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TECHNICAL AND ECONOMIC ANALYSIS OF PRODUCING 250 KW POWER USING THE GASIFICATION SYSTEM AT THE VARIETY WOODS AND GREENHEART LIMITED SAWMILL IN GUYANA.

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***Abstract* — A technical and economic analysis was conducted on the viability of operating a 250 kW wood biomass gasification power plant to produce electricity for the sawmill at Variety Woods and Greenheart Ltd. in Guyana. The major economic cost factors considered in the gasification plant's 20-year life comprised a wood chipper, pellet machine, gasification system and operation and maintenance cost. The researchers did a cash flow projection using a spreadsheet program to determine the net present value (NPV), internal rate of return (IRR), the payback period and the return on investment (ROI). The main cash inflow in the analysis is savings from diesel fuel import to power the current diesel power plant at the sawmill. The implementation of the wood biomass gasification plant will save the company US$ 99,600 annually. In the economic analysis, a sensitivity analysis was conducted by the researchers on the capital cost, which was the major factor affecting the economic assessment. In both scenarios, the economic analysis of the proposed gasification plant shows a positive NPV, which suggests an attractive investment financially. The IRR for case one was found to be 4.70% and for case 2 was 6%. For case 1, the gasification plant's return on investment is 13.3% and for case 2, it is 36.56%. The payback period for the wood biomass gasification system was 20 years 5 months for case 1 and for case 2 was observed to be 10 years 1 month.**

Keywords— **Wood Biomass Gasification plant, Cash flow projection, Net Present Value, Payback period, Return on Investment, Internal Rate of Return**

I. INTRODUCTION

Using biomass to produce power plays an instrumental role in enhancing energy configuration, saving the environment by reducing pollution and contributing to the economic development of rural areas. The biomass power system quality of electricity generation is excellent, it is a highly reliable system, and the technology is mature [1]. The burning of biomass materials such as municipal solid waste, waste from industries, forestry and agricultural biomass waste results in the generation of power. The generation of electricity is achieved by utilizing the burning heat from the biomass after it was converted to combustible gases [2]. This is achieved by high temperatures and inadequate oxygen (air/ oxygen/ steam/

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CO_2) known as the thermochemical process or biomass gasification [3, 4].

The utilization of biomass resources locally plays a pivotal role in reducing dangerous emissions into the atmosphere and decreasing reliance on fossil fuels. Power production from biomass resources can be achieved through the gasification plant. Gasification Plant characteristics, biomass type and quantity available will play a major role in the performance and efficiency of the biomass power system [5].

Carbon dioxide (CO_2) is not added to the atmosphere by the burning of biomass since the amount of CO_2 emitted is the same amount that was absorbed during photosynthesis when the tree was growing [6]. Biomass contains very low sulfur content, therefore the amount of sulphur dioxide (SO_2) released into the atmosphere is low. In addition, biomass improves the fertility of the soil, enhances the capacity of water retention and assists in restoring degraded land since in agroforestry it acts as a carbon sink. As a result, there is a continuous increase in the demand to use biomass as an energy source [7, 8].

Wood biomass gasification systems generate heat and electricity directly from the biomass [9, 10]. Importantly, a significantly larger amount of energy can be produced by the gasification technology as opposed to conventional combustion method [11, 12]. A major advantage of the gasification plant compared to the combustion technology regarding the environment is that the harmful greenhouse gases emitted are better regulated [12]. However, one major disadvantage is the high investment cost [13].

To achieve high quality of the gasification system, it is recommended that the level of moisture in the wood biomass must be 10 wt. % or below and the net calorific is approximately 17 MJ/kg. In addition, for raw samples of wood biomass, its net calorific value is around 15 MJ/kg and its moisture content is approximately 20 wt.% [14, 15]. The electrical power is produced when the wood biomass is used as fuel in the gasification process, this is made possible when the biomass enters the gasifier. The next stage is the engine and turbine or fuel cell. As a result, the synthetic gas produced enters the generator set, which leads to the production of electricity [16].

