveyors, dry biomass bunker (iii) Covered processed (at least 20 days) biofuel storage with overhead shuttle conveyors, heated floor, dry air ventilation (Roof designed to later accommodate PV Solar panels) (iv) Mechanical equipment for log handling and infeed	33.00	25.00
	Refer to **Annexure G**, Table G1, Item 13. Allow for		
7.	*Ash handling and auxiliary site works:* (i) Composting plant and related services (ii) Young tree nursery, including irrigation system	2.00	1.80
	Allow for LED projects (e.g., pole manufacturing) to be established on site		
8.	*Power Station and structural steel building (civils by others):* (i) Boiler(s) and related 4 - 7 day biofuel infeed system (ii) Turbine and alternator with related switchgear and MCC (iii) Water softening plant (iv) Balance of plant and equipment		
	Allow for above installed	380.00	250.00
9.	**Subtotal b) for items 5, 6, 7 and 8**	**427.00**	**282.80**

10.	Add items 1, 2, 3	23.00	15.00
11.	**Subtotal c) (rounded)**	**450.00**	**300.00**
12.	Project management, commissioning, operator training and hand-over, allow for @ ± 11% of Subtotal c). To be divided between the professional team, the design and site teams of all the above suppliers and EPC contractors[9] (rounded)	50.00	30.00
13.	**Total Capital[10] (VAT and escalation excluded)**	**500.00**	**330.00**

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[9] Design, site supervision, project management, commissioning, and related recoverable costs (site and geotechnical surveys, etc.) will be refined prior to the actual final agreements are drawn up, using the international FIDIC guidelines for multi-disciplinary engineering projects.

[10] The capital values of the plant and equipment were extracted from the preliminary budget quotations received during the third quarter of 2023 from four biomass handling and three boiler plant installation groups. In all cases, the quotes were furnished with their own contingencies.

9. ABBREVIATED BREAKEVEN ANALYSIS

This chapter will give the reader a reasonably accurate indication of the capital expenditure [CAPEX] and the operational cost [OPEX] applicable to the two scenarios of this project: for both the 10 MW Power Station and the 5 MW Power Station should be noted that all costs. It are without VAT and escalations and were assessed as accurately as possible during the Q3 2023.

9.1 Capital expenditure

From Table 10, the *Present Value [PV]* of the entire complex is determined as R500 million and R330 million, respectively, VAT and escalation excluded. An interest rate [i] of 11.0% and an instalment period [n] of 20 years is applied to calculate the instalments below:

∴ CAPEX (10 MW) = Instalment PMT_1 = R62.00 million p.a. (rounded) ①

and ∴ CAPEX (5 MW) = Instalment PMT_2 = R40.00 million p.a. (rounded down) ②

9.2 Operational expenditure

The OPEX of the two scenarios of the Power Station can be summarised in Table 11.

9.3 Total cost

The total cost p.a. = (CAPEX + OPEX) 10 MW and (CAPEX + OPEX) 5 MW

= ① + ③ = ② + ④

= R (62.0 + 100.00) 10^6 p.a. = R (40.00 + 55.00) 10^6 p.a.

= R 162.00 x 10^6 p.a. = R 95.00 x 10^6 p.a.

⑤ ⑥

9.4 Expected net energy output per annum

The expected net energy output can be estimated as 9 000 kW net output x 8 000 h.p.a. plant availability for the 10 MW scenario and 4 500 kW x 8 000 h.p.a. for the 5 MW scenario

∴ Energy output (net) 10 MW: 10 000 kW x 8 000 h x 0.9 = 72 x 10^6 kWh p.a. ⑦

∴ Energy output (net) 5 MW: 5 000 kW x 8 000 h x 0.9 = 36 x 10^6 kWh p.a. ⑧

9.5 Levelized cost of electricity (LCOE)

The cost of energy can theoretically be calculated as:

$$\text{LCOE} = \frac{Total\ cost\ p.a.}{Total\ net\ output\ p.a.}$$

∴ LCOE 10 MW = $\frac{⑤}{⑦}$ and ∴ LCOE 5 MW = $\frac{⑥}{⑧}$

$$= \frac{R162.00 \; x \; 10^6 \; p.a.}{72 \; x \; 10^6 kWh \; p.a.} \qquad\qquad = \frac{R95.00 \; x10^6}{36 \; x \; 10^6 kWh \; p.a.}$$

= R2.25/kWh = R2.64/kWh

In both scenarios, VAT and escalation costs are excluded.

Table 11: Operational costs – a summary

Item	**Description of operational items – an extract of the RfPs received from the larger roleplayers in the Boland (Third Quarter 2023)**	**Estimated sum [R million p.a.]**	
		10 MW	**5 MW**
1.	Biomass consumed @ R550/t x 100 000 t.p.a. for the 10 MW scenario and @ R550/t x 50 000 t.p.a. for the 5 MW scenario	55.00	27.50
2.	HR cost	7.20	4.00
3.	Plant maintenance costs @ 4.0% of mechanical plant values of R427 million and R283 million respectively (rounded)	17.00	11.30
4.	Water supply and treatment costs (rounded)	1.50	0.80
5.	Ash removal and housekeeping	1.80	0.90
6.	Insurance @1.2% p.a. of mechanical plant and complex costs of R427 million and R283 million respectively	5.10	3.40
7.	Rental of plot	0.20	0.15
8.	On-site electrical energy consumption costs (excluding diesel for three-wheel loggers and front-end loader): 500 kW x 0.6 x 8 000 h @ R2.50/kWh = R6.0 x 10^6 for 10 MW scenario and ± R4.5 x 10^6 for 5 MW scenario	6.00	4.50
9.	On-site diesel costs (rounded)	0.20	0.10
10.	Cutting bits for horizontal grinder. Allow for	0.40	0.20
11.	Miscellaneous	0.80	0.45
12.	**Subtotal**	**95.20**	**53.30**
13.	Contingencies	**4.80**	**1.70**
14.	**Total OPEX (VAT and escalation excluded)**	**100.00**	**55.00**

9.6 Brief sensitivity analysis

By refining Table 11 to include the R/kWh per total cost line, calculations show that fuel and cost of capital are the two most expensive items of a wood-fired Power Station, as seen in Table 12.

Table 12: Impact per item vs. the total cost of energy generation for the 10 MW scenario

Item	Description of total cost item	R million p.a.	R/kWh	%
1.	CAPEX ①	62.00	0.86	38.22
2.	Biofuel cost (See Table 11, Item 1)	55.00	0.76	33.78
3.	HR costs	7.20	0.10	4.44
4.	Plant maintenance cost	17.00	0.24	10.67
5.	Insurance	5.10	0.07	3.11
6.	Balance of operational cost and contingencies	15.70	0.22	9.78
7.	**Total (VAT and escalation excluded) – See ⑤**	**162.00**	**2.25**	**100.00**

10. COMPARING THE WOOD-FIRED OPTION WITH EQUIVALENT BASELOAD GENERATING SYSTEMS

This chapter aims to give a reasonable comparison of the more popular baseload or dispatchable power generating options, namely:

- PV Solar charged battery energy storage systems
- Diesel generating sets
- Wood-fired Power Stations

For each case, the typical LCOE in R/kWh was determined.

10.1 PV Solar charged battery storage systems

The figures used below were taken from an actual PV Solar, inverter and battery storage system installed in Stellenbosch in July 2023, consisting of:

- 16 x PV Solar panels of 550 Wp each
- 1 x 16 kW Hybrid Inverter
- 2 x 10.65 kWh Lithium-ion batteries

The total cost for the above installation was R351 000 (VAT excluded).

10.1.1 Realistic PV plus battery storage scenario

[R p.a.]

