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PREFEASIBILITY STUDY FOR BIOMASS POWER PLANT, NAMIBIA

BIOMASS SUPPLY CHAIN ASSESSMENT

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31/07/2012

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1 Target and Procedure

1.1 Introduction

The target of this section is to calculate the biomass provision costs for the biomass supply of a 5 MW_{el} biomass power plant at Otjiwarongo and different 20 MW_{el} power plants with bubbling fluidized bed (BFB) boiler or grate boiler at Ohorongo Cement and at Otjikoto Substation. The supply chain incorporates Harvesting, Handling, Storage and Transport components.

A current study based at the University of Stuttgart investigating the harvesting of short rotation coppice and forest residues highlights two harvesting methods as being the most promising. These are:

- **Cutter chipper -** Harvesting and chipping happens in one step, resulting in need for only one calculation. This method was proposed as being the best feasible option in previous studies by Christians and Associates (2010).
- **Cutter collector -** The cutter collector is carried by a tractor or a skid steer. The cutter collector could have a beneficial effect for the harvest of small field sizes and marginal sites. It is not as heavy as a cutter chipper and the farmer can use his own tractor and is more flexible. This method is similar to the rotary saw mounted on a skid steer described as the best option for harvesting in Leinonen (2007).

In an attempt to ensure that the project results in maximum socio-economic benefits a third option is included in the Prefeasibility Study:

- **Motor Manual Harvest**: The motor manual harvest is done by a chain saw. The trunks are moved to the field side for direct chipping by a mobile chipper or storage by a tractor. The mobile chipper can chip the trees up to a diameter of 27cm.

Prior to assessing the financial and technical performance of each supply chain scenario, the broader supply chain context is briefly reviewed.

1.2 Characterising the Encroacher Bush Resource in Namibia

1.2.1 Introduction

The encroacher bush resource has previously been introduced in the Inception Report for this project. Bush encroachment in Namibia has increased drastically over the last 30 years. In 1957 it was reported that some 4.56 million hectares were infested with encroacher bush and this had increased to some 26 million hectares by 2002 (de Klerk, 2004).

Densities of encroacher bush vary widely, with an average yield of between 13 and 18 tonnes per hectare, depending on the climatic region and soil condition in a specific area (Honsbein, et al., 2009). There are around ten primary encroacher bush species whose distribution varies geographically. In the south (nearer Green Coal's operations near Omaruru), swarthaak (*acacia melifera*) is the predominant encroacher bush. When swarthaak is harvested, many trees die as a result of the harvesting and re-growth can be managed with proper aftercare, hence mechanical harvesting is quite attractive in these areas. In the more northerly areas (CCF/Otjiwarongo up to Tsumeb), sicklebush (*dichrostrachys cinerea*) is the primary encroacher bush. Sicklebush is far more difficult to eradicate, is almost impossible to manually harvest (due to its dense and thorny characteristics) and can grow back vigorously after mechanical harvesting (especially where the soil surface is disturbed mechanically by the harvesting equipment – this can even result in worse regrowth than was originally present). With all species, appropriate aftercare (discussed further on) is essential in managing and preventing regrowth.

1.2.2 Land Ownership

Namibia's agricultural sector consists of two specific types of land ownership, namely the commercial farming sector which is based on freehold titles, and the communal sector wherein the land is state-owned in non-title deed areas. De Klerk (2004) reported on the densities of common encroacher species within each of these land categories within heavily affected regions of Namibia. It can be concluded from this study that the commercial farming areas comprise ± 15.7 million hectares out of the total of 26 million hectares encroached by bush. These 15.7 million hectares occur on commercial farms ranging in size from 4000 to 7000 hectares and with the exception of some crop cultivation (de-bushed land) the farms are used predominately for extensive stock (cattle) farming.

It is proposed that commercial farming areas, which entail ± 15.7 million hectares out of the total of 26 million hectares encroached by bush, are focused on for harvesting during the Pre-feasibility Study. For communal agricultural farmland on which farmers have in the past indicated in principle support to allow access to the resource, the standing biomass resource does not belong to them (government holds registered title rights to the land). Consequently, industrial harvesting would be illegal unless government intervenes and provides the affected communities the necessary authorisation. This process may be cumbersome, as the governing bodies of the affected communities must first agree to planned interventions through traditional, local and regional authorities before central government can authorise such interventions.

Combined with the aspect that permission to access biomass communal land must pass through all authorities and that farmers do not have land ownership rights, communal farmers may be unwilling to harvest the resource. The 'short cut' to access this resource in communal areas would be to engage government to roll out a central government harvesting programme documented under the Medium Term Expenditure Framework (MTEF) as coordinated by the Ministry of Finance on an annual basis. The establishment of a Public-Private-Partnership (PPP) would most likely be required.

A focus on commercial farmers to underpin the biomass-to-energy feasibility therefore seems the most promising solution to secure a commercially reliable feedstock, with other suppliers potentially coming on board thereafter.

1.3 Reconfirming the Potential Biomass Resource in Namibia

An assessment of the available desktop information indicates the substantial potential for biomass to energy opportunities related to the encroacher bush. WSP reviewed the desktop information available regarding encroacher bush prevalence and found that the data implied an annual increase of around 3.955% in encroacher bush tonnage.

Table 1: Estimates of Encroacher Bush in the Literature

Year	Reported Bush Inventory at hand	Reported bush encroachment
	Mt	ha
1957	23	4,563,974
1986	72	14,428,000
1991	89	17,800,000
2002	132	26,259,000
2010	176	26,259,000

The increase in encroacher bush is well documented in the academic literature, is widely discussed by relevant stakeholders such as the various commercial cattle farming associations, and has been corroborated by the project team's own anecdotal experiences and observations during the in-country visit (travelling from Windhoek through to Tsumeb in the north).

The above values (as well as the values derived in the companion excel spread sheet indicating growth trends) are based on various literature sources. These include

- De Klerk, J N. 2004. Bush Encroachment in Namibia – Report on Phase 1 of the Bush Encroachment Research, Monitoring and Management Project. Ministry of Environment
- Rawlinson, J. 1994. Meat Industry of Namibia 1893 - 1993. Windhoek, Namibia. Gamsberg MacMillan Publishers. 259pp. ISBN 086848881X, 9780868488813
- Reports compiled in 1985 and 1986 present different figures for bush encroachment, e.g. Here Lubbe and Slater, 1985 present the total bush encroachment potential to be 100 Mt; presented at Conference "Bush Encroachment and Control in Perspective", presented by the Rietfontein Farmers Association and the Grassland Society of Southern Africa, 21 & 22 April 1993, contribution by Mr Chris Shikaputo, Chief Forester, Directorate of Forestry, Ministry of Agriculture, Water & Rural Development, titled "Bush Encroachment in Namibia - an environmental and forestry perspective"
- Joubert, DF; Zimmermann, I. 2002. A crude quantification of wood that is and can be harvested from bush thickening species in Namibia; paper presented at the national forestry research workshop held in Windhoek, Forestry Publication (Proceedings of Workshop) 9:56-66; 12-13 March 2002; and
- Work and simulation undertaken by Honsbein, D. 2011, as part of her PhD Thesis.

Using some high-level assumptions and the 3.955% annual growth to model[1] the impact of bush harvesting indicates that it would take approximately *forty five* 20 MW power plants – all simultaneously commissioned in 2017 – to keep the mass of encroacher bush held constant at 2017 levels (i.e. where the mass of annually harvested wood for fuel supply equals the mass of annual encroacher bush growth). Alternatively, assuming zero per cent growth rate, there would be sufficient encroacher bush biomass to supply a single 20 MW power plants for around 1,142 years. Ten power plants of that size could theoretically be sustained for around 114 years (assuming they were all simultaneously commissioned in 2017).

