Financial and Economic Analyses of Biogas-to-Energy Projects in Brazil

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1. INTRODUCTION

The Alegria Wastewater Treatment Plant is one of the largest wastewater treatment plants (WWTPs) in Brazil. It is owned by the Companhia Estadual de Aguas e Esgotos (CEDAE), the state agency that manages and treats most of the sewage water in Rio.

Sewage at the WWTP is treated through several different processes, including sedimentation tanks and anaerobic reactors. A byproduct of sewage treatment via anaerobic digestion is biogas. After it is processed to required standards of purity, biogas becomes a renewable fuel for electricity generation or a substitute for natural gas. Currently, Alegria WWTP flares the biogas produced in the anaerobic reactors. In doing so, the WWTP is incurring operational costs and wasting a valuable source of energy. However, looking into the future, Alegria WWTP intends to use the energy stored in the biogas to generate electricity or natural gas.

1.A. PURPOSE OF STUDY

This study aimed to analyze what is the best use of the WWTP's biogas from both the financial and economic perspectives. A discounted cash flow (DCF) analysis was used to compare the net befits of a biogas-to-electricity project (Green Electricity Project) and a biogas-to-renewable natural gas project (Renewable Natural Gas Project). The DCF method provides an objective basis for evaluating and selecting investment projects because both the magnitude and timing of expected cash flows in each period of a project's life are incorporated into the analysis.

The two project alternatives were compared based on net present value (NPV) calculated from both the financial (private) and economic (social) perspectives. The financial analysis consisted in comparing revenue and expenses recorded by the concerned economic agents in each project alternative and in working out the corresponding financial return ratios. The economic analysis, however, aimed at identifying and comparing economic and social benefits accruing to the Brazilian economy as a whole.

1.B. METHODS EMPLOYED

The methods used in this study included on-site data collection, literature review and interviews with industry specialists. On-site data collection included gathering technical information about the biogas purification system, such as its components and efficiency, and generators. Literature review was performed for information on Brazilian macro-economic indicators and commodity prices. Lastly, interviews with industry specialists were conducted to collect information on equipment and operation and maintenance costs for both biogas-to-energy projects.

Results from the study showed that both projects have high and positive NPV. However, the RNG project generated larger benefits for both the private investor and the economy as a whole. With regards to the environmental benefits, the emissions reductions obtained through the implementation of an RNG project were also higher than for a green electricity project.

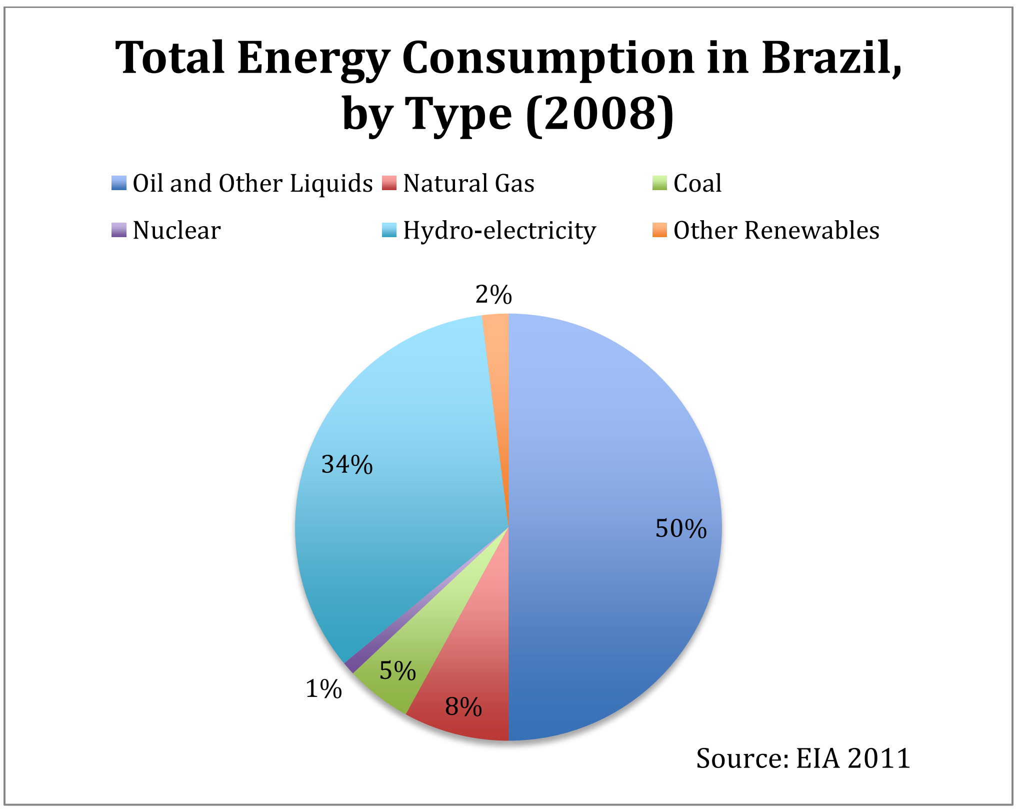
The following sections provide in depth analyses of the methods used to evaluate the biogas-to-energy project alternatives. However, before evaluating Alegria WWTP's alternatives, some background on the current energy-use scenario in Brazil is presented to understand the urgent need for more renewable energy projects in Brazil.

2. ENERGY USE IN BRAZIL AND ENERGY-RELATED CO_2 EMISSIONS

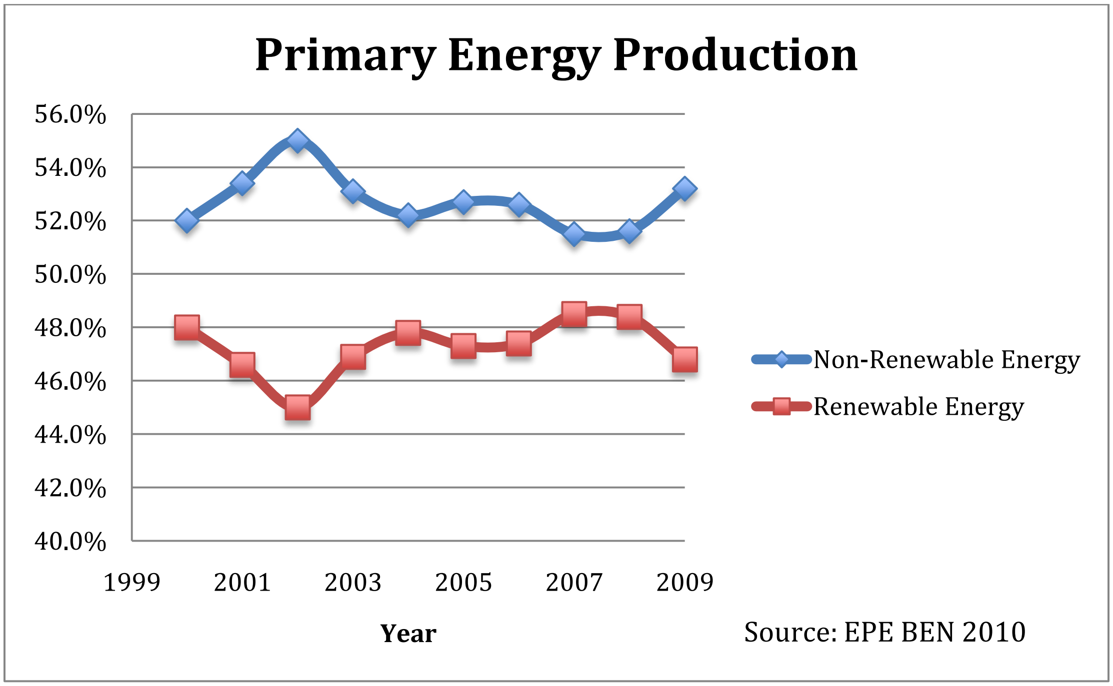
According to the United States Energy Information Administration (EIA), Brazil is the ninth largest energy consumer in the world and the third largest in the Western Hemisphere, behind the United States and Canada. Total primary energy consumption in Brazil has increased by almost a third over the last decade, due, in part, to sustained economic growth (EIA, 2011).

Brazil has also significantly increased its total domestic energy production, particularly in oil and ethanol production. Recent discoveries of large offshore, pre-salt oil deposits could transform Brazil into one of the largest oil producers in the world.

The largest share of Brazil's total energy consumption comes from oil and other liquids (including ethanol), followed by hydroelectricity and natural gas (EIA, 2011).

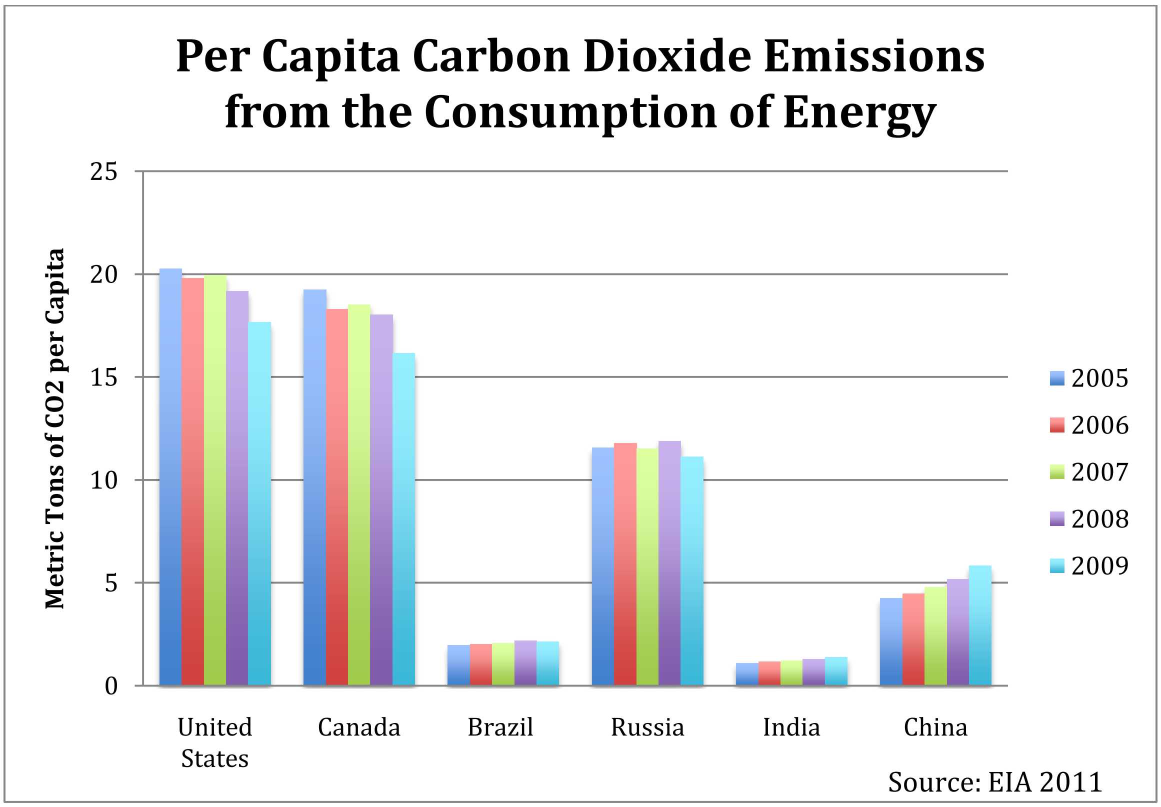


Although Brazil's main source of energy for consumption is fossil fuel based, there has been significant investment in renewable energy production. The types of renewable energy produced in Brazil include: hydroelectric, woody biomass (particularly firewood), sugarcane derivatives (i.e. ethanol and biomass), and other renewables (i.e. wind and biodiesel). As shown in the graph below, renewable energy production has increased about 3% between 2002 and 2008. The non-renewable energy sources shown in the graph below include: petroleum, natural gas, steam coal, metallurgical coal, and uranium (U308).