(i) CAPEX (@ i = 11.5%; n = 10 years; and PV = R351 000) = 59 219 ①

(ii) Operational expenses:

- Maintenance and panel cleaning @ 2% p.a. of capital = 7 020
- Insurance @ 2.2% p.a. = 7 722

∴ OPEX (VAT excluded) = 14 747 ②

(iii) Estimated energy output[11]

16 panels x 0.55 kWp x 0.75 efficiency x 2 017 h.p.a. = 13 312 kWh p.a.

(iv) Cost of energy

$$= \frac{\text{①} + \text{②}}{\text{③}}$$

$$= \frac{59\ 219 + 14\ 742}{13\ 312}$$

∴ LCOE = R5.03/kWh

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[11] Average sunshine hours in Stellenbosch assumed at:
(365 x 0.85) d.p.a. x (an average of 6.5 h.p.a.) = 2 017 h.p.a.

10.1.2 Optimistic PV plus battery storage scenario (for areas of more daylight)

(i) Optimistic energy output

16 panels x 0.55 kWp x 0.75 efficiency x 7.0 h.p.d. x 355 d.p.a

$$= 16\,400 \text{ kWh p.a.} \qquad \text{④}$$

(ii) Cost of energy

$$= \frac{\text{①} + \text{②}}{\text{④}}$$

$$= \frac{59\,219 + 15\,795}{16\,400}$$

$$\therefore \text{LCOE} = \text{R}4.57/\text{kWh}$$

10.1.3 Conclusion

The affluent within the Stellenbosch community are the most likely users[12] of the above PV Solar + inverter + battery storage systems, generally willing to pay up to R5.00/kWh for the baseload electricity generated by using PV Solar-charged battery storage systems.

10.2 General cost of a 5 MW_e diesel-driven Power Station

For a fair comparison between the *levelized cost of electricity* generated by burning diesel versus burning biomass, the following capital cost will be applicable to install, commission and operate a diesel-driven Power Station, using 4 x CAT 3516B - 2275 kVA units[13], capable of a continuous 5.0 MW_e output.

10.2.1 Power Station building

See Table 13 for a summary of the building costs of an appropriate building to house the four large generator sets and auxiliary equipment:

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[12] The Stellenbosch Municipality should take note of this fact which would lead to a significant drop in income to the Municipality for electricity from the more reliable group of services payers.

[13] Several large diesel generating set suppliers (including the agents for Volvo, Cummins and Perkins) were invited to submit quotes to NRGen, but only Barloworld Equipment (agents for Caterpillar) responded in time.

Table 13: Typical capital applicable to a 5 MW diesel-driven Power Station

Item	Description	Capital cost [R'000]
1.	Plot to be on a long-term lease from Stellenbosch Municipality	Long-term lease
2.	Power Station building complete with earthworks, civil-structural steelworks, cladding, small store, office, and workshop. (15 m x 30 m @ R16 000/m^2, rounded)	7 200
3.	Access road, fencing, diesel tank and water supply, allow for	2 000
4.	Substation connection, related switchgear, and cabling, allow for	3 000
5.	**Subtotal**	**12 200**
6.	Contingencies and professional fees, allow for ± 15% of R12.20 x 10^6 (rounded)	1 800
7.	**Total for Power Station building (VAT excluded)**	**R14 000**

10.2.2 Capital costs of diesel generators

See

Table 14 for a summary of the capital for plant and equipment:

Table 14: Capital required for diesel generators for 5 MW continuous output

Item	Description	Capital cost [R'000]
1.	4 x CAT 3516B – 2275 KVA, 400 V gensets as per quotes obtained from Barloworld Power (June 2023)	76 000
2.	4 x Exhaust systems with attenuators	included
3.	Delivery to site, crane work and rigging, installation, and commissioning @ 15% of R76 K (rounded)	11 000
4.	**Subtotal**	**87 000**
5.	Contingencies @ 10% (rounded)	9 000
6.	**Total for diesel plant and equipment (VAT excluded)**	**96 000**

10.2.3 Capital expenditure

The CAPEX can be calculated as follows:

(i) For the Power Station building:

PV_1= R14.0 x 10^6; i = 11.5%; n = 20 yrs.

∴ Instalment Building = R149 300 p.m. x 12

= R1.79 x 10^6 p.a. ①

(ii) For the mechanical plant:

PV_2 = R96 x 10^6; i = 11.5%; n = 10 yrs.

∴ Instalment Plant = R1.35 x 10^6 p.m. x 12

= R16.20 x 10^6 p.a. ②

(iii) Total CAPEX = ① + ②

= (1.79 + 16.20) 10^6

= R17.99 x 10^6

Rounded to = R18.00 x 10^6 p.a. ③

10.2.4 Operational costs

See Table 15 for a summary of the anticipated operational costs of the diesel-driven Power Station.

Table 15: Summary of operational costs @ 5.0 MWe continuous output

Item	Description	[R'000 p.a.]
1.	Diesel fuel consumption @ 5.0 MW_e continuous @ 75% power setting and at its most conservative fuel consumption, (3 machines @ 360 ℓ/h each x 8 000 h.p.a. @ R21.00/ℓ diesel (rounded). One machine on standby	150 000
2.	HR cost of on-site operating staff	4 400
3.	Mechanical maintenance contract @ 6.25% of R96 x 10^6 (excluding turbocharger and top overhauls); allow for	6 000
4.	Allow for annual inspections, top and TC overhauls/service exchange items	4 000
5.	Allow for major overhauls every 15 000 hours @ R10 x 10^6 per machine	8 000
6.	Electrical maintenance	3 000
7.	Building and attenuator maintenance	1 300
8.	Housekeeping and miscellaneous services, municipal rates and taxes	1 200
9.	**Subtotal**	**177 900**
10.	Contingencies and unforeseen breakdowns	18 100
11.	**Total OPEX (excluding VAT) rounded** ④	**196 000**

10.2.5 Generating cost per kWh

The cost of electricity generated by means of the above diesel-driven Power Station can be calculated as follows:

$$\text{Levelized cost of electricity} = \frac{Total\ cost}{Net\ output\ of\ the\ diesel\ driven\ Power\ Station}$$

$$= \frac{CAPEX\ \textcircled{3} + OPEX\ \ \textcircled{4}}{5\ 000\ kW\ x\ 0.95\ x\ 8\ 000\ h\ plant\ availability}$$

$$= \frac{R(18 + 196)10^6 kWh\ p.a.}{36\ x\ 10^6\ kWh\ p.a.}$$

$$= \frac{214\ x\ 10^6}{36\ x\ 10^6}$$

$$\therefore \text{LCOE} = \text{R5.94/kWh}$$

The professional team believes that a large (10 MW_e) output diesel-driven Power Station would be able to produce power at ± 85% of the above ℓcoe. In other words, @ ± R5.05/kWh.

10.2.6 Comparison between three baseload power supply systems

The three dispatchable power generating systems, analysed to date, are compared in Table 16.

Table 16: Comparison between dispatchable power systems

Baseload/Power on demand generating system **Levelized cost of electricity generated**	**Wood-fired application (complete with on-site wood processing works)**	**PV Solar-charged battery storage systems**	**Diesel driven Power Station**
R/kWh (Excluding VAT and escalation)	2.25 - 2.64	4.57 - 5.03	5.05 – 5.94
Average R/kWh	2.45	4.80	5.50
Comparison	**100%**	**196%**	**224%**

From Table 16, the wood-fired application is significantly more cost-effective than the other dispatchable power options currently being used in the Stellenbosch area and elsewhere.

11. OUTSTANDING POSITIVE FEATURES OF A BIOMASS-TO-ENERGY PLANT

11.1 Proven technology

Steam boilers date back nearly 160 years, to 1867 when George Babcock and Stephen Willcox patented their boiler design in New York.

Dual fuel steam locomotives, using coal or wood, were used in South Africa during the Kimberley diamond rush which started in 1871, to rail imported mining plant and equipment from Table Bay Harbour to Kimberley. It was around this time that the *Eucalyptus Camaldulensis* tree was introduced to South Africa, with the first plantations being established in 1898. Eucalyptus billets were used for many decades as a supplement fuel to coal on the Cape to Kimberley rail line, until coal became cheaper and easier to obtain.

