Research Article

Potential of power generation from chicken waste-based biodiesel, economic and environmental analysis: Bangladesh's perspective

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Abstract

This study outlined the potential of biodiesel production from chicken fat waste and electricity generation from biodiesel on the scenario of remote region, Kuakata, located at southeastern Bangladesh based on the cost comparison between diesel and biodiesel-based power generation by HOMER software. The main objective of this case study was to address an integrated simulation-based research outcome to manage chicken skin waste (fat) for biodiesel, generate electricity from the biodiesel and present the potential of greenhouse gas (GHG) reduction from environment by product implementation. Approximate electric load profile of Kuakata and comprehensive emission modeling for this region has been performed by fuel-switching model and RETScreen Expert software. The simulation outcomes presented that 492,695 L/year biodiesel can be produced from chicken skin waste in Kuakata and converted into 883 MWh electricity per annum. The operating cost was 188,062 \$/year, and cost of energy production was 0.214 \$/kWh. The outcomes from this simulation modeling also demonstrated that the annual fuel consumption for base case is 3.7 kWh/m^2 while 1.5 kWh/m^2 is for proposed case with the reduction of 2.2 kWh/m^2 per year. The calculation and simulation results also presented 70.3% GHG reduction in the region which presented drastic drop of environmental pollution.

Keywords Biodiesel · Chicken fat · GHG emission · Homer · RETScreen

Abbreviations

Mt/t	Metric ton/ton
kWh	Kilo watt-hour
MWh	Mega watt-hour
MMBtu	One million British thermal units
Btu	British thermal units
L	Litre
MJ	Mega joule

1 Introduction

The demand of biodiesel is increasing rapidly due to the diminishing petroleum reservation and the environmental consequences of exhaust gases from petroleum fueled engines. Besides, the ever-increasing trend of GHG emission, comprised of CO_2 (77%), CH_4(14%), N_2O (8%) and others, contributed tremendous environmental pollution. This caused alarming situation for living beings. Among GHGs, CO_2 is the most dominant compound [1]. To reduce the pollution, researchers are emphasizing on renewable energy and green fuels such as biodiesel. Biodiesel is extracted from renewable resources consisting of simple alkyl esters of fatty acid. It is expected that, by 2050 the CO_2 emission of whole world will reduce to 25% if biofuel productions are properly estimated and utilized [2]. As Bangladesh is focusing on renewable energy for upcoming decades, biofuel is a best choice besides solar, wind for harnessing energy [3–6]. According to the BPDB report, the percentage of HSD (high-speed diesel) in

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power generation is calculated as 8.5% [7]. This percentage can be increased if diesel is replaced by biodiesel as biodiesel is a carbon neutral fuel. It can be mixed with diesel at 5–20% to reduce GHG emission [8]. If biodiesel is utilized 100% instead of diesel, then it can be considered as one of the best solutions to reduce carbon emission [9]. From the perspective of Bangladesh, the organic raw materials are basically bio-waste which are huge in amount. The bio-wastes are like municipal waste, feedstock, animal fat, non-edible oil, remaining of vegetables that are of no use. According to the quantity assessment (BCAS 1998), the amount of municipal waste is 500 ton per day in 2002 [10]. The projected waste generation is 1500 ton by 2025 [10] which is large in amount for raw materials supply. In case of feedstock, Jatropha (*Jatropha curcas*), Castor (*Ricinus communis*) contain a significant amount of oil, e.g., Jatropha contains around 60% oil, whereas Castor contains 67.7% oil [2]. In Bangladesh, during religious festivals like Eid-ul-Adha, a large number of animals are sacrificed. The fat sources from these animals can be deemed as good raw material for biodiesel production as they are deemed as waste. The above information indicates that biodiesel is a potential source of green energy for Bangladesh in future which may contribute to eliminate mono-dependency on diesel for fuel purpose along with minimization of GHG emission.

