# Economics Feasibility Study of Combustion-Based Small-Scale Biomass Power Plant in Northern Ethiopia

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## Abstract

*Biomass has emerged in the renewable energy area with a high potential to contribute to the energy needs of both industrialized and developing countries. This study aims to analyze the techno-economic feasibility study of a combustion-based small-scale biomass power plant in Northern Ethiopia. The power plant's economic feasibility was analyzed, in terms of the payback period (PBP), Internal Rate of return (IRR), net present value (NPV), and profitability index from the developed discount cash flow spreadsheet for different financing conditions (i.e., for FIT incentive scenario and 5% escalation without incentive Scenario) over the plant lifetime period of 30 years. The technology readiness level of the proposed technology was assessed as almost >TRL-6 (Technology readiness level). The economic result showed that the investment in the power plant is positively justified. The net internal return value is 25.58% which is three times greater than the discount rate of this project (8%) and is an acceptable value. The payback period of the investment is 4.15 years in the operational life of the plant and the rate profitability index is 2.61%. Hence, for the projected 30-year operational period of investment, installing a small-scale combustion-based power plant is feasible in the FIT incentive and escalated scenarios. From the sensitivity analysis, capacity factor and net efficiency changes have almost close impact on the cost of electricity. Maintenance cost has a relatively lower impact on the cost of electricity (COE) compared to the other factors.*

**Keywords:** Biomass, Combustion, Power plant, sensitivity analysis, White eucalyptus

## 1. INTRODUCTION

The world's energy supply has been influenced by fossil fuels for decades, which account for approximately 80% of total consumption of more than 400 EJ per year. From this, biomass accounts for approximately 10–15% of this demand. On average, biomass accounts for about 9–14% of the total energy supply in developed countries such as the United States, and it accounts for about one-fifth to one-third in developing countries (Khan et al. 2009). Biomass fuels can be classified into four main categories based on their origin. 1) primary residues; which include by-products of food crops and forest products (wood, cereals, maize, etc.); 2) Secondary residues; which include by-products of biomass processing for the production of food products or biomass materials (saw and paper mills, food, and beverage industries, apricot seed, etc.); 3) Tertiary residues; that includes by-products of used biomass-derived commodities /waste and demolition wood; and 4) Energy crops (IFC 2017; Khan et al. 2009). Hence, biomass is considered a fundamental source of energy, especially in sub-Saharan countries such as Ethiopia.

Ethiopia is suffering from significant depletion of domestic biomass resources. Therefore, the development of appropriate institutions and technologies to produce renewable energy from biomass is extremely valuable (Diriba Guta 2012). The development and use of biomass power plant systems improve the mitigation of significant health risks through reduced air, land, and water pollution. This technology also improves waste management, nutrient recycling, job creation, the use of surplus agricultural land and modern energy sources in rural areas, and improves land management in countries that have adopted it by law. The economic analysis of the energy potential of biomass has already been studied by many researchers, and the main conclusion is that the viability of biomass projects is influenced by local conditions at the project site, including biomass waste raw material cost, biomass logistics cost, costs of ash disposal, and labor costs (Abdelhady, Borello, and Shaban 2018). Even if it is an ultimate solution for the problem of managing waste and at the same time recovering energy with high stability of power generation and high total energy conversion efficiency, no clear policy regarding biomass power generation in Ethiopia has been announced so far. Therefore, this study aimed at the evaluation of economic feasibility and technological efficiency, availability, affordability, and maturity of the power plant in Northern Ethiopia particularly in the Tigray Regional State.

## 2. MATERIALS AND METHODOLOGY

### 2.1. Data Collection and Study Area

Biomass was collected from Mai-chew particleboard factory in the southern Tigray region of Ethiopia. Tigray region is ecologically rich and eucalyptus trees are abundant. The study area for this study is located in Tigray, Ethiopia, located at a latitude and longitude of 12.7833 and 39.5333 respectively. The bold red color arrow in Figure 1 indicates the location of the collected sample.