The above calculations are obviously hypothetical and are based upon numerous idealised assumptions. They assume (in the first example) on-going exponential growth, do not account for any possible up-scaling in existing debushing activities via arboricide application, do not account for after-care on cleared land, assume that all encroacher bush-impacted land can be accessed for harvesting etc. Despite these idealised assumptions, the numbers clearly indicate that there is no theoretical shortage of encroacher bush biomass at a national scale, certainly not for a relatively small number of 20MW plants i.e. five such plants. The practical and economic constraints around the supply of biomass to the proposed power plants are explored in the rest of this study.

1.4 Competing Options for Farmers

There is a strong driver for commercial farmers to debush their land in order to raise the carrying capacity for cattle. De-bushing is also important for game commercial farmers, both from a livestock carrying capacity perspective as well as from a tourist perspective (allowing tourists to view the game in savannah conditions). Finally de-bushing is important to other stakeholders such as conservation NGO's (like CCF, who view encroacher bush as a risk to the cheetah habitat) and communal farmers.

Several approaches are followed by landowners at present including:

- Manual clearing (using farm labour), typically followed by charcoal making;
- Arboricide (selective) application (typically by crop-sprayer plane);
- Fire clearing;
- Bull-dozing and other mechanical clearing methods;

[1] The spreadsheet with the calculations will be provided to NamPower electronically.

- Mechanical harvesting by EFF.

All of the above are typically followed up by “after-care” programmes to manage the regrowth. After-care typically comprises a mix of manual clearing and/or manual application of non-selective herbicide (usually with a dye added).

- **Manual clearing (using farm labour), typically followed by charcoal making:**

This is a relatively popular option at present, as it allows the farmers to recover the cost of clearing form the sale of charcoal. It is also a source of rural employment. However this option is increasingly unpopular due to the risk of uncontrolled fires. Some farmers have even indicated to neighbours that if a fire breaks out, they will not assist their neighbours if the fire is related to charcoal making.

There are also serious limitations to the ability of manual clearing adequately manage the extent of encroacher bush in Namibia i.e. the manual method is inadequate for halting the spread of encroacher bush, let alone reversing this trend. In fact, based on the growth statistics of the intensification of encroacher bush problems, the manual clearing undertaken to date does not appear to have made a significant impact on even slowing down the spread of this problem.

- **Arboricide (selective) application (i.e. by crop-sprayer plane):**

This option is becoming increasingly accepted and widespread. In research undertaken by the project team as part of this assignment, arboricide application was noted as being at least as popular as the use of mechanical clearing methods. The application of arboricide is seen as the most significant competing alternative to the widespread use of mechanical harvesting. The cost of arboricide application is estimated at present (by the project team) to be around N$ 500 – N$ 700 per ha.

Arboricide has advantages and disadvantages compared to mechanical harvesting. The biggest advantages are that there is typically a longer period before regrowth of encroacher bushes start again, less disturbance to soil, and better conditions for grass regrowth. The negatives are that the land is not immediately cleared; arboricide is not effective against all bushes (especially the highly problematic sickle bush in the north) and is relatively costly. At least one farmer indicated a concern that the widespread use of arboricide may place Namibia’s status for free-range beef at risk (it is not clear whether this is a well-founded risk or not).

- **Fire Clearing:**

Fire clearing does not appear to be a popular option, presumably due to the obvious risk of uncontrolled burning, especially in a country like Namibia. The widespread application of this method is also unlikely to be environmentally acceptable.

- **Bull-dozing and other mechanical clearing methods:**

During the technical team’s site visit, some bulldozing of encroacher bush was observed, while in interview questionnaires, mechanical clearing was noted as being as common as arboricide application. Presumably in some of these instances, the mechanical clearing is undertaken by EFF while in others it is undertaken by the farmers themselves, in which case charcoal production may also follow the clearing process to try recoup at least some of the costs.

- **Mechanical harvesting by EFF:**

This involves cutting the bush and harvesting it for use at Ohorongo Cement. EFF indicates that they get paid by the farmers to clear the land (around N$ 300 – N$ 700 per ha, depending on distances). This apparently does not cover the cost of the actual harvesting operation but acts to subsidise the cost for harvesting for Ohorongo Cement. Harvesting in 2011 is estimated at around 40,000 - 50,000 tonnes of woodchip and EFF hopes to increase this to 85,000 tonnes per annum. EFF has indicated that, based on their experience, they consider it perfectly feasible to supply an additional 150,000 tonnes per annum to supply an biomass power plant.

- **After-care**

Regardless of the method adopted, after-care is noted as being key to maintaining the benefits of the de-bushing exercise.

Summary

Based on the team's discussions with roleplayers and farmers (directly and via questionnaires), it is clear that there is a strong demand for debushing and that many, if not all, farmers are willing to spend money of debushing. The results of the teams engagement with commercial farmers is summarized in Appendix A.

1.5 Characterisation of Harvesting Methods

1.5.1 Manual Harvesting Method

Labour intensive methods have to date been used by many farmers on a small scale mainly to produce charcoal in order to recover de-bushing costs. The potential problem with this method, especially when done on a large scale, is acceptance by the farmers. Interviews carried out with farmers as part of the CBA study highlighted labour intensive methods will not be accepted when done on a commercial basis (i.e. large teams of bush-cutters entering a farm under external control is not favoured) (Honsbein 2009). Related problems mentioned included poaching, uncontrolled veld fires, hygiene and theft. For labour intensive methods the farmers were reported as preferring to do their own harvesting on a small scale and be in control of access to properties. Additionally, the manual harvesting is reported to not be viewed as desirable work by the general (unskilled) labour force: the work is physically very demanding and difficult. There are also doubts regarding the practicality of manual harvesting, especially for the thick areas of extremely thorny sickle bush growth in the north. Having viewed this type of growth, the team is not convinced that this bush could be safely harvested manually, without risk to the workers (i.e. would entail hard manual labour while wearing heavy protective clothing and operating dangerous equipment such as chainsaws in the Namibian day-time heat).

1.5.2 Mechanized and Semi-Mechanized Harvesting Methods

During the same interview process farmers indicated that mechanical harvesting will be acceptable however, the *modus operandi* to be negotiated with the farming community (Honsbein pers comm. 2012). These views have been confirmed in subsequent farmer engagement and interviews undertaken by the project team as part of this study. Therefore two harvesting and transport process chains were identified as being suitable to supply enough wood chips for power plants with an electricity generation between 5 and 20 MW_{el}.

1. Fully mechanized harvesting with cutter chipper (see Figure 1). At Ohorongo Cement and at Otjikoto Substation the fully mechanized process chain will be deployed to supply a 20 MW_{el} biomass power plant. This is mainly because cutter chippers (biomass harvester AHWI BMH480) are already in use at Ohorongo Cement by Energy For Future (EFF).

