Economics of Hydro-Kinetic Turbine for off-grid Application: A Case Study of Gumara River, Upper Blue Nile, Amhara, Ethiopia

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Abstract- This paper examines the economics of Hydro-kinetic turbines (HKTs) to investigate the possibility of usage in rural areas, where the grid is not available. In support of the different efforts endeavored by the Ethiopian Government to increase the availability of electricity. This study was carried out in the Gumara River, upper Blue Nile, Amhara Region Ethiopia. The energy demand of a representative household family is selected for this study. We implemented the most commonly used domestic home appliances for the model with a total wattage of 2.625kW at base load and 4.147 kW at peak load. The total daily power demand of the typical household in the area is 19.26 kWh/day. Then to determine costs of HKTs we used the Life Cycle Cost Analysis (LCCA) methodology. The initial capital cost, replacement cost, and operating and maintenance cost were calculated to determine the economics of HKTs. Then, we applied the HOMER software system design of 5 kW HKTs and 2.5 kW diesel generator to estimate the economics cost of HKTs. In our study, we used $20 per metric ton of carbon emission penalty. The IRR was estimated to be 17.4% and the payback period of 5.6 years with present worth of $4826, and the total Net Present Value of $89,764. The estimated Levelized cost of energy was about $0.42. Our finding indicated that the HKTs technology is economically and technically viable energy option for small scale off-grid electrification. This work also alludes to risk analysis on HKTs.

Keywords Hydro Kinetic turbines (HK), Energy Economics, Levelized Cost of Energy, HOMER Pro.

1. Introduction

Energy issues have been analyzed from an economic perspective for more than a century [1]. This is due to energy being a vital component for economic development, it is a key element in each sector of economic activities [2]. As a result, nations have started to develop and use available energy resources to foster their economic growth. Moreover, the need to transit overreliance on traditional energy sources towards modern energy sources remains important to achieve energy security and reduce poverty in off-grid areas of developing countries. Furthermore, conventional energy sources (such as oil, gas, and coal) are the primary choice to use as energy sources. But their excessive use leads to increase in greenhouse gas emissions and environmental damage [3], which open a door to another alternative (renewable) energy sources. To circumvent these problems, policymakers and engineers have given increasing attention to the development of alternative energy sources such as Solar, Hydro-power, Wind, Geothermal, Ocean, Biomass resources. Over conventional energy sources, renewable energy sources have different advantages:- Eco-friendliness, renewability, less maintenance of facilities, cleanness (improved public health), and enriching energy security [4]. Among these renewable energy sources, Hydro-power, which uses water to generate power, is one of the oldest forms of energy source, matured technology, cheap alternative (in case of Ethiopia) [5]. In the year 2017, 26.5% world energy consumption was renewable electricity, and among this 16.4 % was from hydro-power [6]. In Ethiopian share of hydro-power generation is about 2.55 GW which accounted for 90% of total power generated [7].

Based on type energy used to generate power, Hydro-power can be classified as, 1) Conventional Hydro-power, which uses static head to extract power and, 2) Hydro-kinetic turbines (HK) which uses the kinetic energy of water to extract power from running water current (velocity of water) [8]. Due to huge investment requirement to construct dams, the complexity of turbines and effect on Eco-system considerable criticisms has been raised on conventional hydro-power [9]. A study of Kumar et al. [10] showed that the impact of dams and its catchments at different scales needs an urgent policy on the global scale to deal with Green House Gas Emissions from Hydropower reservoirs. As a result, the hydro-kinetic technology is regarded an as suitable option for small-scale power generation such as application for a household in off-grid electricity generation as compared to the dam-based hydro-power technology [8, 11]. Hence, the footprint created by hydro-kinetic turbines is small as compared to the dam-based hydro-power technology [12]. Hydro-kinetic energy converters can tap into the following types of resources: inland (rivers), tidal, ocean (currents), Irrigation and other man-made canals [13, 14]. Previously feasibility and techno-economic study of hydro-kinetic power generation for use of small-scale hydropower generation especially for off-grid application were studied by Juan et al. and Kanzumba et al. [15, 16]. A similar study of Dhakal et al. [17] showed that gravitational powered HKTs can be easily installed in existing water infrastructures with the cost ranging from $1021-$1261 with generator capacity of 1.6kW.