The reduction in renewable energy production between 2008 and 2009 is mainly due to a reduction in energy from firewood (2.2% reduction), hydroelectric power (0.5% reduction), and ethanol (0.2% reduction). The 2% increase in non-renewable energy is from an increase in crude and shale oil production. The cause of this increase was the start of operation of four production units. Furthermore, three other operating units had their production rates increased (EPE BEN, 2010). However, it can be seen that the general trend shows an increase in renewable energy production and a decrease in non-renewable energy production.

The development of the Brazilian economy has had a significant impact on energy-related carbon dioxide (CO_2) emissions. According to the EIA, Brazil's energy-related CO_2 emissions has increased from 377 million metric tons in 2006 to 420 million metric tons in 2009. This represents an 11% increase in energy-related CO2 emissions. As can be seen in the graph below, per–capita energy-related CO2 emissions have also increased about 9% between 2005 and 2009 (EIA, 2011). China's and India's per-capita emissions have increased by 37% and 27%, respectively. The US and Canada have reduced their per-capita emissions by 13% and 16%, respectively.



Options to decrease energy-related per-capita CO_2 emissions in Brazil include increasing the amount of renewable energy that is produced and consumed in the country. Electricity generated from renewable sources such as biogas provides benefits from displacing electricity generated from non-renewable sources. Renewable natural gas (RNG) is another source of clean fuel that can displace fossil fuel derived natural gas, gasoline or diesel. When RNG is used in place of these fuels to power motor vehicles, it produces major reductions in CO_2 emissions. Developing a biogas-to-energy project for the Alegria WWTP will thus provide high environmental benefits by reducing overall CO_2 emissions.

3. ALEGRIA WASTEWATER TREATMENT PLANT

The Alegria WWTP serves about 1.5 million people and treats up to 57 million gallons per day (MGD) of municipal wastewater. Sewage at the WWTP is treated through several different processes, including sedimentation tanks and anaerobic reactors. These processes can be seen in Figure 1 below.

Figure 1. Alegria WWTP

A byproduct of sewage treatment is an activated sludge that is then treated in anaerobic reactors. The decomposition of sludge in the anaerobic reactor produces a biogas that is composed of mainly carbon dioxide (CO_2) and methane (CH_4). By law, WWTPs are not allowed to vent this biogas into the atmosphere because of its high greenhouse gas content. As a result, WWTPs flare the biogas as this process transforms most of the CH_4 into CO_2. This in turn reduces the 100-year Global Warming Potential by a factor of 24 and makes WWTPs in compliance with environmental regulations.

Several wastewater treatment plants in the United States have begun to use the biogas produced in the anaerobic reactors to generate electricity or renewable natural gas. Some examples of WWTPs that generate electricity include the Columbia Boulevard Wastewater Treatment Plant in Oregon and the Essex Junction Wastewater Treatment Facility in Vermont. At the Columbia Boulevard plant, about half of the biogas is consumed by two 850 kilowatt internal combustion generators which can create about 1.7 megawatts of electricity combined (River Network, 2010). The Essex Junction WWT Facility uses methane from anaerobic reactors to fuel two 30-kW micro-turbines (Northeast CHP Application Center, 2011). The city of Escondido in California has partnered with Southern California Gas and Co. to develop a renewable energy project that will purify wastewater biogas so that is meets state standards for natural gas delivered to homes and businesses (The City of Escondido, 2011).

Technologies used to generate electricity and RNG from biogas have become more robust, and the costs associated with these technologies have decreased. As a result, generation of electricity or RNG at Alegria WWTP has become a cost-efficient alternative for the treatment of biogas at the WWTP.

4. BIOGAS-TO-ENERGY PROJECT ALTERNATIVES

In this section, a detailed description of the processes involved in the biogas-to-electricity project and biogas-to-RNG project is provided.

4.A. GREEN ELECTRICITY PROJECT

The green electricity project includes purifying about 8,000 cubic meter per day (m^3/ day) of biogas to serve as fuel for a generation plant with a capacity of 252 kW. The green electricity would be sold to the grid at a price that is determined by renewable electricity auction–market prices. A process flow diagram for the green electricity project can be seen in Figure 2 below.

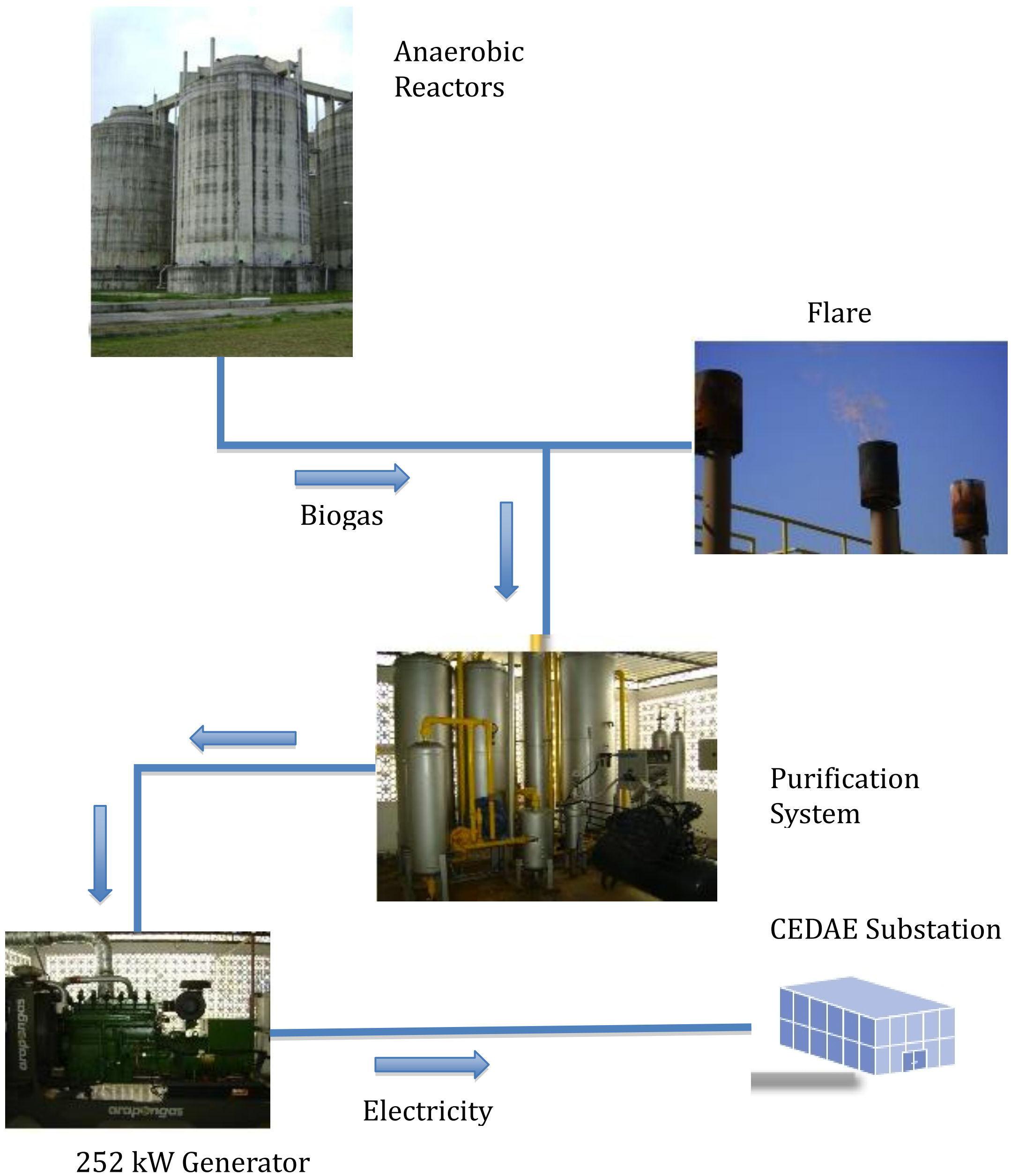


Figure 2. Green Electricity Process Flow Diagram

Mechanical Systems

The first step in green electricity generation includes passing the biogas through a purification system.   This purification system can be seen in Figure 3 below.

Figure 3. Biogas Purification System

For electricity generation, the biogas only goes through steps 1 and 2. Step 1 includes passing the biogas through filters that remove hydrogen sulfide (H_2S). Step 2 includes removing water in the biogas before it is sent to the generator. The rest of the purification system can be used for RNG generation. This system can purify the gas to have 75% methane (CH_4) for electricity generation or up to 97% CH_4 for RNG generation.

As the biogas is purified to 75% CH_4, it is then sent to the generator. The generator chosen for this project is a P250 HE model, manufactured by FG Wilson with a Scania DSI 11 motor and is shown in Figure 4 below. The motor was originally a diesel motor but it was reconfigured by Arapongas in order to run on biogas that has an average composition of 75% CH_4 and 25% CO_2.

Figure 4. Arapongas Generator

Several generator tests were performed to determine the efficiency of the generation unit. It was concluded that the generator was 25% efficient when fueled with a biogas with an average composition of 75% CH_4 and 25% CO_2. This efficiency is expected for a generator that runs on biogas because of the impurities that exist in this type of gas. The generator efficiency curve can be seen in Figure 5 below.

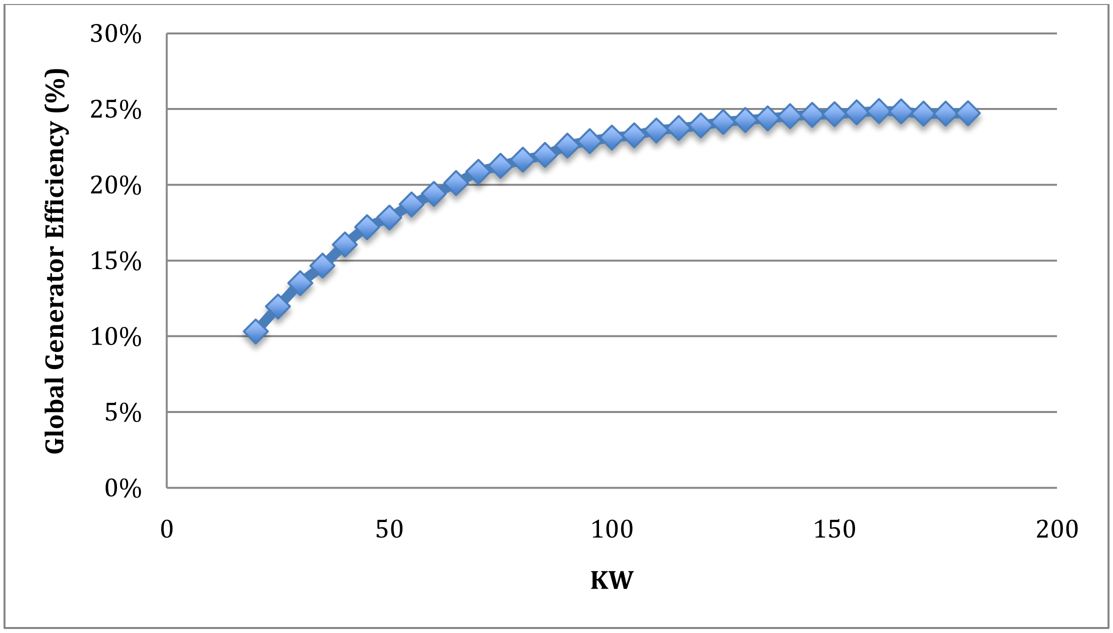


Figure 5. Arapongas Generator Efficiency Curve

Given the amount of biogas that can be produced in the anaerobic reactors and the efficiencies of the generator and purification system, it was determined that the maximum electricity that could be generated at the WWTP was 252 KW.

