Vol-2, Issue-3 PP. 621-628 ISSN: 2394-5788

GLOBAL JOURNAL OF ADVANCED RESEARCH
(Scholarly Peer Review Publishing System)

ECONOMICAL ANALYSIS OF THE IMPLEMENTATION OF A MICRO GAS TURBINE POWERED BY BIOGAS: A CASE STUDY.

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Abstract

In this paper the potential of biogas generation is evaluated through cow manure. The feasibility of implementing the digester is shown using biogas as substitute fuel (LP Gas) and obtain carbon credits. It require a minimum of 200 head of cattle to implement a microturbine system with 30kW power (ISO). Power is evaluated through a simulation with local conditions and it is obtained 21.26 kW. A cogeneration system with efficiency of 45.6% is evaluated. The use of natural gas and biogas produced is compared, showing a difference of 10.5 and 1 year at the time of payback for biogas. 8 different cases were analyzed; with primary and secondary benefits like is electric power production, process heat, carbon credits and sale or consumption of biofertilizer ($15.4x10^{-03}$ USD/kg).

Keyword: Biogas as substitute fuel

1. INTRODUCTION

The demand for electric power production and use the others energetic to heating and air-conditioning are sources of high consumption in agricultural zones of any country. These services are essential to the operation of any kind of activity. In the agricultural sector large amounts of organic waste is generated, which in many cases represent a health problem and the accumulation of waste. All organic wastes undergo a process of decomposition, which can be from a few days to a few months; it depends on the type of organic substance. In the case of cow manure, this process can take up to a year. A pollutant gas is produced by the decomposition the cow manure, and is primarily a mixture of carbon dioxide (CO_2) and methane (CH_4); in a proportion of 40% vol. to 60% vol., respectively. To this mixture of gases are known as biogas, it contains a heating value below LP Gas or natural gas, but it can replace any energy source with some restrictions. This work presents the estimation of potential biogas generation to minimum scale at a farm located in the town of Teoloyucan, Mexico State, Mexico, it has 50 cows but plans to acquire more in a short-time and implement a system for generating and biogas recuperation; and potential use of biogas is to generate electricity [1] and heat for any use. Primary and secondary benefits of the use of biogas are analyzed, initially as an energy use, and after profitably sale or biofertilizer consumption and carbon credits.

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Amortization analysis with different esenarios and biogas utilization are presented; also it estimates cost of building of a low technology biodigester, the acquisition and installation of equipment for power generation [2], and recuperator for heating water, the analiysis is based on estimates and reports the National Commission for Energy Savings[1] (Cogeneration Technology, CONAE)[3].

For amortization analysis (Economic evaluation of the cogeneration study, CONAE) [4, 5], a discount rate of 7.5% and an inflation rate of 4.5% obtained through information of Banxico bank [6] was used.

2. METHODS

The total cost of construction of low technology biodigester was estimated at 28,038 USD ($364,500 pesos), this considered around 8 kg of manure per 100kg body weight [11], thus an average cow produces 32 kg/day. From the above data is corresponding the biodigester would process 6,400 kg daily. For an initial evaluation, it was considered that the biogas replaced the 100% LP Gas; also the production for different utilization scenarios of biogas are presented, It is trough to the sale or replacement of biogas to $38.2x10^{-02}$ USD/L (4.96 $/L) and the decrements prices at $15.4x10^{-03}$ USD ($0.2) (see Figure 1). Subsequently, the use of biogas to price of LP Gas with decreases at $15.4x10^{-03}$ USD ($0.2) was estimated; with the trade of carbon credits at 11 USD per ton of CO_2 [7], the profits made by selling or consumption of biofertilizer (solid/liquid mixture) to $15.4x10^{-03}$ USD/kg (0.2 $/kg) are shown at Figures 2 and 3. The production of biogas per day was estimated conservatively at 35.3 L/kg of manure [8], which is equivalent to a production of 226 m^3 biogas/day. An equivalent conversion substitute fuel with a factor of 0.88 (liters of LP Gas/m^3 biogas) is considered, obtaining a production of LP Gas equivalent 60,637 L/year; with a gain or savings of 23,135 USD/year @ $38.2x10^{-02}$ USD/L ($ 300,759 per year @ $ 4.96 / L). The energy provided by the biogas generated for a year is 3.018 TJ; it was taken into account to estimate CO_2 emissions reduced by burning or replacement of fossil fuel, with a emission factor of 0.147 Mg CO_2eq/GJ [9]; obtaining an annual reduction of 4.44x10-4 Tg CO_2eq with a subvention at 4,880 USD per year (13.0 Mexican Pesos/USD). The benefit of biofertilizer for consumption or sale the income is of 34,638 USD/year ($450,300 per year). The amount of biofertilizer is obtained through a mass balance. For amortization evaluations a depreciation is considered at cost of operation and maintenance (OM) of 7,692 USD/year ($100,000/year) and a cost extra 1,538 USD ($ 20,000) for major maintenance concept every 5 years.