This paper aims to investigate the economics of hydro-kinetic turbines for remote area application. The study also provides a comparative analysis of HK use to examine its possible application for 1) Individual Residents or Community, 2) Private Sector or Government. This case study was undertaken along the bank of river Gumara, in the upper Blue Nile of Ethiopia. Farmers living along the river bank uses diesel-powered water pump for irrigation. Household in the area use bio-mass for cooking need and kerosene for lighting. The day to day activity of the framers is affected significantly by escalating fuel price. These have provided to investigate the economics of Hydropower application.

Since technology development and market penetration of Hydro-kinetic turbine is in infancy stage [9, 18], this paper aims to investigate and study the economics of Hydrokinetic turbines to determine investment cost required to develop the resource for sustainable off-grid clean energy provision. For this purpose, we used a Life Cycle Cost Analysis (LCCA) method to determine investment cost including initial capital cost (purchase, construction, installation, and shipping), operating and maintenance costs, replacement cost and residual values (salvage values). Similarly, cost penalties for emissions of pollutants analyses were used to estimate the carbon saving of HK technologies. Further to investigate the economic feasibility of HK we estimated the Net present value, payback period, IRR, cash flow and return of investment. In addition, for system modelling 2.5 kW diesel generators were used as a backup system. The economic study was done with the help of economics analysis software package Hybrid Optimization Model for Electric Renewable (HOMER Pro).

2. Materials and Method

2.1. Description of the study area

This study was conducted in Gumara River, which is located in the upper Blue Nile. The study area is situated in Fogera Woreda, South Gonder, Amhara National State of Ethiopia. The city of Gumara is located 45km from the regional capital city, Bahirdar. The river is one of the major tributaries of Lake Tana in the upper Blue Nile. River Gumara originates from the Guna mountains south and east of Debre Tabor at an altitude of approximately 3250 m [19]. The river flows westwards for 132.5 km until it reaches Lake Tana. The level of this shallow lake, the largest of Ethiopia [19] makes suitable for application of Hydro kinetic-turbines. Figure 1 shows the total catchment and site location of the study area.

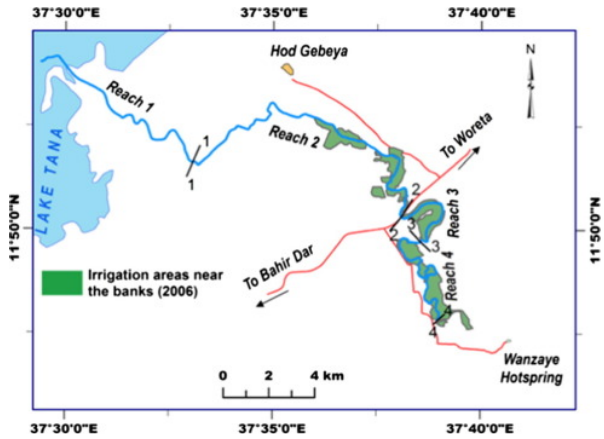


Fig. 1. Gumara river catchment area [19]

The Catchment area has steep with slopes (frequently above 25%) in the high mountainous region in the east, and gentle slopes (below 3%) towards Lake Tana having an average slope of 15% [19]. Majority of the catchment area near the banks used for irrigation as it is shown in Figure 1. According to the Ministry of water, irrigation, and energy (MoWIE) of Ethiopia, hydrological gauging station the deepest point in the river bed is 2.91m [19] with an average width of the river is 34.9m.

