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SUSTAINABILITY ASSESSMENT OF ENERGY HYBRID SYSTEM IMPLEMENTED IN AN ISOLATED COMMUNITY

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Abstract. *The electric power availability in remote communities in the areas of Brazil is a current discussion associated to the warranty of the sustainability of human establishments. This question addresses non-standard energy planning strategies, which should be considered under the optics of small communities sustainability. In this paper, a methodological proposal is applied in an isolated community from central Brazil. The objective of the work is to analyze the viability of that methodology, as well as to verify the potential results in the community. The results indicate the viability of a energetic matrix composed approximately by 75% of renewable energy. Finally the positive aspects of the use of the methodology and the improvement needs are discussed.*

Keywords. Sources of Energy, Sustainability Indicators, Remote Communities, Family Agriculture, Production System.

1. Introduction

The search of the sustainability development in developing countries presents a deeply related to the warranty of conditions economical, social and environmental favorable for small distant communities of the urban centers. The promotion of the development in small communities presents direct reflexes on the establishment of levels of justness space associates to the distribution of the human population in the territory.

The migratory flow of great population contingents of interior areas for the great cities, is characteristic phenomenon and consequence of the development models implanted at those countries. Brazil's huge territory and wealth (and opportunities) concentration in urban regions makes this migration unsustainable. Establishing sustainable communities throughout the country is a challenge that has to be dealt with, in order to assure national sustainable development.

The search of solutions based on decentralized models of electric power generation for remote communities finds application in all of the areas of Brazil (Center West, Amazonian, Northeast, for instance). In a given place, a great solution can be looked for starting from the combination of electric power generation with conventional sources (group generator with diesel engine), renewable sources of energy (energy of wind, for instance) and still independent sources.

The consideration of the use of different sources will depend on the local conditions. This alternative can guarantee a minimum and reliable supply for domestic use and for local production. The economical evaluation of the composition in several ways of energy is an applied exercise of economical planning. This analysis type, provides the great choice under the economical aspect to be used in given scenery. However it is looked for a new form at the present time of establishing great generation strategies, that take into account including factors, considering the components environmental and social of the sustainability. Evaluation strategies of the sustainability of energy sources have been approached recently in the literature.

Several works present methodologies of selection of alternatives in remote communities, with base in integrated analyses. [1] and [2] propose a methodology for evaluation of systems of electric power generation based in sustainability indicators. Such methodology is particularly interesting seen that the selection of systems is approached in an integrated way, considering factors social, economical and environmental. Under the specific aspect of the social sustainability, [3] evaluates a methodology for the quantification of indicators for use of energy. This same theme is discussed in the article of [4]. The discussion of a sustainability use of hybrid sources in isolated communities is a theme approached in the papers of [5], [6] or [7], for remote areas of Alaska, Scotland and Australia, respectively. [8] using as base the methodology proposed for [1] and [2] developed an adapted simplification the Brazilian reality.

The present work has for objective to analyze that methodology, by application in a real case, seeking to evaluate the influence of the electric power generation and to verify them resulted potentials in the community.

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2. Energy Availability in Isolated Community

As [7], it is considered as remote community a human establishment of low population density, with restrictions to the use of conventional sources of energy (without access to lines of energy with centralized generation), with deficient urban infrastructure, with low level of economical density, with difficult access and distant of consuming markets. Evidently those parameters are few specific ones for a necessary characterization of a remote community. This is an open definition that however it becomes operational when the community should be fit in a availability planning of energy. In general, remote communities don't make possible implantations of systems of electric power provision in the strict economical sense, only using as parameters of analysis investment, it disputes and income.

The problem of the energy availability for such communities is always a critical point in the implantation of minimum infrastructure for the isolated population. Municipal public politics in general privilege infrastructure investments in the city headquarters of the municipal district. The generation of energy in smaller communities is usually neglected because of the bass investment return and of the difficulty of collection of the use of energy. In that way, the optics of the viability should be focused with base in wider parameters, seeking the promotion of the local development.