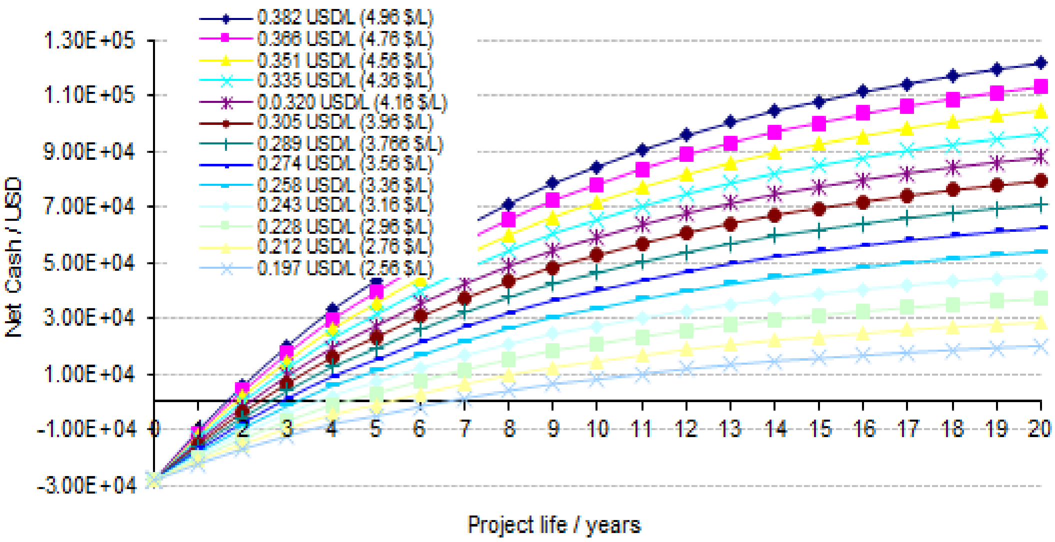

Figure 1. Amortization of biodigester with a maximum price of biogas consumption or sale of $38.2x10^{-02}$ ($4.96) per liter of LP Gas substituted, without regard to carbon credits or sale of biofertilizer.

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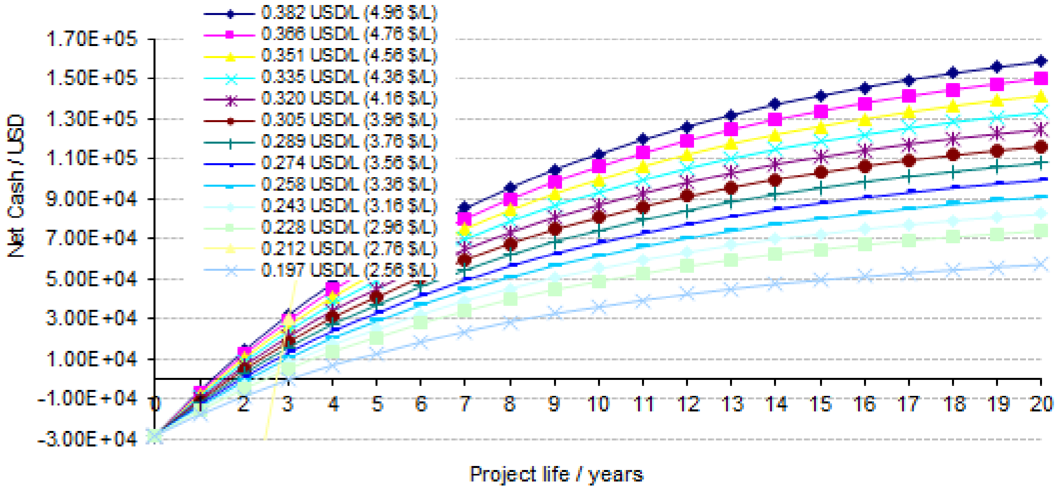

