Assessing the impact of energization in the Colombian Southwest: a case of application using SD

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Abstract— **This paper focuses on the problem of rural energization in isolated regions of Colombia (Not interconnected zones – NIS). Using the Sustainable Livelihood approach we assess the situation of isolated communities before and after energization. Systems dynamics is used for simulating and evaluating energy policies. We apply our approach to the municipality of Jambaló in the Cauca Department, Colombia.**

***Key words*—Systems Dynamics, rural energization, sustainable Livelihoods, Poverty.**

I. INTRODUCTION

Energization seeks to support the domestic, commercial and productive activities of communities. The purpose is the appropriate improvement of life conditions, in a compatible way with the preservation of the environment. In consequence, energization is considered as a strategic component within a wider framework of development (Dyner et al, 2005; DPN, 1999).

Approximately two billion people worldwide lack of electricity services. In Colombia this reaches 1.14 Million inhabitants (IPSE, 2004) and the great majority are located in isolated regions. Approximately 4% of Colombian population is not connected to the grid although they occupy 66% of the national territory. The Not Interconnected Zones (NIZ) are defined (Law 143, 1994; Law 855, 2003) as those that have no access to electricity services through the national interconnected electric system (SIN) whose interconnection is not generally financially viable, because of economies of scale (Orange tree L & Boatman S, 2005, Narváez, 2004).

Energy services in these zones are characterized by low coverage (34% of the population), reduced number of hours of service (8 hours on the average), poor service (quality and reliability), high technical losses, high prices, defaults in payments and customers with very low income (ZAPATA, 2001). It is considered that the installed capacity is approximately 102 MW - 97.2 MW with conventional autonomous generation (mainly diesel plants), 4.7 MW small hydroelectric plants and a nearly 100 kW of photovoltaic (IPSE, 2004).

The energization problem has been approached unsystemically with respect to the selection and implementation of energy alternatives and the allocation of resources at the national and local levels. The corresponding analysis for assessing the effect of policy design does not systemically incorporate the financial, political and environmental dimensions (Alfstad 2004ayb; Tellam, 2004; Landaveri & Sbroiavacca, 2004). It does not either include the social, physical and natural features that are also present in these isolated regions (Bedoya et to the, 1994; Smith & Mesa, 1996; Smith & Pulgarin, 2002; Santos & Linares 2003). This problem has been usually studied without considering approaches of equity, effectiveness, relevancy, and viability, in the allocation of resources (Narváez, 2004). Methodologically there is absence of simulations tools that allow foreseeing the future impact of actual decisions, on the sustainable development of NIZ, before the implementation of a plan for national energization.

This paper describes an SD simulation model that integrates the philosophy of the livelihood capital assets for measuring the state of the communities and the renewable energy sources as alternatives for electricity supply in a NIZ of the Colombian Southwest, for the purpose of supporting energy policy.

The paper initially presents a literature review for rural energization, it then introduces our approach. We follow with a description of the application case for the Colombian Southwest. We show simulation results for this case and finally present our conclusions.

II. LITERATURE REVIEW

The problem of rural energization has been mainly studied in Colombia by the Energy and Mining Planning Unit (UPME) and the Institute of Planning and Promotion of Energy Solutions (IPSE), both dependencies of the Ministry of Mines and Energy. Also, this problem has been studies by the Universidad National of Colombia and Universidad de los Andes.

UPME contracted consultants for designing a structural, institutional and financial plan for the supply of energy to the NIZ, with the participation of the communities and the private sector (HAGLER BAILLY & AENE CONSULTANCY, 2001a, UPME 1999, 2000, 2001, García, 1997). This consultancy also included the characterization of energy demand, the classification of populated centres and the cost estimations for energy supply; as well as the development of a geo-referenced information system.

IPSE designed a methodology for the formulation, evaluation and prioritization of projects of energy solutions for the NIZ (IPSE, 2001).