4.B. RNG PROJECT

The RNG project includes a purification system capable of purifying about 8,000 m^3/ day of biogas as well as compressors with capacity to compress 3,500 m^3 of RNG per day. The RNG would be sold to a natural gas (NG) distributor at the wholesale price of compressed natural gas who would then transport the compressed RNG to a local gas station via trucks with high-pressure cylinders. A process flow diagram for the RNG project can be seen in Figure 6 below.

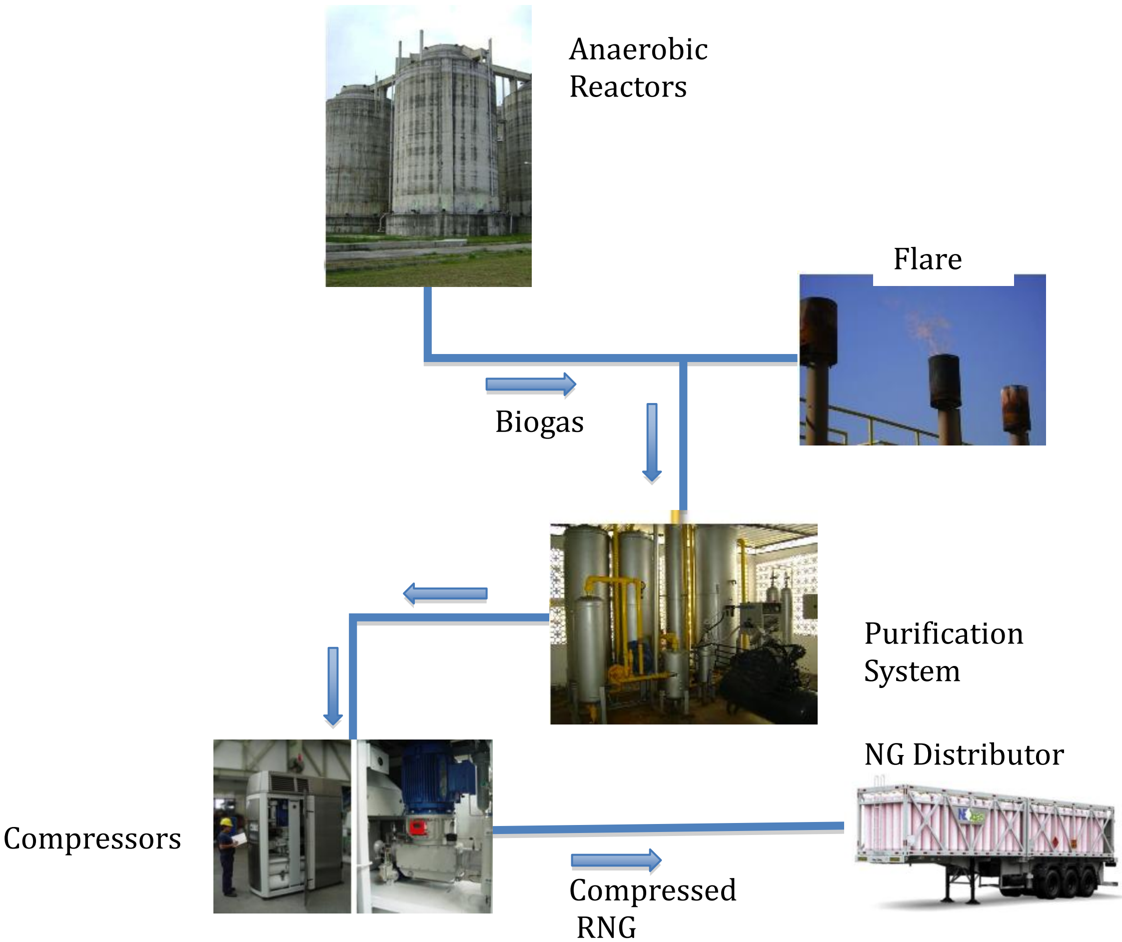


Figure 6. RNG Project Process Flow Diagram

Mechanical Systems

The first step in RNG generation includes passing the biogas through a purification system. This purification system is the same system as the one that is used in the green electricity project.

For RNG generation, the biogas passes through all the stages of the biogas purification system (stages 1 through 6 as shown in Figure 3). Stage 1 includes passing the biogas through filters that remove hydrogen sulfide (H_2S). Stage 2 is a drying tower that removes moisture in the biogas. In stage 3, about 30% of CO_2 is removed as well as the residual H_2S. Stage 4 includes compressing the biogas to a pressure of about ten atmospheres (atm). Because this process creates moisture, stage 5 includes passing the biogas through a compressed-air drying system that removes residual moisture from this process. Before entering stage 6, the pressure of the biogas is reduced to six atm. In stage 6, the biogas passes through a pressure swing adsorption (PSA) filter, where CO_2 and residual moisture are removed. At the end of the purification system, the purified biogas has a concentration of about 97% CH_4 and 3% CO_2.

As the biogas is purified to 97% CH_4, it is then sent to the natural gas compressor. The compressor chosen for this project is a 115-1M-SCA model, manufactured by Aspro (see Figure 7). Two SCA compressors will be purchased for this project in order to have a back-up compressor.

Figure 7. Aspro Compressor

5. FINANCIAL AND ECONOMIC PERSPECTIVES

For a project to be economically viable, it must be financially sustainable, as well as economically efficient. If a project is not financially sustainable, economic benefits will not be realized. Hence, when trying to evaluate project alternatives, it is very important that the analysis be performed from both the financial and economic perspectives.

In this analysis, financial and economic DCFs were constructed to evaluate ten-year biogas-to-energy projects. Financial DCFs were used to determine if the wealth of the private sector increases by the implementation of a biogas-to-energy project. In financial accounting, costs and benefits are allocated so that there is some matching in time. The matching of revenues with expenditures is important because the purpose of the income measure is to determine the change in the value of assets or stocks.

Economic DCFs, however, were constructed to assess the overall impact of the project on improving the economic welfare of Brazilian citizens. This analysis uses shadow prices (willingness to pay and willingness to accept compensation) rather than prices actually paid or received. The economic analysis differed from the financial analysis in that costs related to taxes and environmental and operational licenses were not included. This is because costs related to taxes and licenses represent a redistribution of benefits from the private investor to the government. A different discount rate was also used in the economic analysis since the opportunity cost of obtaining income for the Brazilian economy is different than that of the Alegria WWTP.

6. BIOGAS-TO-ENERGY PROJECT GENERAL ASSUMPTIONS

In this section, general information on the biogas-to-energy project model assumptions are provided. These include macro-economic assumptions and project specific assumptions.

6.A. MACRO-ECONOMIC ASSUMPTIONS

In this section, the macro-economic assumptions made in the financial and economic analysis are described. Assumptions were made because the models included analyses for ten-year projects.

Inflation

Currently Brazil has an inflation-targeting regime that targets the inflation rate at 5%. Figure 8 below shows inflation rates for four developing economies, including Brazil, which were presented by the International Monetary Fund in the 2010 World Economic Outlook (WEO, 2010). As can be seen in the graph, inflation in Brazil was very high in 2002 but then stabilized around 5% in the following years.

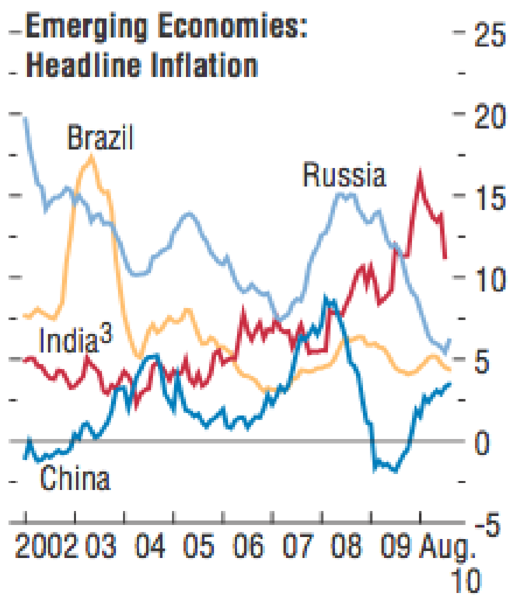


Figure 8. IMF WEO Inflation Rates for Emerging Economies

The Brazilian Central Bank (Central Bank) also releases inflation projections per quarter. Table 1 below presents the Central Bank's inflation projection as of September 2010 (Central Bank Inflation Report, 2010).

Table 1. Inflation Projection & Actual Inflation as of September 2010
(Source: Brazilian Central Bank Inflation Report)

Period	Projected Scenario (%)	Actual Scenario (%)	Average Actual (%)
2010QIII	4.7	4.7	4.9
2010QIV	5.0	5.0	
2011QI	4.4	4.5	4.6
2011QII	4.4	4.4	
2011QIII	4.7	4.7	
2011QIV	4.6	4.6	
2012QI	4.7	4.6	4.4
2012QII	4.4	4.3	
2012QIII	4.4	4.3	

For this analysis, the average actual inflation rate per annum was used for the first three years of both projects and the steady state inflationary expectation rate of 5% was used for the remainder of the analysis.

Growth of Real and Nominal Wages

The Economist Intelligence Unit releases information on the Brazilian workforce via a monthly country report. The report includes several economic indicators, including the average real growth of wages between 2002 and 2010 and a forecast out to 2015. Based on the forecast of average growth of real wages of 1.8% and on the steady state inflationary expectation rate of 5% presented in a previous section, the growth rate of nominal wages assumed for this analysis is approximately 7%.

Discount Rate

The private discount rate used in the green electricity financial analysis is the weighted average cost of capital (WACC) for the Brazilian electricity distribution market. According to the report "Brazilian Electric Power Market and the Cost of Capital of Electric Power Companies," the WACC for the distribution of electricity is between 11% and 13% (Catapan, 2007). A 12% nominal discount rate is thus used for the financial analysis of the green electricity project.

The private discount rate used in the RNG financial analysis is 15% based on conversations with companies in the natural gas distribution industry.

The social discount rate used in the green electricity and RNG economic analyses is the 3-month London Interbank Offered Rate (LIBOR) rate adjusted for inflation. Currently the Brazilian Real three months LIBOR rate stands at 8.62% (Trading Economics: Brazilian Real LIBOR Rate). This rate represents the opportunity cost for the Brazilian economy.