2.2. Economic Parameters

The Life Cycle Cost Analysis (LCCA) and analysis of investment risk were used to study the economics of Hydro Kinetic turbine. LCCA is the most widely used method for assessing the total cost of facility ownership. It takes into account all costs of acquiring, owning, and disposing of an energy system [20]. In the LCCA we considered three types of costs: 1) initial capital cost (cost related to component purchase, construction, installation, assembly, and shipping, operating and maintenance costs), 2) replacement cost, and 3) Residual values (Salvage values). As compared to several economic evaluation methods, the LCCA provides a straightforward and easy-to-interpret measure of economic evaluation. LCCA also includes several economic indicators such as internal rate of return (IRR), and net present value (NPV), theses make LCCA more powerful than other economic evaluation methods.

The economics of HK is assessed by estimating the Net Present Value (NPV). The NPV is a standard method for estimating the time value of money to appraise long-term projects. The Net Present Value (NPV) of HK investment project is computed using the following formula [1];

$$NPV=-\frac{A_o}{(1+i)^0}+\frac{A_1}{(1+i)^1}+...+\frac{A_n}{(1+i)^n} \quad (1)$$

Where *n* is the service life of the project, *i* is an interest rate that the investment wishes to earn and A_0 is net cash flow.

Internal Rate of Return (IRR) is used to rank the projects. The IRR of a project greater than the inflation rate is considered to economically feasible. The formula for estimating IRR is given as [1];

$$0=-\frac{A_o}{(1+i)^0}+\frac{A_1}{(1+i)^1}+...+\frac{A_n}{(1+i)^n} \quad (2)$$

2.3. Carbon Saving

As of today, environmental pollution becomes a great concern, the role of renewable energy sources in environmental protection extensively studied in [21–23]. In the path of achieving to protect the environment, in this study we included carbon saving potential of Hydro-kinetic turbines. Currently, in the study area, diesel and bio-mass are a primary energy source which has a carbon footprint of 400g of CO_2 eq/kWh and 237g of CO_2 eq/kWh respectively [24]. There are two approaches to estimate carbon saving of energy technologies. These are 1) Cap and trade instrument which states paying the energy producers the amount of carbon saved, amount of tariff set by Governments, and 2) Taxing the polluter sectors by quantity of pollutant emitted. In this study to estimate the amount of carbon saved by using Hydro-kinetic turbines, a carbon cap, and trading approach was used. Hence the proposed technology of HK turbine will produce energy without polluting the environment, the best model which constitute this is carbon and trade approaches. With a stronger carbon emissions price through cap and trade approach will facilitate the sustainability and implementations of HK turbines. Different studies estimated price of carbon saving recently. For instance, a study found the price to be about \$20 per metric ton to be \$80 per metric ton by year 2030 [25].

2.4. Uncertainty and Risk

The term uncertainty and risk are applied to unknown outcomes of an unquantifiable situation [1]. In economics, risk is a quantity subject to empirical measurement and the probabilities of alternative possible outcomes. In this study instead of empirical measurements, a risk matrix is used. The risk matrix is used because it is the most useful qualitative risk analysis technique. Risk matrix typically is a two-dimensional matrix where one axis categorizes the risk in terms of qualitative probability (low, medium and high) of occurrence of outcomes and the other axis identifies the seriousness of impacts of these risks in qualitative terms (low, medium, high) [1].

2.5. Resource Assessment of Gumara River

Hydro-kinetic systems convert kinetic energy from flowing water into electricity, or other forms of energy. Accurate predictions of the electricity that would be generated needs resource assessment to characterize and quantify the energy resource specifically for hydrokinetic systems. Available river databases are not suited for Hydro-kinetic energy analysis, the available data is on river discharge [26]. These data used for assessing resource potential in the annual report of monthly average instantaneous flow from the river during 1993-2016. The data was compiled from the Ministry of water, irrigation, and energy (MoWIE) of Ethiopia, this data contains an average daily flow rate in m^3/s of each month.

