# ELECTRICITY PRODUCTION FROM ENERGY FORESTS: RESULTS FROM A FEASIBILITY AND IMPACT SCOPING STUDY IN NORTHERN UGANDA FOR A 50 MWE GRID MODEL

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ABSTRACT: Uganda currently faces an electricity crisis due to high fossil fuel prices and falling levels of lake Victoria affecting hydropower capacities. In this paper, we introduce a feasibility study for a 50 MW biomass fired power plant covering plantation design, conversion technology, environmental and social impacts, anticipated problems, overall economics, project status, and benefits of the project. The 30,000 ha project area consists mainly of Eucalyptus and native *Markhamia lutea* stands. Results indicate that this project can provide electricity to a competitive price which is considerably lower than generated by fossil fuel powered generators.
Keywords: developing countries, electricity generation, forestry

## 1 INTRODUCTION

Uganda currently faces a major energy shortage. Currently, only 5% of the population in Uganda has access to electricity; in rural areas the number is as low as 1%. In a country of over 25 million inhabitants, only 200,000 residential and commercial customers are connected to the grid. The situation in other countries of Sub-Saharan Africa is comparable. Without access to electricity it is difficult to attain the Millennium Development Goals on poverty reduction and environmental sustainability.

In Uganda the total installed capacity is around 400 MWe – mainly from hydropower installations along the Nile – but production recently has been significantly lower because of low water flows. Accounting only for those Ugandans who have grid connection already, currently daily electricity shortages are estimated to be in the range of 200-250 MWe.

Thermal power production with fossil fuel powered generators increased significantly during the last two years and is the only solution pursued so far to encounter electricity shortage in capital.

In 2007 more than 50 % or 200 MWe of the power will be produced by emergency thermal generators with feed-in tariffs of US$ 0.27 /kWh. This, linked with the ninth highest population growth rate in the world, creates a major development issue for the country. Considering climate change, unstable water levels, unreliable fossil fuel supply, high production costs, its contribution to air pollution, and dependency on imports, this is not a sustainable solution and indigenous power solutions must be found.

There is a need to broaden and diversify power production in Uganda and design systems that will provide power to local communities. Renewable energy seems to be the only sensible and sustainable option for a land locked country with high fuel import costs. Against this background commercial feasibility studies have been commissioned to identify bioenergy systems that will provide sustainable supply of electricity to rural areas from woody biomass.

This situation, together with Uganda's policy for renewable energy, creates a business opportunity to provide electrical biomass energy utilising the availability of land and high biomass growth rates to be found in Uganda.

In this paper, we introduce a feasibility study for a 50 MW biomass power plant piloting Ugandas search for lasting solutions to its current power dilemma.

## 2 PROJECT BACKGROUND

The project location is situated in Northern Uganda near Gulu at the Aswa river. Currently there is no grid power in the target area, the population density is low with low competition for food production and the site conditions for bioenergy production are favorable.

The project developer was challenged to identify indigenous power production solutions to complement hydro power. It was resolved that a biomass fired 50 MW plant size would be a promising option under economic aspects. Fed by Eucalyptus plantations, the project lifetime was set at 28 years. A full scale feasibility study, scoping environmental and social impacts was conducted by a consortium of the Irish, French, Austrian State Forest Service and UNIQUE forestry consultants.

## 3 PROJECT LOCATION

Location of the feedstock is the major limiting factor for the project. The first task was to identify sufficient suitable and available land with clear land tenure to grow the feedstock. A figure of 30,000 ha was estimated to be the area that would be required. Land suitability entails good soils suited to woody feedstock production with sufficient rainfall, adequate temperatures and proximity to a river (a requirement of the power plant). Land availability requires having clear land title and the land being unused or under-utilised.

During a national survey of possible sites, an analysis was made of climate, soils, land tenure and population demographics, which was linked to extensive local socio-political knowledge. This revealed that only in Northern Uganda was there sufficient land available, but that even there options were limited. A detailed analysis of soils, rainfall and particularly on demographics, land ownership patterns, size of holdings and land tenure concluded that the Aswa-Lolim / West Acholi area was best suited to meet requirements.