Due to the high raw material price and processing cost of biodiesel, it was not affordable for developing countries like Bangladesh. But now chicken fat-based biodiesel is considered as a consumer-friendly fuel as alternative to diesel due to the cheap raw material. As chicken fat is quite available and very cost-effective source for biodiesel [11, 12]. In transportation sector of Bangladesh, biofuel application has been considered as noteworthy initiative nowadays. But for electricity generation, it is not similarly available like transportation sector. Since maximum percentage of GHG comes from power sector of Bangladesh, biodiesel can be added as another renewable energy source that can contribute to reduction of GHG emission [13, 14]. Moreover, different types of plants are being introduced to get a renewable and sustainable fuel. From [6], waste sources, microalgae from drain water was blended with coal for heat generation in Brunei Darussalam. In Malaysia, timber wastes have been implemented commercially to produce heat and electricity along with negligible pollution effect, very high ignition and good length of flammability [15]. Waste sources from oil palm plants and palm oil mill effluent have been applied to produce industrial biofuel and reduce negative impact of global warming in southeast Asia [16]. Another agricultural and forestry wastes, waste banana stem in Asia was utilized to produce liquid fuel, bioethanol and schemed for pilot scale electricity production [17]. In Nigeria, from *Jatropa Carcus* biodiesel is extracted and is compared with conventional diesel. The yield of biodiesel from *J. Carcus* is 57.6% that is increased than before [18]. In Malaysia, spent coffee ground was studied as a potential source of oil feedstock for biodiesel production as an alternative waste utilization instead of being disposed as municipal waste [19]. According to another study of biodiesel production, the tribological features of rice bran oil (RBO)-based biodiesel has been manifested as an agent to improve lubricity. RBOB was successfully generated by the means of transesterification, and the studied fuels were pure biodiesel (RBOB100), 10% (RBOB10), 30% (RBOB30), and 50% (RBOB50) of biodiesel combined with diesel and pure diesel (RBOB0) [20]. Based on some previous research studies, biodiesel from three different fuels such as neem oil, cottonseed feedstock and sesame oil, properties are tabulated, and it is found that the values are very close to diesel fuel [21]. Non-edible feedstock such as *Ceiba pentandra* showed great potential for biodiesel production, especially in the Southeast Asia due to the availability of the feedstock. A techno-economic analysis is performed to ensure its' viability [22]. Basically, some cheap waste biomass can be used to extract biodiesel with a higher yield percentage. Different agro-industrial waste, animal feather or skin, waste oil, tannery waste, etc., are the prime raw materials for biodiesel. Besides different environment friendly and recyclable wastes are being used as catalyst that increase yield percentage of biodiesel. A worldwide scenario of biodiesel production from different types waste biomass is highlighted in Table 1. The literature review presented adequate evidence that biodiesel can be another alternative and sustainable fuel for green energy production.

The main objective of this research is to propose power generation from biodiesel from chicken skin fat, a green energy in Bangladesh. There are few experimental researches have been carried out on biodiesel from animal fat in Bangladesh. However, to the author's best knowledge, no plant or large-scale-based application has not been reported yet so far though every district of Bangladesh contains plenty of wasted chicken skin for green energy generation. To implement the commercial biodiesel generation from this chicken waste, a detailed project design is needed for forecasting the total chicken waste generation, biodiesel output, economic and environmental benefits. Therefore, this study highlighted the feasibility of biodiesel extracted from chicken skin fat in power generation sector focusing on carbon emission reduction as part of environmental positivity. To measure the GHG emission of this project, different simulations and calculations have been used. Hence, chicken waste management, potential of biodiesel generation from it

Table 1 Worldwide biodiesel production yield from different types of waste biomass

Countries	Potential waste biomass candidates for biodiesel	Biodiesel yield (%)	References
Bangladesh	Waste cooking oil	87.50	[11]
China	Spent coffee grounds	16–17	[47]
India	Tannery waste	97.10	[48]
Egypt	Raw sugar beet agro-industrial waste	93.00	[42]
India	Chicken feather meal	62–75	[43]
Morocco	Chicken skin waste	97.50	[44]
Malaysia	Waste soybean oil	71.20	[49]
Malaysia	Waste cooking oil (waste fish & chicken bone as catalyst)	89.50	[45]
Nigeria	Waste frying oil (coconut chaff as catalyst)	91.05	[50]
Malaysia	Waste cooking oil (eggshell as catalyst)	90.00	[46]

Table 2 Leading countries in biofuel production [23]

Country	Production of biofuel (1000 Mt equivalent oil)
USA	35,779
Brazil	18,552
Germany	3198
Argentina	2828
Indonesia	2503
France	2226
China	2053
Netherland	1680
Thailand	1610
Canada	1160

and GHG reduction by biodiesel implementation in Bangladesh with an integrated scheme are the main scope for this simulation study.