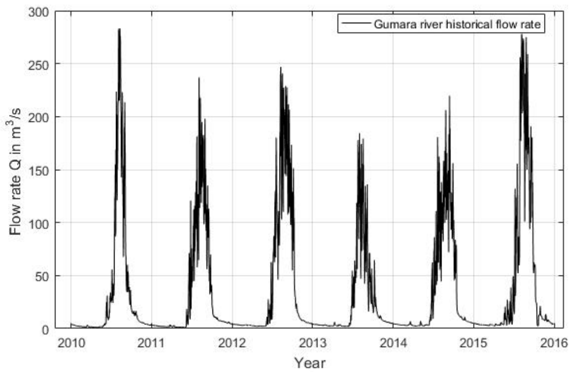


Fig. 2. Historical discharge of Gumara River

Figure 2 shows the average flow rate of each month in which the data recorded from historical data for 23 years (1993-2016). The data illustrates that 50% of the flow rate lies in the range of 1-10 m^3/s, 20% of the flow rate lies in the range of 15-20 m^3/s and 30% of the flow rate lies in the range of 100-250 m^3/s. Even-though, the historical flow rate of the Gumara River is available for 23 years, the data is not directly suitable to predict the power production. For Hydrokinetic turbine application velocity of the river is an important factor. For this study, a direct, measurement of the Gumara river water current (velocity) by using a Valeport BFM002 S-N 2065 Hydrological survey was done at 7 different potential places. Table 1 shows the directly measured velocity of the river at 7 different places along the river to determine the appropriate site and high resource potential site, according to the measured data specific site location at LAT. 11.88, LONG. 37.69 And ALT 1790 m with 2.4 m/s is suitable with highest stream velocity.

Table 1. The velocity of Gumara River at different segment

LAT	LONG	ALT in m	Velocity in m/s
11.70	37.63	1802	1.3
11.81	37.65	1796	1.4
11.862	37.67	1795	1.6
11.84	37.67	1793	1.65
11.86	37.68	1791	1.8
11.88	37.69	1790	2.4
11.89	37.69	1788	2.1

The monthly average velocity distribution of the river Gumara is showed in Figure 3.

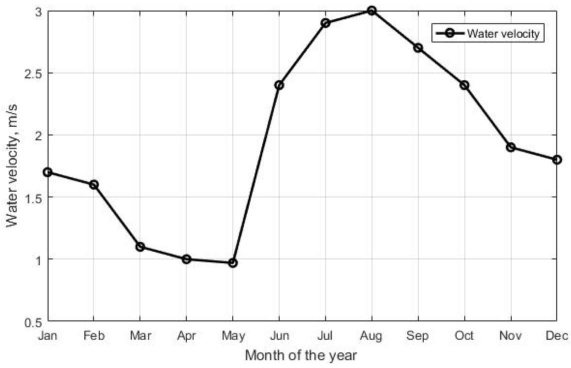


Fig. 3. Average monthly water velocity

The cut-in current river velocity required for hydrokinetic turbines is 0.5 m/s, according to Figure 3 the minimum velocity occurs in dry season of May as 0.97 m/s which is slightly above the cut-in speed, where power generation starts and the maximum stream velocity recorded was in August 3 m/s, where maximum (Rated) power generated.

2.6. Energy Demand Profile of Local Energy Consumers

For versatile use of Hydro-kinetic Turbine to power residents live along the riverside it is important to determine the energy demand profile of taking different scenarios as:

- The household has decided to switch to Hydrokinetic turbine
- The consumer has decided only to use the types of appliances to be used as shown in Table 2
- The consumer has decided to use daily energy from 6 to 23 hr for the appliance as shown in Figure 4.

The primary residential energy demands of the residents are heating and lighting. The residents use biomass to meet the heating and cooking energy needs while kerosene is used for lighting. To determine domestic energy need, we collect a data from a representative family on type of domestic appliance, amount, hour of usage per day, wattage and daily power demand as given in is Table 2.