Figure 2. Amortization of biodigester with a maximum price of biogas consumption or sale of 38.2x10^{-02} USD ($4.96) per liter of LP Gas substituted, it considered the carbon credits but not the sale of biofertilizer

3.1. Analysis with Biogas

In the analysis the model C30 for microturbine of Biogas is considered, using the following values for simulation: with the calculated biogas density 1.0235 kg/m^3 (ideal gas), Compression ratio of 5.1, atmospheric pressure of the location of 77.54 kPa, average ambient temperature of 25° C, η_c=92%, η_t=93%, η_{cc} =100%, η_g=98%, 60% relative humidity and a Capacity factor of 0.8. The simulation results compared with the technical data are shown in the Figure 4. The results of this case are the following: simulated power 21.26 kW, mass flow rate of fuel (biogas) 2.3x10^{-3}kg/s, outlet temperature of the turbine of 313° C, η_{bryton}=21.5%. Thus with these results it was observed that the generation of biogas produced with 200 head of cattle is sufficient to generate electricity with the microturbine and even have a surplus of biogas (2.68 x10^{-03} kg/s - 2.3 x10^{-03} kg/s). For purposes of calculating power generation is considered a constant production. Total energy consumption is considered from the electricity produced. It is consumed on the farm or is delivered and sold to the electrical network of the Federal Electricity Commission (CFE), thus allows the analysis of a range of costs per kWh saved or sold to the electrical network (Distributed Generation, CONAE) [10]. In the analysis the use of natural gas and biogas in the microturbine was evaluated.

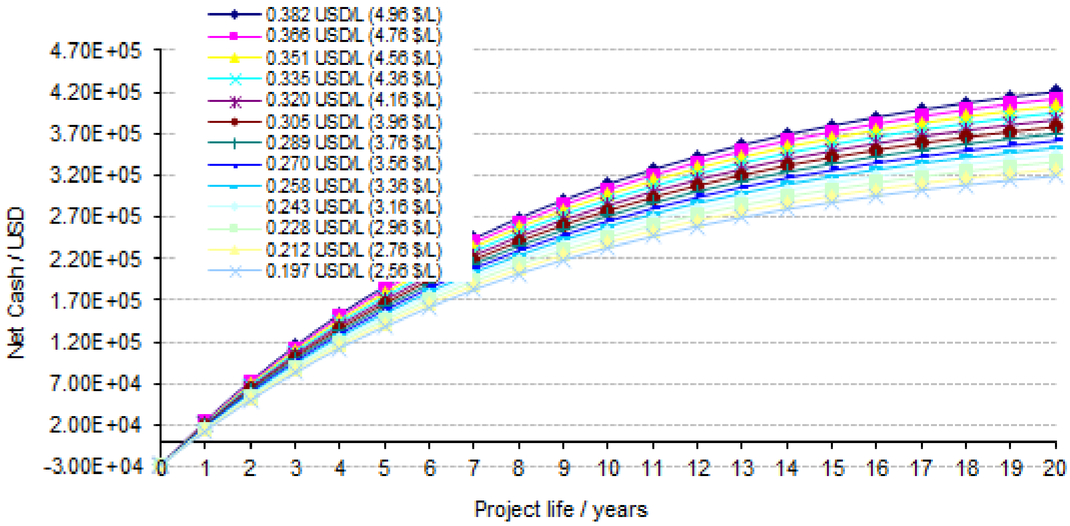

Figura 3. Amortization of biodigester with a maximum price of biogas consumption or sale of 38.2x10^{-02} USD ($4.96) per liter of LP Gas substituted, it considered the carbon credits and sale of biofertilizer.