3. Sustainability Indicators for Energy Generation

The methodology [8] is applied for analysis the degree of sustainability community's remote, related with the energetic matrix, in the basic aspects of the sustainable development. The economical viability, the ecological prudence together with the social concern they form the base of necessary indicators for the proposed evaluation [9].

3.1. Social sustainability

The social paper of the electric power availability in small communities is intimately associated to the indicators of quality of local life. This premise, although it is the key of the present article, it suffers some distortions for the influence of the great centers. Those fasten a consumption pattern besides the necessary for the small communities' development, increasing the social paper of the energy inside of the studied context.

In that way it becomes necessary the use of methods to filter the demand of energy. Some technical visits to the community (an initial social evaluation can determine the studied community's needs) they allow to identify the necessary points and the desires of consumption of the involved families. That would be the starting point for determination of the local energy demand. However, those values of energy need to be filtered to establish a reasonable pattern of energy for the community, so that it turns viable the installation of the source of energy.

The solution found to filter the demand of energy was to just provide the points of the demand of energy that more they affect the indicators. It can be worked like this with defined objectives and to guarantee that the community has the necessary energy to improve its life quality.

The social indicators (Is) are defined then in the points considered relevant, to know: indicators for education, for health, for job, among other considered important to the studied place.
Some observations on the used social indicators are pertinent:

- All of the indicators are normalized for us to present values between 0 and 1. It is considered a positive indicator that with value 1;
- The indicators normalized those are contrary to the tendency, in other words, if their increase indicates larger unsustainable, those will be subtract by 1;
- The measurement of the chosen indicators for community of that study represents a very big effort, seen the lack of local statistics;
- The indicators should have as base parameters thoroughly accepted;
- The used indicators consider a given community's specific socio-cultural aspects, what was defined through data picked at the place;
- They are applied weights for each relative indicator with their importance inside of the scenery.

The group of social indicators chosen here is important to identify a minimum demand to be supplied, guaranteeing levels of quality of life desirable places as soon as is reached. The social indicators delimit therefore, goals the they be assisted inside of a context of energy planning. The economical viability as only factor of decision begins to lose the sense. The evaluation of the energetic matrix installed at the place will be done considering the economical and environmental indicators.

With base in this preliminary technical evaluation, values of minimum demand and projected can be established. The figure 1 presents the items considered for domestic, community consumption of electricity (health center, school, etc.) and in productive processes.

Considering market values for kW.h and growing a projection of the improvement of the social indicators with the readiness of energy, it can settle down an economical estimate of the increment of favorable social conditions that can be proportionate for the process of generation of energy.