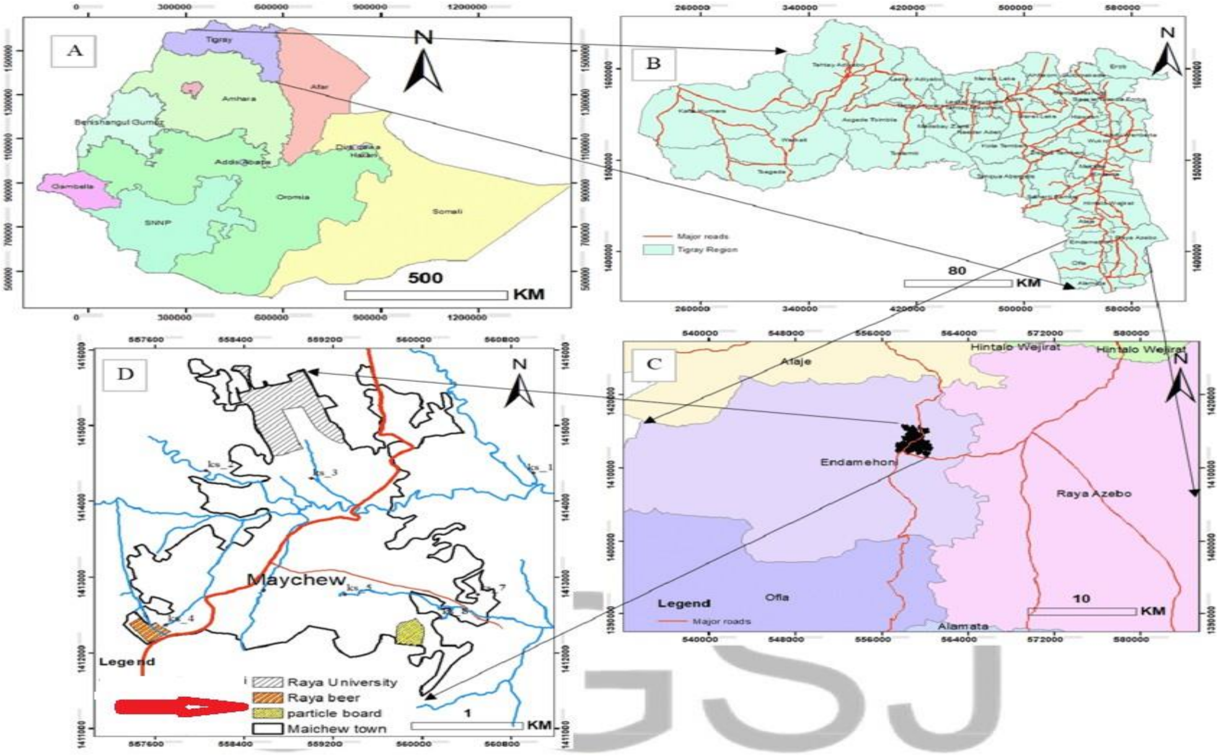

Figure 1: Location map of study and sample collected area (Estifanos, Hagos, and Abrha 2020)

### 2.2. Techno-Economic Analysis

The main objective of the techno-economic analysis was to investigate the profitability potential of the implementation of a biomass power plant in Tigray region, which is located in the northern part of Ethiopia. The goal was to determine the Payback period (PBP), Net present value (NPV), and internal rate of return (IRR) that was considered acceptable for the plant. For the success and commercialization of any new technology, it is essential to know whether the technology is economically viable or not. This approach provides us with a little more insight into the decision-making process and helps us understand why some entities might choose one technology over another.

### 2.2.1. Assessing Technology Readiness Level

A technological assessment evaluates the technical, regulatory, and market conditions that induce the successful deployment of technology. This includes referring to both emerging technologies and existing commercial technologies that currently do not have a significant presence in the market. The technology has the potential to be more cost-effective, perform more efficiently, and produce fewer pollutants. Technological readiness level (TRL) is used to describe the maturity of the technology level based on the procedure of Figure 2 (Gladysz et al., 2020).

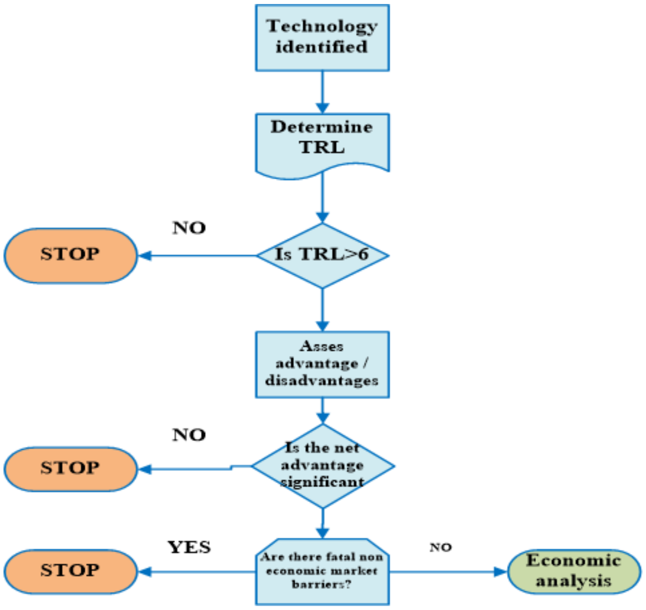

Figure 2: Technological readiness level assessment procedure (Gladysz et al., 2020).

According to the standard measures of technological readiness level, from TRL 2–3 onwards, both environmental and economic performance are underestimated due to hidden deviations from ideal conditions, whereby in scaling various efficiency losses may appear due to the difficulty of mass and energy transfer (Faidi and Olechowski 2020). From TRL-6 ahead, environmental impact and expenses are reduced (Sorunmu, Billen, and Spatari 2020).

Technologies like atmospheric biomass gasification and pyrolysis are less mature and affordable, they are at the beginning of their deployment stage. Others like integrated gasification combined cycle, bio-refineries, and bio-hydrogen are only in the research and development phases as referring in Figure 3. The potential for cost decrement is therefore very heterogeneous and complicated. Only peripheral cost reductions are anticipated in the short-term and developing countries like Ethiopia, but according to an International Renewable Energy Agency (IRENA) report, long-term potential for cost reductions from the technologies that are not yet widely deployed is good (IRENA, 2012).