2 Overall scenario of bio-energy

Nowadays many regions worldwide are focusing on bio-energy besides other renewable energy sources as it has a great potentiality to meet a fraction of energy demand. In 2016, the leading countries in biofuel production are showcased at Table 2 [23].

Table 2 provides a clear concept that USA is in the leading position while Brazil lagged in that sector during the same period. Due to increasing in GHG emission, the USA has remarkably focused and manipulated throughout this sector. By using renewable resources, the country is trying to decrease the emission rate and they are successful in their attempt. According to the 2017-BP Statistical Review of World Energy, since 2005 USA has declined the Carbon emission 758 million Mt which is by far the largest decline of any country in the world over that time span [24]. Recently, China is leading country for carbon emission compared to other regions of the world which is alarming for China as well as the whole world. This largest carbon emitter occupies alone 28% carbon emission and hence no change in ranking of Climate Change Performance Index (CCPI) 2017 result [25]. Therefore, they are taking multiple steps to reduce this high percentage of emission. Focusing on that perspective, China has emphasized on renewable resources. The National Development and Reform Commission's Medium- and Long-Term Development Plan for Renewable Energy in China" says that in between 2010 and 2020 the it will be the reign of biomass, biomass pellet, biofuel, biogas. Agro and forestry-based power generation will lead and add to a new era in upcoming power demand. Now in 2020 the generation will reach to 24GW [26].

2.1 GHG emission in power sector of Bangladesh

According to Table 3, the scenario states that a huge amount of carbon emission comes from power sector. Among them, Ghorasal, Boropukuria, Ashugonj have a large percentage in carbon emission. The largest electricity generating unit of Bangladesh is Ghorashal having capacity 950 MW, and it is a thermal power plant operated by steam. So, this unit is responsible for the largest emission of GHG. Boropukuria is operated by coal and henceforth, it is sure to emit a large amount of GHG from that power plant. In 2012, around 47.72% carbon emission came from electricity generation. The annual growth is 6.67% in carbon emission from 1991 to 2011 mentioned in [7]. From survey of 2016, CO_2 emission report states that 52.8% carbon emission comes from electricity [27]. So, by the time according to this growth, in electricity generation the percentage of GHG emission will increase smoothly if no initiative for alternative to fossil fuel is taken.

Table 3 17 largest point source of carbon emission in power generation of Bangladesh

No.	Installation name	Annual CO_2 emission (Kilotonnes)
1	Ghorashal	4731
2	Boropukuria	2075
3	Ashugonj	1502
4	HaripurBarj	980
5	Khulna	938
6	Chittagong	914
7	Haripur AES	653
8	ShajiBazar	631
9	Shiddhirganj	631
10	Maghnagat-1	490
11	Golapara	479
12	Maghnagat-2	392
13	Dhaka	327
14	Barisal Unocal	261
15	Haripur	218
16	Fenchuganj	182
17	BaghaBari	181

3 Methods and data collection

Methods and data collection are one of the most crucial factors for this research outcome. In this study, the emission modeling, GHG emission calculation and data of Kuakata were assembled from diverse types of sources. The sources were biofuel, climate experts, online database of Kuakata and reports from Google Map, researcher–experts in biodiesel and diesel, related journal articles, technical datasheets, suppliers and manufacturers, and up-to-date websites for the market price of items included in the project. The power generation of fuel and GHG emission model of the diesel and biodiesel from chicken skin was simulated with HOMER (Beta) and RETScreen Expert (version 6.1.0.27). The GHG emission model was plotted based on the fuel-switching method analysis and calculation to compare practical and theoretical result.