Over the last decade, wood biomass has accounted for approximately 10% of the world energy supply [17]. Guyana has about 80% of its land occupied by forest representing nearly 18 million hectares. Sawmill export operations produce various types of wood waste [18]. Wood waste production caused by sawmill operations is increasing rapidly because of a growing demand for forest products. It is reported by the Guyana Chronicle Newspaper that 81,975 tons of wood waste from Guyana sawmills can cause the generation of 631,202, 880,000 British Thermal Units (BTU) of energy which is equivalent to 109,393.87 drums of diesel fuel [19].

The goal of this study is to determine the economic viability of implementing a wood Biomass Gasification System to process about 100,000 tons of wood biomass disposed at Variety Woods & Greenheart Limited (VW&GL) Sawmill in Berbice Bamboo Landing, Guyana. This goal is achieved through these objectives, which are to calculate the net present value (NPV), internal rate of return (IRR), return on investment (ROI) and the payback period (PBP). The savings from diesel import to operate the current diesel power generation system at the sawmill, capital costs, operating costs, loan and inflation rates are used to generate the discounted cash flow projection.

II. ENERGY DEMAND AT VARIETY WOODS AND GREENHEART LIMITED (VW&GL)

Variety Woods and Greenheart Limited operates its processing machines for 8 hours a day, powered by a 325 KVA Cummings generator. The processing machines operate at various times of the day as needed. Upon examining the various machines, it was discovered that the circular saw and edger are the two equipment rated the highest at 127 kW and 23 kW, respectively. There are 2 edgers, both rated at 23 kW, two moulders and one cross cut machine. In addition, the system has an extractor rated at 22 kW.

A 110 KVA Darmount engine is being used for domestic purposes. This generator operated for six hours a day, powering household appliance such as lights, fans and microwaves. Sawmilling machines and domestic housing complex are connected to a local distribution electrical grid owned by Variety Wood & Greenheart Limited.

Table - 1 Energy output for the processing machines

#	Amount	Equipment	Energy Output (kW)
1	**2**	**Circular saw**	**127**
2	**2**	**Edger**	**23**
3	**2**	**Moulder**	**22**
4	**1**	**Cross cut**	**10**
5	**1**	**Trimming**	**10**
6	**2**	**Extractor**	**22**
7	**2**	**Knife Sharpener**	**5**

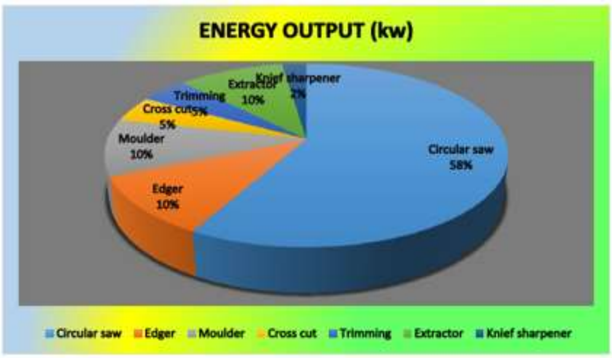

Fig. 1. Percentage of machines of energy output

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III. MATERIALS AND METHODS

Capital Cost

The Biomass Gasification Facility for this economic analysis assumes an output of 250 kW operating 8 to 10 hours a day throughout the year. The Wood Biomass to be used as feedstock will be generated from the logging operations of Variety Woods and Greenheart Ltd. Company. The capital cost for the Gasification System, which includes a generator engine and gas cleanup system, is estimated at US$ 625,000. In addition, the estimated cost for the wood chipper, pellet machine and civil works is US$ 53,000. Therefore, the total capital cost for the Gasification Facility is US$ 678,000. A gasification plant ranging from 10 to 50 kW in Ontario has its capital cost estimated from US$ 2,500 to US$ 5,500 per kW [20]. As a result, the 250 kW Gasification Facility capital cost is calculated at US$ 2,500 per kW.