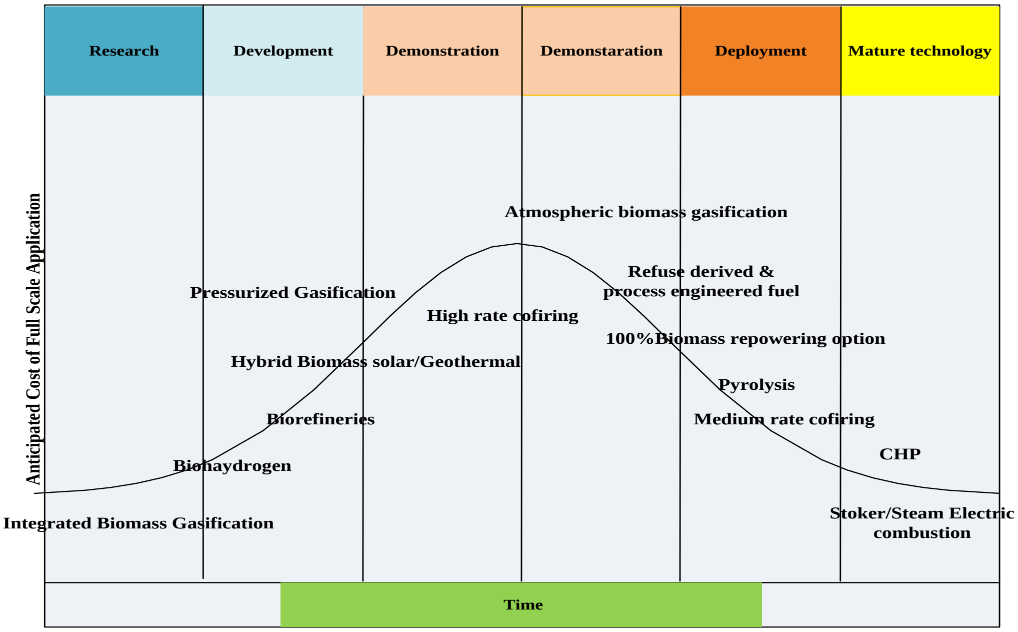

Figure 3: Different biomass power technologies Time vs. anticipated cost (IRENA, 2012)

Assessing a technology in such a case Figure 3 is completed first to avoid conducting a lengthy techno-economic analysis of a fatally flawed advanced technology.

### 2.2.2. Economic Evaluation

Three approaches are combined to evaluate the combustion-based small-scale biomass power plant. Project viability over a lifetime period of 30 years, net present value (NPV), internal rate of return (IRR), and payback period (PBP) were considered under the economic measure of the power plant. NPV allows for keeping a good path of the cash flows over a given period. However, it is sensitive to the discount rate, as a small increase or decrease in the discount rate will strongly affect the NPV final output (Cardoso, Silva, and Eusébio 2019). On the other side, the internal rate of rate (IRR) despite providing a simpler approach evaluates every investment by delivering merely one single discount rate. It is the average annual return rate on the initial investment when considering all costs and benefits over the given project period. As for the payback period (PBP), it presents an easily observable and straightforward analysis when calculating the speed of return, yet, it considers no inflation, financing, or risks associated with the investment.

#### Total Capital Investment

The small-scale biomass power plant in the country is a grassroots project in which, it deserves a Pre-design cost estimation methodology. The total capital investment cost of the plant was the cost of the equipment used to erect the small-scale biomass power plant. This investment cost was estimated, by breaking it down into two five main parts as Battery limits investment, Utility investment, Off-site investment, engineering fees, and Working capital (De Meyer, Venturoli, and Smit 2008). The main purchased plant items were a steam turbine (turbine, gearbox, and electrical generator), steam generator, condenser, and pump. The purchased costs of these equipment were estimated by Aspen process economics analyzer (APEA). In addition, the sizing and equipment type selection and evaluation were performed by this Software. To estimate the cost of equipment or chemicals, for the present time and at the project location, different cost estimation mechanisms were used. Generally, the delivery cost depends on the location of the equipment supplier, the location of the site to be delivered, size of the equipment, and it was estimated by using the logarithmic relationship known as the six-tenths-factor rule (Asante and Hao 2017; Porcu et al. 2019), as suggested by equation (1): -

$$\mathrm{Ca} = \mathrm{Cb}\left(\frac{\mathrm{Q_a}}{\mathrm{Q_b}}\right)^{\mathrm{n}} \tag{1}$$

Where; Ca = Equipment cost with capacity $\mathrm{Q_a}$, Cb = base cost for equipment with capacity $\mathrm{Q_b}$, and n is constant depending on the equipment type.

Some sources of data were available in the open Literature, and Published data are often old. Such data was estimated by equation (2) for the time effect using cost indexes.

$$\mathrm{C_1} = \mathrm{C_O}\left(\frac{\mathrm{I_1}}{\mathrm{I_O}}\right) \tag{2}$$

Where; $\mathrm{C_1}$ is the present cost of equipment, Co original cost of equipment, $\mathrm{I_1}$, and $\mathrm{I_O}$ are index values at the original and present stages of the equipment.

The total capital investment of the small-scale biomass power plant was estimated by considering the time and capacity factors. The total capital cost of the process, services, and working capital was obtained by applying multiplying factors or installation factors to the purchased equipment cost, according to the dominant phase being processed and their relative factor is found in any Engineering economics handbook (De Meyer, Venturoli, and Smit 2008).

$$\mathrm{CF} = \sum_{\mathrm{i}} (F_i * \mathrm{CE}) \tag{3}$$

Where; CF is the total fixed capital cost for the complete system, CE is the cost of delivered equipment and i is a list of items in the total fixed capital cost.

Project contingency, field expenses, home-office engineering, construction activities, and other costs related to construction were computed relative to the total direct cost (TDC) and gives the fixed capital investment (FCI). The sum of FCI and the working capital for the project is the TCI. The Contingency was charged about 10% of the total fixed capital cost. The total capital investment (TCI) was computed based on the total equipment cost using the Lang coefficient method. The Lang factors method is used frequently to obtain order-of-magnitude cost estimates of both direct and indirect costs and is based on multiplying factors by the total purchased equipment cost (Scott 2015).