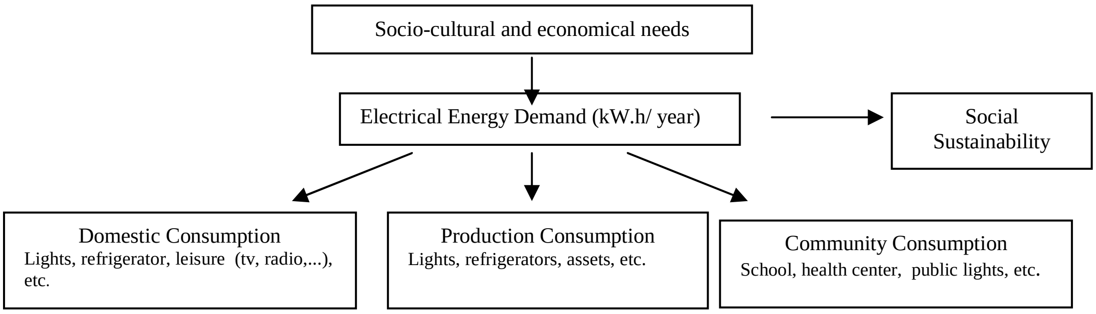

Figure 1. Electrical Energy Demand

3.2. Environmental sustainability

The environmental sustainability of operation of generating units of electric power is associated with an estimate of emissions (solid residues, pollution of the air and of the water) in face of the capacity of support of the ecosystem in which the same is installed. Therefore, the current environmental indicators of the energy use process by system generation should reflect the direct and indirect environmental impacts of this enterprise. [1] proposes a group of indicators that you/they reflect the environmental impact caused by the emissions associated to the generation process and for the manufacture and installation of the system. These indicators will be used in this work, being added however some relevant extra indicators on the environmental impact related to Brazilian ecosystems. The proposed indicators are normalized by the energy in a base of time.

The proposed indicators, together with the economical indicators, they should evaluate in a wide way the generation system that will be used. The environmental indicators can be transformed in economical values, establishing values of cost environmental associate to the generated energy potential. This has been made for systems of generation diesel and wind power [5] and photovoltaic [10]. The main advantage of that approach is the internalize possibility the environmental costs in the economical swinging of the generation project, that is done starting from an integrated evaluation of economical and environmental factors. The general evaluation of environmental impacts for each source alternative can be established.

In the present work, an environmental estimate is used ([11] adapted) associate to the manufacture of systems, considering the materials used in the equipments.

3.3. Economical sustainability

The last groups of indicators are established considering values of investments and operational costs of the generation system to be implanted. It is still considered the induction indicator to the increase of local PIB (gross domestic product). This last one indicative it establishes the direct influence of the installation of the electric power system generation in the dynamics economical place.

The economical indicators will be used directly in the evaluation of the sustainability of the project. With base in the useful life of the used equipments, the cost of the investment can be calculated by kW.h generated.

The total cost associated to the generation process can be calculated by the composition of economical and environmental values in the form:

$$C_T = (C_0(\frac{r}{1-(1+r)^t}) + C_a)/E_a \quad (1)$$

In this equation C_t is the cost of the energy in \$/kW.h, C_o is the total value of investment of the plant, also considering cost environmental joined to the manufacture of the equipment, r is the tax of discount of the investment and t the useful life of the same. C_a is the annual cost of operation, maintenance and associate to the environmental impacts of the generation. E_a is the energy generated in one year.

4. Case Study

This analysis bases on data of the project "Adaptation and use of device methodological participative to support the sustainability development of land reform" establishments, developed in the municipal district of Unaí - MG for Embrapa Cerrados, University of Brasília (Group of Work of the Land reform), National Institute of Agricultural Colonization (INCRA), and institutions local partners. The project possesses financial support of National Council of Scientific and Technological Development (CNPq) and its objective is to promote the sustainable development of land reform establishments through the adaptation and use of device methodological intervention participative in the real environment, that it favors the use of technological and social innovations for those seated. The analysis for that article will be made in one of the establishments worked by the project.

4.1. Community Characteristics

The municipal district of Unaí is located to 180 km of Brasília (in the Center Brazilian West). The temperature average varies from 21 to 24 ºC. The annual precipitation reaches 1397 mm, being 79% concentrated among the months of November to March. In a general way, it possesses characteristics similar to others of the area, presenting the soy cultivation and corn in great properties in the areas of plane relief (plated). The typical explorations of family agriculture appear in the areas of modified relief and in the borders of those plated. Unaí is an important basin milk pan that influences in a decisive way the systems of production of the family agriculture.

Another important characteristic of the municipal district refers to the great number of land reform establishments, which interfere in the logic of the family agriculture, that is the public of this research project.

The studied establishment is approximately 50 km of the headquarters of the municipal district and it benefits 43 families. The data for that analysis are originating from of a first diagnosis accomplished with 28 families of the establishment. For effect of that article, those families will be considered as the community to be worked.

The size of the lots varies from 13,3 to 33 ha. The identified production systems are constituted in agriculture combinations and livestock. In the case of the agriculture the corn cultivations prevail (48,5 ha) and rice (7,5 ha), that possess predominant function of self-consumption (family and animals), with sale of the surplus (Table 1).