Taxes

Relevant taxes to both the green electricity and RNG projects include: (i) PIS- Programa de Integração Social (Contribution to the Social Integration Program); (ii) COFINS- Contribuição para o Financiamento da Seguridade Social (Contribution Social Security Financing); (iii) CSLL- Contribuição Social Sobre o Lucro Liquido (Social Contribution on Net Corporate Profits); (iv) IR-Imposto de Renda (Corporate Income Tax); and (v) ICMS- Imposto sobre Circulação de Mercadorias e Prestação de Servicos (Taxes on Goods and Services). PIS, COFINS, CSLL and IR are profit taxes while ICMS is a value-added tax.

Taxes are charged based on assumed net corporate profits. For the green electricity and the RNG project, it is assumed that corporate net profits are 32%. Based on the activity level and the assumed profit rate, the following tax rates are used for calculating IR and CSLL.

Table 2. IR and CSLL Rates (Source: Consultor Fiscal website)

Activity Level	Assumed Profit Rate	IR	CSLL
Resale of fuels derived from oil, ethanol and natural gas	1.60%	0.24%	12%
Merchandise sale-Hospital Services-Real Estate Activities-Rural Activities	8%	1.20%	12%
Transportation Services	16%	2.40%	12%
General Services	***32%***	***4.80%***	***12%***

PIS and Cofins are charged at 0.65% and 3.0%, respectively (Secretariat of the Federal Revenue of Brazil, 2011). ICMS is a state tax charged on value of merchandise and services sold. Table 3 below provides a summary of the taxes based on selling green electricity and RNG.

Table 3. Summary of Taxes for RNG and Green Electricity Projects

Tax	Rate used in Analyses (%)	Jurisdiction
PIS	0.65	Union
COFINS	3.0	Union
CSLL	12	Union
IR	4.8	Union
ICMS	12	State

6.B. GREEN ELECTRICITY PROJECT ASSUMPTIONS

In this section, the assumptions made in both the financial and economic analysis of the green electricity project are described. Assumptions were made because the models included analyses for ten-year projects.

Operation

The operation of the plant pertains to how many hours the generation unit will be producing electricity per year. For this analysis, it is assumed that the generation unit will generate electricity 24 hours a day during 90% of the time every year. Hence, the generator will operate for 24 hours a day during 329 days per year. The 10% down-time is assumed for maintenance and repairs.   During the 10% down-time, no electricity will be produced and all of the biogas will be flared. No storage of biogas will be required, as all the biogas will be instantaneously used to generate electricity.

Quantities

As mentioned in the previous section, the generator is assumed to generate electricity for 24 hours a day during approximately 329 days a year. This results in about 7896 hours per year of electricity generation.

Given the efficiencies of the purification system (90%) and the generator (25%), a flow rate of about 300 cubic meter per hour (m^3/h) of raw biogas is required on average in order to generate 147 m^3/h of purified biogas. This results in about 3,500 m^3 per day (m^3 /d) of purified biogas. The power output of the electricity generation plant is about 252 KW based on a flow of 147 m^3/h.

Electricity is also consumed during the purification process. Although not much, approximately 6 kW of electricity are consumed during the biogas purification process.

The generator requires maintenance based on the number of operating hours in a year. The total number of changes of parts and pieces of the generator is calculated based on information received from Arapongas.

Depreciation

Depreciation was calculated for the both the generator and the purification system. The straight-line method with an 8.9% depreciation rate for the generator and 10% for the purification system was chosen for the financial and economic analysis. These rates are calculated by the Bureau of Economic Analysis (BEA) Methodology for the depreciation of engines and turbines and fabricated metal products. The BEA methodology is presented in Hulten and Wykoff's article, "The Measurement of Economic Depreciation."

6.C. RNG PROJECT ASSUMPTIONS

In this section, the assumptions made in both the financial and economic analysis of the RNG project are described. Assumptions were made because the models included analyses for ten-year projects.

The operation of the plant pertains to how many days the purification system and the compressor will be online. For this analysis, it is assumed that the systems will be generating compressed renewable natural gas 90% of the time every year. The 10% down-time is assumed for maintenance and repairs.

The SCA will compress the RNG and will discharge the compressed RNG into high-pressure cylinders that can be trucked off site. Figure 9 and 10 below shows how the high-pressure cylinders will be charged and how it will be trucked off site to be sold to a local gas station.

Figure 9. Charging Cylinders with RNG

Figure 10. RNG Distribution Truck

Quantities

As mentioned in the previous section, the compressor is assumed to generate RNG 90% of the time per year (~329 days per year). Given that the compressor will compress RNG on average 3.5 hours a day, there will be approximately 1150 hours of RNG generation per year. In general, 3.5 hours is the maximum amount of time it should take to fill a NG distribution tuck because taking more time will increase the distribution company's cost of capital.

Given a purification system efficiency of 90% and a compressor efficiency of 90%, about 8000 m^3/day of biogas have to be purified and compressed in order to fill a 3200 m^3 RNG distributor truck in approximately three and a half hours. The SCA will compress the RNG at a flow of about 100 m^3/h and will discharge the compressed RNG into high-pressure cylinders that can be trucked off site.

Electricity is consumed during the purification and compression process. The compressor requires maintenance based on the amount of gas it compresses.

Depreciation

Depreciation was calculated for the compressors, electrical ducts and transformer, and the purification system. The straight-line method with the following depreciation rates was chosen for the financial and economic analysis: 8.9% for the compressor, 9.5% for electrical ducts and transformer, and 10% for the purification system. These rates are calculated by the Bureau of Economic Analysis (BEA) Methodology for the depreciation of engines and turbines and fabricated metal products. The BEA methodology is presented in Hulten and Wykoff's article, "The Measurement of Economic Depreciation."

7. FINANCIAL ANALYSIS

In this section, the costs and revenues related to the green electricity and RNG projects are described.

7.A. GREEN ELECTRICITY PROJECT

Capital Expenditures (CAPEX)

Capital expenditures include the initial investments on the biogas purification system, the generator and operating and environmental licenses. The investments in the generator and purification system are RS170,000 and R$110,000, respectively. The operating and environmental licenses cost about R$50,000. These investments are done in 2010, which is year 0 of the project.

Operational Expenditures (OPEX)

Operational expenditures include: (i) operator wages; (ii) generator maintenance; (iii) maintenance of biogas purification system; (iv) electricity purchased from grid; and (v) taxes paid on revenues from selling green electricity.

Costs related to operator wages are calculated based on the assumption that only one employee is required to operate the biogas-to-energy plant. The employee will ensure that the systems are operating well and will be on site for eight hours a day. This operator is also responsible for responding to any emergencies that could happen after hours. The operator will not perform maintenance on the generator as this will be performed by specialized mechanics from Arapongas. A third party will also perform maintenance of the purification system.

The operator will be paid monthly and will receive an end-of-the-year bonus. The bonus is typically equal to a monthly paycheck. The operator wage and bonus are tax-inclusive in both the financial and economic analysis since it is assumed that the operator is otherwise employed. Operator wages are assumed to grow at the rate of growth of real wages.

Generator maintenance costs are calculated based on the number of required repairs and their costs, as provided by the generator manufacturer Arapongas. Generator maintenance costs are assumed to grow at the rate of inflation.

The maintenance costs associated with the purification system are calculated based on the number of filter changes per year and its cost. Purification system maintenance costs are also assumed to grow at the rate of inflation.

Costs related to the purchase of electricity from the grid will vary throughout the years of the project since these costs are dependent on an electricity price distribution model.   The model was developed by using electricity futures contract prices determined in the Brazilian electricity auction. The price of electricity supply from the grid is tax inclusive.

Taxes paid on the green electricity that is sold in the electricity auction include: PIS, COFINS, CSLL, IR, and ICMS.

A summary of the green electricity total costs can be seen in Table 4 below. As can be seen, this project has a present value of total costs of about $991,000 at a 12% discount rate.

TABLE 4. GREEN ELECTRICITY FINANCIAL COST ANALYSIS											
	0	1	2	3	4	5	6	7	8	9	10
Capital Costs (CAPEX)											
Investment (R$/year)											
Generator	170,000										
Purification System	110,000										
Licenses	50,000										
Total CAPEX (R$/year)	330,000										
Operating Costs (OPEX)											
Operator Wages (R$/year)		19,500	20,724	22,152	23,679	25,310	27,054	28,918	30,910	33,040	35,317
Generator Maintenance (R$/year)											
Total oil & lube		10,643	11,112	11,667	12,251	12,863	13,506	14,182	14,891	15,635	16,417
Total spark plug		6,623	6,914	7,260	7,623	8,004	8,404	8,824	9,265	9,729	10,215
Total filter change		5,814	6,070	6,374	6,692	7,027	7,378	7,747	8,135	8,542	8,969
Total liquid change		1,603	1,674	1,757	1,845	1,937	2,034	2,136	2,243	2,355	2,473
Total air filter maintenance		1,971	2,058	2,161	2,269	2,382	2,501	2,626	2,758	2,895	3,040
Total air filter change		2,260	2,360	2,477	2,601	2,731	2,868	3,011	3,162	3,320	3,486
Total valve adjustment		3,942	4,115	4,321	4,537	4,764	5,002	5,252	5,515	5,791	6,080
Purification System Maint. (R$/year)		20,000	20,880	21,924	23,020	24,171	25,380	26,649	27,981	29,380	30,849
Grid Electricity (R$/year)		5,365	5,732	4,393	3,691	2,988	3,249	2,570	2,570	2,570	2,570
Profit Taxes Green Electricity Sold @ Auction (R$/yr)		9,088	9,488	9,963	10,461	10,984	11,533	12,110	12,715	13,351	14,589
Value-Added Taxes Green Elec. Sold @ Auction (R$/yr)		11,444	11,947	12,545	13,172	13,831	14,522	15,248	16,011	16,811	18,370
Total OPEX (R$/year)		98,253	103,074	106,994	111,840	116,992	123,432	129,274	136,156	143,419	152,374
Total Costs (R$/year)	330,000	98,253	103,074	106,994	111,840	116,992	123,432	129,274	136,156	143,419	152,374
Discount Rate	1.00	0.89	0.80	0.71	0.64	0.57	0.51	0.45	0.40	0.36	0.32
PV (@12%)	330,000	87,726	82,170	76,156	71,076	66,385	62,535	58,477	54,991	51,718	49,060
Sum PV of Total Costs	990,295										

Based on the cost schedule presented above and a discount rate of 12%, the average costs of producing green electricity were calculated. The average costs were calculated by dividing the present value of total operational expenditures per year by total kilowatts of electricity generated that year.

TABLE 5. PRESENT VALUE OF GREEN ELECTRICITY AVERAGE COST											
	0	1	2	3	4	5	6	7	8	9	10
PV of Avg. Cost (R$/kWh)		0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02

Financial Profit Analysis

The price at which electricity could be sold today in the Brazilian regulated electricity auction is R$0.15/kWh. This represents the maximum price paid for green electricity in 2010. Throughout the life of the project, the price at which electricity can be sold in in an electricity auction will increase with inflation.

An average annualized price of R$0.05/kWh for green electricity was also calculated by dividing the sum of the present value of total costs by the total production of electricity in ten years. This price is equivalent to the internal rate of return as it is the real price that will set the NPV equal to zero.