### Operating Costs

Operating cost can be expressed as a fixed operating cost and Variable operating cost. Fixed costs are generally costing paid off whether the plant fully working or not, they do not vary significantly with generation. The most common list of fixed operating costs is labor costs, routine maintenance costs, and various overhead items (Schroder et al.,2013; YANAGIDA et al., 2015). Whereas variable operating costs are expenses that depend on the rate of production of the power plant. In bio-energy systems, it is known that the operating cost is subject to unexpected expenses, especially concerning fuel costs and other unforeseen expenses. According to Schroder and Andreas report, the operating cost of a small sale biomass-based power plant in 2020 is 116 EUR/KW (Schröder, Andreas;et al, 2013). The operating cost of a combustion-based steam power plant in this study mainly includes the cost of fuels, labor, maintenance, utility, and ash disposal expenses.

### Biomass Waste- Fuel Cost

Biomass waste Fuel consumption of the power plants was estimated by using equation (4), where Capacity Factor is the capacity factor of the plants, which is set to 85 % in this study, and the lower heating value (LHV) of the biomass fuel refers low heating value of the fuel and $Eff_{el}$ refers electrical efficiency of the plant. Yangida reported that there is a strong scale advantage for steam power plant efficiency and electrical efficiency for this steam power plant can be expressed by $5.762 * \ln(P_{C\ Installed}\ (kw) - 26.65$, where the installed capacity of the power plant ($P_C$) in kilowatts is 910 KW (YANAGIDA et al. 2015). The mass of fuel consumption rate (mfuel)(mass/period) of the combustion-based biomass power plant is then estimated by using equation (4).

$$m_{fuel} = \frac{P_{C\ Installed} * C_f * 8760}{\mathrm{LHVfuel} * \mathrm{Effel}} \qquad (4)$$

Where; $P_C$ installed is the installed capacity of the power plant in KW, $C_f$ is the capacity factor, Effel is electrical efficiency and LHV is the lower heating value of the biomass fuel.

Hence, the cost of fuel is then estimated by using equation (5).

$$\mathrm{C_{fuel}} = \mathrm{m_{fuel}} * \mathrm{C_{fuel,unit}} \qquad (5)$$

Where; $C_{fuel}$, $m_{fuel,}$ and $C_{fuel/unit}$ are the cost of fuel, fuel consumption, and cost of fuel per unit of fuel respectively.

### Labor Cost

Labor cost consists of the numbers of ordinary workers, skilled workers, engineers, supervisors, managers, and office staff (Delivand et al. 2011). The labor cost is estimated by multiplying the number of laborers and the cost of the labor per capita. Yanagida reported in his research on existing steam power plants and found that the required number of operators can be expressed as 0.005*Plant capacity, for power plant capacity in the range of 250kw –1000 kW (YANAGIDA et al. 2015). Expenses of labor for the small-scale steam power plant were then estimated by using equation (6);

$$\mathrm{C_{labor}} = \mathrm{n_{labor}} * \mathrm{C_{labor,capita}} \qquad (6)$$

Where $C_{labor}$, $n_{labor}$, and $C_{labor,\ capita}$ are the cost of labor, the number of laborers, and labor cost per capita respectively.

### Maintenance Cost

Maintenance expenses depend on whether processing materials are solid, liquid, or gas. Handling solid processing material, for example, increases its maintenance cost due to frequent shutdown and fracture of piping and other crucial devices. Given the high maturity of combustion-based biomass power plant systems, maintenance cost is reported to be 1.5–4% of the total capital cost for the combustion plants (Delivand et al. 2011). Within this study, an average value of 3% of the total capital cost is used as the annual maintenance and repair costs of the power plant. The maintenance cost of the power plant is then estimated by using equation (7).

$$C_M = C_{total,capital} * £_{maintenance} \qquad (7)$$

Where $C_m$, $C_{total,capital}$, and $£_{maintenance}$ are the cost of maintenance, total capital cost, and constant maintenance ratio respectively.

### Utility and Ash Disposal Cost

Utility operating costs include expenses like fuel, electricity, steam, cooling water, refrigeration, compressed air, and, inert gas (De Meyer, Venturoli, and Smit 2008). As it was difficult to find specific utility costs for power plants, Yangada assumed that the utility cost of small scale biomass power plant is 0.5% of the initial capital cost of the power plant (YANAGIDA et al. 2015) and the ash disposal cost of the power plant is conducted by using equation (8).

$$C_{ash} = m_{fuel} * 0.01 * C_{ash,unit} \qquad (8)$$

Where $C_{ash}$ is the cost of ash, $m_{fuel}$ is the mass of consumption of biomass fuel and $C_{ash,unit}$ is cost of ash per unit respectively.

### Discounted Cash Flow Analysis

It is used to determine the minimum selling electricity price per kilowatt-hour of power produced. To do this cash flow analysis the discount rate, plant operation life, biomass power plant capacity, escalation rate, and construction start-up duration be specified. To measure the feasibility analysis of the power plant's net present value (NPV), internal rate of return (IRR), payback period, and profitability index are some of the basic engineering economics measurement tools considered in this study. NPV is estimated by the sum of the present value of cash flows minus capital cost, it is calculated by using equation (9) (Ong and Thum 2013).

$$NPV = \Sigma \frac{CF_k}{(1+d)^k} = \Sigma PV \qquad (9)$$

Where k refers to the estimated plant life which is assumed 30 years in this study, $CF_k$ refers to the cash flow of year k, d refers discount rate of the project which is assumed to be 8% a year, and the project with negative NPV is not acceptable when the capital cost is subtracted.

The internal Rate of Return is the discount rate that makes the NPV of the projects equal to zero (Harding et al.,2018).

$$\Sigma \frac{CF_k}{(1+IRR)^k} - C_{capital} = 0 \qquad (10)$$

To estimate the project by internal rate of rate (IRR), the hurdle rate has to be set which is a minimum rate of return for the plant operator will accept the project. In the case of this power generation power plant, 8 % is a rough standard for the value.

