STIRLING CYCLE MACHINES FOR COMBINED HEAT AND POWER

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Abstract. *With the increasing of the per capita electric energy consumption of the world-wide population and the constantly concern about the environment, a new challenge for the energy sector appears: to produce more energy of trustworthy form allied to a low cost and with minimum impact on the environment. In this context, machines that operate with the Stirling Cycle are mainly distinguished for the fact that they get its mechanics energy from an external combustion (being enough any next source of heat to the motogenerator) providing a better management of the natural resources of each region. In the same way, it works in hybrid generation systems, isolated places (stand-alone systems) and when it is used simultaneously in heat generation and electricity (co-generation), it gets about 90 percent of global efficiency. This work deals with a study on the main advantages, impediments and characteristics about the Stirling Cycle using co-generation. Moreover, a comparison of the electric generation costs among Stirling Cycle generator, photovoltaic and grid extension will be presented. Machines of the Stirling Cycle can be used in Brazil, being it a very rich country in biomass, which is a cheap, available, abundant and renewable fuel. Thus, this form of generation contributes for a better exploitation of the existing biomass and for the decentralization of the traditional energy model.*

Keywords: *Decentralized Energy Generation, Co-generation, Stirling Cycle Machines*

1. INTRODUCTION

Nowadays there is a great concern about environmental problems such as the greenhouse effect caused by, among other reasons, an increasing energetic demand. Thus, it has been emerging new challenges for the energy sector like to produce more energy of trustworthy form allied to a low cost and with minimum impact on the environment. According to (Paula, 2004), many alternatives to solve these problems are being searched, such as the electric generation with fuel cells, with photovoltaic panels, among others. Another alternative that has been developed around the world is relevant: it is the co-generation or combined generation of heat and power (CHP).

Considering this context, the Stirling Engine (SE) receives a special attention due to its characteristics: the fact that it presents external combustion and the possibility of using biofuels in the solid, liquid and gas physical state besides the solar energy. Moreover, as stated by (Wilke and Lora, 2004) it can be used in co-generation which guides to a global efficiency (heat more electricity) of 90%.

These engines are excellent to electric generation in isolated places as they present a low maintenance and operation costs, or also they are used in hybrid systems, with photovoltaic panels, working even if there is no solar incidence or just with fuel cells.

In a recent work (Stares, 2005) presents a system in which Stirling Engines are connected to a grid. In this way, the consumers can produce and sell the exceeding electric when production is larger than demand.

2. THE STIRLING CYCLE

As said in (Kongtragool and Wonggwises, 2003), the Stirling Engine is called in this way due to its discoverer, the Scottish reverend Robert Stirling who, in 1816, built up and registered his first prototype as one can find at British Pat. n.° 4081. They were engines of high technology to that period presenting a good performance in relation to other engines. In the mean time, around 1922, due to the development of more resistant steels exposed to elevate working pressures, it starts the arriving of the Otto and Diesel Cycles, turning the Stirling one obsolete and antiquated.

However, with the fuel crisis in the 70 century, SE became a viable proposition with rapid advances in material technology, making possible better heat conductors in addition to more efficient regenerators, as states (Thombare and Verma, 2006). It must be also highlighted a better understanding of the Stirling cycle when it started to be done math modeling through Thermodynamic Laws application in the engine.

According to (Biedermann, 2003), the Stirling cycle is a closed one in which the working gas is compressed in a cold cylinder and expanded in a hot one.

Machines that work with the Stirling cycle follow four reversible thermodynamic processes in sequence, being each one a thermodynamic transformation of the internal gas engine, also called working fluid. Two of four processes that compose the cycle are isothermal and the other two are isochoric.

Pressure (P) *versus* Volume (V) graph and Temperature (T) *versus* Entropy (S) graph are showed below in Figure 1 in addition to a detailed description of the four phases.