The net income for the green electricity project was calculated using the two different prices. Table 6 below presents the sum of the present value of net income for revenues obtained from selling green electricity in the Brazilian electricity auction. Table 7 presents the sum of the present value of net income for revenues obtained from selling green electricity at the average annualized price. As can be seen in Table 7, the present value of net income is equal to zero when green electricity is sold at the average annualized price.

TABLE 6. NET INCOME FOR GREEN ELECTRICITY SOLD AT ELECTRICITY AUCTION PRICE (FINANCIAL)											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Revenues (R$)	(330,000.00)	298,015	311,128	326,684	343,018	360,169	378,178	397,087	416,941	437,788	478,378
Cost (R$)		98,253	103,074	106,994	111,840	116,992	123,432	129,274	136,156	143,419	152,374
Net Income (R$)	(330,000.00)	199,762	208,054	219,690	231,178	243,177	254,745	267,813	280,786	294,369	326,003
Discount Rate	1.00	0.89	0.80	0.71	0.64	0.57	0.51	0.45	0.40	0.36	0.32
PV (@12%)	(330,000.00)	178,359	165,859	156,371	146,918	137,985	129,062	121,145	113,405	106,152	104,964
Sum PV of Net Income (R$)	1,030,220										

TABLE 7. NET INCOME FOR GREEN ELECTRICITY SOLD AT AVERAGE ANNUALIZED PRICE											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Revenues (R$)	(330,000.00)	99,030	99,030	99,030	99,030	99,030	99,030	99,030	99,030	99,030	99,030
Cost (R$)		87,726	82,170	76,156	71,076	66,385	62,535	58,477	54,991	51,718	49,060
Net Income (R$)	(330,000.00)	11,303	16,859	22,873	27,953	32,645	36,495	40,553	44,039	47,311	49,969
Discount Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PV (@12%)	(330,000.00)	11,303	16,859	22,873	27,953	32,645	36,495	40,553	44,039	47,311	49,969
Sum PV of Net Income (R$)	0										

7.B. RNG PROJECT

Capital Expenditures (CAPEX)

Capital expenditures include the initial investments on one biogas purification system, two natural gas compressors, electrical ducts and electric transformer, and licenses. Two compressors are required in order to have one back-up compressor. The investments in the compressors and purification system are R$ 679,000 and R$400,000, respectively. The investment on the electrical ducts and transformer is R$75,000. The operating and environmental licenses cost about R$50,000. These investments are done in 2010, which is year 0 of the project.

Operational Expenditures (OPEX)

Operational expenditures include: (i) operator wages; (ii) compressor maintenance; (iii) maintenance of biogas purification system; (iv) electricity purchased from grid; and (v) taxes paid on revenues from selling RNG.

Costs related to operator wages are calculated based on the assumption that only one employee is required to operate the biogas-to-energy plant. The employee will ensure that the systems are operating well and will be on site for eight hours a day. During five hours of the day, the operator will be operating the purification system and the NG compressor. During the rest of the workday, the operator will be in charge of any other miscellaneous duties that need to be done in the plant. This operator is also responsible for responding to any emergencies that could happen after hours. The operator will not perform maintenance on the compressor as this will be performed by specialized mechanics from Aspro. A third party will also perform maintenance of the purification system.

The operator will be paid monthly and will receive an end-of-the-year bonus. The operator wage and bonus are tax-inclusive in both the financial and economic analysis since it is assumed that the operator is otherwise employed. The bonus is typically equal to a monthly paycheck. Operator wages are assumed to grow at the rate of growth of real wages.

Aspro, the compressor manufacturer, provides service at a maintenance cost of R$0.40/$m^3$. Compressor maintenance costs are assumed to grow at the rate of inflation.

The maintenance costs associated with the purification system are calculated based on the number of filter changes per year and its cost. Purification system maintenance costs are also assumed to grow at the rate of inflation.

Costs related to the purchase of electricity from the grid will vary throughout the years of the project since these costs are dependent on an electricity price distribution model. The model was developed by using electricity futures contract prices determined in the Brazilian electricity auction. The price of electricity supply from the grid is tax inclusive.

Taxes paid on the RNG that is sold to the NG distributor include: PIS, COFINS, CSLL, IR, and ICMS.

A summary of the RNG project's total costs can be seen in Table 8 below. As can be seen, this project has a present value of total costs of about $2,633,000 at a 15% discount rate.

TABLE 8. RNG FINANCIAL COST ANALYSIS											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Capital Costs (CAPEX)											
Investment (R$/year)											
Compressors	679,000										
Electrical ducts, electric transformer	75,000										
Purification System	400,000										
Licenses	50,000										
Total CAPEX (R$/year)	1,204,000										
Operating Costs (OPEX)											
Operator Wages (R$/year)		15,600	16,580	17,722	18,943	20,248	21,643	23,134	24,728	26,432	28,253
Compressor Maintenance (R$/year)		45,990	48,014	50,414	52,935	55,582	58,361	61,279	64,343	67,560	70,938
Purification System Maint. (R$/year)		68,985	72,020	75,621	79,402	83,373	87,541	91,918	96,514	101,340	106,407
Grid Electricity (R$/year)		68,986	72,022	75,622	79,403	83,373	87,542	91,919	96,515	101,340	106,407
Profit Taxes RNG Sold to Distributor (R$/year)		39,621	41,364	43,432	45,604	47,884	50,279	52,792	55,432	58,204	63,392
Value-Added Taxes RNG Sold to Distributor (R$/year)		49,890	52,085	54,689	57,424	60,295	63,310	66,475	69,799	73,289	79,822
Total OPEX (R$/year)		239,182	249,999	262,812	276,288	290,460	305,366	321,043	337,532	354,876	375,397
Total Costs (R$/year)	1,204,000	239,182	249,999	262,812	276,288	290,460	305,366	321,043	337,532	354,876	375,397
Discount Rate	1.00	0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25
PV (@15%)	1,204,000	207,984	189,035	172,803	157,968	144,410	132,018	120,692	110,340	100,878	92,792
Sum PV of Total Costs	2,632,921										

Based on the cost schedule presented above and a discount rate of 15%, the present values of average costs of RNG production were calculated. The average costs were calculated by dividing total present value of operational expenditures per year by total cubic meter of RNG generated that year.

TABLE 9. PRESENT VALUE OF RNG AVERAGE COST											
	0	1	2	3	4	5	6	7	8	9	10
PV of Avg. Cost (R$/m3)		0.18	0.16	0.15	0.14	0.13	0.11	0.10	0.10	0.09	0.08

Financial Profit Analysis

The maximum price at which RNG could be sold to the NG distributor equals the price of compressed natural gas (CNG) offered by the state natural gas distribution company. CNG in the state of Rio de Janeiro is distributed by Companhia Estadual de Gas (CEG) at a price of R$1.1318/m^3. The price of CNG in different states in Brazil during the month of February 2011 is also presented in the graph below.

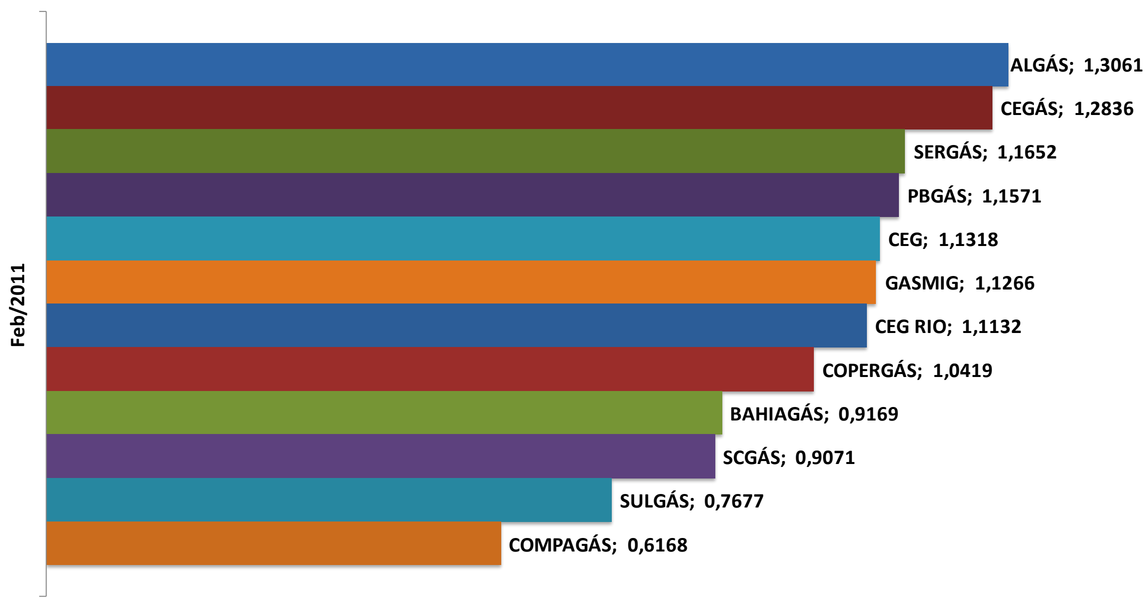


Figure 11. CNG Prices in Brazilian Reais for Different CNG Distributors in Brazil (Source: Neogas)

An average annualized price of R$0.23/ m^3 for RNG was also calculated by dividing the sum of the present value of total costs by the total production of RNG in ten years. This price is equivalent to the internal rate of return as it is the real price that will set the NPV equal to zero.

The net income for the RNG project was calculated using the two different prices. Table 10 below presents the sum of the present value of net income for revenues obtained from selling RNG to a NG distributor at the wholesale price of compressed natural gas. Table 11 presents the sum of the present value of net income for revenues obtained from selling RNG at the average annualized price. As can be seen, the present value of net income is equal to zero when RNG is sold at the average annualized price.

TABLE 10. NET INCOME FOR RNG SOLD TO DISTRIBUTOR AT CNG PRICE (FINANCIAL)											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Revenues (R$)	(1,204,000)	1,299,218	1,356,383	1,424,202	1,495,412	1,570,183	1,648,692	1,731,127	1,817,683	1,908,567	2,078,686
Cost (R$)		239,182	249,999	262,812	276,288	290,460	305,366	321,043	337,532	354,876	375,397
Net Income (R$)	(1,204,000)	1,060,035	1,106,384	1,161,390	1,219,125	1,279,723	1,343,327	1,410,084	1,480,151	1,553,691	1,703,288
Discount Rate	1.00	0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25
PV (@15%)	(1,204,000)	921,770	836,585	763,633	697,038	636,249	580,757	530,103	483,864	441,656	421,027
Sum PV of Net Income (R$)	5,108,681										

TABLE 11. NET INCOME FOR RNG SOLD TO DISTRIBUTOR AT AVERAGE ANNUALIZED PRICE											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Revenues (R$)	(1,204,000)	263,292	263,292	263,292	263,292	263,292	263,292	263,292	263,292	263,292	263,292
Cost (R$)		207,984	189,035	172,803	157,968	144,410	132,018	120,692	110,340	100,878	92,792
Net Income (R$)	(1,204,000)	55,308	74,257	90,489	105,324	118,882	131,274	142,600	152,952	162,414	170,500
Discount Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PV (@15%)	(1,204,000)	55,308	74,257	90,489	105,324	118,882	131,274	142,600	152,952	162,414	170,500
Sum PV of Net Income (R$)	0										

8. ECONOMIC ANALYSIS

In this section, the costs and revenues related to the green electricity and RNG projects are described.