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With Natural Gas as fuel the electricity cost was $12.2x10^{-02}$ USD/kWh ($1.58/kWh) and annual fuel cost was 25,496 USD ($331,443). The cost of the higher tariff of CFE [11] billed by the farm was $25.9x10^{-02}$ USD/kWh ($3.374/kWh), while the minimum tariff was $21.6x10^{-02}$ USD/kWh ($2.804/kWh). With it, amortization analysis was performed. The maximum cost of electricity was considered of $25.9x10^{-02}$ USD/kWh ($3.374/kWh); payback period (PBP) was of the 13 years with a cost of 38,462 USD ($500,000) investment (See Figures 5 and 7). As first case, which presents the cost of electricity generation with biogas, it appeared that this would be 0 USD/kWh for fuel and amortization occurs in capital cost of the equipment used: biodigester, gas microturbine and accessories, with an estimated total investment cost of 66,785 USD ($868,200); and considered a cost of 6,438 USD/year ($83,700/year) by OM and a cost 14,131 USD ($183,700) every 5 years due to major maintenance activity that can provide the same owner and an employee of the farm; with these data is estimated a PBP of 2.5 years.

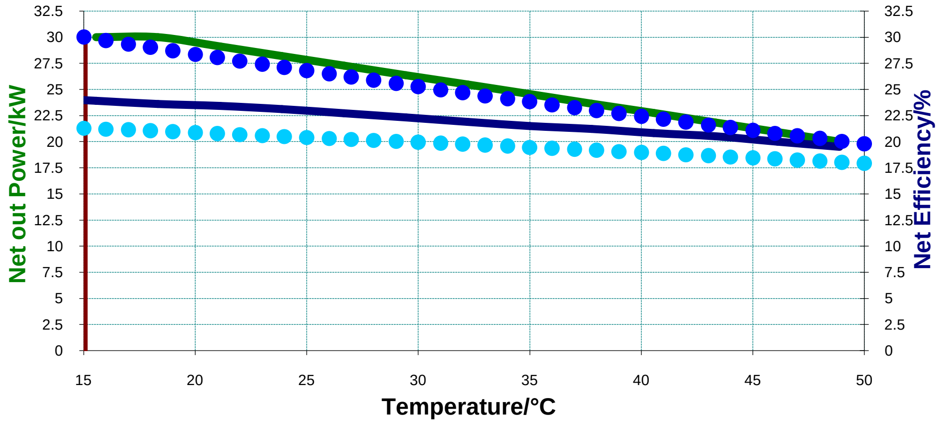

Figure 4. Simulation data vs technical data. The solid lines correspond to the data obtained from the technical data sheet. The dotted lines correspond to the data obtained by the simulation. (Efficiency + 2%).

3.2. Electric Power and Hot Water

The same system is evaluated for electric power and hot water for air-conditioning, with a cogeneration efficiency of 45.6%; obtained through Natural Gas and comparing the profitability by use biogas, so that a global evaluation of the digester with a system of micro cogeneration and heating water is presented. Amortization is estimated by decreasing the cost of energy gradually to detect the extent to which a cogeneration Natural Gas system can be profitable (See Figure 6), it consider a PBP no more than 8 years, which indicates that the cost of electricity it would be $21.6x10^{-02}$ USD/kWh ($2.8/kWh) to make this project feasible, and with the cost of fuel no increase. In this analysis, 8 different cases are proposed to show the advantages of using biogas as a substitute energy and secondary benefits (see Table 1), for these analyzes the cost of electricity to replace was considered all the time at $25.9x10^{-02}$ USD/kWh (38,592 USD/year) [3.37$/kWh (501,700$/año)]. The results for the amortization by the cases proposed are shown in Figure 7, It show that the sale of biofertilizer is widely beneficial to this project, PBP decreasing to almost half the time of that the project represents. For benefits associated with varying power kWh with a cost $15.4x10^{-02}$ USD (0.2 pesos) with decrements successive and considering the benefits provided in case 8 (Figure 8), with a PBP between 1 and 1.8 years, this is mainly because there is a support economic offered by the sale or consumption of biofertilizer.