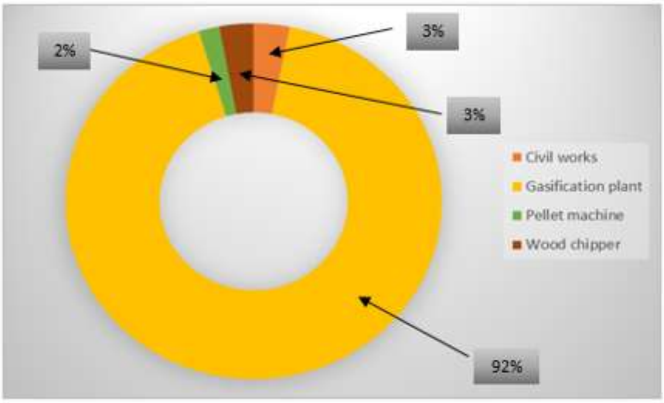

Fig. 2. Capital Cost

Operating Costs

The operation costs can be broken down into fixed and variable operating costs for a Biomass Gasification Plant [21]. The fixed cost for this project includes labour, maintenance of the system and insurance. Fixed cost does not fluctuate with an increase or decrease in production [22]. The operating costs of the 250 kW Gasification Plant, the feedstock cost is excluded since the sawmill produces the feedstock, includes labour cost, maintenance, materials and spares and insurance.

Labour and Office Management Costs

Labour cost was calculated on 6 full-time workers, one labourer, one technician, one bobcat operator, one pellet mill operator and one wood chipper operator. The researchers did not factor Management and administration cost since the sawmill is an existing company and they are already employed. In addition, insurance cost of 1.4% of the capital cost for the Gasification Facility was applied.

Financing

The financing of this project is debt financing. It is assumed that the Biomass Gasification project will be funded through a bank loan for US$ 678,000. A fixed interest rate of 6% was used and a 10-year period to repay the loan. The loan monthly installment is a fixed amount.

Revenues from the Biomass Gasification Plant

Revenues to be gained were computed using savings from diesel imports to operate the existing diesel power generation system at Variety Woods & Greenheart Ltd. The cost for diesel is US$ 99,600 annually, operation and maintenance are US$ 27,309 and spares was US$ 5000, which amounts to US$ 131,909 annually.

Creation of the cash flow model

The cash flow statement considers investment financing opportunities and general economic models relating to various number of parameters. The project economic life, the rate of inflation for the revenue and cost of the project are the general economic factors used to develop the cash flow.

To show the model, the researchers did the cash flow projections for 20 years (Figure 3).

Net Present Value

The Net present value is one of the most significant financial project appraisal techniques [22]. It involves taking all future cash flows and discounting them from both the in-flows and out-flows derived from the project with a specified discount rate and adding them up [23].

The project NPV value is determined by:

Calculation of Net Present Value

The project's NPV is calculated as follows:

$$NPV = CF_O + \frac{CF_1}{(1+R)^1} + \frac{CF_2}{(1+R)^2} + \frac{CF_3}{(1+R)^3} + \frac{CF_4}{(1+R)^4}$$

where NPV represents net present value, CF represents cash flow and R represents the discount rate. The subscripts 0, 1, 2, 3 and 4 represent the respective years.

Using the NPV to decide if the project is a viable one:

- If the NPV > 0 – this means that the projects' cash inflows are higher that the cash outflows. Therefore, the project is a viable investment for investors.
- If the NPV = 0 – this is a neutral situation. It means that the cash inflows equal to the cash outflows, as a result it is not a viable investment.
- If NPV < 0 – this signifies that the projects' cash inflows are lower that the cash flowing out of the project. Thus, it is not an attractive investment.

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Payback period

The payback period is a project appraisal technique that determines the time it takes for the initial investment of a project to be recovered. It is calculated annually based on the project life and the project investment at the start of the project.