8.A. GREEN ELECTRICITY PROJECT

Capital Expenditures (CAPEX)

Capital expenditures include the same initial investments that are presented in the financial cost analysis except costs related to operating and environmental licenses are excluded. These investments are done in 2010, which is year 0 of the project.

Operational Expenditures (OPEX)

Operational expenditures are the same as in the financial analysis except that taxes on green electricity sold are not included in the economic analysis.

Costs related to operator wages and machine maintenance are calculated as presented in the financial cost analysis.

Costs related to the purchase of electricity from the grid vary in the same way as presented in the financial analysis.

A summary of the green electricity total costs can be seen in Table 12 below. As can be seen, this project has a present value of total costs of about R$889,000 at an 8.62% discount rate.

TABLE 12. GREEN ELECTRICITY ECONOMIC COST ANALYSIS											
	0	1	2	3	4	5	6	7	8	9	10
Capital Costs (CAPEX)											
Investment (R$/year)											
Generator	170,000										
Purification System	110,000										
Total CAPEX (R$/year)	280,000										
Operating Costs (OPEX)											
Operator Wages (R$/year)		19,500	20,724	22,152	23,679	25,310	27,054	28,918	30,910	33,040	35,317
Generator Maintenance (R$/year)											
Total Oil&Lube		10,643	11,112	11,667	12,251	12,863	13,506	14,182	14,891	15,635	16,417
Total spark plug		6,623	6,914	7,260	7,623	8,004	8,404	8,824	9,265	9,729	10,215
Total filter change		5,814	6,070	6,374	6,692	7,027	7,378	7,747	8,135	8,542	8,969
Total liquid change		1,603	1,674	1,757	1,845	1,937	2,034	2,136	2,243	2,355	2,473
Total air filter maintenance		1,971	2,058	2,161	2,269	2,382	2,501	2,626	2,758	2,895	3,040
Total air filter change		2,260	2,360	2,477	2,601	2,731	2,868	3,011	3,162	3,320	3,486
Total valve adjustment		3,942	4,115	4,321	4,537	4,764	5,002	5,252	5,515	5,791	6,080
Purification System Maint. (R$/year)		20,000	20,880	21,924	23,020	24,171	25,380	26,649	27,981	29,380	30,849
Grid Electricity (R$/year)		5,365	5,732	4,393	3,691	2,988	3,249	2,570	2,570	2,570	2,570
Total OPEX (R$/year)		77,721	81,639	84,487	88,208	92,178	97,377	101,916	107,430	113,257	119,416
Total Costs (R$/year)	280,000	77,721	81,639	84,487	88,208	92,178	97,377	101,916	107,430	113,257	119,416
Discount Rate	1.00	0.92	0.85	0.78	0.72	0.66	0.61	0.56	0.52	0.48	0.44
PV (@8.62%)	280,000	71,553	69,195	65,927	63,368	60,965	59,293	57,131	55,443	53,812	52,235
Sum PV of Total Costs	888,922										

Based on the cost schedule presented above and a discount rate of 8.62%, the average costs of producing green electricity were calculated. The average costs were calculated by dividing the present value of total operational expenditures per year by total kilowatts of electricity generated that year.

TABLE 13. PRESENT VALUE OF GREEN ELECTRICITY AVERAGE COST											
	0	1	2	3	4	5	6	7	8	9	10
PV of Avg. Cost (R$/kWh)		0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

Economic Profit Analysis

The price at which electricity could be sold today in the electricity auction is R$0.15/kWh. This represents the maximum price paid for green electricity in 2010. Throughout the life of the project, the price at which electricity can be sold in an electricity auction will increase with inflation.

An average annualized price of R$0.04/kWh for green electricity was also calculated using the same method as in the financial profit analysis. This price is equivalent to the internal rate of return as it is the real price that will set the NPV equal to zero.

The net income for the green electricity project was calculated using the two different prices. Table 14 presents the sum of the present value of net income for revenues obtained from selling green electricity in an electricity auction. Table 15 presents the sum of the present value of net income for revenues obtained from selling green electricity at the average annualized price. As can be seen, the present value of net income is equal to zero when the green electricity is sold at the average annualized price.

TABLE 14. NET INCOME FOR GREEN ELECTRICITY SOLD AT ELECTRICITY AUCTION PRICE (ECONOMIC)											
	0	1	2	3	4	5	6	7	8	9	10
Revenues (R$)	(280,000.00)	298,015	311,128	326,684	343,018	360,169	378,178	397,087	416,941	437,788	478,378
Cost (R$)		77,721	81,639	84,487	88,208	92,178	97,377	101,916	107,430	113,257	119,416
Net Income (R$)	(280,000.00)	220,294	229,489	242,197	254,811	267,991	280,800	295,171	309,511	324,531	358,962
Discount Rate	1.00	0.92	0.85	0.78	0.72	0.66	0.61	0.56	0.52	0.48	0.44
PV (@8.62%)	(280,000.00)	202,812	194,510	188,990	183,054	177,244	170,977	165,464	159,734	154,194	157,018
Sum PV of Net Income (R$)	1,473,998										

TABLE 15. NET INCOME FOR GREEN ELECTRICITY SOLD AT AVERAGE ANNUALIZED PRICE											
	0	1	2	3	4	5	6	7	8	9	10
Revenues (R$)	(280,000.00)	88,892	88,892	88,892	88,892	88,892	88,892	88,892	88,892	88,892	88,892
Cost (R$)	-	71,553	69,195	65,927	63,368	60,965	59,293	57,131	55,443	53,812	52,235
Net Income (R$)	(280,000.00)	17,339	19,697	22,965	25,525	27,927	29,600	31,761	33,449	35,080	36,657
Discount Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PV (@8.62%)	(280,000.00)	17,339	19,697	22,965	25,525	27,927	29,600	31,761	33,449	35,080	36,657
Sum PV of Net Income (R$)	0										

8.B. RNG PROJECT

Capital Expenditures (CAPEX)

Capital expenditures include the same initial investments that are presented in the financial cost analysis except costs related to operating and environmental licenses are excluded. These investments are done in 2010, which is year 0 of the project.

Operational Expenditures (OPEX)

Operational expenditures are the same as in the financial analysis except that taxes on RNG sold are not included in the economic analysis.

Costs related to operator wages and machine maintenance are calculated as presented in the financial cost analysis.

Costs related to the purchase of electricity from the grid vary in the same way as presented in the financial analysis.

A summary of the RNG total costs can be seen in Table 16 below. As can be seen, this project has a present value of total costs of about 2,740,000 at a 8.62% discount rate.

TABLE 16. RNG ECONOMIC COST ANALYSIS											
	0	1	2	3	4	5	6	7	8	9	10
Capital Costs (CAPEX)											
Investment (R$/year)											
Compressor	679,000										
Electrical ducts, electric transformer	75,000										
Purification System	400,000										
Total CAPEX (R$/year)	1,154,000										
Operating Costs (OPEX)											
Operator Wages (R$/year)		15,600	16,580	17,722	18,943	20,248	21,643	23,134	24,728	26,432	28,253
Compressor Maintenance (R$/year)		45,990	48,014	50,414	52,935	55,582	58,361	61,279	64,343	67,560	70,938
Purification System Maintenance (R$/year)		68,985	72,020	75,621	79,402	83,373	87,541	91,918	96,514	101,340	106,407
Grid Electricity (R$/year)		68,986	72,022	75,622	79,403	83,373	87,542	91,919	96,515	101,340	106,407
Total OPEX (R$/year)		199,561	208,635	219,380	230,684	242,576	255,087	268,250	282,100	296,672	312,005
Total Costs (R$/year)	1,154,000	199,561	208,635	219,380	230,684	242,576	255,087	268,250	282,100	296,672	312,005
Discount Rate	1.00	0.92	0.85	0.78	0.72	0.66	0.61	0.56	0.52	0.48	0.44
PV (@8.62%)	1,154,000	183,724	176,835	171,186	165,721	160,435	155,321	150,374	145,588	140,958	136,478
Sum PV of Total Costs	2,740,618										

Based on the cost schedule presented above and a discount rate of 8.62%, the present values of average costs of RNG production were calculated. The average costs were calculated by dividing total present value of operational expenditures per year by total cubic meter of RNG generated that year.

TABLE 17. PRESENT VALUE OF RNG AVERAGE COST (ECONOMIC)

	0	1	2	3	4	5	6	7	8	9	10
PV of Avg Cost (R$/m3)		0.16	0.15	0.15	0.14	0.14	0.14	0.13	0.13	0.12	0.12

Economic Profit Analysis

The price at which RNG can be sold to the NG distributor is the same as that presented in the financial analysis.

An average annualized price of R$0.24/ m^3 for RNG was also calculated by dividing the sum of the present value of total costs by the total production of RNG in ten years. This price is equivalent to the internal rate of return as it is the real price that will set the NPV equal to zero.

The net income for the RNG project was calculated using the two different prices. Table 18 below presents the sum of the present value of net income for revenues obtained from selling RNG to a NG distributor at the wholesale price of compressed natural gas. Table 19 presents the sum of the present value of net income for revenues obtained from selling RNG at the average annualized price. As can be seen, the present value of net income is equal to zero when RNG is sold at the average annualized price.

TABLE 18. NET INCOME FOR RNG SOLD TO DISTRIBUTOR AT CNG PRICE (ECONOMIC)											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Revenues (R$)	(1,154,000)	1,299,218	1,356,383	1,424,202	1,495,412	1,570,183	1,648,692	1,731,127	1,817,683	1,908,567	2,078,686
Cost (R$)	-	199,561	208,635	219,380	230,684	242,576	255,087	268,250	282,100	296,672	312,005
Net Income (R$)	(1,154,000)	1,099,656	1,147,748	1,204,822	1,264,729	1,327,607	1,393,605	1,462,876	1,535,583	1,611,895	1,766,680
Discount Rate	1.00	0.92	0.85	0.78	0.72	0.66	0.61	0.56	0.52	0.48	0.44
PV (@8.6%)	(1,154,000)	1,012,388	972,808	940,142	908,570	878,053	848,557	820,048	792,492	765,858	772,787
Sum PV of Net Income (R$)	7,557,703										