The livestock, in a general way, it is guided for the production of milk. In this type of production system, the farmer uses the pastures in the period of rains (October to May) and feed the animals, in a special way the cows in production and the calves, with grass and cane triturated, corn and some protein source in the period of the drought (June to September). That system type depends on the readiness of energy to triturate the representatives of the feeding.

Only 09 families possess electric power in the houses. Of those, only 06 possess crusher for the making of the ration. Other 11 possess crushers moved to diesel. The other families does not feed the animals in the drought, being that, allied the low quality of the feeding supplied the animals, one of the reasons for the low production in that period (48720 liters), in relation to the production at that time of rains (99660 liters).

Table 1. Main products and revenue.

Product	**Quantity**	**Unity**	**Revenue (US$)**
Rice	6860	kg	766,26
Corn	138180	kg	13638,37
Milk	148380	l	8631,12
Cheese	10104	kg	6076,29
Cattle (cows)	31	head	5272,73
Cattle (oxen)	33	head	1276,62
Total			**35661,38**

4.2. Local Energy Demand Specification

The use of the electric power is always growing, always demanding more electricity to assist, along the time, the local needs. That electric power need and the high pattern demanded initially by the community implicate in a more complex situation when it is quantifying the demand of energy. Being like this, to analyze the demand, some parameters are stipulated from way to model the approached scenery. The initial demand longed for by the community is filtered. They are considered about main points to be assisted, those that influence with larger weight the sustainability indicators adopted. Like this, strategic points are chosen so that they improve the respective way indicators to dry the excesses in the demand. Besides, it becomes necessary to base the analysis in a temporary reference, where it is determined the time in that the community will be evaluated. That period of time serves as base for the analyses of the energy demand, economical evaluation, social evaluation and still for the environmental evaluation. In the present work the temporary base is of one year given the installation of the energetic matrix, being that moment the mark zero of the analysis.

For the strategic evaluation, the demand of energy was subdivided in 4 great groups to know: Domestic use, community Center, School and Health center. Those subdivisions are associated directly to the groups of chosen social indicators. This way, the analysis is facilitated once the simplicity of those groups, front to the supply of energy (with satisfied important needs), it turns easy the visualization of the main points. The table 2 presents the amount of the equipments considered for each group.

Finally, it should be defined the potentials of local generation, those are the amount of hours of heatstroke (solar potential), medium speed of the wind (potential of the wind), price of the liter of the diesel (generation motor) in this case the transport cost should be included, amount of hours to be lit up a day (support of batteries and amount of solar plates), days a week (determination of the base of time worked) and finally the quotation of the dollar (15/10/2002). The values related at price and cost are found at the internal market.

Table 2. Amount of equipments for each group

Equipments	Domestic Use	Community Center	School	Health Center
TV in colors 14 pol	19			
Radio	19			
Refrigerator 2 doors			1	1
Refrigerator 1 door	19			
Freezer		2		
Domestic refrigerator	10			
Fluorescent lamp	90	10	10	5
Electric motor	5			

The sum of the potencies demanded by all from the groups is 46,79 kW.

Table 3. Local economical characteristics.

Usage of lights in hours/day	Liter of diesel ($)
6	0.39
Days/week	**Dollar exchange rate (15/10/2002)**
7	3,85
Excessive exposure to solar light in hours / day	**Annual discount rate**
10	0,1

4.3. Methodology Implementation and Results

Known the demand and the generation potentials, the methodology looks for to find a great point in a crossing of curves. For so much the environmental cost is considered in compensation to the investment in the equipments. That great point is given varying the energetic matrx of an almost conventional configuration, with the use of diesel engines, until an almost alternative, using generators by wind basically. That variation feels in four cases where the percentage assisted by each system is altered in a growing way in the sense of the renewable energetic matrix. The table 4 presents such variation.