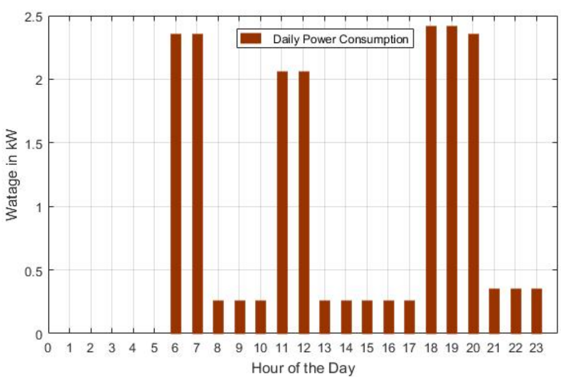


Fig. 4. A daily energy usage profile

According to our survey daily consumed the energy of the selected representative family is 19.26 kWh/day as given in Table 2. Figure 4 shows the daily wattage profile of the domestic appliance. As the figure illustrates most of the peak load occurs at 6, 19 and 20 hrs, no-load from 0 to 5 hrs of the day and baseload for the rest of the day.

Peak load is used to describe a period in which electrical power is expected to be provided for a period significantly higher than average supply level. Peak load fluctuation may occur on daily, monthly, seasonal and yearly cycles. Daily total energy demand is 2.625 kW to find the peak load a 1.58 load correction factor was used; therefore, the design is at peak load of the demand which is 4.147 kW.

2.7. Hydro-kinetic Turbine Selection

Hydro-kinetic turbines are similar to wind turbine devices in terms of design, operation and working principle. This makes them easy to install with-out constructions of impoundment or river diversion. There are numerous efforts in developing portable Hydrokinetic turbine by the different developer to further make the application and usage more versatile. Different variety of these turbines are available on the market, the most popular manufacturers are listed in Table 3.

For this case study, New Energy (Canada) Vertical axis Hydro-kinetic turbines 5 kW EVG 005H for residential household energy demand was considered for appraisal option. According to the website of the company, these turbines are especially suited for residences, farms, remote installations, and small communities where the requirement for electricity is modest or resource available is limited in size. Figure 5 shows the power curve provided by the company website, which depicts that the system can run up to 24 hours, and it is suitable to power critical appliances.

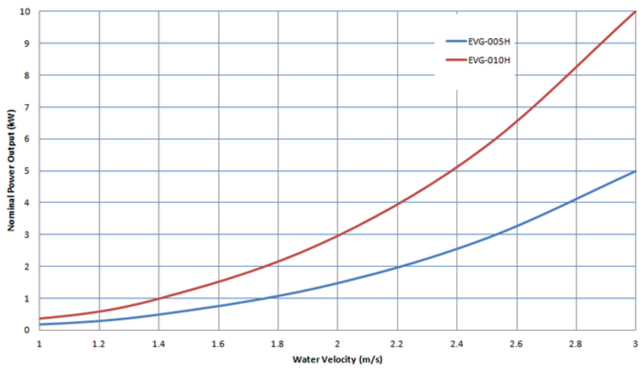


Fig. 5. The power curve of EVG 005H [27]

3. Economic Analysis

To conduct the economic analysis of the HK Capital Cost, Replacement Cost, O&M, Real interest rate, Cost Recovery Factor, Net Present Value (NPV), IRR annual cost, annual benefit, and cash flow diagram are employed for this study. Major economics parameters that were considered are given in Table 3:

3.1. Initial Capital Cost

The initial capital cost is the sum of the turbine system cost and the balance of station cost, which includes a turbine, generator,

Table 2. Domestic appliances energy profile

Appliance	Wattage each in W	Amount	Wattage total in W	Usage Hour per day	Daily power usage in kWh/day
Cooking	2000	1	2000	7	14
Bulb	60	6	360	8	2.88
TV (21")	200	1	200	8	1.6
Radio	20	2	40	12	0.48
Mobile charging	5	5	25	12	0.3
Total			2,625		19.26

Table 3. Manufacturers of Hydro-kinetic turbines [28]

Manufacturer	Type of turbine	Rated Power kW	Rated speed m/s
Ocean Renewable Power Corp.	Horizontal axis	50	3
New Energy Corp.	Vertical axis	5/10/25/125	0.5-2.4
Energy Alliance (Russia)	Cross axis	5	3
Lucid Energy	Gorlov (Helical)	5/10	0.6
Alternative Hydro Solutions Ltd.	Cross axis	2/3	1.25

Table 4. Economic parameters

Metric	Value	Reference
The nominal interest rate in %	9.5	National Bank of Ethiopia [29]
Annual inflation in %	11	National Bank of Ethiopia [29]
Project life in year	25	
Replacement in year	8	

Power electronics devices, foundation, installation, shipping costs. These costs do not include financing fees, because these are calculated and added separately through the fixed charge rate. The costs also do not include a debt service reserves fund, which is assumed to be zero for balance sheet financing. The total initial capital cost required for 5 kW EVG 005H hydro Kinetic Turbine is $22,500 [27].