PBP is expressed as:

P = I / C

P – payback period

I – initial investment

C – is the net cash flow annually [24]

Return on Investment (ROI) is the ratio of the net income over a specified time period and the investment cost which results from the investment of certain resources at a specified point in time.

$$\mathrm{ROI} = \frac{\text{Gain from Investment} - \text{Cost of Investment}}{\text{Cost of Invesment}} \quad [25]$$

The IRR is referred to as the internal rate of return which is calculate similarly to the net present value (NPV) with the exception of equating the NPV to zero [26].

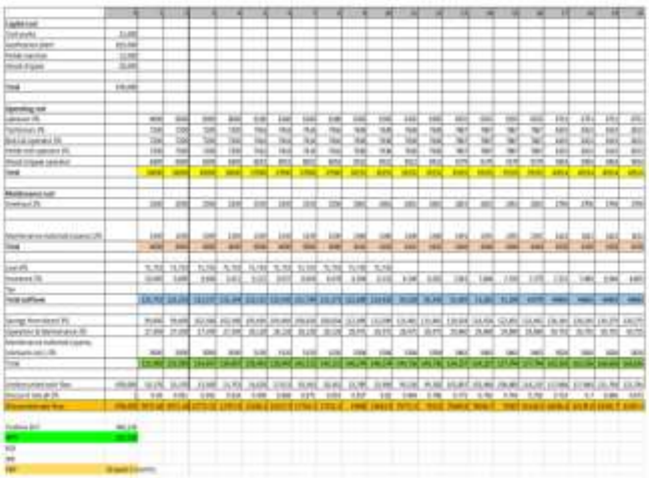

Fig. 3. Cash flow statement

Sensitivity Analysis

The researchers performed a sensitivity analysis on the capital investment of the wood biomass gasification plant. The assessment involved applying a 50% subsidy on capital cost and finding the NPV, payback period, IRR and ROI. These project appraisal techniques were compared against the capital investment scenario when no subsidy was applied. For scenario one, the capital investment was found to be US $678,000 and in case two (50% subsidy) the capital invests reduced to US $353,230.

IV. RESULTS AND DISCUSSION

The researchers estimated the economic analysis of the Biomass Gasification plant for power generation using NPV, payback period, ROI and IRR. The economic assessment for this project shows that the capital cost is GUY$ 152,000,000 or US$ 678,000. The Biomass Gasification Plant cost is GUY$ 140,625,000 which represents 92.1% of the capital investment, civil works is GUY$ 4,725,000 which represents 3.1%, the pellet machine cost is GUY$ 2,700,000 representing 1.78% and wood chipper price is GUY$ 4,500,000 which accounts for the remaining 2.96% of the capital cost.

To operate the plant annually, it will cost GUY$ 8,100,000, which represents 5.76% of the plant cost. The annual maintenance of the gasification plant will cost GUY$ 900,000, which represents 0.64% of the biomass plant cost. Annually, the operation and maintenance cost are GUY$ 9,000,000, which represents 5.92% of the capital cost for this project. The capital investment for this project is very high, it is approximately 17 times the cost for operating and maintaining the plant annually.

The researchers estimated the economic analysis of the Biomass Gasification plant for power generation using NPV, payback period, ROI and IRR. Table 2 shows the results for scenario one when there is no subsidy and table 3 illustrates the economic results for scenario two when a 50% subsidy is applied to the capital investment for the gasification project.

Table – 2 Results without subsidy

KEY RESULTS	
NPV	282,528
PBP	20 years 5 months
ROI	13.3%
IRR	4.70%

Table – 3 Results with 50% subsidy

KEY RESULTS	
NPV	852, 365
PBP	10 years 1 month
ROI	36.56%
IRR	6%

In both cases, the NPV is positive, which suggests the wood biomass gasification plant is viable to invest in for power generation to operate the sawmill. The payback period with no subsidy is 20 years 5 months and with 50% subsidy of capital cost is 10 years 1 month. Importantly, the return on investment with no subsidy is 13.3% and with subsidy is 36.56%, an increase of 23.26%, the project is an excellent investment for both scenarios since the ROIs are positive. The authors found the IRR to be a positive value in both cases.