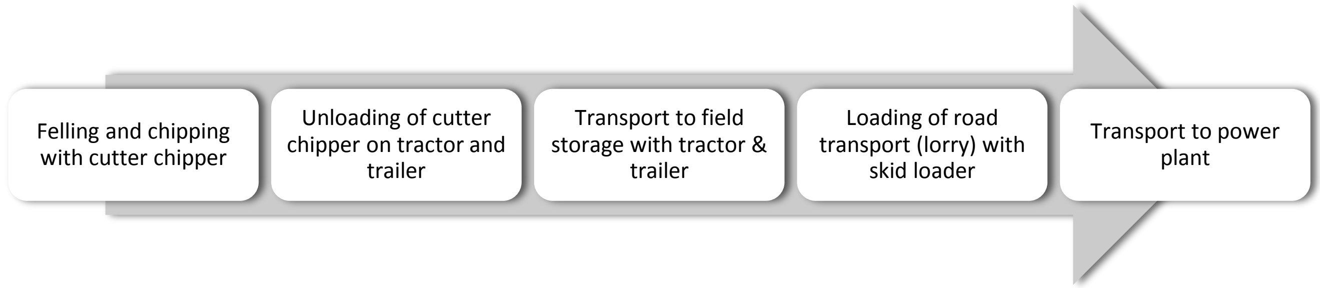

Figure 1: Process chain of fully mechanized harvesting and transport

2. Semi mechanized harvesting with skid steer and mobile chipper (see Figure 2). This harvesting process chain will be deployed at Otjiwarongo to supply a 5 MW_{el} biomass power plant. At Otjiwarongo tests have been undertaken by the Cheetah Conservation Fund (CCF). Therefore a good knowledge basis with this kind of harvesting method exists. Furthermore Leinonen (2007) concluded that the most cost efficient method to harvest and supply wood chips is with the semi mechanized supply chain. However the limit of this statement is that the fully mechanized process chain was not tested in the study.

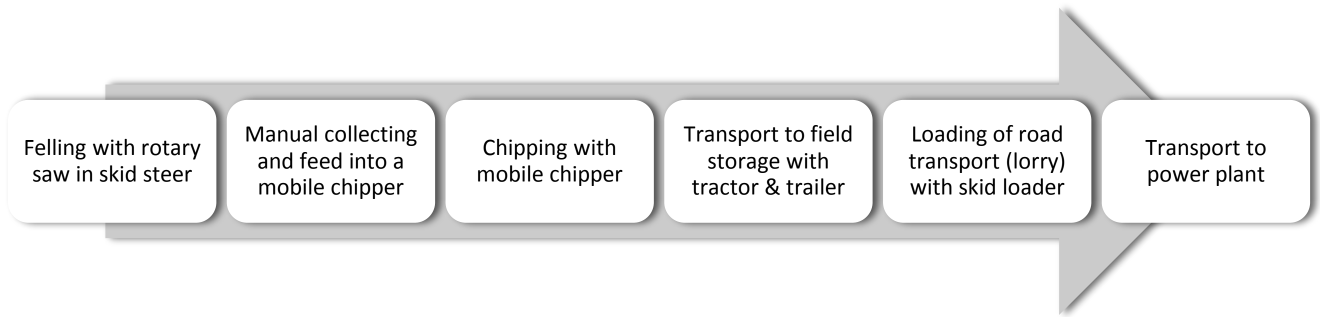

Figure 2: Process chain of semi mechanized harvesting and transport

To give a better picture about the harvesting and transport procedure, in Figure 3 an exemplary harvesting and transport approach is shown. The farm is harvested and the wood chips are transported with tractor and trailer to the field storage. At the field storage the wood chips are loaded via the skid loader on the road transport (transport 2) and brought to the power plant. It is assumed, that each farm is connected to the main road.

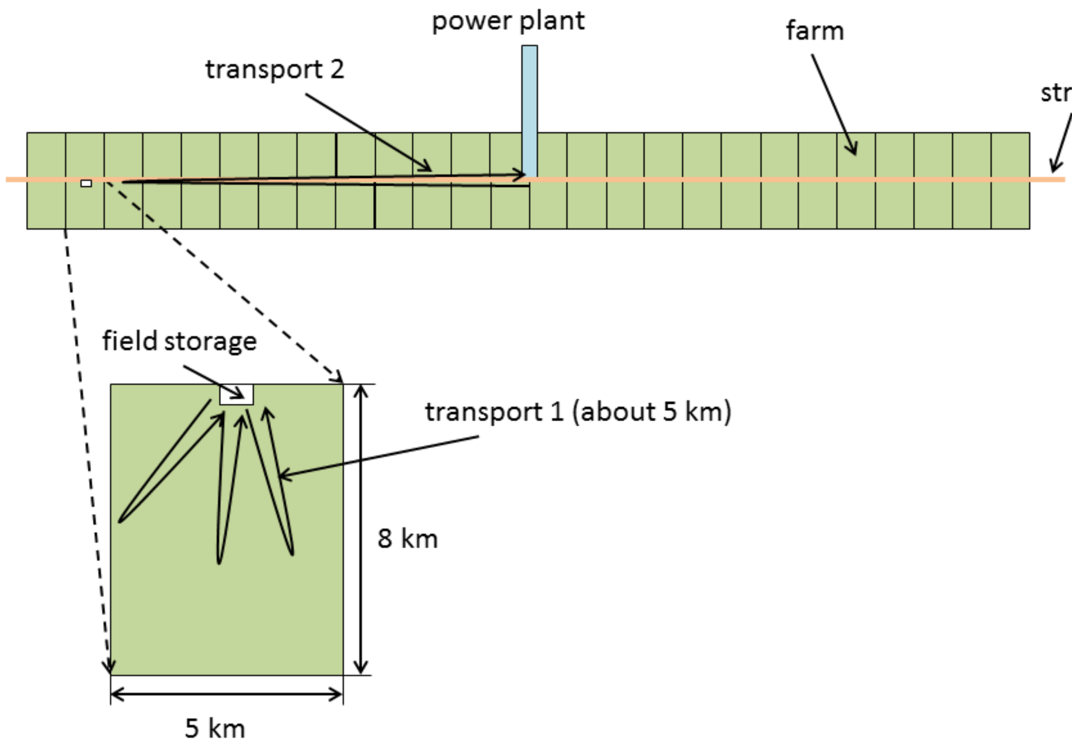

Figure 3: Exemplary harvesting and transport procedure with transport-1, field storage, and transport-2 to the power plant site

2 Input Data

Based on the above described harvesting and transport process chains (see Figure 1 and Figure 2), the biomass supply costs for the different power plants at Otjiwarongo, Ohorongo and Otjikoto are analysed. This assessment hereby takes into account the following factors:

- Price of machinery (cutter chipper, skid steer, rotary saw, chipper, tractor trailer, road transport);
- Labour wages (workers and supervisors);
- Productivity of the machinery (including road transport at a range of distances);
- Logistics and maintenance workforce required;
- Fuel price.

In the following the input data to calculate the biomass supply costs is presented. In section 2.1 until section 0 the needed data for the biomass supply calculation is described.

2.1 Basic Data

The basic data which is presented in Table 2 till Table 4 is valid for the two harvesting process chains at all sites. The inflation rate is set to 6.5 % and the exchange rate is used from 3rd of July 2012.

The wages rise from an unqualified worker (N$/annum 18,000) to a semiskilled worker, who is able to operate a tractor with trailer (wage: N$/annum 24,000) to a qualified worker, who is able to operate a cutter chipper (wage: N$/annum 36,000). Monthly salary of supervisors are N$/annum 96,000 and those of harvesting managers N$/annum 420,000. To maintain the machinery a Namibian maintenance engineer is needed with a salary of N$/annum 360,000.

Due to the rainy season harvesting can only be executed within 9 months of the year (refer to Table 3). Additionally the working time is about 24 days per month and 8 hours per day. The wages are however paid per annum.

The weight of bush chips after harvesting is about 0.1694 tonnes moist mass (t_{mm}) per m³ and the energy content of bush chips after harvesting is about 16.5 MJ/kg (Table 4). The average size of a farm in Namibia is assumed to be about 5,000 ha. The EIA conditions for harvesting include a maximum harvesting of 50% of any farm and a maximum of 500 ha per farm per annum. As well, a “harvestable land availability factor” is included, which accounts for either unwillingness of farmers to clear their land or other impacts on the harvesting radius such as alternative land use. To account for the harvesting service, which will be executed on the farmers land, the amount paid by farmers for the harvesting service can be set. Within the baseline calculation this amount is set to 0. However the sensitivity analysis covers the farmer payment in more detail.