### Discount Rate

The discount rate is the interest rate used to determine the present value of future cash flows in a discounted cash flow (DCF) analysis. This helps determine if the future cash flows from a project or investment will be worth more than the capital outlay needed to fund the project or investment in the present. To calculate the cash flow analysis of the Techno-Economic Analysis of a Small-Scale Biomass to-Energy-Gasification-Based System, Porcu also adopted a discount rate of 8% (Porcu et al. 2019). In this research work, the discount rate refers to the interest rate charged to the commercial banks and other financial institutions for the loans they take from the Federal Reserve Bank through the discount window loan process, and second, the discount rate refers to the interest rate used in discounted cash flow (DCF) analysis to determine the present value of future cash flows.

#### 2.2.2.1. Price of Electricity

According to information from the Ethiopian Electric Utility (EEU), the current price of electricity for the industry is 1.2927 ETB/KWH, which is about 0.02318 USD/KWH. According to the Ethiopian Energy Power Business Portal new report (eepBp) (Tigabu Atalo, n.d.,2020), identifying off-grid power locations and introducing subsidy programs or incentive mechanisms for a renewable energy source in a deep area is an invaluable task to achieve sustainable developmental goal-7 (SDG-7). The price of electricity in this research work is considered as the price of electricity with escalation and the price of electricity FIT incentive.

#### Price of Electricity with Escalation

The price of electricity escalation rates is an important facet of energy-saving performance contracts. These stipulated rates dictate the flow of USD savings that will be available, given a guaranteed level of energy savings, to pay for the debt service i.e., initial project price plus interest, as well as the project servicing costs such as operations and maintenance or measurement and verification. The annual escalation rate of this project is assumed as a 5% yearly increment. In this case, the price of electricity is adopted as 1.2927 ETB/KWH or 0.02318 USD/KWH as per Ethiopia's electric utility's current price of electricity for industry.

#### Price of Electricity FIT Incentive

Feed-in tariff incentive is a reason for the success of many developed countries such as Germany and Greece in extending renewable and private off-grid energy in a short period. The successes of many countries using feed-in tariffs have several reasons (Peerapong and Limmeechokchai 2014). FIT offers long-term security for investors through guaranteed and fixed tariffs for long periods on a relatively high level, the existence of well-built financial subsidy programs, regional investments towards economic and social welfare, technology-specific and location-dependent differentiation, and stable government regulations. So, FIT programs have been proven, by experience from some European countries to make larger and faster electricity market penetration at a lower cost than any type of promotion. The price incentive of the FIT Scenario helps for the off-grid and private renewable technology to build sustainable development.

#### Taxes

Income tax is averaged over the plant life and that average was calculated on a per-kilowatt basis. The amount of income tax to be paid by the potential of the scale of the power plant varies annually due to changes in the volume of product produced and the allowable depreciation deduction. Three-year tax-free is taken as a global average for start-ups. This is because the depreciation and loan interest deductions are greater than the net income. In the case of our country, many recommendations were raised (Tigabu Atalo 2018) for renewable energy power plants to be free from tax and to charge positive incentives. Hence in this study, tax-free economic evaluation is considered to motivate and penetrate private renewable energy easily and quickly throw-out the country.

## 3. RESULT AND DISCUSSION

### 3.1. Evaluation of the Power Plant Economics

The economic analysis of the biomass power plant is a critical component of the project assessment, involving a detailed evaluation of the financial aspects associated with the plant's development and operation. This section covers key financial metrics and analyses, including the overall total capital investment cost, the overall operating cost, the cash flow analysis, and the sensitivity analysis, as outlined below.

Table 1**:** Summary of biomass power plant cost generated from Aspen Plus and typical factors

| Items | Factor | Description | Amount in USD |
|---|---|---|---|
| **Investment of direct cost** | | | |
| Total equipment purchased cost, TEPC | 1 | Of TEPC | 240,100.00 |
| Purchased equipment installation | 0.47 | Of TEPC | 112,847.00 |
| Instrumentation and control system | 0.2 | Of TEPC | 48,020.00 |
| Piping (installed) | 0.7 | Of TEPC | 168,070.00 |
| Electrical(installed)equipment's | 0.1 | Of TEPC | 24,010.00 |
| Building | 0.2 | Of TEPC | 48,020.00 |
| Services facility (off-site &utility) | 0.3 | Of TEPC | 72,030.00 |
| Site preparation | 0.1 | Of TEPC | 24,010.00 |
| **Total plant direct cost (TPDC) =** $\Sigma DC$ | | | **737,107.00** |
| Engineering design and supervision | 0.33 | Of TEPC | 79,233.00 |
| Construction and Expenses | 0.41 | Of TEPC | 98,441.00 |
| **Total plant indirect cost (TPIC)** | | | **177,674.00** |
| TIDC=Total plant direct cost + Total plant Indirect cost | | | **914,781.00** |
| Contractors fee (CF) | 0.21 | Of TEPC | 50,421.00 |
| Contingency (C) | 0.40 | Of TEPC | 96,040.00 |
| **Fixed capital investment (FCI)=TIDC +C +CF** | | | **1,061,242.00** |
| Working capital (WC) | 0.86 | Of TEPC | 206,486.00 |
| **Total capital Investment(TCI)=FCI + WC** | | | **1,267,728.00** |

