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Mobilising Renewable Energy Investments

Uganda: Captive Power

Case Study: 200 kW Rice Husk fuelled Biomass Plant at a Rice Factory

SITUATION DESCRIPTION

This project Case Study investigates the feasibility of a biomass power plant investment at a rice mill in Jinja, Uganda. The Case describes a grain miller that has biomass residues available, faces power outages that reduce production and therefore revenue and is interested in improved power supply.

The rice miller intends to increase the quantity and improve the quality of their main products (rice and soon maize) by increasing the capacity utilisation of existing machinery. For this purpose, several measures are being carried out, e.g. the conversion of the heat supply for the dryers from diesel to rice husk. Generally, rice has been mainly dried in the open-air due to high diesel costs. However, this has been limited by unfavourable weather conditions. In addition, mechanical drying increases quality and quantity of the finished product, and thus revenues.

At the time of writing (mid-2018), 20,000 tonnes of paddy rice were processed per year, generating 4,400 t of rice husk. With an intended capacity increase to 30,000 t/y of paddy rice in the near future, the amount of rice husk would rise to approximately 6,600 t/y. Usually, the rice husk is sold as a fuel and transported off-site when a buyer is found.

The rice mill is supplied with electricity by Umeme as a tariff code 20 (medium industrial) customer. The annual electricity needs of the site after expansion (to include a maize mill and mechanical drying) are estimated at 2,100 MWh. Based on 330 nominal load days this corresponds to a mean load of 265 kW. The future total installed capacity of the factory equipment is 750 kW and the calculated potential maximum demand is up to 675 kW. The rice mill is operated 24 hours per day, 7 days per week with no seasonal variations. Electricity consumption (kWh/h) is evenly distributed across the day, 50% during the daytime shoulder period (12 hours) and 50% during the evening and night time peak and off-peak period (6 hours each).

The Umeme electricity supply is affected by power outages that are estimated at 14.6 days (4%) per year in Jinja area.

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BIOMASS POWER PLANT CONCEPT

This Case Study describes a relatively small captive power plant based on a water-steam cycle without the generation of process heat[1]. The fuel for the plant is rice husk available onsite. The net electrical capacity of the captive plant should cover the rice factory's base load. A major requirement is a high availability (reliability) of the plant to limit the impacts of grid power outages on rice production. The technology proposed is classical combustion combined with a water-steam cycle with a steam turbine. Given the small capacity, a single or double stage turbine, which are simple and robust, are considered. Such turbines have relatively low electrical efficiency but are economically attractive for this Case given the relatively low market price for rice husk. For the same economic reasons, co-generation (combined heat and power generation) for drying is not considered. A plant using gasification technology combined with direct combustion of the gas in a motor engine was not chosen due to a lack of proven reliability at 8,000 nominal load hours.

The power plant is connected to the grid and is operated continuously in parallel to the processing facilities, with a minimum downtime. The plant is sized to cover the base load, while demand exceeding the net capacity of the plant is met by the grid. The plant is designed to operate off-grid (i.e. in island mode) during grid power outages. During short periods of low power demand, it is assumed that either an agreement can be made with the regulator to spill any surplus electricity into the grid or it will be fed into a load bank. In any case, it is assumed that an estimated 5% of the biomass plant generation is not used by the rice mill.

PLANT CHARACTERISTICS

The proposed captive biomass plant has the characteristics shown in **Table 1**. The net electrical capacity of the system was set at 200 kW to match the assumed base load of the rice factory after the increase in production. The 7,920 nominal load hours (90.4% capacity factor) are based on the 330 operating days of the factory and the assumption that production will be increased (due to mechanical dryers and less power outages). The expected system lifetime of 20 years could vary depending on the quality of plant and O&M practices.