Kuakata, known as daughter of sea of Bangladesh, is situated at Kalapara Upozila, Patuakhali Zilla, Barisal, southeastern Bangladesh. Its longitude and latitude are 21° 49′16″ N and 90° 07′ 11°″ E, respectively [28]. Despite being a visiting site, more than 90% of the dwelling households have no access to electricity. The number of rural dwellers is maximum here, and the source of income mainly depends on fishing [29]. Being an island and detached from national grid, decentralized power generation is earnest necessary for this location. As diesel-based power generation is popular in decentralized power generation, the location has been chosen for biodiesel implemented study compared to diesel. Table 4 has shown the total number of dwellers and institutions [29, 30]. An approximate electric load profile is designed here considering simple load having 20 W energy saving CFL bulb and 40 W ceiling fan. Among the load profiles every community clinic has at least 20 beds for the patients [30]. As the location has not been developed yet, there is still insecurity to a healthy life. Upon considering the electrical load profile, daily energy consumption of the corresponding dwellers = 2.42 MWh (after calculation).

The load calculation per day has been considered in this study, and hence the weather is considered summer on which period, the maximum demand is needed. If the loads are served for 24 h, then 2.4/24 = 100 kW that is the peak demand for Kuakata. Total Data mentioning number of schools, houses, markets and others are showcased in Table 5.

3.1 Chicken fat as potential source of biodiesel in Kuakata

Considering only poultry waste, recent data reveal that total poultry farm in Barisal is 5947 [31] on an average having a small farm can accommodate 200 to 500 fowls, while the numbers reached 2,500 and 3,000 for medium and big farms, respectively, according to BPIA depicted in the report [32]. As Kuakata is in Barisal division, the biodiesel prepared from chicken waste can be easily supplied in Kuakata for electricity purpose. From one chicken, around 100 g skin can be collected which was experienced the experimental result of biodiesel production in Bangladesh [33]. According to a survey conducted at 2017, the annual demand of meat is 6.73 million Mt referred from [30]. Considering the population of Barisal, on an average, it is said that a large number of chickens are sold residentially and for restaurants and different hotels. From chicken waste, using different chemical

Table 4 The total number of dwellers and institutions of Kuakata

Total households	2065
Educational institutions	05
Community clinic	03
Religious institutions	02

Table 5 Approximate electrical load Profile of the dwellers of Kuakata

Households	3 CFL and 2 Ceiling Fan
Educational institutions	4 CFL and 4 Ceiling Fan
Community clinic	10 CFL and 10 Ceiling Fan
Religious institutions	2 CFL and 2 Ceiling Fan

mechanisms, maximum yield percentage can be reached up to 95% based on the research so far [34].

4 Cost comparison between biodiesel and diesel fueled electricity

To analyze the cost of biodiesel and diesel, HOMER software (BETA version) is used here. A 200 KW generator is considered here which is fueled by diesel first. According to some recent research, the input of diesel and biodiesel properties is given here from [7]. Price of diesel is input 63 taka/L [35] [1USD = 82 taka] according to the recent market value.

Then biodiesel-based generation is simulated, and the fuel property is input according to latest research outcome. Based on the animal fat/waste cooking oil-based biodiesel, the price per liter is half of diesel. The price is \$0.37/L that is 31 taka/L [34]. Tables 6 and 7 provide chemical properties and simulation outcome of diesel and biodiesel.

The cost analysis given in Table 8 clarifies the cost-effective property of biodiesel. The above cost analysis report states that net present cost of biodiesel will be two times less than diesel-based power generation and COE for diesel is 35.83 taka whether for biodiesel it is 17.87 taka which is more cost-effective. Here is a point to be noted that the overall cost mainly depends on fuel price. Table 8 describes the overall cost comparison profile between diesel and biodiesel which depicts that considering net present cost and operating cost, biodiesel is much cheaper than diesel. As, animal fat like chicken waste is free of cost, so there is no need to buy it and this is the factor which differentiates between animal fat/waste cooking oil and plant-based biodiesel. For plant-based biodiesel, the price per liter exceeds over \$1–2 which is costly for countries like Bangladesh depicted from [7].