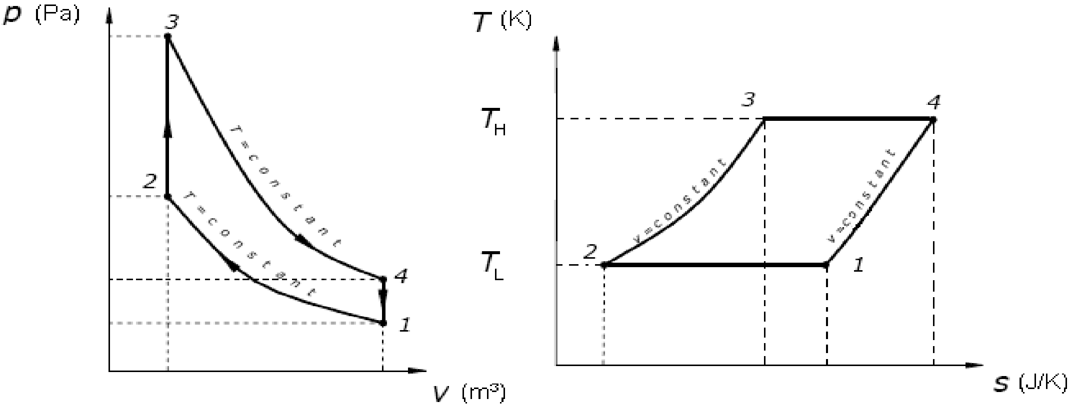


Figure 1. Stirling Cycle Graphic: Pressure x Volume and Temperature x Entropy

On a recent study (Thombare and Verma, 2006) consider that the cycle starts at point 1 of the graph PV and TS. At this time, it occurs the beginning of the working fluid compression in the cold piston while volume is at most and pressure and temperature are at least of their respective values, according to point 1 in the graph above. The four processes of the thermodynamic cycle are:

Process 1-2: *(Isothermal compression process)* – During compression process from 1 to 2, compression piston moves towards regenerator while expansion piston remains stationery. The working fluid is compressed in the compression space, machine effect work (W_c) and the pressure increases from P_1 to P_2. The temperature is maintained constant due to heat flow from cold space to surrounding. Work is done on the working fluid equal in magnitude to the heat rejected (Q_L) from the cycle. There is no change in internal energy and there is a decrease in specific entropy.

Process 2-3: (isochoric heat addition process) – In process 2-3, both pistons move simultaneously, the compression piston towards regenerator and expansion piston away from regenerator, so that volume between pistons remains constant. The working fluid is transferred from compression volume to expansion volume through porous media regenerator. Temperature of working fluid increased from minimum temperature to maximum temperature by heat transfer from regenerator matrix to working fluid. There is a gradual increase in temperature of working fluid while passing through regenerator cause increase in pressure. No work is done and there is an increase in the specific entropy and internal energy of the working fluid.

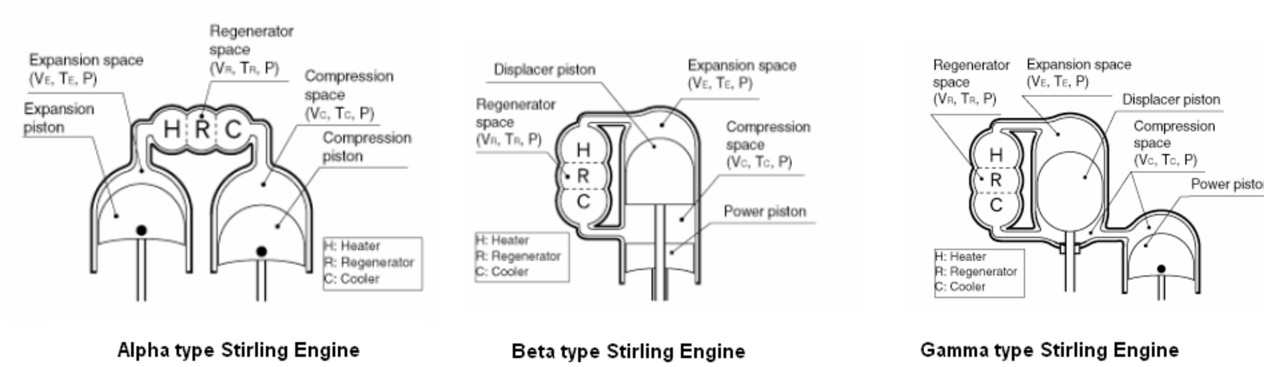
Process 3-4: (Isothermal expansion process) – In the expansion process 3-4, the expansion piston continues to move away from the regenerator while compression piston remains stationery. As the expansion process, the pressure decreases as volume increases. The temperature maintained constant by adding heat to the system from external source at maximum temperature. Work (W_E) is done by the working fluid on piston equal the magnitude to the heat supplied (Q_H), according to Eq. 2 . There is no change in the internal energy, but an increase in the specific entropy of the working fluid.