From this history, it’s evident that using wood-fired boilers to generate steam is an old and proven technology, and widely used throughout the world. More recently, biomass-to-energy systems are gaining popularity in selected applications where biomass is available in large volumes such as in Europe and Scandinavia, or where encroacher bush or alien invasives are causing ecological difficulties, such as in Namibia and South Africa.

Adding to the increasing popularity of B2E systems are further technological improvements to boilers. Higher pressure and temperature boiler designs are leading to higher efficiencies, and especially in *Combined Head and Power* systems [CHP-systems], the renewable biomass application is slowly replacing fossil fuels as the primary energy source.

11.2 Simple to operate

It is relatively simple to operate woody biofuel infeed equipment, the boiler itself, the turbine, and air-cooled condensers, and can be done by semi-skilled operators. One of the more complex portions of the boiler system is its water softener – the boiler water treatment apparatus with its related chemistry. However, no operational difficulties are foreseen considering the large number of boilers and thus water softeners in use in the Western Cape. The skills exist in the province to operate these boiler systems, and once the proposed B2E plant is up and running, maintaining the semi-automatic water treatment apparatus will become a daily routine for the plant operators.

11.3 Labour intensive – a desired characteristic within South Africa

Labour intensive projects – especially those creating permanent employment – are ideal for communities with large unemployment. Labour intensive operations are seen as one of the outstanding positive features of the proposed B2E Power Station. The following direct and permanent jobs could be created by implementing this project over both its phases, from 5 MW to 10MW over the next decade or so:

- Biomass harvesting from the riparian zones: 90 (5MW) to 120 people (10MW)
- Re-establishing old woodlots totalling 7 000 ha could lead to the employment of between 140 and 210 people.
- On-site wood storage, handling, and processing: 20 to 30 people
- The Power Station itself: 40 to 55 people

- The ash handling, composting, and new tree nursery section: 50 to 60 people

This equates to a total of 340 to 475 permanently employment opportunities (for a 5 MW and later the larger 10 MW B2E Power Station) in the Western Cape over the next decade.

Many of the above permanent job opportunities will assist young people who are currently not employed and looking for work in plant operation, logger and truck driving, tree felling, or nursery work.

11.4 More positive than negative environmental impacts

11.4.1 Addressing the negative impacts

The relatively small number of negative impacts are addressed in Table 17.

Table 17: Addressing the negative impacts

Item	Description of negative impact	Addressing/softening the impact
1.	CO_2 emissions from boiler stack	After cooling these CO_2 and H_2O-vapour emissions down to < 30°C, the gases can be circulated through the proposed covered young tree nursery
2.	Emissions > 150°C at top of stack	Over and above the normal economisers fitted to pre-heat boiler infeed water, the exhaust gas temperature of the stack can be harvested as waste heat for several applications, including further drying of the biofuel, or pre-heating of irrigation water of the neighbouring nursery.
3.	Noise levels of the steam turbine	The turbine rooms will be built for sound attenuation
4.	Noise levels of the fans of the air-cooled condenser	Care will be taken with the diameter, pitch, and rotational speed of these fans to reduce noise levels
5.	Noise levels of the on-site wood processing equipment	The chipper/grinder will be working during daytime in partially enclosed structures and will be driven by electrical power packs
6.	Between 12 and 15 x 30 tonner payloads will be arriving at the site during working days – mainly conveying solid raw wood or logs or billets in large trucks for the 10 MW Scenario[14]	Catering for on-site wood processing has already reduced low bulk-density loads (trucks filled with wood chips). The site will also be selected at a geographical point preventing large trucks from driving through the centre of Stellenbosch town or on the R44 between Somerset West and Stellenbosch
7.	By removing trees, less oxygen is generated	Approximately 7 000 ha of new young trees are planned to be established. A 10 to 12-year planting and harvesting

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[14] For the 5 *MW scenario* the number of raw wood truckloads to the Power Station is estimated to be between 6 and 8 x 30 tonner payloads per working day (not over weekends). This scenario, or a slightly larger scenario, appears to be the more likely outcome of this project.

		cycle is planned at the licenced woodlot sites. Refer to **Annexure K**

11.4.2 The positive impact

Table 18 gives a list of the larger number of positive impacts which this project could generate.

Table 18: List of positive impacts

Item	Description of positive action	Remarks
1.	**Environmentally** On-site composting plant	Absorbing wood-ash, sewage, and biomass fines screened out of the biofuel
	Establishing 7 000 ha of biofuel woodlots and forests	Oxygen-generating trees to be planted in large numbers every year; a continuous operation
	Carbon (CO_2) removal	The B2E Power Station would remove > 1.0 kg of CO_2 per/kWh generated from the atmosphere; this translates to > 72 000 t.p.a. of CO_2 reduction in the 10 MW scenario
	Could replace between 25 and 50 large (> 500 kVA) diesel gensets in use during periods of loadshedding	Since power generated by the B2E Power Station would be > 50% less expensive than power generated by diesel-generators, local businesses will (hopefully) terminate their standby-power contracts and replace it with an uninterrupted power supply contract via the Stellenbosch Municipality
2.	**Socially** A billeting plant near Baardskeerdersbos, Elim and Napier to supply 12 000 to 15 000 t.p.a. of billets to the B2E Power Station for 10 years, renewable for a further 10 years	Could provide much-needed permanent employment to these communities as part of an existing pole manufacturing sawmill while producing billets from the tops and tails of the harvested trees. Applicable to the 10 MW scenario For the 5 MW scenario, Baardskeerdersbos area would be too far away for the economical supply of biomass
	More than 400 new direct permanent jobs could potentially be created	The tree felling, plantation work, on-site wood processing, Power Station operating, compost plant equipment operation, and on-site nursery operations will all be labour-intensive projects
	Additional opportunities close to the B2E site	The woodyard could implement SMMEs for adding value to harvested alien trees, such as: The production of poles for the fruit and vegetable industry Beekeeping and recreational activities in the woodlots and surrounding firebreak forests (for the 10 MW scenario)

		A sub-tropical agricultural venture using waste heat and CO_2 to increase yields A refrigerated distribution depot using steam in an absorption cooling process
3.	**Financially** A stable power-generating industry with a techno-economical service lifespan of more than 25 years can be established	With a stable supply of biofuel and a stable offtake of dispatchable electricity; a project in which the few negative impacts are overshaded by a host of positives
	A good example of a well-balanced green, circular, and sustainable local economic development project	Growing its own fuel, employing many people whilst generating renewable and dispatchable electricity at an affordable rate; a potential incubator project Giving a reasonable value to “unwanted” wood will kickstart a host of new biomass-related industries while making the control of alien trees sustainable

11.5 Addressing on-site parasitic load with PV Solar

As soon as the Power Station has proven itself as a reliable source of dispatchable electricity at an affordable rate and is running well, supplying energy for the 400 to 600 kW of on-site power-consuming apparatus can be addressed. Most of this parasitic load will be experienced during the daytime when the on-site wood processing plant made up of the chipper, screening plant and biomass handling conveyors is in operation. The roof of the biomass storage bunkers should be planned so that future PV Solar panels can be installed not only to improve the net output of the Power Station, but also to save biofuel – the most expensive operational cost item in a B2E project.

12. KEY SUCCESS FACTORS

This chapter will deal with the 'top five' *Key Success Factors [KSF]* which need to be in place to secure the viability of this project.

12.1 KSF 1: Ensuring an affordable cost of power generation

The *Levelized Cost of Electricity [LCOE]* should ideally not exceed R2.40/kWh (excluding VAT and escalation costs, as calculated in December 2023). It will become challenging to sell dispatchable electricity at a cost higher than this, mainly because of stiff competition from the sugar industry in KwaZulu-Natal, which is selling baseload power at a cost as low as R1.05/kWh. (Stefan de Villiers, ex-CEO Energy Exchange). [It is the view of the authors that this can only be achieved when the bagasse infeed to the steam-generating part of the plant is costed at close to R100/t or lower. This is not feasible in the wood-burned power plant scenario where biofuel needs to be harvested and prepared before burning].