Table 2: Basic financial and labour data

	Unit	NamPower scenario
inflation rate	%	6.5
exchange rate	N$ to Euro	0.1
fuel cost (Diesel)	N$ / Liter	10
lubricating oil cost	N$ / Liter	21.3
labour costs (unqualified worker)	N$ / annum	18,000
labour costs (semiskilled worker)	N$ / annum	24,000
labour costs (highly trained)	N$ / annum	36,000
supervisor	N$ / annum	96,000
maintenance engineer	N$ / annum	360,000
harvesting manager	N$ / annum	420,000

Table 3: Working hour data

	Unit	Value
working days per month in Namibia	day / month	24
working hours per day in Namibia	hour / day	8
harvesting months per year in Namibia	month / year	9

Table 4: Biomass and farm specific data

	Unit	Value
weight of bush chips after harvesting	t_{mm} / m³	0.1694
energy content of bush chips after harvesting	MJ / kg	16.5
average farm size	ha	5,000
maximum allowed harvesting in one farm	%	50
harvestable land availability factor	%	50
Amount paid by farmers for harvesting service	N$ / ha	0

Due to the rainy season harvesting can only be executed within 9 months of the year (refer to Table 3). Additionally the working time is about 24 days per month and 8 hours per day.

2.2 Machinery Data

The machinery investment data for the fully mechanized harvesting is shown in Table 5 and for the semi mechanized harvesting in Table 6. For all machinery used in the different process chains the investment is given as well as the maintenance and insurance in per cent of the investment. With the help of the life time of the machinery, the yearly cost of the machinery can be calculated. The “size of the storage” of the trailers or the cutter chipper is needed as well as the maximal allowed freight weight to review whether the technology used can handle the calculated amount of wood chips. Additionally in Table 5 and Table 6 the fuel and oil consumption is displayed as well as the time requirement of the machinery for a working step.

Table 5: Technology and cost data of harvesting and transport machinery for the fully mechanized harvesting method

		Cutter chipper	Tractor	Trailer	Skid loader	Towing vehicle = lorry	Trailer = lorry
Capital Investment	Thousands N$	4,000	913	214.5	1,408	920	520
Maintenance & insurance	% of investment / a	5	5	5	5	5	5
life time	annum	10	12	15	12	6	10
size of storage (or shovel for skid loader)	m^3	25	-	81	2.3	-	80
max weight in storage	tonnes	4.235	-	13.7	-	-	14
average speed	km / h	-	15	-	-	50	-
fuel consumption (Diesel)	litre / h	36.3	11.9	-	12.2	-	-
fuel consumption (Diesel)	l/100 km	-	-	-	-	35.3	-
lubricating oil consumption	litre / h	0.363	0.119	-	0.122	-	-
lubricating oil consumption	l/100 km	-	-	-	-	0.353	-
time requirement	hour per ha	1	-	-	-	-	-
yield of moist mass	t_{mm} / ha	10	-	-	-	-	-
time requirement unloading	H	0.05	0.05	-	-	0.05	-
time requirement loading	h /t_{mm}	-	-	-	0.06	-	-

Table 6: Technology and cost data of harvesting and transport machinery for the semi mechanized harvesting method

		Skid steer	mobile chipper	Tractor	Trailer	Skid loader	Towing vehicle – lorry	Trailer – lorry
Capital Investment	Thousands N$	281.5	750	913	214.5	1,408	920	520
Maintenance & insurance	% of investment / a	5	5	5	5	5	5	5
life time	annum	10	7	12	15	12	6	10
size of storage (or shovel for skid loader)	m³	-	-	-	81	2.3	-	80
max weight in storage	tonnes	-	-	-	13.7	-	-	14
average speed	km / h	-	-	15	-	-	50	-
fuel consumption (Diesel)	litre / h	7	-	11.9	-	12.2	-	-
fuel consumption (Diesel)	l/100 km	-	-	-	-	-	35.3	-
lubricating oil consumption	litre / h	0.07	-	0.119	-	0.122	-	-
lubricating oil consumption	l/100 km	-	-	-	-	-	0.353	-
time requirement	hour per ha	1	-	-	-	-	-	-
yield of moist mass	t_{mm} / ha	7.5	-	-	-	-	-	-
Chipping productivity	t_{mm} / day	-	40.3	-	-	-	-	-
time requirement unloading	h	-	-	0.05	-	-	0.05	-
time requirement loading	h /t_{mm}	-	-	-	-	0.06	-	-

2.3 Site Specific Data

In Table 7 and Table 8 additional required site specific data is displayed. According to the harvestable land availability factor of 50% a 5 MW_{el} power plant will exhibit an average road transport distance of about 35 km whereas to supply a 20 MW_{el} power plant at Ohorongo Cement, the average road transport distance between the field storage and the power plant site is about 65 km (refer to Figure 3) and at Otjikoto about 55 km. The road transport radius at Ohorongo is bigger due to the additional 85,000 tonnes harvesting per annum for the cement kiln. Therefore the harvesting radius at Otjiwarongo is about 35 km. The radius increases to about 55 - 65 km at the sites in Ohorongo and Otjikoto.

Table 7: Transport distance data for a 5 MW_{el} and a 20 MW_{el} power plant

	Unit	5 MW_{el} power plant	20 MW_{el} power plant	20 MW_{el} power plant
		Otjiwarongo	Ohorongo	Otjikoto

Harvesting area --> field storage	km	5	5	5
field storage --> Power plant	km	35	65	55

To calculate the needed amount of machinery as well as the resulting biomass supply costs the required yearly biomass input of a 5 MW plant at Otjiwarongo and all 20 MW power plants at Ohorongo and Otjikoto are shown in Table 8. Additionally the yearly harvesting area in ha per annum is shown.

Table 8: Required yearly biomass input of a 5 MW plant at Otjiwarongo and 20 MW power plants at Ohorongo and Otjikoto

	Biomass input	Harvesting area
	t / a	ha /a
Otjiwarongo – Supplier A	45,247	4,525
Ohorongo – Supplier D	147,226	10,516
Ohorongo – Supplier C	147,226	10,516
Ohorongo – Supplier E	141,167	10,083
Ohorongo – Supplier B	147,226	10,516
Otjikoto – Supplier D	154,386	11,028
Otjikoto – Supplier C	154,386	11,028
Otjikoto – Supplier E	151,535	10,824
Otjikoto – Supplier B	154,386	11,028

3 Results

The results are presented in the following. Depending on the required yearly biomass input at the power plants, in **Error! Not a valid bookmark self-reference.** the machinery requirement for harvesting and transport is shown.

To avoid a failure of the harvesting process, a security portion of the minimum required machinery for harvesting and transport is added to the calculation. Hereby 50% of the minimal required machinery is additionally added to the overall machinery requirement, to account for maintenance outage of machinery as well as outage of machinery due to new harvesting site development and therefore transportation of the harvesting machinery.

At Ohorongo and Otjikoto fourteen (14x) cutter chippers are needed to harvest the required biomass. Additionally about fourteen (14x) tractor & trailers are needed to cover the transport distance between the harvesting site and the field storage. At the field storage eleven (11x) skid loader are used to load the wood chips on between 24 - 27 lorries (depending on the power plant site), which cover the distance between the field storage and the power plant.