The Energy Institute of the National University of Colombia in Medellin has developed planning tools and methodologies for rural energization regarding the problems of power expansion, considering multiple objectives and genetic algorithms (Bedoya et to the, 1994; Smith & Mesa, 1996; Smith & Pulgarin, 2002).

The University of the Andes has carried out research related to water services and energy supply in isolated and rural regions, considering the sustainability of solutions and focusing on productivity improvements and the population's welfare (Chain et al, 2003).

Also, the University Pontificia de Comillas in Madrid - Spain, developed decision support systems for rural electrification in development countries (Santos & Linares, 2003).

However, all previous research has not addressed the overall impact of energisation over the communities, as their focused has been on financial, political and environmental aspects of development, leaving aside the natural, human, economic and social dimensions.

With regard to this, the National University of Colombia has been working since September 2002 in association with the Imperial Collage London, on a research project “Renewable Energy for Sustainable Livelihoods” (RESURL) that aims to identify, measure and evaluate the factors that contribute or hinder the efficient energy developments in remote rural zones, using a participative and multidisciplinary perspective (Resurl, 2005).

Within this framework, Dyner et al (2005) developed an SD model that accounts for the contribution of energy to the sustainability of rural livelihoods in a global generalised-way. That research however does not address particular interconnected zones.

Experts have frame the importance of new policies for a sustainable energy future (Elkins, 2004; Gross, 2004, Mitchell & Connor, 2004), where the sources of renewable energy, human behaviour, economic costs, social acceptance, infrastructure, security and mainly, incentives for clean generation of electricity and development of the communities, will play an important role in the near future.

The model presented ahead is based on the research conducted by Dyner et al (2005) that undertakes systemically the multidimensional problem of rural energization and its effect on development. Here, we further develop the model proposed by Dyner et al (2005) and include an application.

III. Sustainable livelihood approach

We now present the framework that has been used for the problem of policy assessment for the energization of NIZs.

The concept Sustainable Livelihood (SL) was proposed in the report of the Advisory Group of the World Commission on Environment and Development (WCED), based on policies for development that link poverty and environmental degradation (DIFID, 2005).

SL is a way to think about goals, possibilities and priorities for development, aiming to accelerate poverty eradication. SL responds two fundamental questions: What institutional mechanisms do they allow some poor people to achieve a Sustainable and sure Livelihoods when others fail? And, how policies and strategies help to support people that live in the poverty? (DIFID, 2005).

The added value of this concept and methodology is that it is focused on the reduction of poverty in a sustainable way, since it seeks to build links between the macropolicies and the microreality, starting from an integral focus of the environmental, social and economic topics, with the aim of attaining medium and long term sustainability.

The Rural Sustainable Livelihoods Advisory Committee (SRLAC), with the support of the Institute of Development Studies (IDS) elaborated a well-known tool as the Framework of the Sustainable Livelihoods.

This framework includes a number of elements: Context of Vulnerability, Assets or capitals, Structures and transformation processes, Strategies as regards Livelihoods and Achievements as regards Livelihoods. This paper focuses on assets or capitals to carry out a measure of the current and future state of the development of communities before and after an energization plan.

Descriptions of capitals are next:

Human capital represents knowledge, employment, skills and health.

Social capital refers to social networks, political and civilian organisations.

Natural capital considers land, forest, sea, water, air quality, biodiversity.

Physical capital includes land, forest, sea, water, air quality, biodiversity.

Financial capital consists of money for consumption and production, savings, assets, loans.

A high value for a capital (near 20) means that the community performs well regarding this asset. This is illustrated in Figure 1 (DIFID, 2005; Henao, 2005).