To keep the LCOE below R2.40/kWh, this project should endeavour to limit the following costs to the values below:

(i) Cost of dry biomass (@ < 25 % M.C. and > 13.0 GJ/t) from a mixture of tree species, in hogfuel or chips or billet format, should be kept below R550/delivered to the boiler plant (VAT and escalation excluded).

(ii) Cost of capital must be kept well below an interest rate of 11.5% p.a.

(iii) Compensation of R380/t for CO_2 reduction, for not using fossil fuels, should be applied to enable the project to reduce its cost of generation by approximately R0.38/kWh, or to ensure a "Stumpage payment" to the 7 000 ha woodlot projects of approximately R380/t. Refer to Table 18, Item 1, Carbon (CO_2) removal.

A stumpage payment of >R380/t to the woodlot managing and harvesting group will contribute handsomely to ensure the sustainable re-establishment of the 7 000 ha woodlots of the Boland. This scenario is essential for the 10 MW output Power Station.

12.2 KSF 2: Long-term security of biomass supply

A steady supply of approximately 100 000 t.p.a of biomass is needed to produce a continuous output of 9 000 kW x 8 000 h.p.a. = 72 x 10^6 kWh p.a. To achieve this, the 7 000 ha of woodlots must begin producing biofuel from year 10 or 11 onwards. This is to replace the biomass harvested from the riparian zones which will most likely begin to dwindle after approximately 10 to 15 years into the project.

It is essential to ensure a steady biomass supply to the Power Station for 20 years and longer. With the future of the woodlots secured, the project life can theoretically be extended indefinitely.

For the smaller 5 MW net output Power Station, the woodlots are not essential.

12.3 KSF 3: Securing long-term off-take agreements at an optimum output level

Power Purchasing Agreements [PPAs] must be in place to ensure viability. Simply put, for the 5.0 MW Scenario: 4 500 kWe (net output) x 8000 h.p.a. = 36 x 10^6 kWh p.a. needs to be sold at the agreed tariff over the long-term (e.g., 10 years, renewable for a further 10 years) and at an agreed escalation formula. This will be a transaction between the Power Station owners who are holders of the IPP licence, and a group like the Energy Exchange of Remgro for example.

12.4 KSF 4: Optimising the cost of capital

This feasibility study was done using a compounded interest rate of 11.50% p.a. throughout and borrowing 100% of the approximately R500 million capital required for the 10 MW Power Station. The total capital cost for the 5 MW Power Station will be closer to R330 million (VAT excluded, Dec 2023).

The cost of capital thus represents approximately 38% of the LCOE for the 10 MW scenario. See Table 12. Furthermore, for the 5 MW scenario, the annual instalment of R330 million is calculated at R40.00 million p.a. (See ②, §9.1). This would translate to R40 x 10^6 ÷ 36 x 10^6 kWh p.a. = R1.11/kWh or 42% of the LCOE of this scenario @ R2.64/kWh (See §9.5). The professional team believes that several innovative options exist to lower this cost of capital.

12.5 KSF 5: Working towards a green circular economy

This project can potentially employ many skilled and semi-skilled local people (approximately 340 to 475) into permanent jobs.

Young trees will be planted, while mature trees will be harvested daily for the planned 20 years and beyond. Depending on the quality, the trees will be converted into several products such as mainly poles, firewood, and biofuel. Secondary small industries could be established such as composting (using wood-ash from the boiler, biomass chips and sewage sludge from the surrounding Wastewater Treatment Works), a young tree nursery, beekeeping, and other agri-forestry activities.

The Power Station, woodlot and related industry employees will be able to afford the full range of municipal services. Preliminary estimates suggest that a minimum wage bill of approximately R80 million p.a. will be paid out to the 10 MW Power Station employees, woodlots, transporters, machine operators and other direct job opportunities. Indirect job opportunities (pole-making, firewood, compost, beekeeping, and other agri-forestry activities) could equal the above wage bill over time.

As soon as the re-establishment of the woodlots appears to be successful and financially sustainable, enough biomass can be secured to warrant the implementation of a second 10 MW wood-fired Power Station – probably close to Grabouw.

Therefore, the proposed Stellenbosch 5 or 10 MW Biomass Power Station can be seen as an demonstration project of significance importance in the green, circular economy. However, starting with the smaller 5 MW Biomass Power Station project will be pose less risk as it does not need to rely on the biomass supply of the woodlots/plantations currently owned by the National Government's DFFEA managed by the SOE, Mountains to Ocean (MTO).

13. THE PROPOSED FINANCIAL AND OWNERSHIP MODELS

This chapter will consider potential business models for the project.

13.1 Market analysis

To secure the necessary financing for the B2E Power Station, the establishment of a Power Purchase Agreement [PPA] is imperative. While PPAs are common in the industry, it is noteworthy that, in South Africa, such agreements have predominantly been negotiated directly with Eskom by the large independent power producers (IPPs).

13.1.1 Identification of potential off-takers

Recognising this, three potential off-takers crucial for the project's success were explored:

a) Single larger off-taker:

Definition: A single, substantial electricity consumer within the municipality.

Considerations: The viability of this option hinges on identifying a large entity capable of committing to a significant portion, if not the entirety, of the power plant's capacity. Likely candidates for this role include Stellenbosch University or other major business premises within the Stellenbosch Municipality.

Advantages: Streamlined negotiations and a more secure revenue stream.

Challenges: Limited pool of potential off-takers, requiring a comprehensive commitment from a single entity.

b) Stellenbosch Municipality [SM] as the off-taker:

Definition: SM itself procures electricity and redistributes it within its distribution network.

Considerations: In principle, the market is confined to the municipality's consumption, though in practice, it may be a fraction thereof. This arrangement requires a comprehensive understanding of the municipality's energy needs and distribution capabilities.

Advantages: Localised distribution and potential synergies with SM’s energy management strategy.

Challenges: Market limitations tied to municipal boundaries, necessitating careful planning to optimise sales.

c) Renewable energy trader:

Definition: An energy trader, such as Earth & Wire, acts as an intermediary that has the capability to wheel the electricity to customers across the national grid, and even into other distribution areas.

Considerations: This option provides potential access to a broader market beyond the SM, offering flexibility in selling electricity to various customers.

Advantages: Increased market reach, potential for diversification, and mitigation of risks associated with a single local market.

Challenges: Complex negotiations with an intermediary, potential regulatory considerations, and dependence on the national grid infrastructure.

13.1.2 Long-term Power Purchase Agreement

While a long-term PPA typically spanning 20 years is a standard industry practice, securing such agreements poses unique challenges in the context of all three of the identified potential off-takers.

Consumers within the electricity market in South Africa are not accustomed to long-term agreements for supply. They may find it challenging to commit to a 20-year PPA. This resistance is rooted in a historical preference for shorter contractual terms, typically 3 to 5 years, for various other services. Tailoring the PPA terms to align with consumer expectations while ensuring the project's financial viability will be crucial and will likely be severely constrained by the need to achieve bankability.

The energy market, especially in open markets outside South Africa, is highly price-sensitive. The ability to secure a long-term PPA is intricately linked to the offered price. Lower prices enhance the likelihood of agreement, but this places pressure on the financial feasibility of the power station. The project faces pricing competition from Eskom and embedded generation options such as PV Solar with battery energy storage.

While loadshedding by Eskom could create a market premium for firm and secure power, this concept has not been thoroughly tested in the local market. Determining the extent of this premium and its acceptance by consumers is uncertain. Exploring the market dynamics and potential willingness to pay a premium for uninterrupted power supply is essential if this project is pursued further. Engaging with stakeholders to gauge perceptions and expectations will be needed to inform pricing strategies.