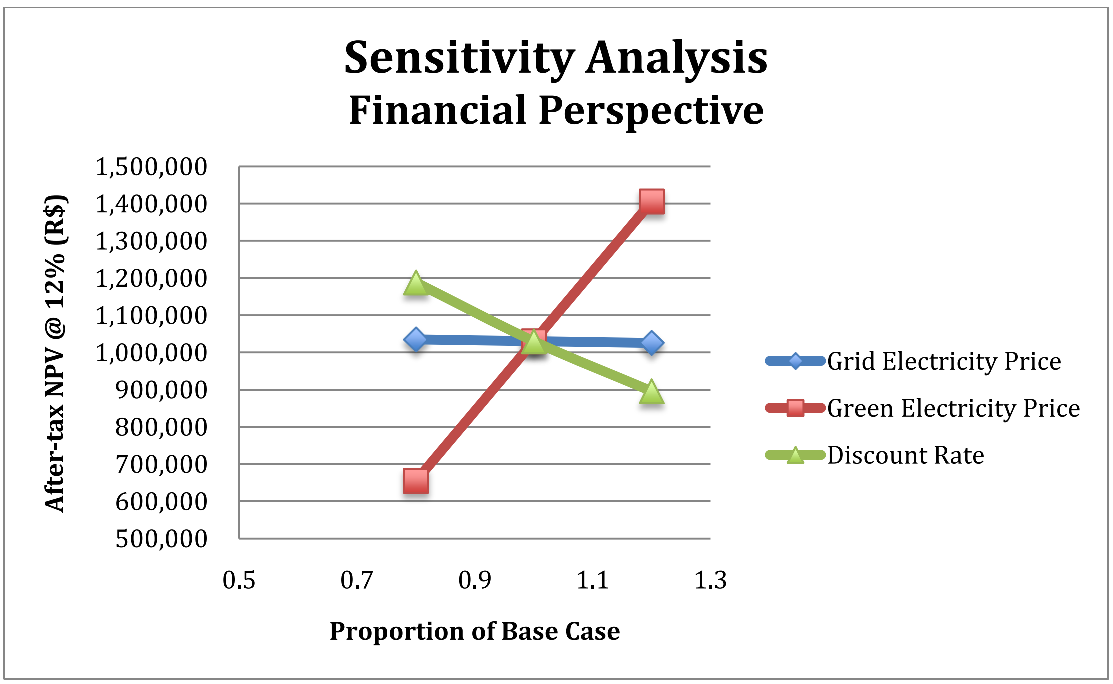
TABLE 19. NET INCOME FOR RNG SOLD TO DISTRIBUTOR AT AVERAGE ANNUALIZED PRICE											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Revenues (R$)	(1,154,000)	274,062	274,062	274,062	274,062	274,062	274,062	274,062	274,062	274,062	274,062
Cost (R$)	-	183,724	176,835	171,186	165,721	160,435	155,321	150,374	145,588	140,958	136,478
Net Income (R$)	(1,154,000)	90,338	97,227	102,876	108,341	113,627	118,741	123,688	128,474	133,104	137,583
Discount Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PV (@15%)	(1,154,000)	90,338	97,227	102,876	108,341	113,627	118,741	123,688	128,474	133,104	137,583
Sum PV of Net Income (R$)	0										

9. SENSITIVITY ANALYSIS

A sensitivity analysis was performed to understand how the variability of input and output prices and interest rates impact the projects' NPV.

9.A. GREEN ELECTRICITY PROJECT

A sensitivity analysis was performed to evaluate how the NPV of the green electricity project varies with a change in grid electricity prices, discount rates, and in green electricity auction–market prices. Base prices and discount rate were increased and decreased by 20% in the financial model.

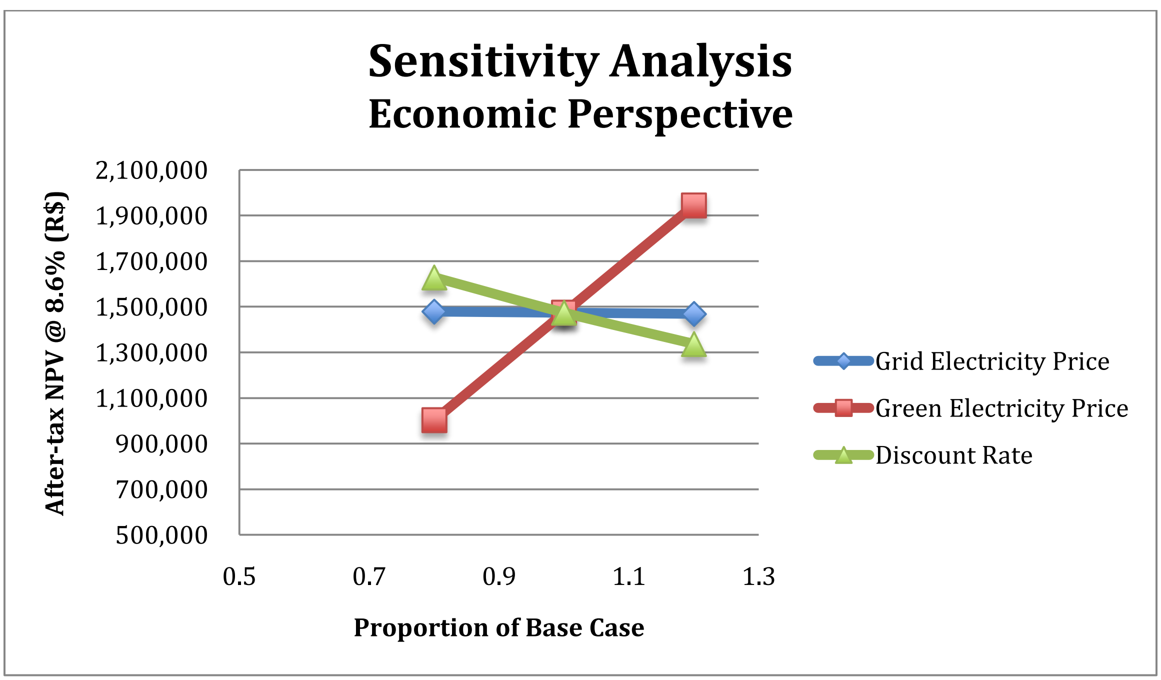


As can be seen from the graph above, an increase or decrease of 20% in grid electricity prices does not have a large effect on the NPV of the project. This is because a small amount of electricity is consumed to generate green electricity. A change in the green electricity auction–market price or discount rate, however, has a significant effect on NPV.

The green electricity auction-market price has a large effect on NPV since it has a direct effect on revenues. If green electricity prices are high, then revenues will be high as well. A 20% increase in prices causes NPV to rise by 36%. A 20% reduction in prices causes NPV to decrease by 57%. As prices decrease, revenues will tend to equal costs.

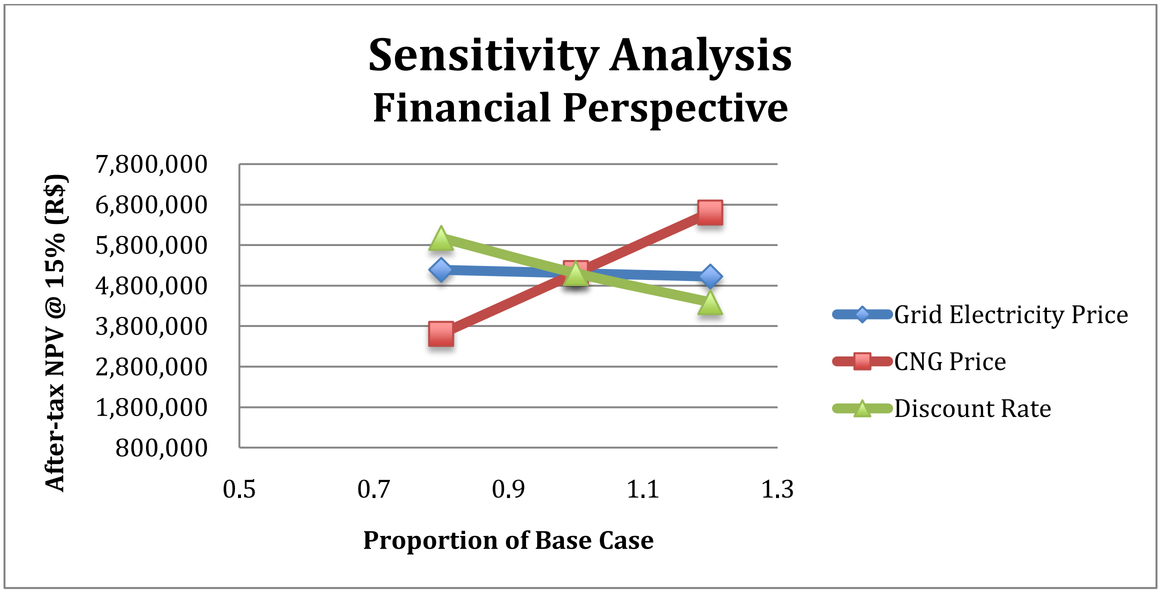
The variability in the discount rate affects NPV because a smaller discount rate increases the value of the future cash flows. A larger discount rate, however, reduces the magnitude of future flows. A 20% increase or decrease in discount rates causes NPV to reduce or increase by 15%, respectively.

A sensitivity analysis for the economic model was also performed and is presented in the graph below. As can be seen, the results are very similar to those obtained with the financial model data.



9.B. RNG PROJECT

A sensitivity analysis was performed to evaluate how the NPV of the RNG project varies with a change in grid electricity prices, discount rates, and CNG prices. Base prices and discount rate were increased and decreased by 20%.

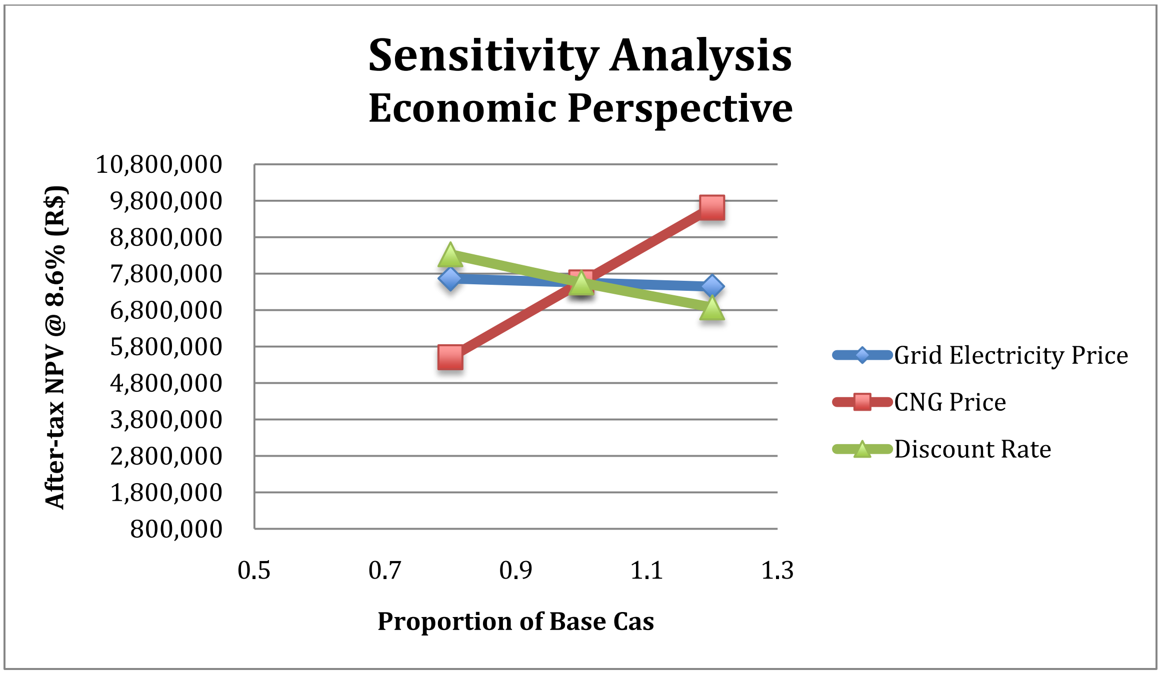


As can be seen from the graph above, an increase or decrease of 20% in grid electricity prices does not have a large effect on the project NPV. This is because a small amount of electricity is consumed to generate RNG. A change in the CNG price or discount rate, however, has a significant effect on NPV.

The CNG price has a large effect on NPV since it has a direct effect on revenues. If CNG prices are high, then revenues will be high as well. A 20% increase in prices causes NPV to rise by 29%. A 20% reduction in prices causes NPV to decrease by 41%. As prices decrease, revenues will tend to equal costs.