For tree growth the monthly rainfall distribution is very important. In Gulu, the closest town to the project site, the mean monthly rainfall distribution is higher than 50 mm/months for 9 months a year. A monthly rainfall of 50 mm is considered as the minimum for planting operations. Access to water is important for the plantation and the power plant but the reliance on the Aswa river is reduced by installing a power plant air cooling system and the nursery will operate with groundwater pumps. Considering the topography, the rainfall regime and the water table it is unlikely that the plantation establishment will result in water deficiencies in the area.

**Figure 1**: Map of project location.

Monthly temperature in Uganda is only fluctuating slightly around 25 ° Celcius. The minimum temperature does not limit tree growth in Uganda, except in montane regions of Mt Elgon and the Ruwenzoris.

For tropical soils the samples show high, favourable nutrient levels. Although the Ca and Mg levels were largely sufficient, K levels were low. Available nitrogen was not analysed due to the difficulty to bring cold samples to the laboratory. However, the topsoil has high humus content. The sandy-loamy soil texture is very favourable for tree growing and there is no risk that during the dry season the tree root system is damaged which can happen if the soil has a high clay content. However, fertilisers have to be applied carefully as the soils are susceptible to leaching. At the investigated soils K, B, Cu, and Mn deficiencies are likely considering the slightly acid soils and the envisaged intense plant production. Soil depth varies between 60 cm and a few meters.

In the framework of the study more than 20 land owners were identified, together they own an area of nearly 40,000 ha. The individuals each own blocks between 500 and 2,500 ha which are very big land holdings in Uganda. The remaining land is assumed to be owned by other big unknown land owners and many small land owners towards the eastern side of the area. Initial discussions were held with the landowners who expressed their willingness to be involved. To ensure continued local support for the project land purchase is not recommended. Indicative rental prices were discussed with some of the 8-12 landowners concerned and an annual rental in the region of up to US$17 /acre would be acceptable to landowners.

## 4 TECHNOLOGY

To keep transport costs low, the plantation will surround the power plant. The plant would be situated next to the Aswa River. Based on the feedstock the consultant proposes a Fluid Bed combustion technology with a steam turbine cycle (condensing turbine). This proven and reliable biomass technology will deliver 373 GWh/year at a 50MW net (55 MW gross) capacity running 85% load factor. Although the life of the plant is 40 years, the project lifetime only considers 28 years.

The steam turbine cycle operates at 485°C; 75 bar without reheating. The Fuel Power Input is 187.9 MW and its Electrical Efficiency 29.54 %.

Considering that the power plant only has an electricity conversion efficiency of less than 30% utilizing the steam is important. However, for the financing of the investment it is considered that there is no market for this amount of heat. Potential users for the steam are agricultural processors (maize, rice drying, fruit concentration and powder production). In an early stage of the project contacts with agricultural industries will be established to explore respective options.

## 5 BIOMASS PLANTATION

### 5.1 Species

Existing agricultural residues are not a viable option given the scattered location and limited volumes concerned. When considering tree species it is good science and good risk management only to use species, varieties or hybrids that have proven their adaptation to local conditions. For this reason *Eucalyptus grandis* is recommended as the primary source of feedstock using improved seed from South Africa. E. grandis is the only species that provides proven growth in plantation conditions in Uganda to start with. A tree improvement programme will allow for considerable improvement of planting material by the second rotation and allow for the trials of clones developed in Brazil and Thailand.