At Otjiwarongo the semi mechanized harvesting is executed with six (6x) skid steers, nine (9x) mobile chippers in combination with nine (9x) tractors & trailers. At the field storage three (3x) skid loaders are needed and six (6x) lorries are sufficient to bring the biomass fuel to the power plant.

To reach the power plant at Otjiwarongo, the road transport needs on average 42 minutes. Including a 26 minute loading and unloading of one road transport lorry, a lorry will arrive at the power plant about every 31 minutes. A transport run i.e. bringing the wood chips to the field storage with the tractor and trailer and to the power plant with the lorry including the way back takes about 2.5 hours.

Compared to Otjiwarongo, at Ohorongo the frequency of lorries arriving at the power plant site is much higher, due to the large amounts of trucks. Though the road transport needs about 1 h and 20 minutes to reach the power plant, a truck will arrive about every 10 minutes. At Ohorongo, the transport run takes about 3 hours and

30 minutes. At Otjikoto due to the shorter transport distance, fewer lorries can be deployed and therefore also every 10 minutes a lorry will arrive at the power plant.

Table 9: Machinery requirement for harvesting and transport at a 5 MW plant at Otjiwarongo and 20 MW power plants at Ohorongo and Otjikoto

	5 MW plant Otjiwarongo	20 MW plant Ohorongo				20 MW plant Otjikoto			
Supplier	**A**	**D**	**C**	**E**	**B**	**D**	**C**	**E**	**B**
Cutter chipper	-	14	14	14	14	14	14	14	14
Skid steer	6	-	-	-	-	-	-	-	-
mobile chipper	9	-	-	-	-	-	-	-	-
Tractor	9	14	14	14	14	14	14	14	14
Trailer	9	14	14	12	14	14	14	14	14
skid loader	3	11	11	11	11	11	11	11	11
towing vehicle - lorry	6	27	27	26	27	24	24	24	24
Trailer - lorry	6	27	27	26	27	24	24	24	24

Based on the tables above, the upfront capital investment required for each site location is determined as follows:

- Otjiwarongo: 31.45 million N$
- Ohorongo:120.73 to 122.89 million N$
- Otjikoto: 118.57 million N$

Details of the capital investment required for each scenario showing costs needed for each type of machinery are presented in Table 10 and Figure 4. Total upfront capital costs are converted to annualized figures using the annuity factor which is based on discount rate and equipment useful life. Total initial capital costs and the corresponding annualized cost are shown in the table.

Table 10: Capital investment required to purchase harvesting and transport machinery

	5 MW plant Otjiwa-rongo	20 MW plant Ohorongo				20 MW plant Ojikoto			
	Supplier A	Supplier D	Supplier C	Supplier E	Supplier B	Supplier D	Supplier C	Supplier E	Supplier B
Cutter chipper	0.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00
Skid steer	1.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
mobile chipper	6.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tractor	8.22	12.33	12.33	12.33	12.33	12.33	12.33	12.33	12.33
Trailer	1.93	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90
skid loader	4.22	14.78	14.78	14.78	14.78	14.78	14.78	14.78	14.78
towing vehicle - lorry	5.52	24.84	24.84	23.46	24.84	22.08	22.08	22.08	22.08
Trailer - lorry	3.12	14.04	14.04	13.26	14.04	12.48	12.48	12.48	12.48
Total (Milo. N$)	**31.45**	**122.89**	**122.89**	**120.73**	**122.89**	**118.57**	**118.57**	**118.57**	**118.57**

Annualized Total (Milo. N$)	4.77	18.23	18.23	17.83	18.23	17.44	17.44	17.44	17.44

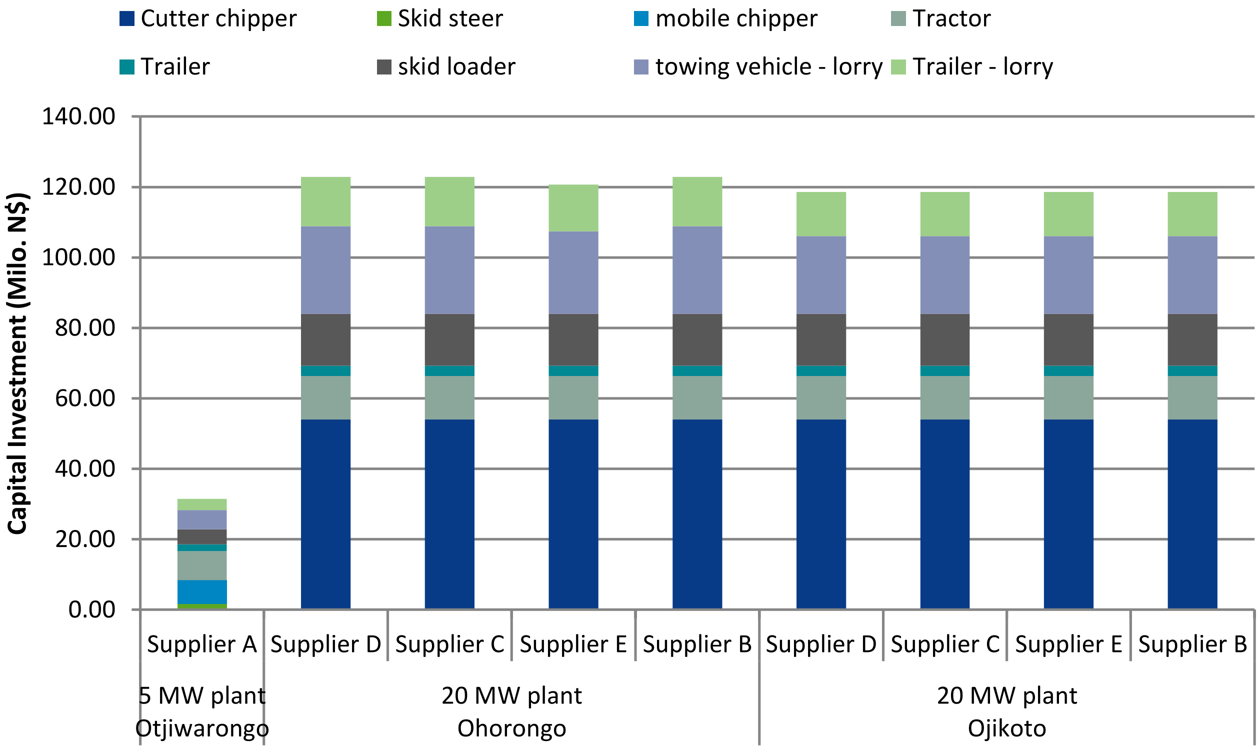

Figure 4: Capital investment required to purchase harvesting and transport machinery

To operate the harvesting and transport process for every site about 70 to 85 people are needed (refer to Table 11). At Otjiwarongo the semi-mechanized harvesting process required a large amount of unqualified worker to operate the mobile chipping. The harvesting can be performed with 4 skid steers with rotary saw. At the site in Ohorongo and Otjikoto nine operators of the cutter chippers are needed. According to the transport machinery, the same amount of semi-skilled workers is needed to operate the tractor. At Otjiwarongo a maintenance crew of 10 workers and two maintenance engineer are required. The amount of maintenance workers double for the sites at Ohorongo and Otjikoto and a third engineer is required. Additionally at every site one head of harvesting is required to manage the work force.