3.2. Replacement Cost

Replacement cost is a reducing fund factor to cover long-term replacements and repairing of major turbine components, such as blades and generators. The replacement cost is used to calculate the annualized replacement cost and this cost is not meant to account for inflation. For this study the replacement cost for 5 kW EVG 005H taken as equal to the investment cost.

3.3. Operations and Maintenance Cost (O&M Cost)

Operations and Maintenance Cost (O&M) covers the day to day scheduled and unscheduled maintenance and operations cost of cost in-cured running a Hydro-kinetic turbine. Different designs, due to varying complexity, may have different O&M costs. However, many new configurations have insufficient operating experience to extract a meaningful O&M cost history. Hence, for this study the operation and maintenance cost was estimated in such a way that the operation year was divided into 5 groups and we considered the following cost pattern as given in Table 5:

Table 5. O&M cost pattern

Year	O&M cost
1-5	1.5 % of capital cost
6-10	1.5 % of capital cost + 1.5 % of previous O&M
11-15	1.5 % of capital cost + 3 % of previous O & M
16-20	1.5 % of capital cost + 4.5 % of previous O&M
21-25	1.5 % of capital cost + 6 % of previous O&M

Computing the total value of O&M cost based on given O&M cost pattern for 25 years life span of the turbine a total of $1,739.6 is needed, which is equivalent cost of 86.98 $/year.

3.4. Diesel Generator and Battery Economics

Currently resident around Gumara River uses biomass for heating need, and for lighting, local households use kerosene, diesel generator, and solar panel. For this study, only a diesel generator is considered to compare the economic cost with hydro-kinetic turbines. A 2.5kW diesel generator as a backup system is used, the initial capital cost of such generators reaches up to $2500, O&M cost is about 2% of the capital cost, the replacement cost is the same as the initial capital cost of the generator, this generator consumes 0.74 l/hr of fuel. To store the amount of excess electricity produced a 1kWh Lead Acid battery was used in system modelling, which has a capital cost of $300.

4. Result and Discussion

4.1. System Configuration and Modelling

To Study Economics of Hydrokinetic turbine, a stand-alone hybrid system optimization program released by the US National Renewable Energy Lab (NREL) in 2000 HOMER Pro v3.11.65 is used. The program allows for flexible renewable energy hybrid system design using a library of components that can be inserted into the system, including a diverse set of electricity generators, energy storage, and load options [30]. In Homer Pro hydrokinetic is includes as a component system shown in Figure 6, previous feasibility studies conducted by [16] was assuming as wind turbine by replacing the wind turbine power-curve with the HK power curve of the selected hydrokinetic turbine by altering the wind speed information with the river current velocity [31].

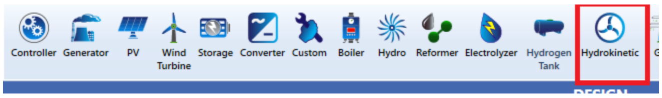


Fig. 6. Component list available in Homer Pro

To study the economics of hydrokinetic turbines a system design was developed in HOMER Pro, the design includes A 5 kW hydrokinetic turbine, a 2.5 kW diesel generator for back up and to store excess electrolytic produced a 1 kWh battery with AC to DC converters used for modelling as shown in Figure 7.