1) The accompanying Model Business Case investigates the feasibility of three hypothetical biomass plant scenarios, including a combined heat and power (CHP) system. The Model Business Case is accessible at www.get-invest.eu

TABLE 1. Biomass plant characteristics

PARAMETER	UNIT	VALUE
Rated thermal input	MWth	2.2
Fuel: rice husk, LHV	MJ/kg	14.0
Annual use (at nominal load)	hours	7,920
Quantity biomass required	t/y	4,526
Electrical efficiency	%	10
Gross electrical capacity	MW	0.22
Own consumption	%	10
Net electrical capacity	MW	0.20
Expected annual production	MWh/y	1,584
Construction period	year	2
Investment timing 2018 (year –1)	%	30
Investment timing 2019 (year 0)	%	70
Lifetime of plant	year	20

Coincidentally, the rice husk consumption of the plant for 200 kW net capacity corresponds closely to the quantity of rice husk already available at present. Because even more rice husk will be available after the expansion, and due to potential supply from neighbouring rice mills, a larger captive plant could be considered in case **a)** the base load of the rice mill will be greater than 200 kW or **b)** a more attractive feed in tariff could be negotiated for the sale of any excess power.

CAPITAL AND OPERATING COSTS

Capital expenditure (CAPEX) includes the costs for engineering, purchase, construction and commissioning of the plant. For transport and import (e.g. from Europe to Uganda via Mombasa, Kenya), additional costs of 10% are assumed.

For annual maintenance and insurance costs, a percentage of the plant CAPEX is applied. The staff costs are based on three shifts per day with three operators, a technical manager and a plant manager familiar with rice husk power. Fuel "costs" account for lost revenue from reduced rice husk sales. A UGX-EUR exchange rate of 0.000235 is used.

TABLE 2. CAPEX and annual OPEX

COMPONENT	UNIT	UNIT COST	PROJECT COST	
			EUR	UGX
CAPEX				
220 kW plant	EUR/kW	7,700	1,711,000	7,288,000,000
Studies & permits	–	–	125,000	532,000,000
OPEX				
Fuel cost 4,526 t	UGX/kg	25	26,600	113,100,000
Personnel	–	–	57,400	244,500,000
Consumables	–	–	16,000	68,200,000
Maintenance	%	1.8	30,800	131,200,000
Insurance	%	0.8	13,700	58,300,000

The Case Study is based on an investment in EUR. The analysis is performed before any consideration of financing. The effects of currency exchange rate fluctuations or hedging costs are also not considered. Furthermore, no generation licence is required for a self-consumption captive power plant of this size. An EIA may be needed depending on the existing environmental licence and other factors.

Levelised Cost of Electricity for the Biomass Plant

The levelised cost of electricity (LCOE)[2] is calculated using a discount rate of 8% and calculating the system costs and electricity production for each year separately using the discount factor. The discount rate is based on an assumption that the project owner could access debt in a hard currency at an interest rate of 7%[3].

In Uganda, the Sustainable Use of Natural Resources and Energy Finance (SUNREF) initiative developed by Agence Française de Développement (AFD) could be a notable option for such projects. Alternative discount rates are also shown for comparison.

Twenty-two years are considered (two years development and construction, 20 years operation). The division of the present value of costs by the present value of electricity production results in the LCOE.

TABLE 3. Levelised cost of electricity

ITEM	EUR/kWh	UGX/kWh
LCOE at 8% discount rate	0.244	1,041
LCOE at 10% discount rate	0.261	1,113
LCOE at 12% discount rate	0.280	1,191
LCOE at 14% discount rate	0.299	1,275

Comparison to Actual Electricity Costs

The electricity production costs of the biomass plant are compared to grid electricity bills for the rice mill without considering the monthly fixed service fee (EUR 5.26, UGX 22,400) charged by the utility, as this charge cannot be avoided.

The captive plant will be able to reduce the maximum demand charge of the rice mill as peak demand will be reduced by the output of the biomass plant (EUR 3.91 or UGX 16,644 per kVA per month). Therefore, savings for peak demand reduction are considered in the analysis.

The energy charges per kWh for code 20 (medium industrial) customers for the three time-of-use periods are presented for the 4th quarter of 2017.

To assess the cost of electricity that the biomass plant would offset in the future, the Umeme energy charges were adjusted for annual inflation. A rate of 4% was applied, based on recent trends and electricity sector forecasts[4]. The same inflation rate was also applied to the operating costs.