Table 11: Labour requirement for harvesting and transport at a 5 MW plant at Otjiwarongo (Supplier A, semi mechanized harvesting) and 20 MW power plants at Ohorongo and Otjikoto (Suppliers B-E)

	Supplier	A	D	C	E	B	D	C	E	B
Cutter chipper	highly trained worker		9	9	9	9	9	9	9	9
Skid steer	highly trained worker	4	-	-	-	-	-	-	-	-
mobile chipper	unqualified worker	48	-	-	-	-	-	-	-	-
Tractor	semiskilled worker	6	9	9	9	9	9	9	9	9
skid loader	semiskilled worker	2	7	7	7	7	7	7	7	7
towing vehicle - lorry	semiskilled worker	4	18	18	17	18	16	16	16	16

Supervisors	highly trained worker	8	5	5	5	5	5	5	5	5
Maintenance crew	highly trained worker	10	20	20	20	20	20	20	20	20
Other	Maintenance engineer	2	3	3	3	3	3	3	3	3
Other	Head of harvesting	1	1	1	1	1	1	1	1	1
Sum	unqualified worker	48	-	-	-	-	-	-	-	-
Sum	semiskilled worker	12	34	34	33	34	32	32	32	32
Sum	highly trained worker	22	34	34	34	34	34	34	34	34
Sum	Other	3	4	4	4	4	4	4	4	4
Sum		85	72	72	71	72	70	70	70	70

For the annual production of about 45,000 tons of biomass per year at Otjiwarongo, the harvesting and processing facilities (including transport from farms to the processing facility) requires a full team of approximately 85 employees for the semi mechanized harvesting. One team member will be management, 63 will be working in the field as machine operators and supervisors, 4 will be working at the field storage, 5 on the road transport and the remainder (12) will be working as maintenance and support staff.

At Ohorongo and Otjikoto, for the annual production of about 150,000 tons of biomass per year, the harvesting and processing facilities (including transport from farms to the processing facility) requires a full team of approximately about 70-72 employees for the fully mechanized harvesting. One team member will be management, 20 will be working in the field as machine operators and supervisors, 9 will be working at the field storage, 19 on the road transport and the remainder (23) will be working as maintenance and support staff.

The total cost of fuel harvesting and delivery are evaluated on an annualized cost basis using the **annuity method**[2]. Using this approach a total annual cost for labour, maintenance, and capital repayment are calculated. The upfront capital costs associated with purchase of machinery are converted to annual costs using a capital recovery factor which uses the equipment life and discount rates. The yearly costs per ton of each process chain are calculated. As can be seen in Figure 5 the costs for the 5 MW plant at Otjiwarongo are higher (about 317 N$/t) than those at Ohorongo or Otjikoto (between 275 and 297 N$/t). Responsible for the main part of the costs is the harvesting phase, including the chipping. Transport with tractor and trailer as well as with lorry show similar high impact on the biomass supply cost. At Ohorongo the cost is about 14 N$/t lower than at Otjiwarongo. At Otjikoto the costs are about 11 N$/t lower than at Ohorongo. The lower cost at Otjikoto results mainly out of the increasing harvesting radius at Ohorongo Cement due to the biomass demand of the already existing cement factory. Also the higher biomass demand of the power plants at Otjikoto results in a higher utilization of the machinery of the process chain and therefore lower biomass supply cost.

[2] The annuity method allows for the capital costs associated with the various plants to be converted to an annualized cost or per tonne of fuel costs, as per the assumptions listed in Tables 4 and 5. This method more easlity allows NamPower or an IPP to evaluate the fuel supply cost obtained from 3rd parties.

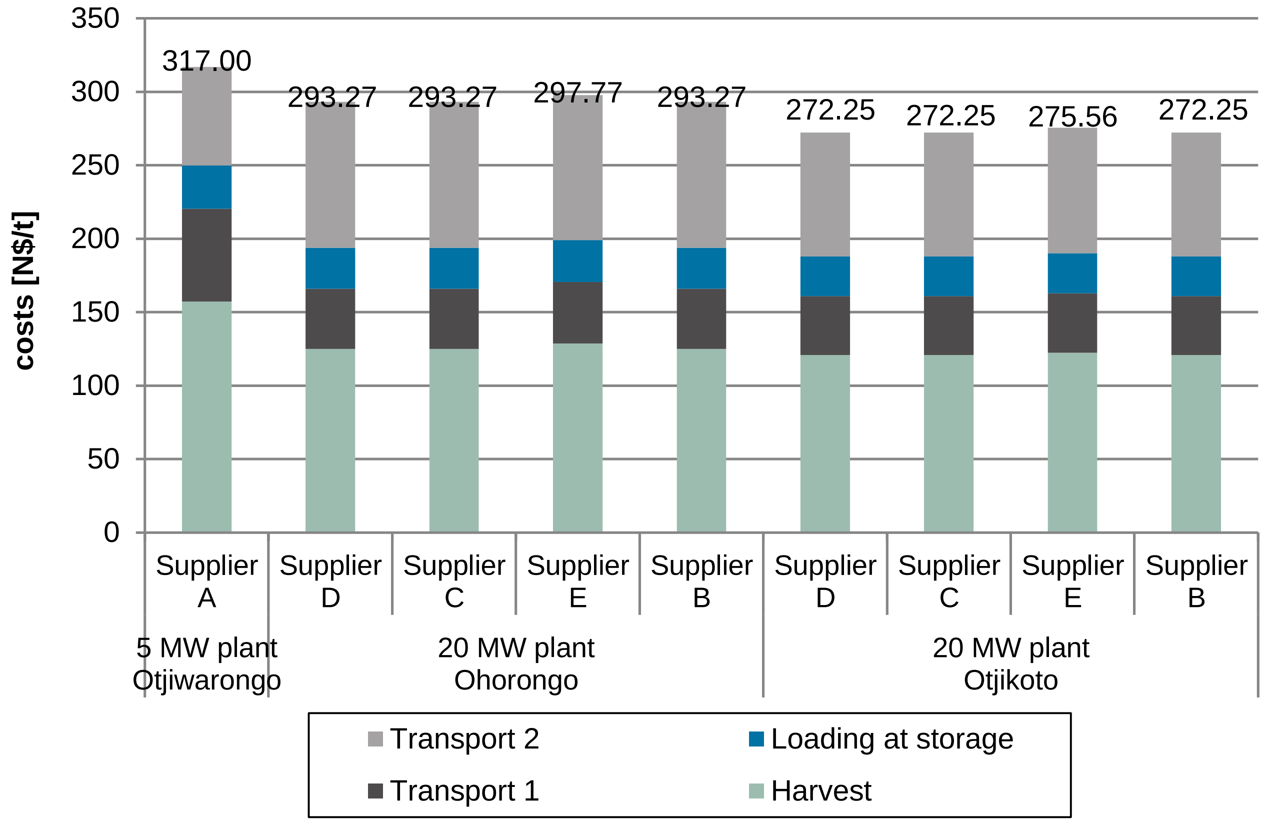

Figure 5: Biomass supply cost of process chain in N$ per ton

The biomass supply costs in N$/t, divided into labour, fuel and machine costs are shown in **Figure 6**. A large proportion of the total costs are caused by the fuel costs. Also the machine costs have a similar impact on the overall costs. At Ohorongo and Otjikoto the labour cost only impact slightly on the biomass supply costs, because of the non-labour intensive fully mechanized harvesting process chain. Due to the large workforce for chipping in the semi mechanized harvesting process chain, the labour costs impact considerably more on the biomass supply costs at Otjiwarongo.