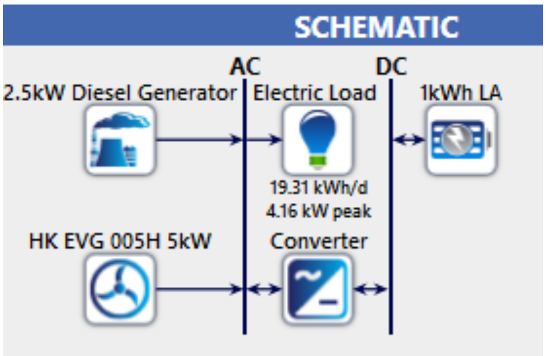
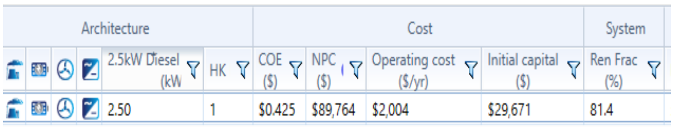


Fig. 7. System Design Used

Homer Pro then simulate a viable system for all possible combinations of the equipment, After 129 feasible system simulation the wining system is shown in Figure 8 with the Net present value of $89,764, initial capital cost requirement of the system is $29,671, the Levelized cost of energy (LCOE) which is $0.425 and 81.4% renewable resource penetration which means only 18.6% of energy will be needed form the diesel generator.



Architecture						Cost				System
				2.5kW Diesel (kW)	HK	COE ($)	NPC ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)
				2.50	1	$0.425	$89,764	$2,004	$29,671	81.4

Fig. 8. Overall results

4.2. Economics of Hydro Kinetic Turbine

Economic constraints that were used in the model are the discount interest rate of 9.5%, an inflation rate of 11% with Project life span of 25 years which are the primary criterion to calculate the present worth of HK project, the IRR and payback period of the system configuration.

Table 6 shows an optimized result for the current base system selected which contain Hydrokinetic turbine with back up diesel generator for this system the present worth is about $4,826, the annual worth of $161, IRR of 17.4% and the payback period of 5.16 years.

Table 6. Economics result of hydrokinetic turbine

Metric	Value
Net Present Value $	89,764
Present worth $	4,826
Annual worth $/year	161
Return of investment %	13
Internal rate of return %	17.4
Simple payback	5.16 years
Discount payback	5.14 year

Figure 9 shows cash flow expenses of the project for 25 years life span as capital, replacement, salvage, operating and fuel cost.

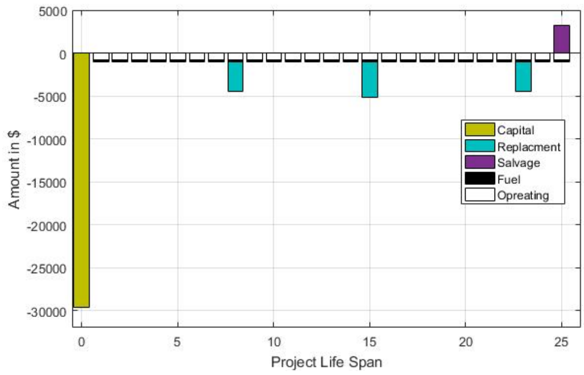


Fig. 9. Cash flow diagram

4.3. Levelized Cost of Electricity (LCOE)

The Levelized cost of electricity (LCOE) is a measure of the cost of a power source which compares different methods of electricity generation on a consistent basis. It is an economic assessment of the average total cost to build and operate a power-generating asset over its lifetime divided by the total energy output of the asset over that lifetime. The LCOE can also be regarded as the average minimum cost at which electricity must be sold in order to break-even over lifetime of the project. From our result, the estimated Levelized cost is about $0.425.

4.4. Monthly Energy Production and Emission

The system configuration uses diesel generator as back up to the HK power generation. Our findings show that from the total of 19,459 kWh/year energy demand 18,146 kWh/year power comes from Hydrokinetic turbine and the remaining 1,313 kWh/year is from 2.5 kW Diesel generator. Hence the majority of the electricity is coming from Hydrokinetic turbine as shown in Figure 10. However, during the dry months from March to April and May the diesel generator cover the majority of the power have required because the river flow rate decreased. Whereas in rainy season 11,884 kWh/year excess electricity is produced, which can be stored in battery and at LCOE $0.425 the excess electricity can be sold to other community.