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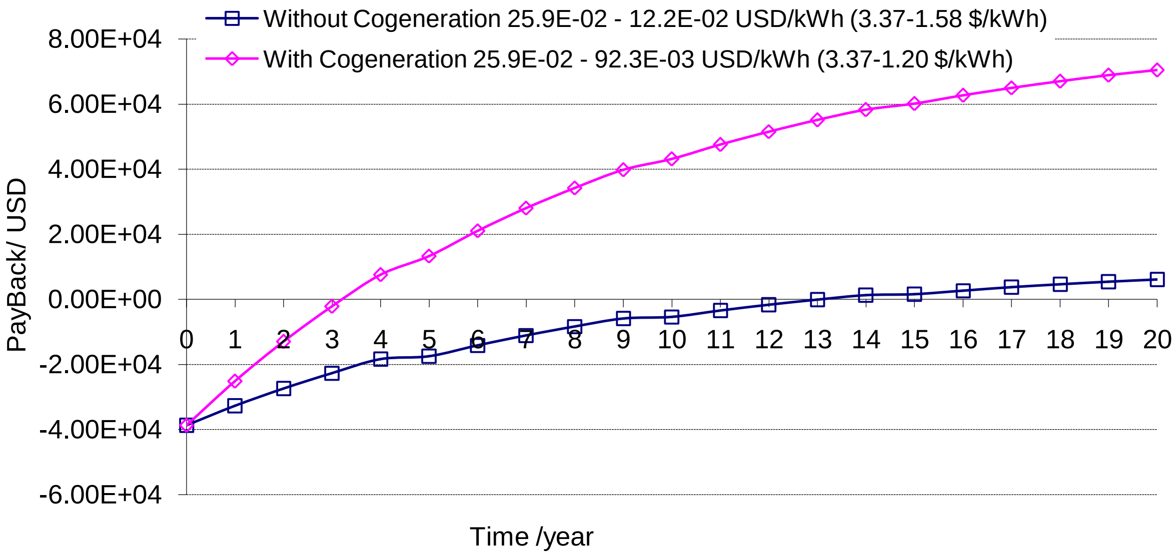

Figure 5. Comparison of the amortization using microgeneration system with Natural Gas, considering a total consumption (Electric Power and heat).

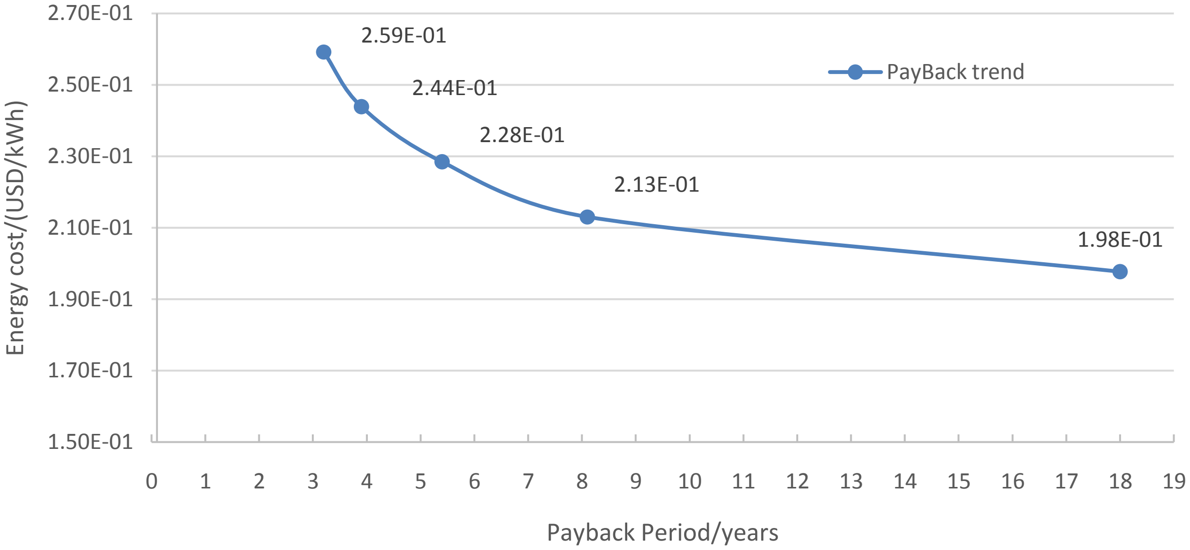

Figure 6. Trend of profitability to implement a system for generating electric power using a cogeneration microturbine Gas, kWh cost and its relation with fuel.

Table 1. Cases studied for calculation of amortization with biogas as fuel.

Item	Cases								Savings or Benefits	
	1	2	3	4	5	6	7	8	$/year	USD/year
Electric Power	x	x	x	x	X	x	x	x	501,699	38,592
Hot Water		x		x			x	x	110,598	8,508
Carbon credits			x	x		x		x	63,450	4,881
Biofertilizer					X	x	x	x	450,320	34,640

Also the benefit of power generation and heat to varying is analyzed with decreases of $15.4x10^{-03}$ USD/kWh (0.2$/kWh) cost of electric power (Figure 9).