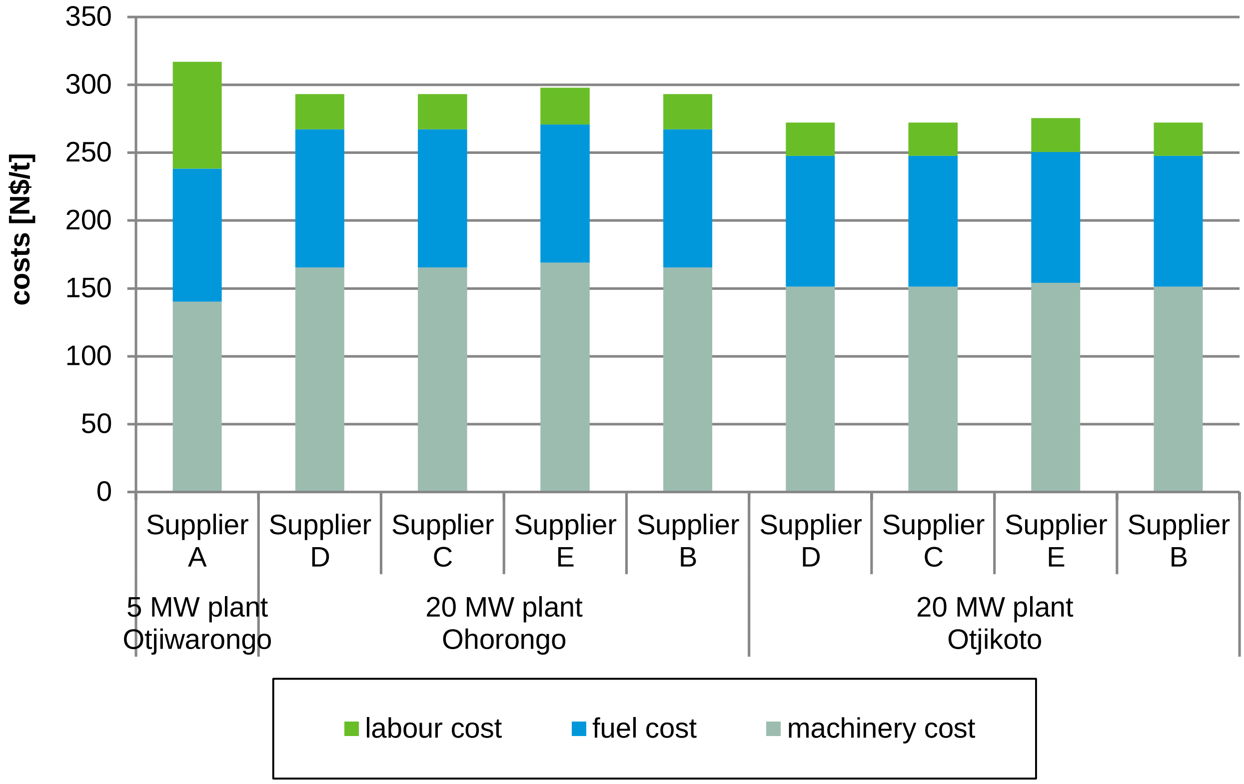

Figure 6: Biomass supply cost of process chain in N$ per ton, divided in labour, fuel and machine costs

4 Limitations

Some limitations should be considered, even though they are not reflected in the analysis above:

Otjiwarongo: For Otjiwarongo, CCF appear confident that they can obtain different EIA conditions compared to EFF. Specifically they feel that by adopting a more selective and environmentally sensitive approach, they can get permission to harvest 100% of each farm. However, as this is not yet proven, the analysis has remained with the more conservative EIA assumptions for now.

It is also noted that CCF have around 45,000 ha of their own land available as well as a large neighbour with a further 45,000 ha. This 90,000 ha has the potential to sustain the Otjiwarongo plant fuel supply for the first 20 years of its lifespan.

Ohorongo: A key limitation at Ohorongo is that the cement plant requires around 85,000 tonnes per annum for its own supply, in addition to that of the biomass power plant. This creates an element of competition. Taking this additional fuel demand into account increases the required harvesting radius by about 10 km and costs by about 20 €ct/MWh (this has been incorporated into the financial analysis).

Otjikoto: A limitation at Otjikoto is the surrounding terrain, with the Otavi Mountains to the south and somewhat more rocky and hilly terrain in other directions compared to Otjiwarongo and Ohorongo. Hence, land availability for harvesting will be more challenging (especially to the south), probably resulting in a larger harvesting radius being required. More detailed land surveying may be needed to properly characterize this issue.

5 Other Issues to Consider

Besides the economics, other issues to consider for each scenario are the environmental impacts associated with the differing techniques as well as the socio-economic benefits, the access to land for debushing (CCF reportedly as access to 90,000 ha already) and commercial arrangements i.e. for biomass supply to be fully outsourced or to be undertaken by an entity related to the power plant owner. These issues are discussed in the companion reports to this document.

6 Conclusion

In the "Harvesting, Handling, Storage and Transport" section two harvesting and transport process chains were analysed. A third manual process chain was excluded due to farmer rejection. The following outcomes can be summed:

1. Fully mechanized harvesting with cutter chipper exhibits the lowest biomass supply costs for the site at Otjikoto. At Ohorongo however the biomass supply costs are only slightly higher. All together the biomass supply costs are with about 275 N$/t at Otjikoto and 295 N$/t at Ohorongo Cement, requiring 123 and 119 Milo. N$ in capital investment, respectively. To handle the fully mechanized harvesting, storage and transport a work force of about 70 - 72 people is needed, depending on the harvesting method.
2. Semi mechanized harvesting with skid steer and mobile chipper shows higher biomass generation costs due to a labour intensive harvesting and chipping. The required work force is 85 people i.e. higher than the work force at Ohorongo and Otjikoto. However at Otjiwarongo the biomass supply is about one third lower than at Ohorongo or Otjikoto. Nevertheless the biomass supply costs are not much higher at 317 N$/t at the site in Otjiwarongo and would require 31 Milo. N$ in capital investment.

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Appendix A – Farmer Engagement

SURVEY ON FARMER ENGAGEMENT FOR THE COMBATTING OF BUSH ENCROACHMENT: NAM-POWER BIOMASS PRE FEASIBILITY STUDY

Lithon Consulting were appointed by WSP to undertake farmer engagement on the issue of harvesting of encroacher bush. This forms part of both the original Pre-Feasibility scope of works as well as the additional commission received thereafter to investigate this issue.

APPROACH AND METHODOLOGY

1. Lithon Project Consultants (Pty) Ltd has drafted a questionnaire regarding the use of encroacher bush by farmers and to ascertain the farmers' opinions on how they would see what would be viable in terms of harvesting encroacher bush for the envisaged project by NamPower.

2. A cover letter and the questionnaire was sent to the Farmers Association of Rietfontein on 24 April 2012 who in turn sent the documents to ±180 of their members. After a poor response from the farmers, NamPower and KfW agreed to expand the scope of works for farmer engagement. Subsequently, the Consultant contacted the Namibian Agricultural Union (NAU) with a request to resend the letter and the questionnaire again under the name of the NAU and to emphasise the importance of the research. This was done on 18 June 2012 and the questionnaire was sent to all members of the NAU in the applicable regions (±500).

3. A total of 13 farmers responded to this round of questionnaires being sent.

4. During a follow-up, the Consultant then contacted a further 16 farmers telephonically and sent the questionnaire again to 11 farmers who provided the Consultant with an email address. Only 3 farmers returned the questionnaires, which resulted in a total of 16 questionnaires being received for evaluation. (One response (farmer no. 8) is regarded as an outlier and his/her responses are viewed with some caution.)