2) Levelised cost of electricity (LCOE) is the ratio of lifetime costs to lifetime electricity generation, both discounted back to a common year using an assumed discount rate

3) Loan interest rates for medium size biomass plants in Uganda may range from 5–6% (e.g. supplier credit or export finance) on hard currency to 23% on UGX from local commercial banks. The discount rate assumption used in this Case is based on the AFD-funded SUNREF facility available locally at the time of writing for captive power projects at about 6–7% interest on USD loans, as described in the financing section of the accompanying Developer Guide accessible at www.get-invest.eu

4) See the accompanying Developer Guide accessible at www.get-invest.eu for more details

In order to determine annual cost savings, the projected captive plant electricity yield was calculated and a corresponding amount of electricity from the grid was assumed to have been offset, considering 5% of generation that will not be used by the rice mill as noted earlier. The cost that would have been incurred if electricity had been purchased from the grid was compared against the cost of production from the biomass plant.

In addition, benefits from increased rice and maize processing due to the reduction of outages were considered in the analysis.

In order to confirm project attractiveness, the net present value (NPV)[5] and internal rate of return (IRR) as well as the payback period were calculated. These were based on the captive plant investment, the savings on the difference between the energy and demand charges for grid electricity and the annual operations and maintenance (O&M) costs of the system and revenue from increased production.

The assumed electricity bill based on an annual electricity demand of 2,100 MWh and a maximum demand of 675 kW can be broken down approximately as follows:

- **Fixed service charge:** EUR 63.12 or UGX 268,800
- **Maximum demand charge:** EUR 31,671 or UGX 134,816,400
- **Time-of-use energy charge:** EUR 271,093 or UGX 1,154,720,000

The total electricity bill is therefore EUR 302,827 or UGX 1,290 million. The assumed biomass plant would have saved around EUR 224,296 or UGX 955 million in the first year, which is about 74% of the total electricity bill.

In addition, the biomass plant will generate additional revenue from rice sales due to the avoided power outages. The factory is expected to generate EUR 207,371 or UGX 883 million based on an assumed outages frequency of 4% corresponding to 13.2 days of the total 330 days of production.

5) Net present value (NPV) is the difference between the present value of the project future cash flows and initial investment. The present value is the current worth of a future sum of money or stream of cash flows given an assumed discount rate representing the investment risk

TABLE 4. Umeme tariff code 20 (medium industrial)

TIME OF USE TARIFF	VALUE	UNIT	+VAT
Peak	0.1733	EUR/kWh	0.2044
Shoulder	0.1329	EUR/kWh	0.1568
Off-peak	0.0812	EUR/kWh	0.0958
Peak	738.00	UGX/kWh	870.84
Shoulder	565.90	UGX/kWh	667.76
Off-peak	345.70	UGX/kWh	407.93

TABLE 5. Project indicators

ITEM	UNIT	VALUE
Project NPV	EUR	1,006,848
Project NPV	UGX	4,288,668,047
Project IRR	%	14.8
Payback period	Years	8

Value Added Tax

Value Added Tax (VAT) at 18% on equipment is not considered in this Case Study analysis as it is a throughput tax. Although VAT is applicable on bioenergy and related equipment, it is not capitalized in the CAPEX in the economic model because as a throughput tax it may be recoverable from rice factory sales. Furthermore, other tax incentives (e.g. investment deduction allowance) that may be available for the project are not included in the economic assessment, which could bring benefits that offset the application of VAT.