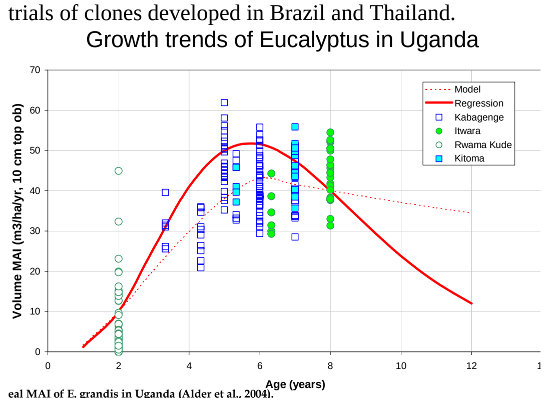

**Figure 2**: Growth trends of Eucalyptus in Uganda [1].

Native species will form approximately 15% of the planting (4,000 ha). These are required for the wildlife corridor that runs through the area, to line the river and streams, for international best practices certification (e.g. FSC) and for their environmental reasons. The main native Ugandan species considered is *Markhamia lutea*. It has a good growth (about half that of the Eucalyptus) and it will coppice after harvest. It can therefore serve as an insurance reserve for the power plant to be harvested if for some reason the yield of Eucalyptus is reduced (from fire for example). In addition, a small proportion of other native species will be planted to complement the Markhamia, e.g. nitrogen fixing species such as Albizia ssp. will increase the biodiversity and improve the growth of the Markhamia.

The strategic advantage for using Markhamia is that even though its growth will be around half that of Eucalyptus it can be used as a feedstock as an emergency measure.

### 5.2 Determining rotation length and area demand

Having identified the most appropriate species, estimates were made as to the production potential from the preferred site. Working from recent Ugandan yield models it was estimated that on a 3-year rotation 75 m3 (25 m3/annum) could be produced per ha and 121 m3 per ha (30.35 m3/annum) using a 4-year rotation. This has major implications on the area required. Based on a laboratory analysis of a sample of eucalyptus and linking this to the power plant requirements (calorific value) for Eucalyptus, a 3-year rotation would require 30,000 ha while a 4-year rotation would require 24,600 ha. When considering additional area for secondary species and biodiversity, areas for the power plant and forestry centre, areas for roads, area for fire breaks and area for a new village the total project requirements would be approximately 36,000 ha and 30,000 ha for a 3-year and 4-year rotation, respectively. Considering only the mean annual increment (MAI), a longer rotation would be favorable, however, under economic perspective, the benefit of an increased MAI is outweighted by a decreasing internal rate of return due to a longer start up period without harvest and later payback periods.

**Table 1**: Key figures of the biomass project considering 3 and 4 year rotation periods.

| Parameter | 3 yr rotation | 4 yr rotation |
|---|---|---|
| Influence on area demand | | |
| MAI per ha | 25 m³ | 30.35 m³ |
| Total Volume (m3 to 5 cm top diameter) | 75 m³ | 121.3 m³ |
| Harvest volume ($m^3$/ha) | 63.8 $m^3$ | 103.1 $m^3$ |
| Calorific value E. grandis at 30% moisture content (MWh/t) | 3.48 | |
| Heat fuel input per MWh | 187.9 | |
| Wood required at boiler (30% moisture) in m³/ha | 510,000 | |
| Specific Gravity | 0.46 | |
| Standing timber required ($m^3$/y.) | 635,000 | |
| Feedstock area required (ha) | 31,000 | 26,000 |
| Total project area incl. worker village | 36,000 | 30,000 |

The table above demonstrates that moving from a near optimal rotation length (in terms of maximum MAI) of 4 years down to 3 years results in an increase of more than 20 % in the total project area required. The financial impact of this is also very significant.

### 5.3 Other aspects

There are a number of key operations for the establishment of a best practice plantation, namely Plant Production, Site Preparation, Planting, Forest Maintenance, Forest Protection, Road Construction, Harvesting and Transport.

Plant production will centre on a purpose built nursery using improved seed from South Africa. This will be capable of producing 3 cycles of Eucalyptus seedlings for planting each year. In addition there will be a plant improvement programme that will put down trials for Eucalyptus varieties and hybrids as well as other tree species. This will result in improved planting stock available for the second rotation or even before.

Harvesting and forwarding is by far the most labour intensive activity providing from year 4 onwards 1,082 jobs. In the feasibility study labour-intensive working procedures received preference over fully mechanized procedures - if financially viable - considering the shortage of employment opportunities in Northern Uganda. A comparison between fully mechanised harvesting using a feller buncher and manual harvesting with chain saws revealed that the costs are similar but the manual harvesting is less sensitive to break downs and is more socially adapted.