Process 4-1: (isochoric heat rejection process) – In process 4-1 both pistons move simultaneously to transfer fluid from expansion space to compression space through regenerator at constant volume. During the flow of working fluid through regenerator, the heat is transferred from the working fluid to the regenerator matrix reducing the temperature of working fluid to minimum temperature. No work is done; there is a decrease in the internal energy and the specific entropy of the working fluid.

3. THE STIRLING ENGINE CONFIGURATION

The elements of Stirling Engine include basically two cylinders of different temperatures connected to a regenerator which works as a preheater that absorbs heat during the hot piston flow to the cold one after releasing this heat during inverse flow. However, if more power is required, more than two cylinders can be used. In Figure 2, it is showed the three levels of the cylinder coupling: alpha, beta or gamma configurations that are used in conformity with the available space.

Alpha couplings present two pistons in separate cylinders, which are connected in series by a hot piston (heater), a regenerator and a cold piston (cooler). This configuration is the simplest one because the displacer is not necessary to the working fluid motion, but it is necessary a complete piston seals to keep a constant working gas volume. This configuration can be arranged with multiple cylinders in order to obtain more power. If there are only two pistons, they can be arranged in 90° angle for application in vehicle motors, for instance.



Alpha type Stirling Engine

Beta type Stirling Engine

Gamma type Stirling Engine

Figure 2. Stirling Engines and Different Forms of Cylinder Configurations (Alpha, Beta and Gamma)
Source: Thermodynamic Fundamentals for Energy Conversion Systems

The others two configurations are called displacement Stirling Engines since the working fluid is moved from the highest temperature space to the lowest one through the power piston.

Beta engines use displacer-pistons and power pistons. This configuration presents the original one which was patented by Robert Stirling in 1816. The displacer moves the working fluid between the hot space and the cold one of the cylinder through its heater, regenerator and cooler. The power piston, located in the cold space cylinder, compresses the working fluid when it is in the cold space and expands it when it is moved into the hot space.

The gamma configuration uses separated cylinders similar to Beta engine, however, the cooler, heater and regenerator are connected in series. The gamma engine with double-acting piston arrangement presents theoretically the highest mechanical efficiency. Also, the engine cylinder should be designed in vertical type in order to reduce bushing friction and this arrangement provides an advantage of simple crank mechanism.

4. THERMODYNAMIC MODELING OF STIRLING CYCLE ENGINE

To a better understanding of the Stirling cycle, it was developed a thermodynamics modeling, showing step by step which parameters contribute to the output power and system efficiency.

Stirling Engine is a thermal machine that operates between two temperature levels, heat and cold, in this way it produces useful work, exposed in Figure 3.

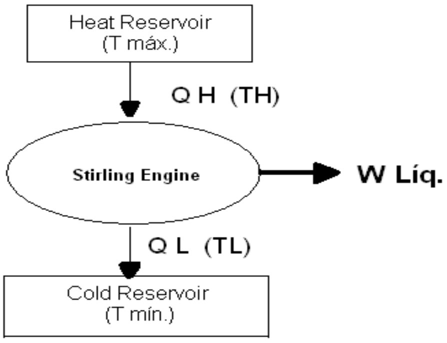


Figure 3. Thermal Stirling Machine

Hence, it can be done the thermal modeling by applying the First Thermodynamic Law, presented in Equation (1), in order to reach the expression of the liquid work carried out by SE:

$$Q = \Delta U + W \tag{1}$$

Taking into consideration the cycle phases as being thermodynamically reversible, the fluid working mass (m) is always constant and the regenerator efficiency as being the highest (100%), it is considered that there is no change in the internal energy of the system, obtaining Equation (2):

$$Q = W \tag{2}$$

According to the complete description of the Stirling Cycle, the temperature change in phases 2-3 and 4-1 is caused by the crossing of the working fluid through the regenerator, and since its efficiency was considered 100%, the heat amount received by the working fluid during phase 2-3 is equal in module to the transferred one by the regenerator in phase 4-1. Thus, such heat quantities are in the same value and, therefore, they have no influence in the other phases.