13.1.3 Ownership models for the B2E Power Station

Choosing the right ownership model is crucial for successfully implementing and operating the B2E Power Station. Two predominant ownership models are considered: 1) the conventional ownership model and 2) the Independent Power Producer (IPP) model. Each model has distinct characteristics that must align with both the project's goals and the preferences of potential off-takers.

In the **conventional ownership model**, typically adopted by large energy-intensive industries, the owner funds and operates the power plant. This model suits entities with both the financial capacity and technical expertise to manage a thermal power plant. However, it is less suitable for the identified potential off-takers, including a single larger off-taker, the municipality, or energy trader, due to scale, competency, and operational challenges. For instance, a single large off-taker in Stellenbosch will lack the operational expertise for power plant management, and many municipalities in the country struggle with maintaining the competence to operate their water treatment facilities.

On the other hand, the **Independent Power Producer model** is characterised by IPPs specialising in building and operating power plants, selling electricity as their primary business. This model is ideal for smaller-scale projects such as the 5 MW Power Station where the IPP can maintain a critical mass of experienced staff. The IPP model is well-suited for entities lacking the expertise or interest in direct ownership and operation. It allows off-takers to focus on their core activities while benefiting from reliable energy supply.

IPPs bring extensive experience building and operating power plants, ensuring ongoing operational efficiency and long-term viability. They enable off-takers to benefit from professional plant management without direct involvement, and IPPs with a fleet of thermal power plants can achieve economies of scale in operations.

In considering the required competencies and experience, a larger off-taker may consider investment but lack operational competencies. In contrast, IPPs bring specialised skills and experience in plant operation and maintenance. The choice between the two models should also account for the economies of scale, with the IPP model being particularly well-suited for the smaller scale of the 5 MW B2E Power Station. Furthermore, the IPP model ensures the ongoing operation of the Power Station, contributing to the long-term viability and allowing off-takers to benefit from continuous energy supply without operational burdens.

Further exploration and engagement with potential IPP partners will be integral to shaping the project's ownership structure.

13.2 Regulatory considerations

Addressing the regulatory implications of load shedding is imperative for successfully implementing the B2E Power Station. One of the project's primary objectives is to limit the impact of load shedding, and resolving the regulatory aspects is critical to achieving this goal.

If the identified off-taker is a large municipal consumer, their vested interest would be in achieving no load reduction and thus ending their load shedding. Similarly, if the off-taker is the Stellenbosch Municipality itself, they would seek a proportional decrease in their load reduction. However, addressing these concerns may encounter resistance from Eskom, which, guided by operational challenges and equity considerations, has hesitated to engage in discussions where certain entities receive preferential treatment.

The regulatory environment, or the establishment of a special dispensation, becomes a prerequisite for the successful implementation of the project. This entails creating a framework or regulatory pathway allowing entities such as municipalities or significant consumers to receive specific considerations regarding loadshedding mitigation. To date, the mitigation of the impacts of load shedding has only been achieved through embedded generation.

Other regulatory considerations include the National Energy Regulator of South Africa (NERSA), Grid Connection Codes and Standards (compliance with the National Control Centre’s grid connection codes is crucial for integrating the power station into the national electricity grid), and Municipal Regulations (collaboration with local municipalities is vital for compliance with municipal regulations governing electricity distribution and infrastructure).

Establishing an enabling municipal environment may be a concern if the off-taker is a large municipal customer that leaves the grid (a so-called “grid defector”). In this case, the municipality will lose the revenue from the mark-up between the municipal sale price to the customer and the purchase tariff from Eskom. Electricity sales are known to contribute a significantly portion of the income of municipalities in South Africa.

13.3 Financial model and discounted cash flow analysis

13.3.1 Financial model assumptions and results

The success of the biomass-to-energy power station project hinges on a robust financial model and a comprehensive business case, both serving as prerequisites for securing financing. While a preliminary Discounted Cash Flow (DCF) model has been presented here, the responsibility for developing a complete business case will lie with the owner should the project progress.

Unlike the simplified LCOE calculation presented earlier in this report, the financial model considers various critical components. These include the total installed capital cost, grid connection expenses, financing, and associated costs. The model also considers biomass fuel costs, fixed operations, and maintenance (O&M) expenses, depreciation, debt servicing coverage (DSCR), and the profit margin for the owner.

Below in Table 19 are the parameters used for the DCF analysis and the assumed values for the base case for each of the parameters.

Table 19: Discounted cash flow analysis input parameters

B2E Power Station DCF analysis		
Parameter	**Base case value**	**Unit**
Capital cost parameters - CAPEX		
EPC costs (1)	336	Million ZAR
Contingency cost (2)	15	(%) Percent of EPC
Owner's cost (3)	10	(%) Percent of EPC
Loan parameters		
Loan percent (4)	100	(%) Percent of CAPEX
Loan term (5)	10	Years
Interest rate (6)	11	(%)
Operating cost parameters - OPEX		
Fixed operating cost (7)	3	(%) Percent of CAPEX
Fuel cost per unit (8)	500	ZAR/tonne
Fuel use (9)	6.7	Tonnes/full load hour
Variable operating costs (10)	1000	ZAR / operating hour
Plant annual capacity factor (11)	70	(%) Percent of rated power
Production per hour (12)	5000	kWh/h
Other parameters		
Income tax rate (13)	28	(%) Percent of Taxable Income
Project life (14)	25	Years of Production
NPV discount factor (15)	13	(%)
Price of produced electricity (16)	**3.64**	**ZAR/kWh**

Notes on parameters used in the cash flow analysis are as follows:

Capital cost terms

1. EPC is the cost to engineer, procure and construct the generator plant and the ancillary equipment, termed the balance of plant. This number was obtained from proposals received

from several engineering contractors. In addition, an allowance of R36 million was added for the estimated cost to connect the Power Station to the electricity grid.

2. Contingency is a cost that must be added to all projects to account for known and unknown undefined costs that arise in the implementation of the project. The value is based on industrial experience based on project complexity and level of definition of EPC cost estimates.

3. Owner's cost covers those costs paid by the project sponsor not covered within the scope of the EPC, including permitting costs, project control, training, and other activities throughout the development period.

Loan terms

4. The first loan related term is the percentage of the capital cost that is to be covered by the loan. Normally, financial agencies would expect that the project sponsor would inject some of their own capital into the project. For this project, it was assumed that the sponsor will require complete financing to construct the project.

5. The second loan parameter is the payback period. This defines the period of time in which the financial agency funding the capital costs expect to be paid back their investment and interest on that capital outlay. The bank will be expected to be paid back first and the term will be so as to minimise the risk of early termination of the project.

6. The third parameter for the loan is the interest rate. As inflation is not being considered in this analysis, this interest is the real interest rate, not the nominal rate. The bank will consider the probable expected inflation over the term of the loan and the nominal rate would include a value for this expected inflation.

   Amortisation of the loan during the defined payback period based on these parameters is set as an annual cost calculated within the Excel calculations.

Operating costs

7. Fixed operating costs are the costs needed to operate and maintain the facilities whether the plant is utilised or not. This also encompasses non-direct operating costs such as insurance, etc. These are an annual cost and, as per industrial practice, are set as a percentage of the capital costs.

8. The main variable operating cost is fuel cost, which is directly related to the number of hours that the plant is operated and the rate it is operated. Fuel cost is per unit of fuel to be used, in this case, ZAR per tonne of biofuel.

9. Related to the unit cost of fuel is the amount of fuel that must be used to operate the plant at a given output. In this case, the fuel consumption rate is a parameter supplied within the engineering contractor proposals.

10. In addition to the cost of fuel, there will be some other operating costs related to the use of the plant, such as operating costs for equipment to move fuel into boilers, etc. This should not be a large cost and an estimate of R1 000/operating hour was assumed.