Roads are an essential capital investment for sustainable long-term viability. A 6 km un-tarred road will be built from the main road to the proposed power plant site. Given the flat site and large block size a roading density of 12 m / ha can be used which will require 357 km of road for the 4-year rotation option and 433 km for the 3-year rotation option. Forest roads will use local technology, materials and methods and will be carefully maintained.

Fire Breaks will be 15 m wide and mowed/sprayed 3 times a year. Where there are roads this will be 6m on either side of the road. Both roads and fire breaks require approximately an additional 4 % of area.

Site preparation is preceded by careful site analysis to determine where the most productive areas are and to determine the site preparation and fertilizer regimes required for each site. Growing of Eucalyptus requires total weed control and good site preparation. Sites will be mowed, sprayed to kill grass, disked, ploughed, fertilised with a base fertilisation of single phosphate and sprayed again against weeds before planting. Subsequent planting will be undertaken manually as this is more cost effective and flexible than using planting machines. Planting cannot take place all year and will occur in an 8-month planting season.

Plantation maintenance will involve monitoring, weeding and fertilization of the crop post planting. This is integrally linked to forest protection, which involves maintenance of firebreaks, fire patrols, monitoring for insect of disease damage and both human and animal trespass.

Following a cost benefit analysis, it was concluded that harvesting should be based on a manual felling and debranching system with tractors pulling a load series of whole log trailers, which will be brought to the forest road for transport to the power plant. Chipping of timber into chips will be done at the power plant as this is more cost efficient and will provide greater quality chips. Thus for the planned biomass power plant for Uganda two parallel chipping lines will have to be installed. The chippers will use large amounts of power from the power plant to operate.

The Power plant and Forestry HQ will be based at the river and will require a site area of 20 ha. Finally, it is recommended that a further 300 ha be allocated for the development of a village to accommodate workers south of the main Pakwatch – Gulu road.

The economic study reveals that a feedstock price of US$ 15.8/MWh or US$ 55/ton at 30 % moisture would be required for the forestry element to achieve an IRR of 11.2 %. A depreciation period of 5 years was assumed across all machinery. Given this as a feedstock price the power plant would need a minimum feed-in tariff of US$ 0.135 per kWh make the project economically feasible (IRR of 11.2 % ) at a plantation lifetime of 28 years. The payback period for the project is 11 years and the maximum accumulated cash demand to implement the feedstock production part of the project is US$ 45 million. The price for chipping amounts to ~ US$ 1.3 per m³.

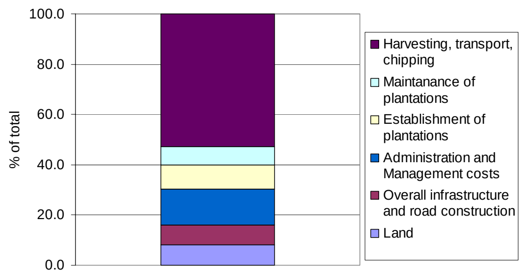


**Figure 3**: Cost shares of biomass production.

## 6 OVERALL PROJECT ECONOMICS

The power plant investment costs are estimated at US$165 m and another US$ 50 m for the plantation establishment totalling US$ 215 m occurring in the first 5 years of the project life. Table 2 shows tariff options for different tax and subsidy regimes (applied for a € 10 million grant from EU ACP Energy Facility). The tariffs quoted are in real, 2007 dollars and levelised across the 25 year life of the power plant.

**Table 2**: Tariff options considering different tax and subsidy situations.

| kWh | US $ cents | U.Sh. |
|---|---|---|
| Full Price, No Tax Exemption, No subsidy: | 11.4 | 204 |
| Price with Full Tax Exemption and No Subsidy: | 10.1 | 180.5 |
| Price with No Tax Exemption and €10m EU Subsidy: | 11.0 | 196.5 |
| Price with Full Tax Exemption and €10m EU Subsidy: | 9.8 | 175 |

The Ugandan Electricity Regulatory Authority (ERA) in November 2006 has published feed-in tariffs for renewable energy production for applications smaller than 20 MW. Unfortunately, the Authority has not recognized power projects that are aiming to produce biomass on a sustainable basis for electricity production as proposed in this feasibility study. The only biomass project type considered in the renewable energy feed-in tariff is bagasse fired power production.