Table 2**:** Generalized basic financial estimated results

| *List of Items* | *Amount* |
|---|---|
| Total Facility Capital cost (USD) | 1,267,728.00 |
| **Electric and Fuel--base year** | |
| Net Electric Capacity (KW) | 910 |
| Capacity factor (%) | 85 |
| Annual hours | 8400 |
| Net Station Electric Efficiency (%) | 12.6 |
| Fuel Heating Value (KJ/Kg) | 18,675.5 |
| Fuel consumption Rate (Tone/Hr) | 1.392198335 |
| Fuel power (Kw) | 7,222.222222 |
| Annual Net Generation (kWh) | 6775860 |

| | |
|---|---|
| Annual fuel consumption (Tone/year) | 11,694.46601 |
| Capital cost per net electric capacity (USD/KW) | 1,393.1077 |
| Fuel Ash Concentration (%) | 0.98 |
| Annual Ash Disposal (Tone/year) | 114.6057669 |

The cost of raw materials and product selling prices tend to have the largest influence on the economic performance of the process. The cost of fuel and price of product power depends on whether the materials in question are being bought and sold under a contractual arrangement either within or outside the company or on the open market.

Table 3: Overall operating cost financial evaluation results

| List of items | Cost (USD) | USD/year |
|---|---|---|
| Fuel Cost (USD/T) | 2.78417 | 32,559.4073 |
| Labor Cost (USD/year) | 12161.27047 | 12,161.27047 |
| Utility (USD/year) | 1200.5 | 1,200.5 |
| Ash Disposal (USD/Year) | 2871.7412 | 2,871.7412 |
| Maintenance cost (USD/year) | 7203 | 7203 |
| **Total Operating Cost** | | **55,995.91897** |

### 3.1.1. Cash Flow Analysis

In the Development of cash flow analysis for 30 years of the operational life of the power plant with an 8% discount rate, the electricity prices with incentive and without incentives were considered.

#### 3.1.1.1. Cash Flow Analysis with Escalation

In the first two deployment years of the power plant, the net cash flow is negative, because of 1,267,728 USD investments paid out without any income. But, from year 3 onwards the production is working properly as shown in Figure 4. In this cash flow Scenario, there is no FIT incentive but the cash inflow is escalated every year by 5%. Therefore, the amount of income is then increased step wisely. At the end of the operational life of the plant, the amount of cash inflow and net saving is around four times greater than the FIT with incentive scenario.

In this case, there is no constant agreement or contract with electricity users. Charging an escalated electricity price every year is so activated. According to information from the Ethiopian Electric Utility (EEU), the current price of electricity for the industry is 0.0359 USD/KWH, and this charge is taken per kilowatt-hour and 5% escalation per year for the without incentive electricity price scenario. The net income in year three is 275,115 USD/Year whereas cash inflow in year thirty is 1,027,131 USD/year. With this principle, the net saving in year three is 219,119 USD/year; whereas the net income in year 30 is 971,135 USD/year.

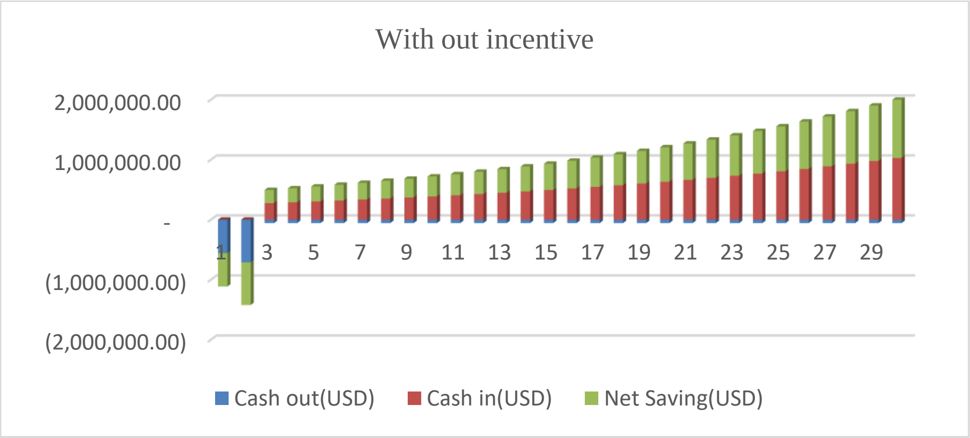

Figure 1: Graph of net cash flow of the graph under the operational life of the plant without incentive

#### 3.1.1.2. Cash Flow with FIT Incentive

In the first two years, a total amount of 1,267,728 USD is invested with 556,834.73 USD/year in the first year and 710,893.27 USD/year in the second year respectively. In the Feed-in tariff scenario, the constant contractual agreement will be performed with the electricity user. Besides, there is neither increment nor decrement situation in the in-cash flow every year. The amount of money collected in each year is constant, which is 417,983 USD/year cash inflow and 361,987 USD/year net saving. The contractual agreement in this scenario is considered as a smooth flow. Cash inflow in this case in year three is, approximately the same as the amount of cash inflow collected in year nine in the escalated scenario.