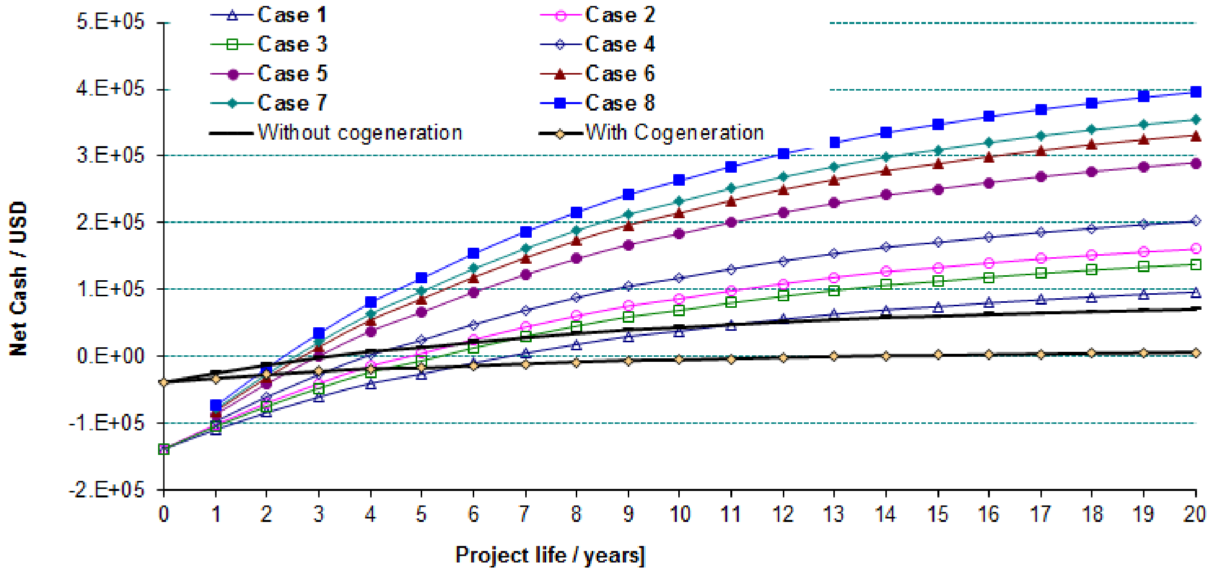

Figure 7. Analysis of amortization for each of the cases.