Sensitivity Tests and Other Scenarios

A sensitivity analysis was performed on key parameters to test the result of a change in the variables on the economic performance of the project. The parameters were:

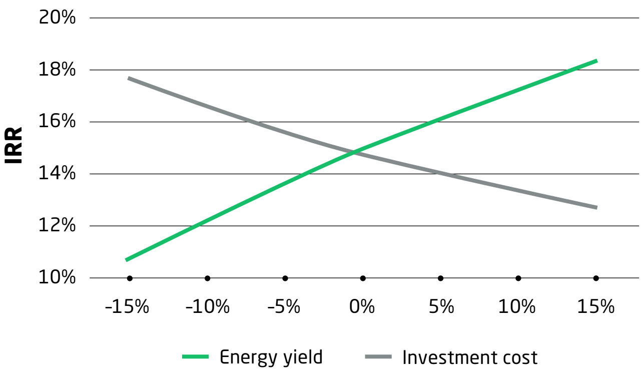
- The energy yield
- The investment costs
- The discount rate

Two further scenarios were also considered:

- Electricity bill savings including VAT
- A one-off reduction in the tariff by up to 50% in 2020 to simulate a possible outcome of lower power generation costs as new large hydro dams are commissioned in Uganda

The sensitivity tests confirm the feasibility of the investment as the IRR does not drop beyond an acceptable level even if the investment costs increase or the energy yield decreases by 15%.

FIGURE 1. IRR test against variation of input assumptions



The NPV of the project remains positive even when the discount rate increases by 30% to 10.4%.

In the base case analysis, VAT on the purchase of grid electricity is not considered as a cost that can be avoided by on-site generation. However, some facility owners may consider VAT as a cost item to factor into investment decision making. In that case, the electricity bill savings are higher and the project is more attractive.

The effect of tariff reduction by up to 50% in 2020 (keeping the same inflation rate assumptions) is shown next.

FIGURE 2. NPV test against variation of the discount rate

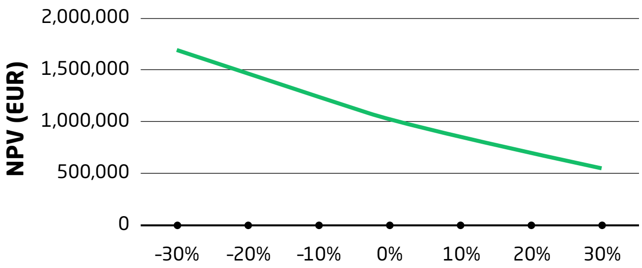


TABLE 6. Project indicators – VAT on electricity bill

ITEM	UNIT	VALUE
Project NPV	EUR	1,446,207
Project NPV	UGX	6,160,116,753
Project IRR	%	17.3
Payback period	Year	7

TABLE 7. Project indicators – one-off tariff reduction in 2020

ITEM	IRR %	NPV EUR	NPV UGX
10% reduction	13.3	762,760	3,248,974,000
20% reduction	11.8	518,671	2,209,281,000
30% reduction	10.1	274,583	1,169,587,000
40% reduction	8.2	30,495	129,893,000
50% reduction	6.2	–213,593	–909,801,000

Other Project Benefits

The biomass power plant may also provide additional benefits. These include:

- **Reactive power cost savings:** If the rice mill were paying reactive power penalty charges due to inductive loads and a low power factor, the generation from the biomass plant could provide reactive power compensation, which might reverse the situation. In 2017, a reactive energy penalty charge of UGX 40/kVArh/month (EUR 0.0094) and reactive energy reward compensation of UGX 20/kVArh/month (EUR 0.0047) were applicable.

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The first series of GET.invest Market Insights are published in early 2019 covering four renewable energy market segments in three countries, namely: renewable energy applications in the agricultural value-chain (Senegal), captive power (behind the meter) generation (Uganda), mini-grids (Zambia) and stand-alone solar systems (Zambia).

Each Market Insight package includes **a)** a 'how to' Developer Guide, **b)** Model Business Cases and **c)** Case Studies. The Developer Guide enables the reader to navigate the market and its actors, to understand the current regulatory framework and lays down the step-by-step process of starting a new project/business. The Model Business Case analyses project economics and presents hypothetical, yet realistic, investment scenarios. It hence indicates the criteria for a viable project/business to enable the reader to identify the most cost-effective project/business opportunities. The Case Study analyses the viability of operational or high-potential projects/businesses to highlight lessons learnt and industry trends.

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GET.invest is supported by the European Union, Germany, Sweden, the Netherlands, and Austria, and works closely with initiatives and industry associations in the energy sector.

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