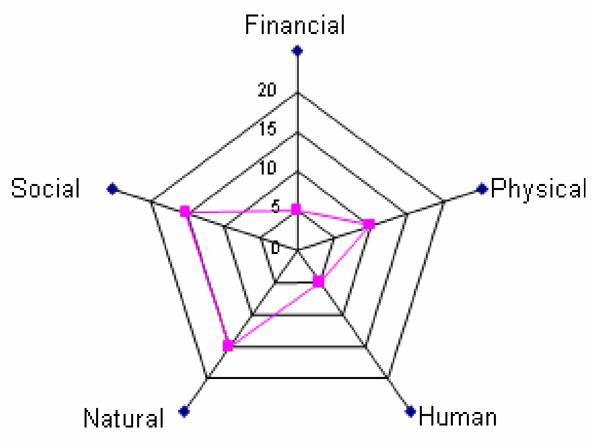

Figure 1. Pentagon of capitals

IV. MODEL

In this section the conceptualization of the problem is presented by using causal diagrams that show the most relevant variables that intervene in the evaluation of policies for rural energization.

The following diagram describes the main relationships between energy demand, energy supply and their effect on development and the environment (Dyner et to the, 2005; DPN, 1999). As can be appreciated energy supply contributes to the development of communities but at the same time damages the environment (contributing negatively to development).

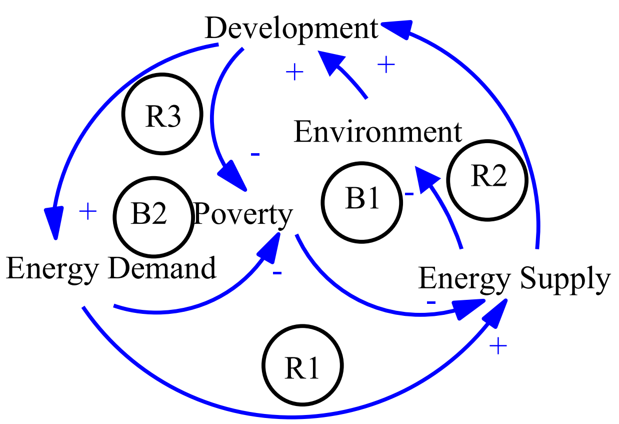

Figure 2 Causal Diagram of the problem of not interconnected isolated rural communities

R1 is a reinforcing cycle of energy supply, (development and energy demand): Energy plays an important role on human well-being (WORLD BANK, 1996, 2003a, 2003b; Alley, 2003; UNDP, 2003). Our dynamic hypothesis is: to more development, more energy demand.

Reinforcing cycle R2 (develop, poverty, energy supply). However, the environment imposes a limit for development - Balance cycles (B1) (develop, poverty, energy offer, environmental conditions) and B2 (develop, energy demand, energy supply, environmental conditions).

Resources for the energization of the NIZ are (HAGLER BAILLY & AENE CONSULTANCY, 2001b):

1. Resources to Support to the NIZ. FAZNI with a budged of US$ 70 million (Flores, 2005).
2. National Fund of Bonuses for projects of rural coverage. FNR.
3. Resources to Support to Rural Energization. FAER.
4. FOES. Resources for social energy.
5. Resources of international cooperation, ONG`s, among others.

Next a dynamic hypothesis is presented on the process of energization (Figure 3).

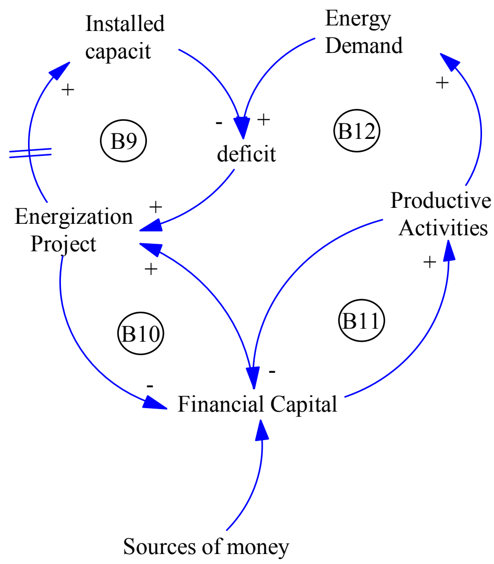

Figure 3 Abstraction of the energization process

Figure 3 shows that energy supply (installed capacity) aims to satisfy demand (electricity consumption) under the archetype of search for a goal (Sterman, 2000), where delays in formulation, evaluation and execution of the energization projects produce an oscillatory behaviour, creating a bouncing balance between demand and supply, and between the financial capital and productive activities. Figure 4 shows the corresponding stocks and flows diagram.