Considering isothermal phase 1-2, in which there is heat rejection (Q_L), and isothermal phase 3-4, in which there is heat addition (Q_H), the liquid work ($W_{LÍQ}$) produced by the system is equal to the difference between the inside energy from the heat source (Q_H) and the outside (Q_L) one from the system cold temperature reservoir. Thus, one obtains Equation (3):

$$W_{LÍQ} = Q_H - Q_L \tag{3}$$

The heat amount added and rejected by the working fluid in processes 1-2 and 3-4 influences directly in the increasing and reduction of the system specific entropy (graph T versus S), according to Equation (4), in which ds is the gas specific entropy variation

$$Q = \int T.m.ds = T.m.(s_F - s_I) \tag{4}$$

The gas specific entropy variation is given by Equation (5), in which c_{vo} is the gas specific heat and R is a constant value.

$$\Delta s = s_F - s_I = c_{vo}.\ln(\frac{T_F}{T_I}) + R.\ln(\frac{V_F}{V_I}) \tag{5}$$

Substituting Eq. (5) in Eq. (4) in addition to considering the heat amount Q_H and Q_L related to temperatures of heat reservoir (T_H) and cold one (T_L), it is obtained Equation (6) and Equation (7):

$$Q_H = T_H.m.[c_{vo}.\ln(\frac{T_4}{T_3}) + R.\ln(\frac{V_4}{V_3})] \tag{6}$$

$$Q_L = T_L.m.[c_{vo}.\ln(\frac{T_2}{T_1}) + R.\ln(\frac{V_1}{V_2})] \tag{7}$$

Yet, by the graph (T *versus* S) it is noticed that T_1 is equal to T_2 and that T_3 is equivalent to T_4. Hence, doing these considerations in Eq. (6) and Eq. (7) being already solved the logarithm; Equation (8) and Equation (9) are reached.

$$Q_H = T_H.m.R.\ln(\frac{V_4}{V_3}) \tag{8}$$

$$Q_L = T_L.m.R.\ln(\frac{V_1}{V_2}) \tag{9}$$

V1/V2 = V4/V3 is defined Compression Ratio (maximum volume divided for minimum volume), Equation (10):

$$r_c = V1/V2 = V4/V3 \tag{10}$$

Applying Eq. (10) in Eq. (9) and (8) it is obtained Equation (11) and Equation (12):

$$Q_H = m.R.T_H.\ln(r_c) \tag{11}$$

$$Q_L = m.R.T_L.\ln(r_c) \tag{12}$$

Substituting, then, Eq. (11) and (12) in Eq. (3), it is obtained Equation (13) which shows the variables that influence the liquid working carried out by Stirling Engine.

$$W_{LÍQ} = Q_H - Q_L = m.R.(T_H - T_L).\ln(r_C) \tag{13}$$

Thus, it becomes clear that the work obtained by the Stirling Engine depends directly on the three variables, considering that the working fluid mass is constant: the gas specific constant is R (showed in Table 1), the temperature gradient ($T_H - T_L$), that is the temperature difference among the heat reservoir and cold one, and the compression ratio that is the volume division contained into the piston during the expansion and the compression.

Any working fluid with heat capacity may be used by Stirling cycle engine. The most usual are Helium, Nitrogen, Hydrogen, being it the best gas, but it is very difficult to be sealed besides being dangerous, or Air that is cheap, but with low efficiency.

Table 1. The most usual working fluid used in SE.

Gas	R (J/Kg. K)	Heat Transfer
Air	287	1
Helium	2080	1.42
Hydrogen	4120	3.42
Sodium-Potassium eutetic	x	32.62
Nitrogen	297	x

(x): Not Available Data

Source: (Thombare, 2006)

Other form to increase indirectly the work is the pressure elevation, but it is an exclusive variation of each engine and it must be done a test for acquiring the pressure to get a secure operation.