Discounted cash flow comparison
Figure 3 shows the effective change in the NPV when the capital cost reduces from US$ 678,000 to US$ 353,230. This change in capital cost is assuming a 50% subsidy on the capital investment. It represents the loan being reduced from US$ 71,733 to US$ 35,323 annually to be paid for the first 10 years of the project life. As a result, the NPV changes from 282,528 to 852,365. Therefore, the biomass gasification project becomes a more significant, worthwhile investment if we reduce the capital cost by 50%.

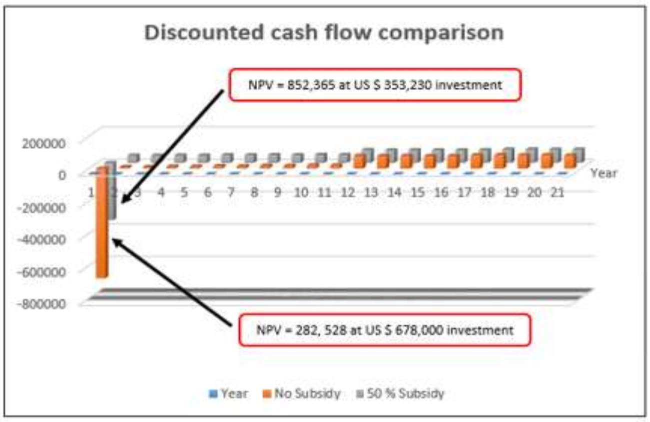

Fig. 4. Discounted cash flows for both scenarios

Figure 4 illustrates the payback period for case one with no subsidy and case two with 50% subsidy of capital cost. The cumulative discounted cash flow for case one shows 20 years, 5 months' payback period for a project life of 20 years. Comparatively, for a 50% subsidy, the payback period becomes 10 years one month.

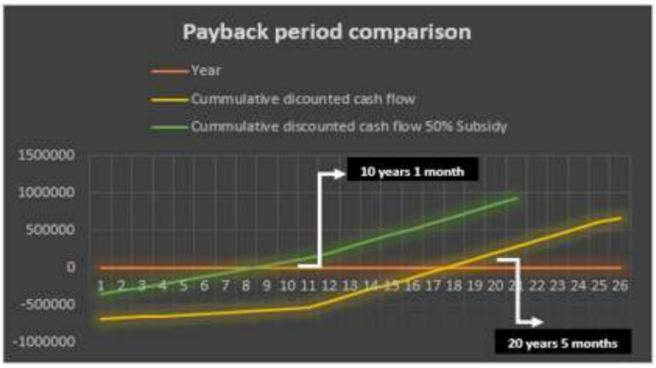

Fig. 5. Payback period without subsidy and with subsidy

V. CONCLUSION

The economic analysis was done to evaluate the viability of the biomass gasification plant for power generation. A cash flow projection was created using capital cost, operation and maintenance cost, insurance, maintenance materials and loan payment as the cash that flows out of the project. The cost of producing electricity to power the sawmill operation by the gasification plant is significantly less when compared to using the diesel power system. This is so because the wood waste generated from the sawmilling operation is free fuel that will be used in the biomass gasification system. However, the company imports diesel at a cost of US$ 99,600 annually to generate power from the diesel power plant. As a result, the implementation of the wood biomass gasification plant will save the company US$ 99,600 annually. In addition, the use of the gasification technology will ensure a reduction in damaging gases to the atmosphere and simultaneously reduce large landfills caused by the wood waste.
The economic analysis of the wood biomass gasification project was done over the system 20 years' life. The technique used to determine the viability and profitability of the gasification system was to obtained the NPV, payback period, ROI and IRR for two scenarios (cases), case 1 was calculated using no subsidy and case 2 was found assuming a 50 % subsidy on the capital investment. The NPV for both cases were found to be positive values which indicates that investing in this system is an attractive option. The discount rate used was less than the calculated IRR in both scenarios. The payback period for case 1 was 20 years 5 months and for case 2 was determined to be 10 years 1 month. The ROI for the gasification plant for generation of power in case one was 13.3% and for case 2 was 36.56%.

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