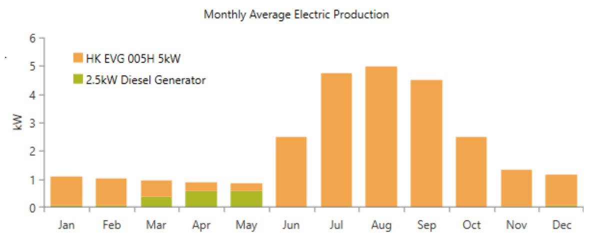


Fig. 10. Monty electricity production

Figure 10 shows that above 80% of electricity comes from renewable energy. This shows that the HK-diesel hybrid energy system will result in carbon emission reduction. Since 18,146 kWh/year energy is produced form HK the equivalent amount of carbon emission reduction by using HKTs was calculated by using 0.4 kg of CO_2 eq/kWh as a factor 7,258.4 kg of CO_2 eq/year (7.258 ton of CO_2 eq/year) can be saved. Hence, applying carbon cap and trading price of $20 per metric ton, a total of $145.16 can be recovered yearly. Through 25 years life of the project, $3629 will be generated from carbon trade, as a result, this carbon trading will significantly lower the LCOE of the system. However, during the dry month the diesel-powered generator covers the energy demand the amount of Carbon product emitted is shown in Table 7.

Table 7. Amount of Emission

Quantity	Value	Unit
Carbon dioxide	2803	kg/yr
Carbon monoxide	21.2	kg/yr
Unburned Hydrocarbons	0.772	kg/yr
Particulate Matter	1.29	kg/yr
Sulfur Dioxide	6.88	kg/yr
Nitrogen Oxides	24.1	kg/yr

4.5. Risk Matrix of Hydro-kinetic Turbine

For the application of Hydro-kinetic turbines, the following risks are identified as; [5, 15, 32]

Risk 1: Lack of policy support and public attitude
Risk 2: Un-expected flood and intermittent flow rate
Risk 3: Infancy of Hydrokinetic technology
Risk 4: Conflict of interest with irrigation
Risk 5: Interest to invest in renewable energy

Then by setting one axis categorizes the risk in terms of qualitative probability (low, medium and high) of occurrence and the other axis identifies the seriousness of impacts of these risks in qualitative terms (low, medium, high) Table 8 shows the risk analysis of hydrokinetic turbines.

Table 8. Risk matrix impact probability analysis

Probability/Impacts	Low	Medium	High
Low	Risk 1		Risk 2
Medium		Risk 3 & 4	
High			Risk 5

Our study showed that the interest of private investors to invest in renewable energy posed a risk of a high probability of impacts. To mitigate the risks the government should follow the energy subsidy policy to render positive externalities. Energy subsidy policy should include favourable loans, tax credits and deductions, and Feed-in Tariffs.

5. Conclusion

The aim of this paper was to study the economics HKTs turbines for rural application to meet the electricity demand of residents. A specific site at Gumara River in the upper Blue Nile with an average water speed of 2 m/s is used, which is suitable for HK application. A HOMER software was used to study economics by using a New Energy EVG 005H 5 kW HK turbine with a 2.5 kW back up diesel generator. According to the study an $89,764 Net present value is calculated. The system worth $161 per year with the simple payback period of 5.16 years. The IRR calculated is 17.4%, usually, if IRR is greater than the inflation rate, which is 11%, it shows that the project is economically feasibility. The LCOE of the HK diesel hybrid system calculated in this study is about $0.425. However, if we account for the amount of carbon emission reduction by applying carbon cap trade approach 145$/year can be recovered. This helps to bring down the LCOE of the system. According to our study, the initial capital cost required is about $29,671, which is unfordable by individual residents. As a result, to examine possible application of HK we recommended the project should be initiated by community level or private sector. Also, to render positive externalities government should affirm an initiation to mitigate the risk posed on HK technologies by developing an energy subsidy policy to promote the private sector. Therefore, HK is a newly emerged Renewable technology which is especially new to Ethiopia market can be considered as a viable option to power rural resident located out of the grid reach.

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