Table 6 Chemical properties of diesel and biodiesel input in HOMER

Chemical properties	Diesel	Biodiesel
Price (\$/L)	0.77	0.37
Lower heating value (MJ/kg)	50	40
Density (kg/m$^{3)}$	873	878
Carbon content	88%	77%
Sulfur content	0.33%	0%

Table 7 Simulation result of diesel and biodiesel input in homer

	Diesel	Biodiesel
Capacity of generator (kW)	200	200
Initial capital (\$)	5000	5000
Operating cost (\$/year)	3,85,140	188,062
Net present cost (\$)	4,928,381	2,409,061
Fuel consumption (L/year)	492,695	492,695

5 Emission model of Kuakata

The section basically discusses about the emission of GHG by fuel-switching model at first. From this modeling, it will be ensured that how much carbon emission reduction will be possible if diesel is replaced by biodiesel annually. At the second phase, percentage of GHG emission reduction will be calculated from GHG emission calculation as well as via RETScreen Expert software.

5.1 Fuel-switching model

Fuel-switching model inter-relates the GHG emission with the movement of fuel prices. It shows that how fuel price can change emission if fuel is switched. Ultimately, the model gives the reduction in emissions as a function of changes in the fuel prices. In Kuakata, if diesel is replaced by biodiesel, how much CO_2 emission will be reduced is shown in this model. Taking the regional fuel-switching model as an input, it looks like this [36]. Equation 1 presents calculation of total emission reduction. Improving the plant's overall electric efficiency, plants with this design can reach efficiencies of over 50%. Usually, the plant efficiency of diesel fueled power plant is around 40–50% [36, 37]. The efficiency is considered 50% to ease the calculation. The equation is given below:

$$\mathrm{ER}(\tau_1,\tau_2) = \Delta\%\ \mathrm{diesel}(\tau_1,\tau_2) \times \mathrm{total\ gen} \times \left(\frac{3.413}{\eta_1} \times f1 - \frac{3.413}{\eta_2} \times f2\right) \tag{1}$$

where ER = Emission Reduction = the changes in each of the fuel prices in \$/MMBtu.

Table 8 Cost comparison of simulation result between diesel and biodiesel

Cost	Diesel	Biodiesel
Initial cost (\$)	5000	5000
Operating cost(\$/year)	3,85,140	1,88,062
Net present cost (\$)	49,28,381	24,09,061
Cost of energy (\$/kWh)	0.437	0.218

f_1, f_2 = emission factor of diesel and biodiesel

η_1, η_2 = efficiency of plant for diesel and biodiesel = 50%

Δ% diesel (τ1, τ2) = percentage change in fuel price for diesel with respect to biodiesel in $/MMBtu

Annual generation of electricity for Kuakata = 2.42*365 = 883 MWh

Regional emissions reductions are calculated by multiplying the regional fuel-switching effect, % diesel, by the total electricity generation in the region to obtain the amount of electricity in MWh that switches from diesel to biodiesel. This amount is then multiplied by the difference in CO_2 emissions per unit of electricity in tCO_2/MWh for biodiesel and diesel, thus subtracting the added emissions due to generating the electricity with biodiesel from the emissions reduction due to removing generation from diesel. Based on this formula, overall calculation parameter is tabulated in Table 9.

After calculation, Δ% diesel = 51.27

The unit conversion from Btu/gallon to Btu/L is basically calculated based on formula of density.

Density = M/V

where M = mass of fuel in kg and V = volume of fuel in L; 1 gallon = 3.79 kg and density of diesel and biodiesel is considered based on [34].

Emission factor of diesel, f_1 = 0.387 Mt/MWh [38]

Emission factor of biodiesel, f_2 = 0.156 Mt/MWh [38]

Annual ER = 51.27*883*(3.413/0.5) (0.387 − 0.156) Mt = 71,400 Mt

From this emission modeling, it is predicted that at a large amount of carbon emission reduction is possible annually if biodiesel is harnessed commercially.