Thus, if we divide the work by the time unit (second), it is obtained the Power, represented in Equation (14):

$$P = \frac{W_T}{s} = \frac{m.R.(T_H - T_L).\ln(r_C)}{s} \tag{14}$$

As every thermal machine, Stirling Engine presents its theoretical performance (η_S) or thermal efficiency equal to or limited to the Carnot performance (η_C), showed in Equation (15).

$$\eta_C = \eta_S = 1 - \frac{T_L}{T_H} \tag{15}$$

5. APPLICATIONS OF THE STIRLING ENGINES

There are many uses of the Stirling Engines, for example, in vehicles, tested by General Motors and Ford Companies but without considerable success. In conformity with (McDonald, 1994) Stirling machines can be used in refrigeration, just inverting the cycle described in section 4, obtaining temperatures about 251 K, with SE of 75 W input power. Another application is in the space probes developed by NASA that acquired its heat through radioactive decay.

One of the most and more promising applications of the Stirling Engine is the electric generation through the coupling of a generator in which it is also possible to be used the co-generation in different places, companies and hotels, for instance.

One of the best advantages of the Stirling Engine Generator is the characteristic of obtaining its energy through an external heat source such as any biofuel, according to the availability of the region where it was placed, including the solar energy.

Stirling Engine Generator that obtains heat through solar energy is a special engine that is used with a concentrator, industrially called Dish Stirling System. The SE is placed on the concentrator focus following the sun during the whole day in order to acquire more heat. The technology is promising, but it is in the pre-industrial stage.

Considering the high flexibility of the SE in relation to the use of fuels and being Brazil a rich place in organic material from natural origin, an excellent option to the electric generation in this country would be the implantation of Stirling Engines which operate from the biomass burning *in natura* or from its gasification, as stated by Barros *et al.* (2004).

In Barros *et al.* (2004) is also found that the term biomass embodies the vegetable material generated through the photosynthesis and its products, such as: forest, agricultural and animal residues, organic material contained in the industrial, domestic and municipal leftovers, etc. These materials contain chemical energy provided by energetic transformation of the solar radiation. It can be directly discharged by combustion or converted through any process in other energy sources, to any aimed end, such as alcohol and vegetable coal.

When the biomass is burned or gasified, the tenor of particles and harmful gases are not so expressive, as presented in Figure 4, and with the development of new technologies, it is waited that harmful gases of combustion turn to zero.

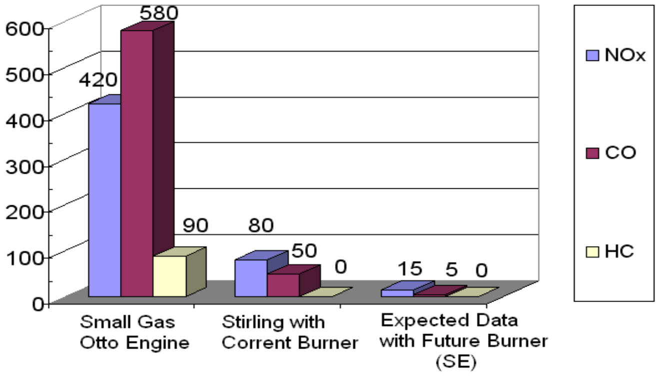


Figure 4. Emissions of NOx, CO and HC of Conventional Engines and Stirling Units (mg/m³)
Source: Adapted from SOLO Stirling Engine (2002)

Besides presenting low pollutant levels in its burning, the use of biomass as a heat source is a highly cheap fuel, as one can conclude from Corria *et al*. (2006), many times available without any cost, such as rice biomass in Rio Grande do Sul State, in addition to help avoiding of greenhouse effect since it emits low level of CO_2.

Another advantage by the use of electric generation with SE is the fact that there is the possibility of CHP implantation, increasing the global efficiency system, because the thermal losses that would occur are almost totally converted in the water heating.

It can be noticed in Figure 5 that there is a big energy amount spent to obtain hot water, in conformity with (Martins, 2005), and that it could be saved by the CHP implantation.

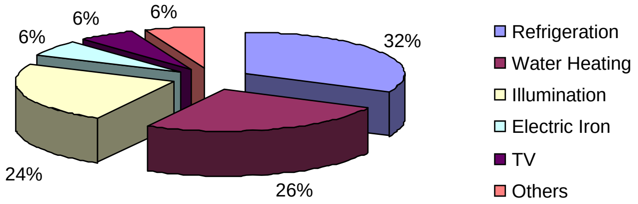


Figure 5. Residential Consumption of Electric Energy by the Final Use.
Source: Martins, COBEP-2005.