The variability in the discount rate affects NPV because a smaller discount rate increases the value of the future cash flows. A larger discount rate, however, reduces the magnitude of future flows. A 20% increase or decrease in discount rates causes NPV to reduce or increase by 16.5%, respectively.

A sensitivity analysis for the economic model was also performed and is presented in the graph below. As can be seen, the results are very similar to those obtained with the financial model data.



10. EMISSIONS REDUCTIONS

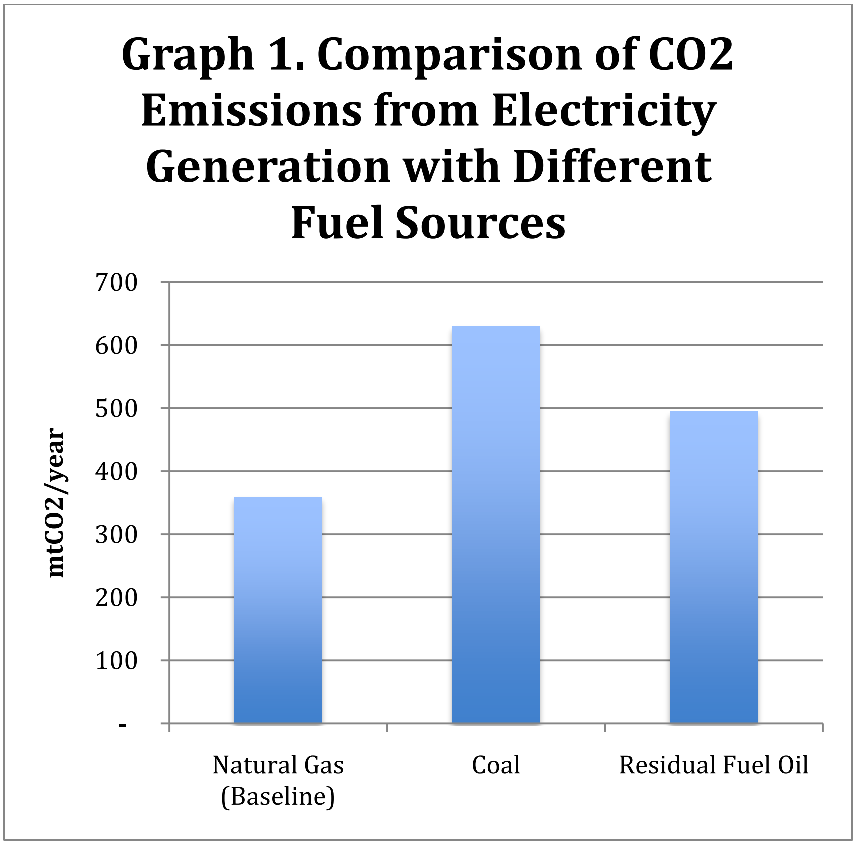
Both the green electricity project and the RNG project have potential to reduce CO_2 emissions. The green electricity project can reduce CO_2 emissions if it replaces electricity generated in thermal power plants with fuels such as coal or residual fuel oil (i.e., diesel). The RNG project can reduce CO_2 emissions if it replaces gasoline or diesel that is combusted in car engines.

10.A. GREEN ELECTRICTY PROJECT

The emission reductions from the green electricity project were calculated by assuming that the 252 kW generator generates electricity for 24 hours a day during 329 days in a year. The fuel used in the generator is assumed to have the same properties as natural gas that is combusted in stationary sources. The baseline emissions from combusting natural gas in the green electricity project were calculated based on the natural gas emission factor of 53 kg CO_2/MMBTU (Appendix H of the instructions to Form EIA-1605) and the energy conversion factor of 1 kWh/3412 BTU. Baseline emissions from the combustion of natural gas in a thermal power plant are shown in Graph 1 below.

The emissions from the combustion of coal or residual fuel oil were also calculated and compared to the baseline emissions from generating green electricity. Based on the coal emission factor of 93 kg CO_2/MMBTU (Appendix H of the instructions to Form EIA-1605) and the energy conversion factor of 1 kWh/3412 BTU, the emissions from combustion of coal in a thermal power plant were calculated and can be seen in Graph 1 below.

The emissions from the combustion of diesel were calculated by using the same method as for the calculation of coal emissions. However, a diesel emission factor of 73 kg CO_2/MMBTU (Appendix H of the instructions to Form EIA-1605) was used in the calculations. A summary of the total CO_2 emissions from each source of fuel is presented in Graph 1.



Based on the CO_2 emissions analysis presented above, it was determined that generating green electricity at the Alegria WWTP can help reduce CO_2 emissions by 271 metric tons (mt) of CO_2/ year (equivalent to a 43% reduction) and 136 mtCO_2/ year (equivalent to a 27% reduction) by displacing electricity that would otherwise be generated with coal or residual fuel oil, respectively.

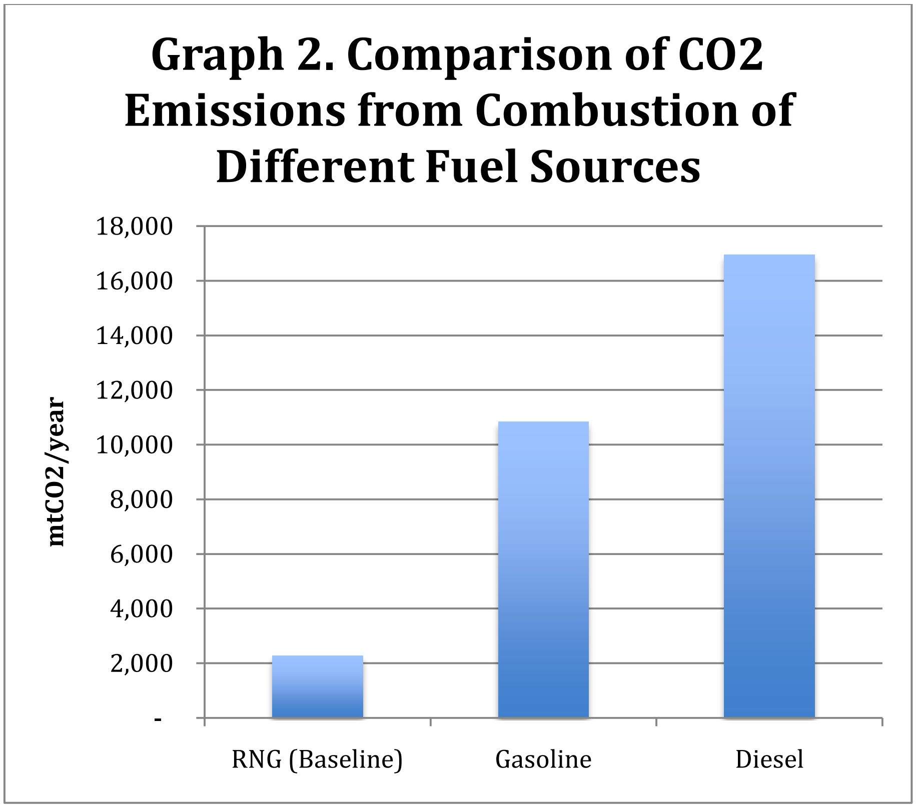
According to the United States Environmental Protection Agency (EPA) Greenhouse Gas Equivalencies Calculator, a reduction of 271 mtCO_2/ year is equivalent to: (i) retiring 48 passenger vehicles per year; (ii) avoiding CO_2 emissions from consumption of 572 barrels of oil; and (iii) avoiding CO_2 emissions from electricity use in 30 US homes for one year. Alternatively, a reduction of 136 mtCO_2/ year is equivalent to: (i) retiring 24 passenger vehicles per year; (ii) avoiding CO_2 emissions from consumption of 287 barrels of oil; and (iii) avoiding CO_2 emissions from electricity use in 15 US homes for one year.

10.B. RNG PROJECT

The emissions reductions from the RNG project were calculated by assuming that 3,500 m^3/day of RNG is generated during 329 days in a year. Based on the energy content of Brazilian natural gas of 26.8m^3/MMBTU (MME Natural Gas Monthly Bulletin, 2010) and natural gas emission factor of 53 kg CO_2/MMBTU (Appendix H of the instructions to Form EIA-1605), the emissions from combustion of RNG were calculated and can be seen in Graph 2 below.

The emissions from the combustion of diesel or gasoline were also calculated and compared to the RNG emissions. The emissions from the combustion of gasoline were calculated based on the assumption that 269 vehicles (3,500m^3/day * 1 vehicle/13m^3) with an average gasoline tank volume of 20 gallons could be replaced with RNG. The gasoline energy content of 0.115 MMBTU/gal (EV World Energy Content of Fuels, 2011) and the gasoline emission factor of 53 kg CO_2/MMBTU (Appendix H of the instructions to Form EIA-1605) were also used in the calculations. According to Appendix H of Form EIA-1605, the emission factor for gasoline is 71 kg CO_2/MMBTU. However, because the gasoline in Brazil has a 25% blend of ethanol, only three quarters of gasoline emissions are considered in the calculations.

The emissions from the combustion of diesel were calculated by using the same method as for the gasoline emissions. However, an energy content of 0.131 MMBTU/gal (EV World Energy Content of Fuels, 2011) and a diesel emission factor of 73 kg CO_2/MMBTU (Appendix H of the instructions to Form EIA-1605) were used in the calculations. A summary of the total CO_2 emissions from each source of fuel is presented in Graph 2.



Based on the CO_2 emissions analysis presented above, it was determined that generating RNG at the Alegria WWTP can help reduce CO_2 emissions by 8,558 $mtCO_2$/ year (equivalent to a 79% reduction) and 14,676 $mtCO_2$/ year (equivalent to a 87% reduction) by displacing gasoline or diesel that would otherwise be combusted in car engines.

According to the United States EPA Greenhouse Gas Equivalencies Calculator, a reduction of 8,558 $mtCO_2$/ year is equivalent to: (i) retiring 1,522 passenger vehicles per year; (ii) avoiding CO_2 emissions from consumption of 18,055 barrels of oil; and (iii) avoiding CO_2 emissions from electricity use in 942 US homes for one year. Alternatively, a reduction of 14,676 $mtCO_2$/ year is equivalent to: (i) retiring 2,611 passenger vehicles per year; (ii) avoiding CO_2 emissions from consumption of 30,962 barrels of oil; and (iii) avoiding CO_2 emissions from electricity use in 1,616 US homes for one year.

11. CONCLUSION

Based on the financial, economic and environmental analysis, it is recommended that Alegria WWTP invest in an RNG project. The financial and economic analyses show that the RNG project will have a net present value that is approximately five times larger than the green electricity project.

The sensitivity analysis also shows that the RNG project will provide higher benefits to the WWTP than the green electricity project. When the worse-case scenario, which is when CNG base case prices are reduced by 20%, for the RNG project is compared to the best-case scenario for the green electricity project, which is when green electricity auction prices are increased by 20%, the RNG project still has a much higher NPV than the green electricity project.

With regards to the environmental benefits, the emissions reductions obtained through the implementation of an RNG project are much higher than for a green electricity project. By implementing an RNG project the Alegria WWTP will provide an environmentally and economically sustainable solution for biogas treatment and will serve as a model for other wastewater treatment plants in Brazil.

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