Table 4. Percentage of the demand of energy for the head office in the cases

	1º case	2º case	3º case	4º case
Generator	70%	50%	30%	15%
Wind	20%	30%	50%	70%
Solar	10%	20%	20%	15%
Total	**100%**	**100%**	**100%**	**100%**
% renewable	**30%**	**50%**	**70%**	**85%**

Like this, making the distribution of energy to be assisted by each configuration of systems can be calculated the analyzed community's most important indicators. It is still, to lift the investments and the costs related to each system, besides the environmental. The tables 5, 6 and 7 present the indicators environmental, social and economical respectively. The table 8 supplies the environmental economical cost involved in each one of the cases. The best result, in other words, characterizing a great point in this system, it is presented in the graph of the figure 2.

For this case study, the great point of the renewable energetic matrix is between 70 to 80% renewable. That high percentage of the energetic matrix becomes possible die the potential of solar generation and wind (mainly) of the area, as well as the demands of energy filtered. What translates her in the necessary and enough consumption for the community. In that way the investment in the equipments is appropriate exactly to the local need.

Regarding the environmental indicators, it stands out the use of aluminum and of the diesel oil. Those walk in contrary senses the measure that the head office goes if turning renewable. It diminishes the amount of burned fuel and it increases the use of the aluminum (table 5). In a more necessary comparison of the situation, it is observed that the total cost tends the measure that increases the percentage of the renewable energetic matrix to decrease. The individual variations among the cases are more visible in the system photovoltaic due to the high cost of the equipment (table 8).

Concerning the social indicators (table 6), the considered improvements are out relative the possibility of the adults' professional education of the schedule of work. With the energy installed in a community center, it is at night possible the people's professionalization. There is still the possibility of storage of medicines facilitating the service to the local health, among other improvements. On the other hand, the community energy would allow the installation of collective equipment for cooling of the milk, what would mean an increase of at least 10% in the received price and consequently increase of the community's PIB.