11. A major parameter affecting every aspect of the project economics is the capacity factor for which the generator operates. This affects income and costs as well as specific amortisation costs. For a plant operated in base load use, this would be expected to be initially in the 70% - 80% range, with some decline over time, accounting for downtime for scheduled and unplanned maintenance and repairs.

12. The last parameter in determining the plant's operating performance is the amount of output that the plant would expect for each hour of operation. The rated output was used for this analysis.

Other parameters

13. Income tax rate is required for after-tax calculations. This is the tax paid on the net income after capital cost amortisation, operating cost, and depreciation. This analysis found that unless the price was high, there was not sufficient income to account for all the depreciation and the effective income tax rate was zero.

14. Project life is the expected term in years of the facility's operation.

15. The NPV discount factor is the assumed discount rate for calculating net discounted cash flow obtained by the project sponsor. This is a subjective value that is generally set higher than the weighted average cost of capital to account for the perceived risks in the project.

16. The price for the electricity sold by the plant is the final parameter in the discounted cash flow analysis and undoubtably the most significant. This is the parameter that defines the success or failure of the project.

13.3.2 Financial model results

The results from the discounted cash flow model are summarised in Table 20. While there is a positive cumulative cash flow down to a value below R 3.30/kWh produced, it takes a price of at least 3.7 to have a positive cash flow during the loan repayment period.

Table 20: Discounted cash flow model output summary

Price - (1)	**3.3**	**3.7**	**4.0**
	Million ZAR		
Cum. Net Cash - (2)	822	1 129	1 359
DCF @13% - (3)	46	111	158
Annual CF during loan - (4)	-10	1.8	11
Loan Coverage Ratio - (5)	0.86	1.03	1.15

The parameters in this summary are as follows:

1. The parameter being compared is the price of the produced electricity in ZAR/kWh.

2. The first result is the total net cash flow derived from the project, which is to say the cumulative income minus expenses over the term of project.

3. The second parameter is the cumulative discounted cash flow with a discount factor defined as 13%.

4. The next parameter is the annual cash flow during the loan repayment period. If the project does not return sufficient cash flow during the loan repayment period, the project sponsor would be required to meet this income deficiency.

5. The loan coverage ratio is the ratio of the annual net income during the loan period to the cost of the loan. This ratio should be above 1.0.

The shape of the cumulative net cash flow for the three reference prices is shown in Figure 6. As can be seen from these curves, for any price below R3.64/kWh there is a negative cash flow during the loan repayment period.

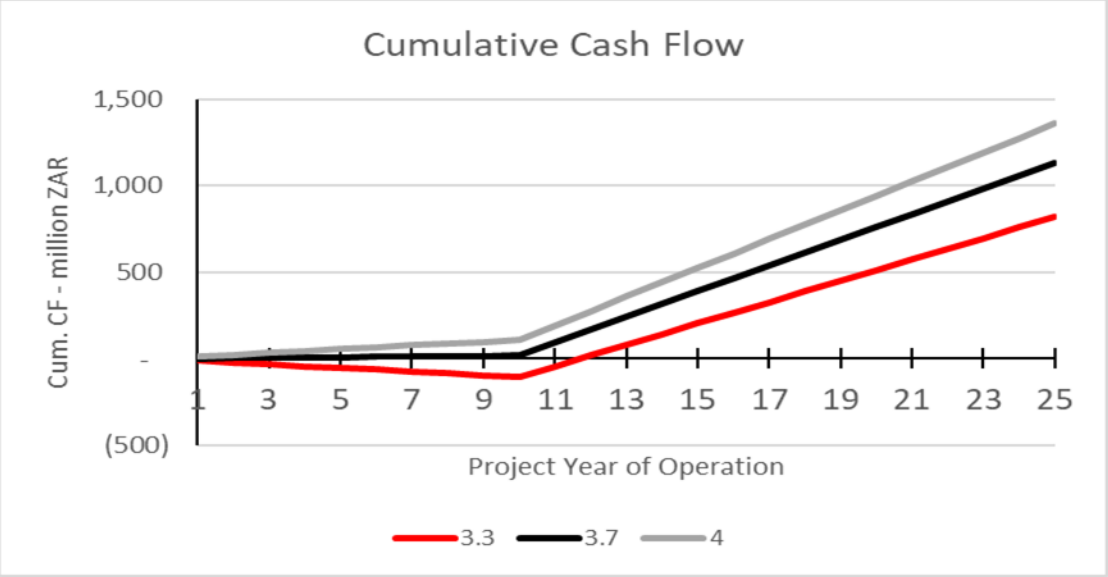

Figure 6: Cumulative cash flows at various electricity prices

It is important in any project analysis to understand the sensitivity that the discounted cash flow has to the various input parameters. This sensitivity can be demonstrated in a tornado diagram as shown in Figure 7, which shows the change to the "breakeven" price for the various parameters. For this exercise, breakeven price is the price needed for a loan coverage ratio of 1.0.

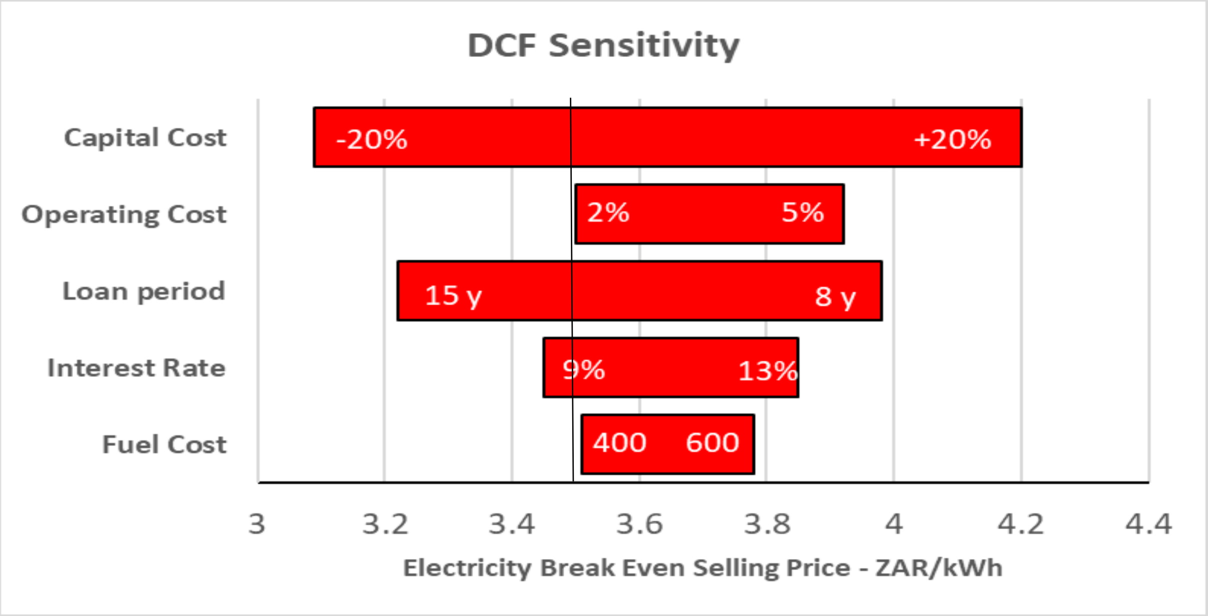

Figure 7: Sensitivity analysis of LCOE

In this chart in Figure 7, each of the parameters was varied with all other parameters remaining at their base values. These parameters were varied as follows:

1. Capital cost is varied by a minus 20% to a positive 20% below and above the base capital cost estimate.

2. The annual fixed operating cost is varied from 2% of the capital cost to 5%, compared to the base of 3%.

3. The loan repayment period is varied from 8 years to 15 years, compared to the base of 10 years.

4. The interest rate on the loan is varied from 9% to 13% compared to the base assumption of 11%.

5. The fuel cost is varied from R400/t to R600/t fuel, compared to the base of R500/t.

On conducting the DCF analysis, several challenges surfaced, highlighting potential impediments to the financial viability of the B2E Power Station project.