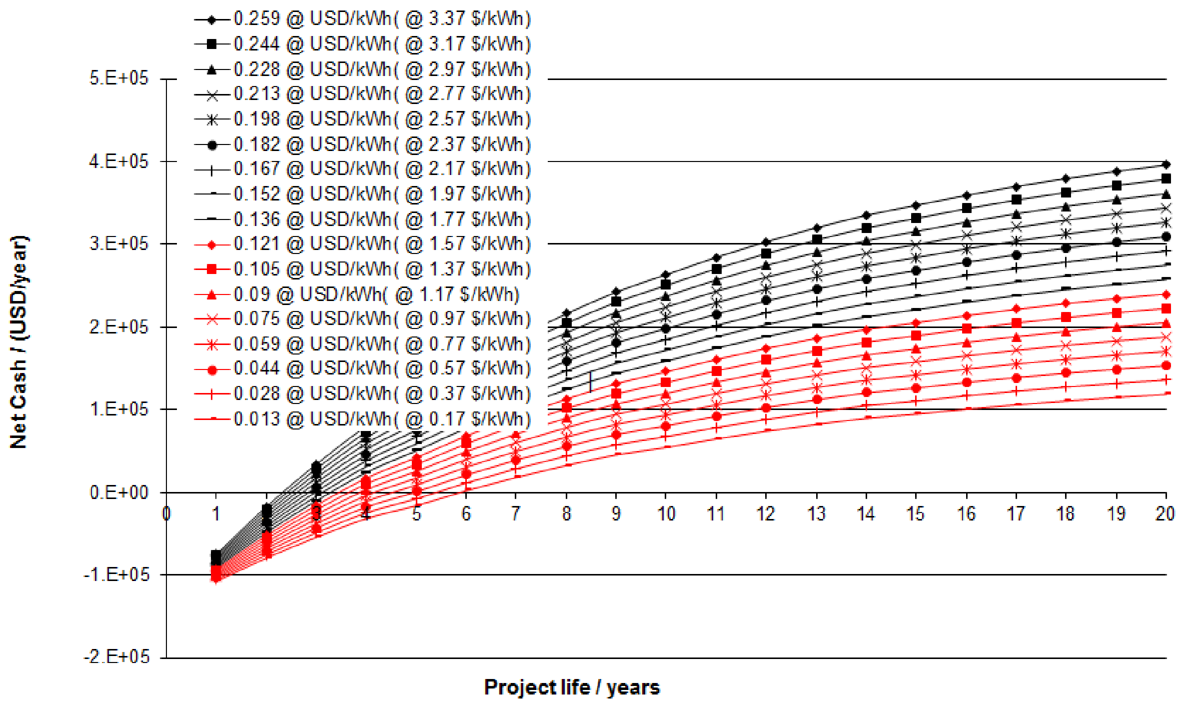

Figure 8. Economic Benefits varying the cost of kWh by sale or consumption of biofertilizer, cogeneration and carbon credits (Case 8).

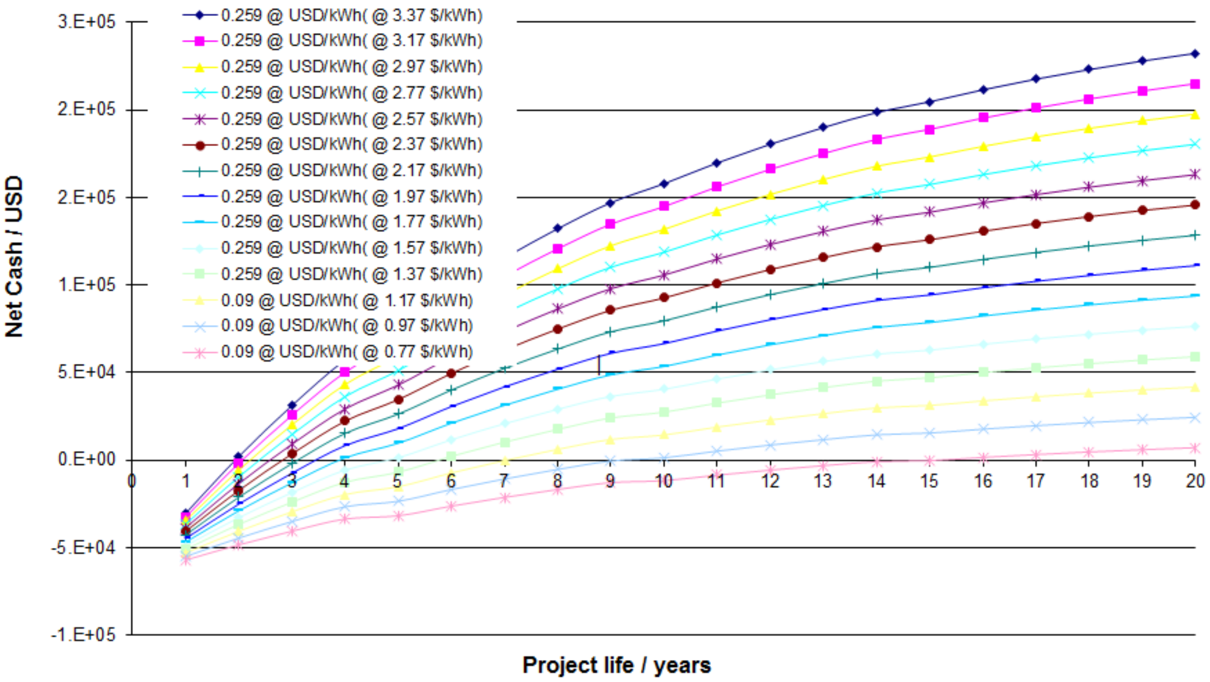

Figure 9. Economic Benefits varying the cost of kWh by electric power and hot water (Case 2).

3. CONCLUSIONS

The feasibility of installing a biodigester and a gas microturbine to use the biogas produced is shown. Similarly, it is possible that another project of this nature can be adapted to this methodology although it considers other variables, and each them shows substantial advantages and benefits. In summary, it is very beneficial to take advantage by capturing the biogas produced and use it as energetic replacement from the LP Gas or Natural Gas.

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