Such energy amount (J) spent in the water heat in the liquid state (293 K) is caused by the high specific heat of it (c_p= 4181 J/Kg.K) as it is showed in Equation (16), in which m is the water mass (kg) and ΔT is the temperature difference between the initial and final state.

$$Q = m.c.\Delta T = m.c.(T_{final} - T_{inicial}) \tag{16}$$

Searching by a high efficiency in the electric generation and by the expense reduction with hot water is the reason that companies, such as Whispergen™ and SOLO™, started to produce Micro-CHP Units (power bellow 100 KW), whose working is showed in Figure 6.

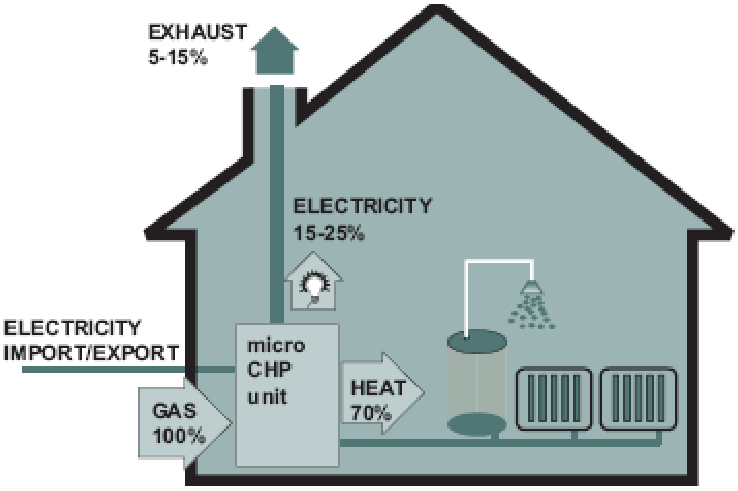


Figure 6. CHP with Stirling Engine and Energy Conversions
Source:E.A. Technology

Through this picture it is noticed that only 5 to 15% of the total gas energy is not utilized. Thus, it can be affirmed that the global efficiency of this cycle is high (about 90%). It is also presented that the consumer advantage turns to exporter of electric energy, when the system is connected to the public grid and the production exceeds the demand.

In residences, it is usual to adopt SE for CHP because of low level of noise, safe operation and low maintenance cost, besides its motion parts are not in contact with combustion residues, providing a long life for them, as confirmed by Corria *et al.* (2006).

6. INSTALATION COST COMPARISION AMONG STIRLING ENGINE, PHOTOVOLTAIC AND GRID EXTENSION

It is estimated that in Brazil there are around 12 million people who do not have access to electric energy (MME, 2005) and among those, there are 80% in the countryside, most of them in isolated places. In this section, it will be presented an installation cost comparison from the Gasifier/SE, photovoltaic and a possible grid extension for a possible electric generation in those places.

To the comparison suggested in this section, it was considered a consumer of a typical residence in a rural area, in which the consumption is distributed according to Table 2:

Table 2. Daily Consumption Determination (Wh) of a Typical Rural Residence.

Load	Power (W)	Utilization / day (h)	Consumption / day
Light* live room	23	4	92
Light* bedroom 1	23	3	69
Light* bedroom 2	23	3	69
Light* kitchen	15	4	60
Light* restroom	11	1	11
Light* laundry room	15	2	30
Light* balcony	15	3	45
Television 20”	90	5	450
Receiver by satellite	25	5	125
Stereo System	20	4	80
Refrigerator 1 door	90	10**	900
Others	500	0.25	125
Total	**850**	**Total**	**2056Wh**

* Compacted Lights
** Period of the Compressor turned on to guarantee the aimed inside temperature.

As it can be notice, in this residence it was not considered the electric shower because it will be used SE operating with CHP and in the Photovoltaic Generation it can be used solar collectors to obtain hot water without the necessity of implanting electric shower.

6.1. Photovoltaic Generation

Considering that Brazil is a country with good rates of solar radiation incidence in any part of its territory, as stated by (ANEEL, 2005) such generation form is showed as interesting. In this way, it will be presented its installation cost analysis.