13.3.3 Profit margin challenges for debt servicing

The analysis reveals that profit margins struggle to effectively service the debt throughout a significant portion of the project's life. A high tariff price premium becomes necessary to achieve the targeted Debt Service Coverage Ratio (DSCR). This will increase the pressure on the project to secure a long-term Power Purchase Agreement (PPA) to sustain financial stability.

13.3.4 Depreciation constraints resulting from debt coverage

The cash flow analysis highlights a constraint in the depreciation schedule, which is by necessity, spread over the years with that service the debt. Hence, depreciation is not accelerated during the early years of the project life, as desired to maximise the discounted cash flow.

An owner with a substantial balance sheet could potentially benefit from rapid depreciation, leading to a need for economic considerations at the corporate level rather than the project level presented in the current analysis.

13.3.5 Impact of additional costs on required tariff

Grid connection costs, project contingency costs at 15%, and fixed Operations and Maintenance (O&M) expenses significantly increase the required tariff.

The tariff, initially estimated at R3.00 using the simple Levelized Cost of Electricity (LCOE), now faces upward pressure.

13.3.6 Necessity for a long-term PPA

The project's financial health is contingent on securing a long-term PPA to ensure stable revenue streams aligned with the DCF requirements.

These hurdles underscore the intricacies of achieving financial viability for the B2E Power Station. Addressing these challenges requires strategic planning, negotiation skills in securing favourable PPAs, and potential exploration of corporate-level economic considerations. Furthermore, continual refinement of the financial model, risk mitigation strategies, and collaboration with financial experts will be essential to navigate these hurdles and enhance the project's overall economic sustainability.

14. SWOT AND RISK ANALYSIS

14.1 SWOT analysis

The following SWOT analysis summarises the current factors impacting on the proposed Stellenbosch 10 MW Biomass Power Station project. These risks can be reduced by making the project smaller and more capital- and fuel-cost efficient.

Table 21: SWOT analysis

STRENGTHS	WEAKNESSES
• Proven and simple technologies proposed • LCOE lower than other dispatchable power options • Will have a lower escalation rate than Eskom over time • A stable biomass price will make alien invasive tree control sustainable for the first time in the long (approaching 30 years) history of this effort • Widespread and diverse supply base of biomass in the Boland – minimising the impact of local/isolated flooding or other access issues associated with a small concentration of biomass harvesting sites • Part of a major new green circular economy and job-creating initiative, especially when long-term re-establishment and better management of state-owned woodlots can be obtained • Using a renewable fuel, off-setting many tonnes of CO_2 emissions generated by coal-fired power stations	• A relatively complex and multifaceted project with many role-players • At R2.25 – R2.64/kWh the LCOE is still more expensive than Eskom from a municipal perspective • At an LCOE of R 3.64 it would be difficult to find power off-takers • Large biomass supply base to manage

OPPORTUNITIES	THREATS
- Selling uninterrupted power to the local community, Stellenbosch University, and other industries at much less than PV Solar battery power and diesel-driven power generation - Combined heat and power [CHP] opportunity for the larger food processors of the Western Cape – could become the CHP utility centre for surrounding energy-intensive agri-processors - Absorption cooling – refrigerated storage depot potential near the Power Station - Agri-forestry projects can be accommodated in and around the 7 000 ha woodlots as well as recreational facilities and natural fire breaks - On-site SMME opportunities — Pole manufacturing — Charcoal, biochar, activated carbon production — Nurseries, compost, growing medium production - CO_2-replacement and carbon credits can be pursued in the near future; these are not taken into account for this study - A B2E and PV Solar energy mix can bring the blended LCOE down to lower than Eskom retail rates with near 90% reliability (Capacity factor) - If constructed at the SM WWTW bordering the landfill site, methane gas from both facilities can be burnt-off in the boiler of the Power Station, gaining further kW output at a low cost	- Biomass supply chain problems — Low political will to re-establish woodlots — Strikes — Wildfires — Floods/access to harvesting areas - High biofuel prices - High interest rates - Viability sensitive to drop in Power Station energy output and technical availability - A reliable Eskom supply with high technical availability at a low cost

14.2 Risk analysis

The major risks associated with this project can be summarised and addressed as follows:

14.2.1 Running out of fuel

Running out of fuel is highly unlikely, given the large and diverse biomass supply base. In short, if the price paid by the Power Station makes sense to the biomass harvesting contractors, there will be no shortage of biomass.

The introduction of the woodlot strategy (Refer to **Annexure K**) will ensure long-term biofuel supply. The woodlots are, however, only necessary for the larger 10 MW Power Station scenario, and only from approximately year 10 onwards.

14.2.2 Biomass supplied from the riparian zones dries up

The riparian zones analysed for this study are increasing in biomass volumes by approximately 180 000 t.p.a. (See **Annexure A** by the CSIR). If a 10 MW B2E Power Station uses 40 000 t.p.a. from this supply base, it is estimated that this resource will begin to dwindle by years 10 to 15.

A smaller 5.0 MW B2E Power Station will need less biofuel from this resource (Especially from the areas > 100 km away from the Power Station) and this supply base will thus last much longer.

It must also be noted that a fair percentage of biomass is available from old and recycled fruit orchards, industrial waste wood, and solid wood from the municipal garden refuse transfer stations.

The security of biomass supply is expected to improve as the project's sustainability becomes better known.

14.2.3 Low political will to allow the re-establishment of woodlots

The 7 000 ha of licenced state-owned woodlots are currently lying fallow and in a state of neglect. This project hopes to be the catalyst to revive the overhauling and long-term sustainable management of these woodlots for a range of products, including timber poles and biofuel. For the first time in nearly 30 years, a sustainable plan is on the table for these woodlots of the Boland, for approval by the authorities.

14.2.4 The perception that a price of approximately R2.50/kWh is too high for renewable uninterrupted baseload electricity

Although the baseload electricity generated by the proposed 5.0 MW Stellenbosch Power Station, at more than R3.60/kWh, appears to be much higher than PV Solar @ R0.90/kWh, it must be stressed that by the time solar power generation is upgraded with battery storage to be regarded as "dispatchable power", or "power on demand", it cost close to R4.80/kWh, or approximately 33% more expensive than Biomass Power. See Table 16.

By comparison, however, the sugar industry in KZN offers baseload power (as a by-product of their core sugar-business) at < R1.10/kWh. It must, however, be borne in mind the bagasse biofuel input costs of the B2E power generating boilers at the sugar mills are kept at near zero. This power still needs to be imported ("wheeled") from KZN to the Western Cape at an additional charge of >R0.30/kWh, payable to Eskom and is nearing full output capacity. It should be noted that the sugar industry of KZN is shrinking and will continue to shrink as the centre of gravity of this agri-industry is moving further north into Mozambique.

It is also fair to say that the Stellenbosch Biomass Power Station can produce baseload power at a lower cost than any other renewable dispatchable power source in the Western Cape, even without taking the CO_2-reduction compensation or any other form of Carbon Credit into account.

14.2.5 Finding sufficient long-term off-take

Ideally, for the Power Station to be economical, most of its net energy output must be absorbed by the companies buying its power as part of the PPAs. It would therefore be essential to enter into a PPA able to absorb the following minimum package of power p.a.:

> 4 500 kW net output x 8 000 h.p.a. @ say R3.50/kWh = R126 x 10^6 p.a. (VAT and escalation excluded) for say 10 years, renewable for a further 10 years, at agreed escalation rates p.a.

It may be possible to reduce the cost even further by optimising some of the components of the Power Station, obtaining firm cost proposals in an open tender process from the EPC contractors, and find additional funding from sources in the form of either grants or at lower interest rates. [*An MEng (Industrial Engineering) research study has been registered in February 2024 at the SU Faculty of Engineering to continue with the refining of this project to improve the cost of electricity generation to a more acceptable level of (say) R 3.00/kWh*].