## 7 SELECTED ENVIRONMENTAL ISSUES

On land close to the Nile because it is likely that this land will be re-gazetted into a Wildlife Corridor with a 10 km buffer on both sides of the Nile. In this area increased Elephant damage can be expected. Jatropha curcas will be planted as a natural fence.

The use of native species on 15 % of the plantation area qualifies the project for a FSC certification which is desired by the investor to demonstrate sound environmental and social management of plantation.

Biodiversity areas are established in riverine areas etc. the level of wildlife in these areas will increase dramatically. This issue has to be dealt with actively by the project to ensure that informal hunting does not occur with the associated risks of fire.

The project has the potential to offset 2 million tons of $CO_2$ tradable as tCERs under the CDM regulations of the Kyoto protocol.

## 8 SELECTED SOCIAL ISSUES

The population density in the project location is low with low competition for food production. Community management is not a technical component but is an important part of operating energy plantations, especially in Africa. This should not be regarded as an additional expense and as a nuisance factor but as part of corporate social responsibility which more than pays for itself in terms of goodwill and cooperation from the local community. We have considered capital investments of US$ 360,000 to build a hospital, a school etc. and made an annual budget allocation of US$ 265,000 which will be spent on health (Doctor, 2 nurses), fire awareness programmes, wells, bursaries and awards, competitions etc. The decision as to how this is spent should be done together with local community groups and local authorities and managed by the unit manager for community management.

Furthermore, the tax revenues will contribute to develop district infrastructure, the power production in the north will balance the national grid and hopefully the project can electrify 11 nearby towns. It can be expected that the power will stimulate economic development in northern Uganda e.g. agro-production and value adding processing.

## 9 ANTICIPATED RISKS AND PROBLEMS ENCOUNTERED

The following points are of major importance and have to be addressed in the next steps:

- Land tenure and lease arrangements with land owners;
- Forest growth and timber density predictions not robust;
- High political risk (recent history of civil strife);
- Renewable feed-in tariffs in Uganda do not recognize respective projects (same treatment as bagasse co-generation project);
- No demand for (process) heat, revenues from excess steam and heat not considered;
- Capacity building demand is extremely high and responsibility of the investor to develop social

infrastructure.

## 10 PROJECT STATUS

There are ongoing negotiations on land lease and a Power Purchase Agreement. The establishment of Eucalyptus tree species trials is already contracted as well as the collection of additional environmental data. There are preparations for a international environmental and social impact study based on this scoping study and the target to reach financial close is December 2007.

## 11 ANTICIPATED PROJECT BENEFITS

On a national scale, this biomass power plant will complement and diversify reliance on hydropower in Uganda. It provides considerably cheaper power than the fossil fuel driven generators brought to Uganda to address the current electricity crisis in a short term.

It replaces the need to import oil using an indigenous, self sustaining biomass. Such fuel is economical, renewable and green, attractive to donors, and brings underutilized degraded grassland back into production.

Acholi power project contributes to national reconciliation process, generates employment and stimulates economic development in northern Uganda. More than 1,500 direct and mostly low skilled jobs (see Table 3) will stimulate northern economy, outgrower schemes of forest for local farmers a possibility. The project would be the first power production in this range in the North and would balance the national grid and hopefully the project can electrify 11 nearby towns. Its power could stimulate agro-business adding value to crops in the North and boosting the regional economy.

Moreover, the model presented in this article has high replication value in Africa

**Table 3**: Employment overview including power plant.

| Emplyment category | Number of employees per category |
|---|---|
| Managing and Department Directors | 5 |
| Upper management | 6 |
| Middle management | 37 |
| Lower management | 25 |
| Foremen | 44 |
| Skilled labour | 653 |
| Un-skilled labour | 774 |
| Total staff | 1,556 |

## 12 LITERATURE

[1] Alder, D., Drichi, P., Elungat, D. 2004. Yields of Eucalyptus and Caribbean Pine in Uganda. Report to the EU Forest Resource Management and Conservation Programme.