For the calculation of this system it was considered the solarimetric data of Santa Maria city – RS, extracted from SUNDATA Program, developed by CRESESB-CEPEL, in which it was verified an incidence of 2,5 KW/m^2 on June, the month with less solar incidence during the year.

According to (Imhoff, 2007), to a consumption of 2,056 KWh and to such rate of solar radiation, it is necessary 10 batteries of 150 Ah and 14 photovoltaic panel modules of 80 W_P.

Considering that the cost of each photovoltaic panel is R$ 1.500,00 and that each battery is R$ 750,00, so the total installation cost by consumer (C_T = R$/ Consumer) is expressed in section 6.3.

6.2. Stirling Engine Generation

Brazil is a tropical country with abundant and equally divided biomass where the electric energy generation using Stirling Engines becomes attractive.

The economical analysis is done from an electric motogenerator group, composed by a Gasifier more SE, of 10 KW of power, operating with biomass, being found free of costs besides being burned in a gasifier. To that motogenerator it can be used the maximum power of 10 consumers (1KW to each consumer).

In conformity with Lora *et al.* (2006), the implantation cost of Gasifier/Stirling Engine module is between 1.120-3.000 US$/KW (about 2.640-6.600 R$/KW). Taking into consideration an installed power of 10 KW and opting for the highest value (6.600 R$/KW), then the total installation cost (C_T) divided by number of consumers (N) is given in function of implanted Gasifier/Stirling Engine number (GSE), according to Equation (17):

$$C_T = [(66000).GSE]/N \tag{17}$$

It is presented the total cost by consumer (C_T = R$/ Consumer) of the electric generation system through the Gasifier/Stirling Engine in section below.

6.3. Grid Extension

In the case of places not so far away from the electric distribution lines, a possible grid extension can turn it profitable, depending on the distance of these centers and on the number of consumers.

Depending on the load to be maintained and of the system expansion perspectives, the consumers can be divided into three classes: A, B and C. As stated Rodrigues *et al.* (2005), a rural typical consumer fitted in the Consumer Class C and it is highlighted that it can be connected to at most 10 consumers in the transformer.

The most used distribution line model to these places is the single-phase line with return by ground (MRT – Aluminum). This model can be utilized to loads of until 55KVA, elevated load to those communities.

As the single-phase distribution lines transmit in a voltage of 13,8 kV and the distributed voltage to consumers will be of 220 V, being necessary to add transformers to the voltage reduction. To this system, according to NTAES 02 (item 6.13), the transformer must be a single-phase, and the minimum power will be of 10 kVA. Moreover, the connection between transformers and consumers is carried out by aluminum lines of low voltage (BT) can not exceed 250m, with a space and one pole to each consumer (NTAES 02).

The used values to the cost calculation of the grid extension are presented in Table 3, quoted also in Rodrigues *et al.* (2005), which indicates an average among the obtained prices in the Electrification Companies of Rio Grande do Sul State.

Table 3. Costs of Grid Extension

Description	**Costs**
Distribution Line MRT (R$/Km)	7.718,05
Low Voltage Conductor (R$/250m)	1.955,00
Single-phase 10 kVA Transformer (R$)	1.550,00

To the calculation of total installation cost by consumer (C_T = R$/ Consumer) one must consider the distance of them until the grid (DCR), the conductor extension of low voltage (BT), being considered the maximum distance allowed (250 meters) multiplied by number of consumers (N) and number of transformers (TM), showed in Equation (18):

$$C_T = [(DCR) + (BT.N) + (TM)] / N \qquad (18)$$

According to the technical rules adopted, the total installation cost by consumer (C_T = R$/ Consumer), of the three compared systems, is exposed in Table 4:

Table 4. Cost by consumer of the Grid Extension Implantation in function of the Distance, of the Photovoltaic and of the Gasifier/SE