14.2.6 Technical availability of the Power Station

The 5.0 MW Power Station will be designed, constructed, operated, and maintained to run at approximately 4 500 kW minimum net output at a near continuous period of 8 000 h.p.a. (or 91% of total time p.a.). This is a conservative engineering norm and is achieved at most similar plants worldwide. Minimum technical maintenance levels, however, must be maintained by the on-site crew of fully qualified engineers, technicians, artisans, and well-trained plant operators. A more conservative approach of 70-80 % Capacity Factor was proposed earlier in Chapter 13. See Table 19, note (11). The equipment suppliers are however confident that the power plant can run at 90 % to 92 % technical availability (Plant Capacity) at a continuous basis for at least the first 10 years, by adhering to the minimum maintenance standards. Thereafter it could reduce to 85% by year 20.

A new dimension of plant security to prevent theft, sabotage, and induced breakdowns has emerged in South Africa in the last 20 years and will have to be thoroughly catered for using security systems of ultra-high integrity and efficiency.

14.2.7 Life after loadshedding

Even if loadshedding can be minimised over the next 5 to 10 years, the need for renewable baseload power in the Western Cape will remain high and appropriate to the circular green economy. The professional team believes, as soon as the re-establishment of woodlots can be granted, that the proposed 5 MW Power Station can be duplicated elsewhere, or an even larger 10 MW Power Station can be introduced. The Grabouw area is in dire need of job creation and is a central point of nearly 4 000 ha of licenced woodlots.

Grabouw has the added advantage of being close to the Steenbras 180 MW hydroelectric pumped storage station. A scenario to build a larger (say 20 MW) biomass Power Station to run in tandem with the Steenbras hydro plant has good merit. Such a combination could lead to a better addressing of demand peaks (or periods of loadshedding) for the Cape Metro. In fact, this scenario could lead to the further expansion of the woodlots on the marginal land of the Steenbras Dam catchment area. A shallow and rocky piece of land only fit for selected agri-forestry projects.

15. KEY FINDINGS AND CONCLUSION

The following key findings were made:

i) Sufficient volumes of biomass are available to supply a more than 5.0 MW_e (net output) Biomass Power Station for the next 20 years, from a supply base of approximately 100 km radius from the proposed site at the *Wastewater Treatment Works [WWTW]* of *Stellenbosch Municipality [SM]*, next to SM's main intake substation from Eskom.

ii) The biofuel supply to the proposed power plant will consists of a mixture of raw wood obtained from:

   - Invasive alien trees harvested in the riparian zones of the Berg, Breede, Zonderend, Bot and Hex Rivers, as the primary resource.
   - Old fruit orchards as a secondary source.
   - Raw wood and waste wood from the surrounding (privately owned) woodlots, harvested windbreaks, municipal garden refuse sites and transfer stations, as a tertiary source.

iii) The most economical way to prepare the biomass that is to be delivered to the Power Station site, would be in whole logs, trunks, and pole-shaped pieces, trucked in 30 - 32 t payloads for use in the wood-fired plant, where it is to be processed further into hogfuel.

iv) Experienced and reliable biomass harvesting and transporting companies exist in the Western Cape, who are keen to enter into long-term biofuel supply agreements at the prices and specifications required by the proposed power plant.

v) Reputable and reliable local B2E Power Station engineering, procurement, commissioning (EPC) companies are available in the Western Cape, willing and eager to participate in this project.

vi) The proposed 5.0 MW_e Power Station can generate dispatchable power at approximately <u>R3.64/kWh</u> when running at near full load for approximatel 75% of the time (Capacity Factor), which could make it attractive to traders like Energy Exchange, EnPower Trading, and others, like the Stellenbosch University, to enter into long-term *Power Purchasing Agreements [PPAs]* with the *Independent Power Producer [IPP]* and the owner of the new 5 MW power plant. The potential exists to then blend the baseload power (@ ± R3.64/kWh) with e.g. PV Solar power (@ ± R0.90/kWh) to obtain a blended baseload renewable power product of approximately <u>R3.00/kWh.</u>

vii) The estimated cost of R3.64/kWh for electricity generated by the 5.0 MW B2E Power Station is less expensive than electricity generated by diesel generators of equivalent size and capacity factor @ > R5.50/kWh, or supplied by PV and battery energy storage systems @ > R 4.80/kWh. Refer to Table 16.

viii) The preferred site for this project is at the WWTW of SM next to the main Eskom intake substation and landfill site. This location can benefit the SM in multiple ways:

   - Sewage sludge from the WWTW can be composted and pasteurised on the same site in aerated windrows, processing sludge, woodchips, and ash from the Power Station into a marketable growing medium product for larger tree nurseries and fruit farmers.

- Methane gas from the neighbouring landfill site can be burnt in the combustion chamber of the boiler of the Power Station instead of flaring it off to atmosphere.
- The B2E Power Station will then be close to the main substation and its baseload infeed can be planned to optimise the distribution of power to selected areas, which in turn would benefit from having an uninterrupted power supply at a small premium to their current electricity bill. In fact, these clients of the SM are currently paying large sums for diesel and PV Solar-charged battery systems to mitigate their losses due power outages.
  [In fact, most of them are already paying more per unit of electricity when the total cost of their Municipal power supply package is taken into account. Excluding their additional diesel and related costs].

ix) Another advantage of the location at the main Eskom intake substation at the WWTW is that the electrical power can be supplied either directly to SM, without a wheeling agreement with Eskom, or via the Eskom grid, with a wheeling agreement to other off-takers anywhere in South Africa.

x) One of the outstanding features of the proposed B2E project is that its projected escalation curve for cost of energy will be significantly flatter than the average 15% p.a. increase by Eskom over the last 10 years. It is foreseen that a blended (PV Solar + B2E) price of say R3.00/kWh will soon be lower than most of the other baseload retail power suppliers, including Eskom.

xi) The PV Solar blended option could also reduce the biofuel requirement of the B2E Power Station. A 25% PV Solar blend will reduce the biofuel demand to approximately 40 000 t.p.a., thus reducing the required biofuel supply base size further, leading to shorter supply distances and a further reduction in the average delivered costs of biofuel.

xii) The number of large 30 t payload trucks to transport approximately 40 000 t.p.a. biomass of logs, trunks and poles to the power plant can be calculated at approximately 1 333 truckloads p.a. or 7 - 8 deliveries per working day for 180 days p.a.

xiii) Approximately 8 000 t.p.a of biofuel and refuse derived fuels can be made available from the Garden Refuse Handling and Materials Recovery Facility of SM. The number of truckloads importing biofuel from afar will then further reduce to a maximum of 7 lorries per day for approximately 180 days p.a.

16. RECOMMENDATIONS AND WAY FORWARD

The following recommendations can be made:

- i) It is clear from this study that the project is technically feasible and uses existing, proven technology.
- ii) A secure and sustainable supply chain of biofuel can be established to ensure that the B2E Power Station can operate for at least twenty years.
- iii) At an estimated cost of R 3.64/kWh at a capacity factor of 75%, it will be difficult to find willing customers to be supplied from this power station without some other non-monetary incentive.
- iv) The following options may exist to implement the project:
    - a. Obtain a sponsor/donor that will provide the estimated R334 million capital expenditure at either a very low interest rate, or as a grant to demonstrate the technology in the South African context.
    - b. Investigate the option to find an off-taker prepared to pay R3.64/kWh for uninterrupted electricity. (This will also need Stellenbosch Municipality to support this option to wheel this power uninterrupted during load shedding.)
    - c. Investigate a possible combination of these options.
    - d. Reduce the LCOE to approximately R 3.00/kWh and lower by blending the above B2E power with power from PV Solar during the day.
    - e. Apply for Green Finance grants and/or concession funding to reduce the cost of capital.

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