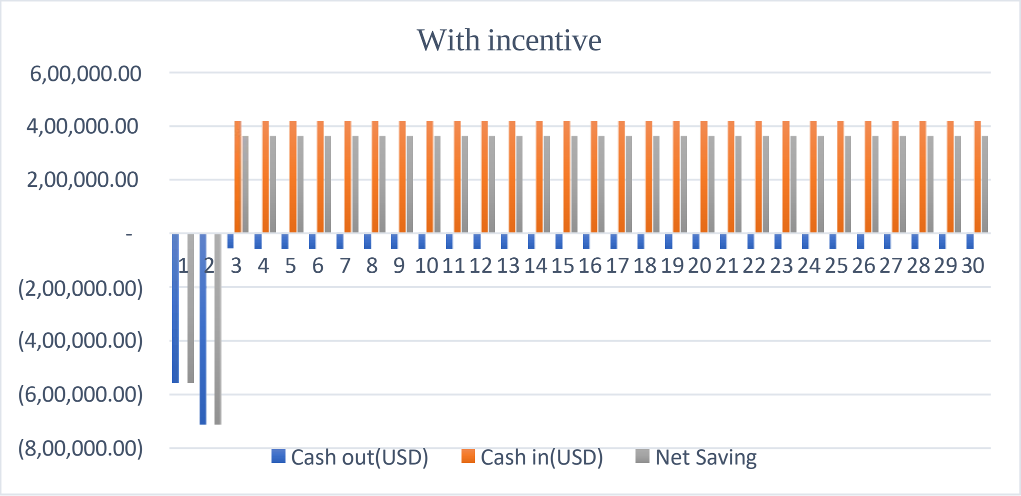

Figure 5: Graph of net cash flow of the graph under the operational life of the plant FIT with incentive.

### 3.2. Electricity Price Scenarios

#### 3.2.1. Electricity Price for FIT Incentive Scenario

The estimated net present value (NPV), which is the summation of the discounted present value of each year in the 30-year operational life of the plant for this scenario, of this situation is 2,304,588 USD/30 years. This value indicates how much the project will increase the investor's property over the whole project period in today's money value and, it is an excellent tool for comparing different projects. If NPV has a negative result, the project is not to be realized without suffering losses taking into account the assumed discount rate. Based on the results of the cash flow analysis of the power plant on the 30 years of operational life, the investment would be repaid in 4.15 years for the Feed-in tariff scenario. Generally, In the Electricity price for the FIT Incentive scenario, the net present value is 2,304,588 USD/30 years greater than total capital investment, the net internal return value is 25.58% which is three times greater than the discount rate of this project (8%), the payback period of the investment is also 4.15 years in the operational life of the plant and the rate profitability index is 2.61% which is greater than zero. Hence, 30 operational years of investment in small-scale combustion-based power plants is feasible in the FIT incentive scenario.

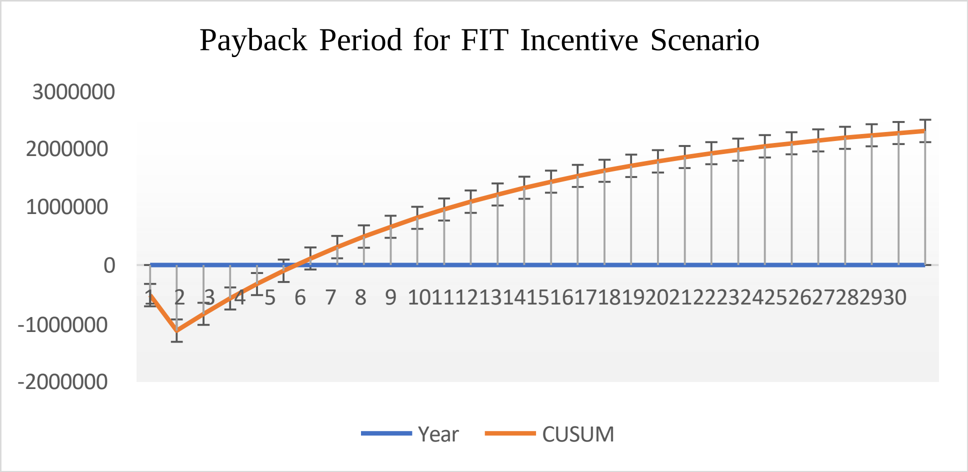

Figure 6: Graph of the payback period for the FIT incentive Scenario

### 3.2.2. Electricity Price for No Incentive Scenario

In the no incentive scenario, the price of electricity is escalated by 5%, while the electricity price is 0.035991 USD/KWH according to the current Ethiopian electric utility price. As in Figure 7 shown payback period for the escalated no-incentive scenario is 8.29 years which is around twice the years of the FIT incentive scenario. But the annual income money increases step wisely each year. The sum of the net savings of this scenario per 28 years of operational years without considering the deployment time of the project is 3,312,868.395 USD.