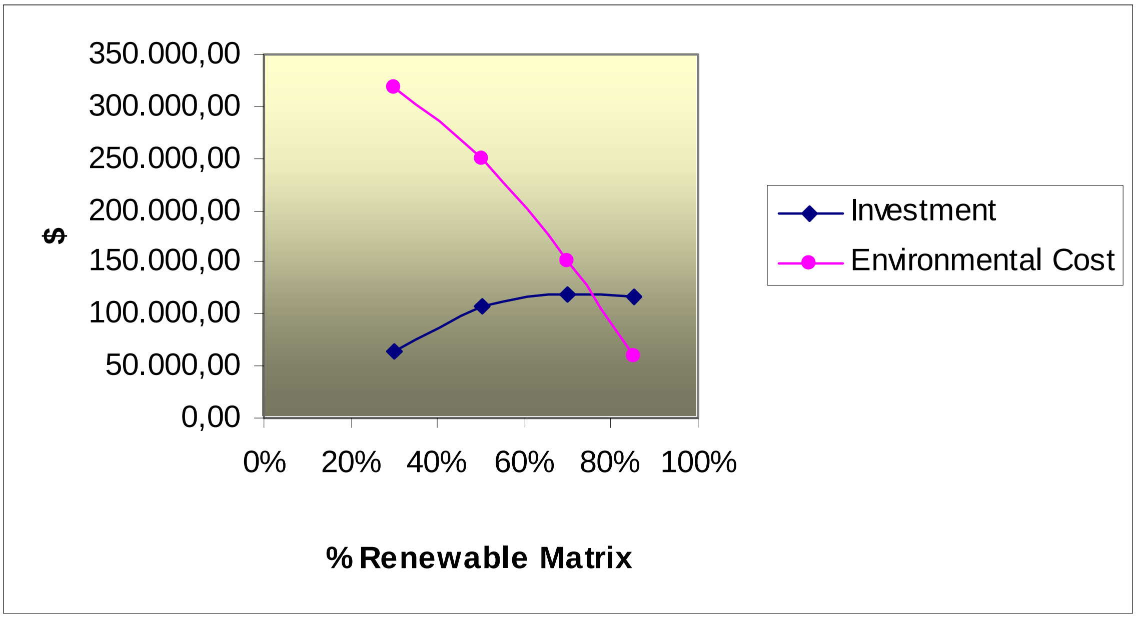

Figure 2. Cost Environmental x Investment: Great point

Table 5. environmental Indicators

		Cases				
Simb	**Indicators**	**1º**	**2º**	**3º**	**4º**	**unit**
IA1	**Use of the Fuel**	34360,2504	24543,036	14725,8216	7362,9108	l
IA2	**Use of Aluminum**	23099,328	34648,992	57748,32	80847,648	kg
IA3	**Emissions of CO2**	10,59360848	8,23475002	5,5863479	3,45527448	kg
IA4	**Emissions of SO2**	0,010876358	0,008874066	0,006261356	0,003996613	kg
IA5	**Emissions of NOx**	0,032290781	0,024481369	0,01636922	0,010133739	kg

Table 6. social Indicators

		Without energy		With energy	
Simb.	Indicators	Value of Is (stipulated)	Valor dos Is (calculado/normalized)	Value of Is (stipulated)	Value of Is (calc/normalized)
Is1	**Primary Education**	26	1	26	1
Is2	**Professional Education**	0	0	5	0,714285714
Is3	**Illiteracy**	46	0,233333333	35	0,416666667
Is4	**Bathroom Existence**	19	0,678571429	19	0,678571429
Is5	**Sanitary Existence**	16	0,571428571	16	0,571428571
Is6	**Service to the Health**	0	0	1	1
Is7	**Basic sanitation (sewage)**	15	0,535714286	15	0,535714286
Is8	**Life expectation**	60	0,25	60	0,25
		Value of Ind. of Social Sust.		**Value of Ind. of Social Sust.**	
		0,45		0,69	

Table 7. economical Indicators

		Cases				
	Economic Indicators	**1º**	**2º**	**3º**	**4º**	**Unit**
IE1	**Investment**	$65.088,05	$106.718,70	$119.000,00	$115.884,94	$
IE2	**Operacional Cost**	$31.555,06	$45.368,36	$46.509,47	$41.029,20	$
IE3	**Variation of PIB**	10	10	10	10	%

Table 8. Cost economical and environmental

	Cost (EcoEnv)/kWh ($/kWh)				Cost (EcoEnv) TOTAL ($)			
	Cases				Cases			
	1º	**2º**	**3º**	**4º**	**1º**	**2º**	**3º**	**4º**
Solar	4,9	4,9	4,9	4,9	61.444,69	122.893,76	122.893,76	92.167,04
Wind	0,18	0,18	0,19	0,19	4.264,07	6.355,36	10.700,92	14.964,99
Generator	3,92	3,92	3,94	3,98	316.671,96	226.573,40	136.474,84	68.896,11
				Total	382.380,72	355.822,52	270.069,52	176.028,14

5. Conclusion

That community's study made possible a larger understanding of the important factors for the analysis of the local sustainability of the energy point of view. Considerations of local characteristics as well as vocations for certain products are relevant points when it is to get better and to adapt the productive system. Still associate the those ideas and aiming at to insert a local energetic matrix, the challenge becomes still larger, because the demand of energy is always growing and like this demanding enlargement of the energetic plant.

Although the methodology still needs alterations to turn her more he/she needs, their results are satisfactory when it is determining the hybrid head office to be installed. Some relative improvements at the cost of the pollutant ones emitted, temporary considerations in if treating of the useful life of the equipments and the need of the change of components after that time should be treated in a dynamic analysis of that nature.

For that case study, the improvement for the community is evident, the local government's help, incentives the production and specialized agents' community aid can bring better results of the indicators and like this to improve the quality of their residents' life.

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