5.1.1 GHG emission reduction calculation

For GHG emission analysis, there are two available methods. The first one is direct emission factor which is permitted by IPCC, and another one is life cycle analysis (LCA) which measures the condition on the whole life cycle and in this sense is a more comprehensive approach. Here, LCA methodology is chosen as direct emission factor only considers the emission directly from power plant which may not be feasible and practical [39]. But in LCA analysis, the calculation of GHG emission is based on production–transportation distribution as the electricity basically depends on their efficiency and energy mix [39]. According to LCA emission factor for

Biodiesel = 0.156 tCO_2/MWh [38]

Total GHG Emission for electricity usage [39] = [Emission Factor(t/MWh) × Electricity used (MWh)] Mt

According to report from IPCC, for Bangladesh, the emission factor for electricity [40] = 0.637 tCO_2/MWh

Considering all type of fuels for whole country,

GHG Emission = (0.637 × 2.42) = 1.54 Mt

For Biodiesel, GHG Emission = (0.156 × 2.42) = 0.378 Mt

GHG emission reduction = (1.54 − 0.378)/1.54 × 100 = 75.45%

The simulation result by RETScreen provides the GHG emission information in Table 10. Table 10 showcases that how biodiesel can be alternative green fuel in fuel consumption, fuel cost and GHG emission reduction purpose. Moreover, the emission reduction is calculated considering transmission and distribution loss for Bangladesh in power sector showcased in Table 11.

The simulation of GHG emission for biodiesel shows the practical analysis considering all parameters based on updated database from NASA and different websites. For residential purpose, average standard area of a single tiny house is 46 m^2 [41]. Annual fuel consumption for base case is 3.7 kWh/m^2, and for proposed case it is 1.5 kWh/m^2 and fuel is saved annually 2.2 kWh/m^2. Upon this consideration, it is shown in Table 10 and hence, the reduction shows 70%. So, the GHG emission calculation and

Table 9 Calculation parameters for emission modeling

Parameters	Diesel	Chicken fat-based biodiesel
Higher calorific value (Btu/L)	30,206	29,358
Price of fuel ($/L)	0.76	0.36
Price of heat rate($/MMBtu)	25.16	12.26

Table 10 Summary of GHG emission in biodiesel consumption

	Fuel consumption (kWh)	Fuel cost (BDT)	GHG emission ($tCO_2/m^{2)}$
Base case	25,564	38,289	7.9
Proposed case	6718	4751	2.4
Savings (amount)	18,845	33,538	5.6
Savings (%)	73.7%	87.6%	70.3%

Table 11 Emission analysis compared to base case and proposed case

Fuel type	Biodiesel
GHG emission factor	0.156 kg CO_2/kWh
Transmission and distribution loss	11.2%
Base case (tCO_2)	3.6
Proposed case (tCO_2)	1.1
Gross annual GHG emission reduction (tCO_2)	2.6
GHG emission reduction (%)	70

simulation result are close enough which clarifies that the emission reduces around 70% for Kuakata.

6 Case outcomes, discussion and limitations

The study basically focused on GHG emission reduction and cost of biodiesel compared to diesel in electricity generation. The fundamental case outcomes are mentioned here:

- Biodiesel prepared from animal fat/waste cooking oil is cost-effective enough rather than other plant-based feedstock for biodiesel in Bangladesh scenario.
- The power generation from that biodiesel can fulfill the demand of small remote region where there is no electricity access like coastal areas or islands.
- Fuel switching model predicts that at an average annually around 70,000 Mt carbon emission can be reduced if diesel is switched by biodiesel commercially.
- Calculation of GHG emission analysis reports that around 75% emission reduction can be possible for Kuakata if biodiesel is used as fuel, and simulation report from RETScreen also predicts it reduces GHG emission about 70%.
- The cost of energy can be reduced if biodiesel is produced from animal fat/waste cooking oil with cheaper cost. The simulation also presents that COE of diesel is 35.83 Tk where for biodiesel it is 17 Tk which is half of diesel-based COE.
- The limitation of this study is that the key parameters and calculation of GHG emission are gathered from the literature review. This study simulated the collected data for biodiesel production from chicken skin fat based on the specific region of Bangladesh, biodiesel conversion to electricity and economic and environmental point of views. This study did not perform the experimental research analysis for this biodiesel production and conversion into electricity. Another shortcoming of this study is that the efficiency of plant for diesel and biodiesel was assumed (η_1 and η_2 are 50%) based on the literature, while the efficiency of plan may vary. Changes in the efficiency rate may influence the overall cost investment and total amount of GHG emission. Since this is not an experimental-based work but simulation-based study, the formulae were collected from previous experimental research studies and technical reports. Design outcome is our main concern for this perspective since no experimental study has been performed on this region yet though the area contains abundant raw material for biodiesel generation. We believe these design outcomes will be pioneer for research concern by govt. and non-govt. organizations of Bangladesh in coming future.