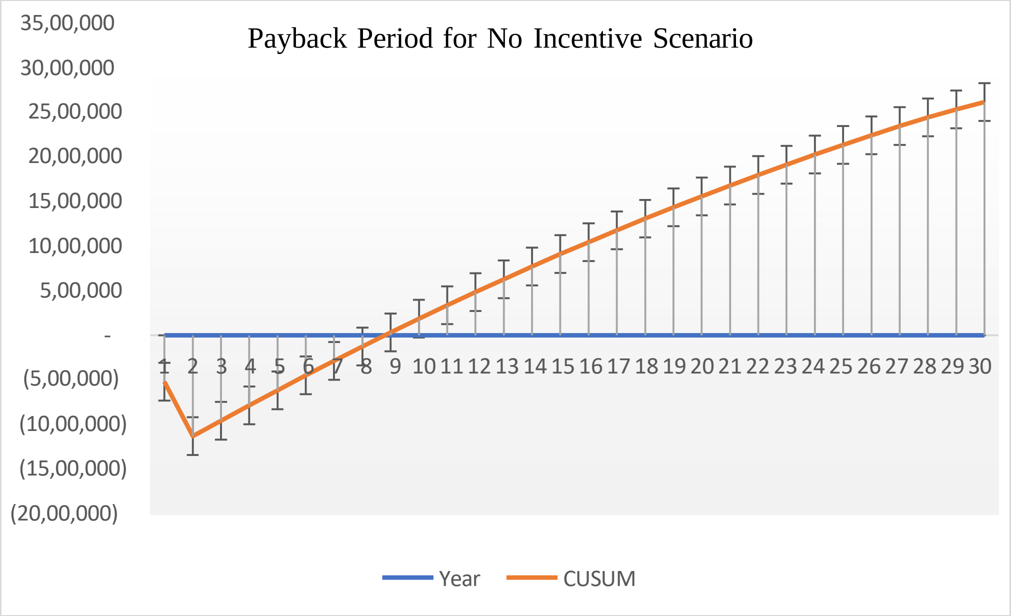

Figure 7: Graph of the payback period for no incentive Scenario

Generally, in the electricity price for escalated no Incentive scenario, the net present value is 2,605,260.2 USD/30 years greater than the total capital investment, and in the FIT incentive scenario, the net internal rate of the return value is 21.24%, which is three times greater than the discount rate of this project (8%) and around 4 years greater than the FIT incentive scenario. The payback period of the investment is also 8.29 years which is twice the FIT scenario in the operational life of the plant and the rate profitability index is 2.73% which is greater than zero and close to the value of the FIT incentive scenario. Hence, 30 operational years of investment in small-scale combustion-based power plants is feasible in the escalated no-incentive scenario.

### 3.3. Sensitivity Analysis

Sensitivity analysis was performed to understand how sensitive a plant's profitability is to changes in the parameters that drive cost and revenue. The parameters are percentages that are over crossed by the cost of electricity and assumed relative change. So that, an analyst can see the impact of percentage changes in capital cost, maintenance cost, capacity factor, fuel cost, ash disposal contempt ratio, and net efficiency in the variables on the overall financial return measures. This method was also used to examine the sensitivity of financial returns to changes in prices, which easily fluctuate according to supply and demand and constitute a major portion of the electricity selling price. Capacity factor and net efficiency changes have an almost close impact on the cost of electricity. Maintenance cost has a relatively lower impact on the cost of electricity (COE) compared to the other factors.

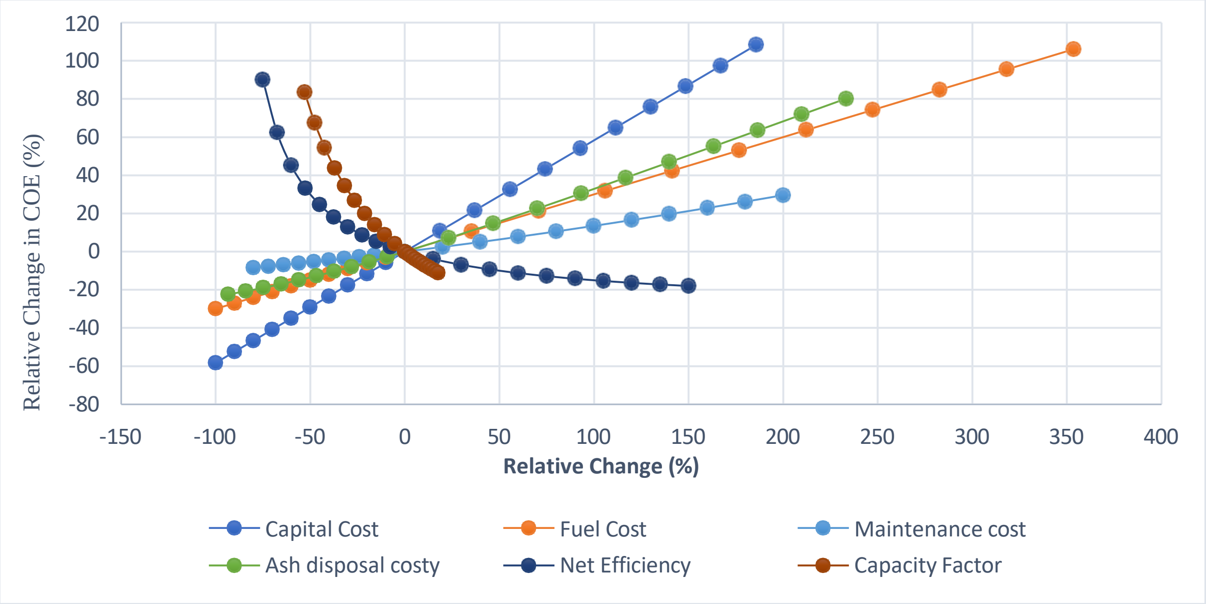

Figure 8: Graph of sensitivity analysis of different parameters

## 4. CONCLUSION

In recent years considerable attention has been paid to renewable power generation from biomass, especially in small-scale biomass power plants. Several technological plant configurations have been proposed and investigated, but so far, definitely preferable technological solutions have not been found yet. In, this study the technological readiness level of the basic equipment of the power plant >6 is considered.

The electricity price for the FIT incentive scenario has a net present value of 2,304,588 USD/30 years which is greater than the total capital investment (1,267,728 USD). The net internal return value is 25.58% which is three times greater than the discount rate of this project (8%). The calculated payback period of the investment is 4.15 years in the operational life of the plant and the rate profitability index is 2.61%. Hence, for the projected 30-year operational period of investment, installing a small-scale combustion-based power plant at the factory's site is feasible in the FIT incentive and escalated scenarios.

### Authors' Contributions

**LTG, FAB,** and **TGG** conceived the problem of the study, prepared research proposals, and developed the overall design of the research; prepared the first draft of the manuscript as well as approved the manuscript for submission.

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### Availability of data

The data sets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

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### Competing Interests

The authors declare no competing interests

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