Consumers (N)	**5**	**10**	**15**	**20**	**25**	**35**	**40**
Grid Extension (Km)							
3	6.895,83	4.425,42	3.705,28	3.267,71	3.067,17	2.793,69	2.688,85
5	9.983,05	5.969,03	4.734,35	4.039,51	3.684,61	3.234,72	3.074,76
10	17.701,10	9.828,05	7.307,03	5.969,03	5.228,22	4.337,30	4.039,51
20	33.137,20	17.546,10	12.452,40	9.828,05	8.315,44	6.542,46	5.969,03
60	94.881,60	48.418,30	33.033,87	25.264,15	20.664,32	15.363,09	13.687,08
100	156.626,00	79.290,50	53.615,33	40.700,25	33.013,20	24.183,71	21.405,13
Photovoltaic	28.500,00	28.500,00	28.500,00	28.500,00	28.500,00	28.500,00	28.500,00
Gasifier / SE	13.200,00	6.600,00	8.800,00	6.600,00	7.920,00	7.542,86	6.600,00

6.4. Electric Generation Comparison

Through the proposed comparison in the previous sections, it is possible to notice some peculiarities: when the installation costs are divided *per capita*, it is noticed that the costs in the photovoltaic generation remain constant because of the increasing electric energy demand, and that it grows proportionally to the number of implanted panels and batteries.

Another peculiarity is the fact that there are some raises to the costs in the case of Gasifier/SE generation and Grid Extension, due to that there is no relevant flexibility of Stirling Engine power strips and of the implantation necessity of a minimal power transformer (10KVA) in the case of extension grid.

The yellow cells in Table 3 represent the lowest implantation costs of generation from the Gasifier/SE when compared to the two other alternatives. The circled cells in red demonstrate that the starting of the Photovoltaic generation would have a higher feasibility of implantation in the presence of a possible grid extension.

Following, it is presented Figure 7 to point out the implantation costs of the three technologies studied and present as the grid extension costs are high to large distances even though there is an expressive number of consumers.

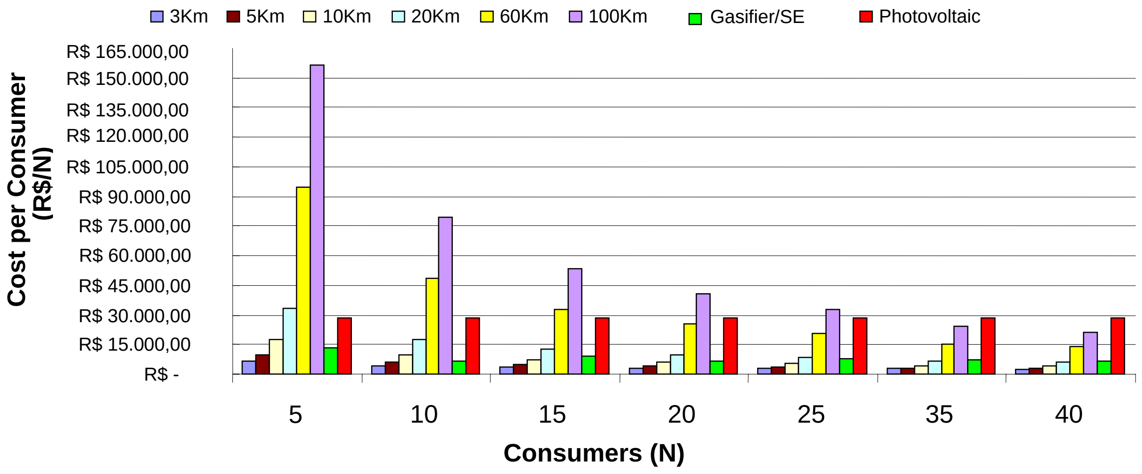


Figure 7. Installation Costs (R$/N) of Three Researched Technologies.

7. CONCLUSIONS

In the search of trustful electric generation, low cost in addition to a low environmental impact, Stirling Engines are showed satisfactory, mainly due to its flexibility in relation to the fuel uses, besides they can be solid, liquid or gas or also solar energy. Another advantage to be considered is the fact that they are utilized in CHP, increasing, thus, their global efficiency and reducing a relevant amount of spent energy while heating water.

From the installation cost analysis of the different forms of electric generation, it is noticed that from 10 Km it is already found some cases in which it is better the application of Gasifier/SE and, as this measure and the number of consumers enlarge, this generation form turns more attractive.

It is also aimed that, with a manufacture in series of Stirling Engines, the acquisition cost reduces and provides an alternative form of heat and electric generation even cheaper, focusing on the possibility of a better management of the natural resources of each region.

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