5. In addition to the above, the Consultant accompanied (in a separate vehicle) the project Technical team as well as NamPower staff to the following places:
   - Green Coal in Omaruru
   - Ohorongo Cement / EFF
   - Tsumeb region (Otjikoto Substation)
   - Cheetah Conservation Fund

   The purpose was to engage with the above parties, including harvesting managers, with respect to understanding their experiences in engaging with farmers on a commercial basis, as well as to assess first-hand the way in which the harvesting operations take place on farmers' land. During the course of the travels, informative discussions were also held with the owners of Ohange Lodge (near EFF), where the team was staying, and who are themselves commercial farmers (cattle and game) and are members of the farming union in the region of Ohorongo Cement. It also allowed the Consultant to review some of the information received from the perspective of both the farmer and the harvester (Green Coal, EFF, CCF etc.). This allowed the Consultant to compare the information, and to ensure that each party was providing a true and accurate representation of the situation (for example, allowing the Consultant to compare information received from EFF, with that reported by some farmers, to an actual quote received by a farmer from EFF for debushing), as in some instances there were concerns that various parties (including farmers) would not necessarily provide a genuine reflection of their willingness to pay for mechanical debushing.

This approach deviated somewhat from the proposed "additional farmer engagement" methodology (which envisaged the Consultant travelling to meet with individual farmers, separate from the Technical team's travels), however it was decided that this approach would provide the Consultant with a better (and more balanced) understanding of overall context and the likelihood of farmers being interested in engaging with any potential harvesting scheme on a commercial basis.

EVALUATION

6. A copy of the complete questionnaire with all farmers' information (with names removed, to provide anonymity) will be provided electronically (excel file) to NamPower. A summary of the results is shown below in Table 1.

7. The main aim was to establish which methods farmers have used to combat bush encroachment on their farms, the use of the bush if any, the advantages / disadvantages they experienced by the different harvested methods and to what extent they would see an involvement by external users of bush.

8. The following table summarises the information received from the 16 farmers contacted:

Table 1

	Questionnaire	SUMMARY (no. of respondents / comments)
1	What method(s) have you used to combat existing bush encroachment? (If more than 1 method is used, repeat questions 1 to 6)	
	Mechanical removal	9
	Manual (labour intensive) harvesting	9
	Chemical treatment	10
	Other (Details):………………………………………	Fire (1)
	None	0
	If harvested, what is the current use for harvested wood?	Charcoal (4), fire wood (2)
2	How successful, in your opinion, was the method? Or What was the outcome? In terms of:	
2.1	Cost:	
	Expensive, but necessary	9
	Covered my costs and benefitted from improved rangeland	6
	Made a profit and benefited from improved rangeland	3
-	Further details: ……………………………………	improved rangeland (1)
2.2	Grass Production – short term (1-3 yrs):	
	Excellent	9
	Acceptable	5
	Poor	0
-	Further details: ……………………………………	improved quantity but not yet quality
2.3	Grass production - long term (> 3years)	

	Excellent Acceptable Poor Further details: ………………………………………	7 7 0 perennial grasses slow to establish
3	Return of bush (short and long term). A: time until noticed again; and B: time until perceived as a problem	
	A. noticed: <1 year 1- 3 years 3-7 years 7+ years	<1 yr: 1 1-3 yr: 9 3-7 yr: 1 7+ yr: 2
	Further details: ………………………………………	
	B. problem: <1 year 1- 3 years 3-5 years 5+ years	<1 yr: - 1-3 yr: 2 3-5 yr: 6 5+ yr: 1
	Further details: ………………………………………	none
4	Density / cover of other unwanted species appearing after clearing	
	i) species: ..………………………..……………………	A. melifera, D. cinerea
	ii) time to appear: ………..……………………………	2-4 yrs
	iii) regrowth perceived as result of clearing?: …….	yes = 6
	iv) problem?: …..……………..………………………	Yes, regrowth
	v) other: ..……………………….………………………	0
5	Ground water – any noticed changes :	
	Positive:	Yes = 4
	Negative:	0
6	Any other changes (e.g. biodiversity)	
	i) Insects / invertebrates: ……………………………	very little
	ii) Birds: ………………………………………………	very little
	iii) Mammals: …………………………………………	Cheetah (2), herbivores (2)*
	iv) Plants: ……………………………………………	very little
	v) Soil (moisture): …..…………………………………	very little
7	In your opinion, what would be the most useful intervention(s) to solve the problem of existing bush encroachment (mechanical, arboricides, labor, other)?	
		mech = 5 chem = 5 fire = 1 labour = 1 combination = 3 aftercare needed = 7
8	In your opinion, what would be the most (likely) negative effects of combat-ing bush encroachment (academic / experience?) resulting from:	
8.1	Mechanical bush clearing: …………………………..	regrowth, must apply aftercare
8.2	Application of arboricides: ..…………………………	regrowth, must apply aftercare
8.3	Labor intensive bush harvesting: …………………	regrowth, must apply aftercare
9	In which way would you think, you would be willing to get involved in the harvesting of bush?	
	i) Prefer to have (external) harvesters harvest: ……………………	6.00
	ii) Prefer to harvest myself & have collected: ……………………	8.00

	iii) Prefer to harvest myself & deliver:	3.00
	iv) Prefer to have no involvement at all:	2.00
10	What would you be willing to invest / expect to receive into/ from combating bush encroachment should a large project in need of biomass offer the opportunity to harvest / clear bush on your farm?	
		wide range of comments, but bottom line is should be affordable
11	What methods, do you think, will be the best form of preventative management after the following different harvesting methods?	
11.1	Mechanical bush clearing:	mainly chemical aftercare
11.2	Application of arboricides:	mainly chemical aftercare
11.3	Labor intensive bush harvesting:	mainly chemical aftercare

* Possibly this is just a result of better visibility of animals rather than an actual increase in animal numbers.

9. From Table 1 and from the personal interviews and discussions with farmers, the following assumptions can be made:

   9.1 The farmers are very well aware of the problem with the encroacher bush and many farmers have already taken up the battle to combat encroacher bush with different methods. (This opinion may be biased due to the fact that it is only farmers who are aware of the problem and already have been involved in the combating of encroacher bush, that have actually returned questionnaires). On the basis of this survey, mechanical and arboricides are about equally popular and viewed as equally effective (with proper after-care), with each offering their own advantages e.g. arboricides have a longer effect than mechanical clearing where the bush regrowth is typically within the first year after clearing, depending on the type of vegetation. *Dichrostachys cinerea* is a much more aggressive grower than *Acacia melifera*.

   9.2 Farmers are generally willing to invest in the combatting of the bush encroachment and emphasise that proper aftercare is vital to maintain a reasonable clear land. The farmers do not see the bush as a renewable resource, they want their farms properly cleared and the main aim is to increase the carrying capacity of their farms. If the bush is seen as renewable resource from a farmers' perspective, they should be paid for the harvested bush.

   9.3 At this stage it seems from the interviews that only farmers who make use of charcoal makers are actually recovering their costs. There is however a negative connotation towards charocoal makers in terms of uncontrolled movement and poaching on the farms, as well as the high risk of veldfires. Some farmers who have engaged in charcoal making were actually told by their neighbours that they will not assist the farmer if there is a veldfire which is the result of the charcoal making process.

   9.4 All other combatting methods are costing the farmers money.

   9.5 Due to the direct dependence on the climatic conditions and rainfall, farmers are very hesitant to commit themselves for long term contracts which are going to cost them a specific amount each year. They would assess their position after the rainy season each year and base their needs for debushing on that assessment.

10. Farmers are aware of the problem and are more than willing to engage in bush clearing. This must be affordable and must have a long term effect on their range land i.e. increased grazing capacity.

11. Mechanical bush clearing is an attractive option, since it delivers fast and visible results in terms of cleared land. The effect of regrowth however poses a problem since there is insufficient data on what effect (too short period since clearing) this mechanical clearing will have in the long run.

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