6.1 Validation scenario

For this study, two simulation software applications are used based on practical data. The data are collected from different latest research outcomes like prices of diesel and biodiesel, density of the fuels, lower calorific value, carbon and sulfur content, emission factor of diesel and biodiesel in respect of Bangladesh, etc. [8, 9, 11, 21, 27]. In HOMER, for determining COE of diesel and biodiesel, different chemical properties and prices are collected from previous experimental research studies from reports, technical data and research articles discussed on [8, 11, 12, 18, 20, 21]. As chicken skin fat is a daily-basis waste in Bangladesh and free of cost to collect, biodiesel derived from chicken waste has been considered as nearly half of cost of diesel based on the current scenario of market price in Bangladesh [11, 12]. The simulation outcome also provides that result in all type of costs including net operating cost, present cost and others based on the inputs provided and the inputs were collected from current fuel market [35]. Moreover, biodiesel yield is a great concern for simulation of overall fuel amount and economical perspective. Experimental yield percentage varies from 80 to 90% if proper reaction time, catalyst, reaction methods are used. In this study, transesterification method is considered for extraction of biodiesel from chicken skin fat and reaction time is considered 8–9 h which is the best period to extract maximum fuel from chicken skin fat [12, 42, 43]. Moreover, KOH, $Ca(OH)_2$, fish and chicken bone, eggshell, etc., are applied as catalysts to increase the yield percentage and can be achieved up to 95% [8, 12, 33, 34, 42–46]. As all materials implied in this experiment are available, home-made, free of cost, the price of biodiesel per liter is much less than diesel [12]. Besides, initial cost is considered $5000, as it is a small-scale project for remote region in Bangladesh.

Another software RETScreen Expert is applied to compare the GHG emission reduction between simulation and calculation both. In this simulation, the location and weather of Kuakata are collected from NASA. Here, load profile is drafted based on population of Kuakata, total houses of this location, number of different educational and religious institutions. The data are collected from population census of Patuakhali and another research article focused on Kuakata [28–30]. Moreover, GHG emission factor for biodiesel is determined from different reports like German Watch, Eco-Region, Econometrica and others [38–40]. Also, in this software, for more justification, the emission is calculated considering one more parameter that is per unit area of house. The data are collected from previous research outcome also. To consider transmission and distribution loss in electricity for Bangladesh, the data (11.2% loss) are collected from Bangladesh Power Development Board [7]. Based on the information, the software provides its outcome. To evaluate the simulation result, calculation methodology of GHG emission from San Padro Waterfront Project has been applied [39]. The result also resembles the simulation output. Hence, around 70% GHG emission can be reduced and cost of energy (COE) for biodiesel is $0.214 that is almost half compared to diesel ($0.436). So, the simulations outlined that this study can always be environment-friendly, economic and sustainable energy strategic model.

Based on the explanation in above, all the key inputs to design this project has been gathered from realistic and authenticate data sources, research articles and technical reports. The amount of raw materials for biodiesel production has been collected from target location, Kuakata. The market price of diesel as well as other input has been collected from market price of Bangladesh. Thus, the project was designed through commercial software. Therefore, the aim of this study was to outline the overall process into commercial design for future implementation by government/non-government organizations. Moreover, for an educational/research institution, it was difficult to manage funding for pilot/large-scale implementation which is one of the major drawbacks of this simulation-based research.

7 Conclusion

For standby support in power plants and decentralized power generation for remote areas, diesel-based generator is the best choice in Bangladesh. However, having high carbon content and being a costly fuel, diesel can hardly meet consumers' demand. Therefore, biodiesel is the best alternative for diesel which can fulfill the consumers' demand besides being cost-effective and environmentally benign. As a result, this study provides an analytical report suggesting two merits of biodiesel: reasonable cost and GHG emission reduction which is far better than diesel economically and environmentally. Hence, this study concluded that if biodiesel can be produced and implemented commercially, diesel would be replaced or mixed with biodiesel for energy purpose and a fraction of energy demand can be fulfilled through a sustainable energy source.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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