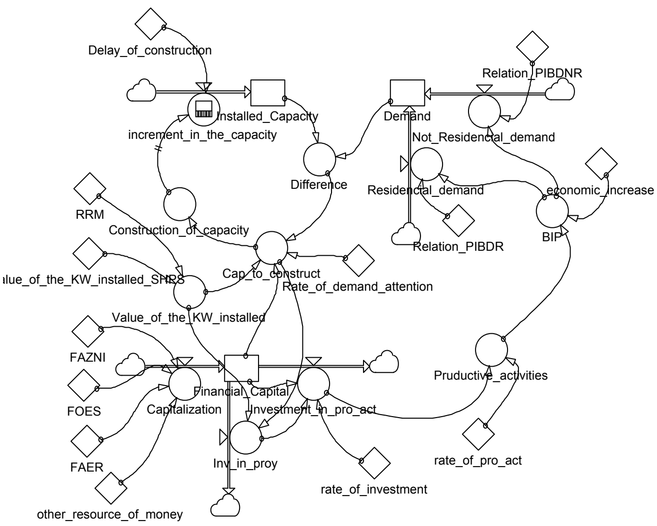

Figure 4. Part of the flow chart and levels of the process of Energization. (Supply - demand)

V. APPLICATION CASE

A NIZ of the Colombian Southwest was selected for this case of application. This is integrated by the rural community of Baendilla, La Esperanza, La Marqueza and Loma Larga in the Municipality of Jambaló, Cauca department, and zone of the aborigine Páez community, which includes 370 inhabitants (RESURL II, 2004, DAMAGE 2006)

Although the department of the Cauca is interconnected with lines of 115 kV to the National Interconnected System, and its entire municipal heads, including Janbaló, possess circuits for electricity distribution at 34.5 kV, 13.2 kV and 7.6 kV, these communities (Baendilla, La Esperanza, La Marqueza and Loma Larga) lack of electricity services and sewerage systems.

Next we indicate the assessment that has been undertaken for the determination of the community's capitals and assets associated to the Sustainable Livelihoods framework, previously discussed. Interviews were conducted and questioners were run for these purposes.

HUMAN CAPITAL

The educational level is low: around 36% are illiterate, 61% attended elementary education and 3% high school.

More than 90% of those interviewed consider very important the access to education.

Regarding health, nearly 60% of those interviewed lack access to this service and around 75% of those perceive that the service is unsatisfactory.

SOCIAL CAPITAL

Many Town councils of Cauca are organized as associations. Associations are public entities of special character that are accountable to the State and the community for the resources that manage. This is the case of the Association of Indigenous Town councils of the north of the Cauca, ACIN. (ACIN, 2003)

Community activities have been carried out and some projects have been executed. Some successful projects are: homes for the care of children, vaccination and environmental programs. The projects related with energy and aqueduct have failed.

The main activities carried out in community are water collection, cultivation, construction of housings and roads. Additionally other organized activities are carried out in the community as the vaccination and the minga (expression of Quechua origin that designates a form of collective work).

All the leaders interviewed say that the women participate in the community decisions and they consider that it is important the participation of them in the decisions making.

NATURAL CAPITAL

Land ownership constitutes a patrimonial asset and not a production asset as they are exploited deficiently. Land that should be devoted to the agricultural production is used for extensive cattle rising, affecting production levels (DNP, 2003c).

The indigenous community develops programs of lands recovery that have been deforested for the commercialization of wood; and also protect the environment and water sources, as well as aims to reconstruct harvesting traditions (Díaz, 2003).

This region possesses some forest extensions which are rich in water resources. For this reason the community has plans for conservation, protection and recovery of natural resources (Díaz, 2003).

According to the national statistical administrative department (DANE, 2006) this region presents winds with speed average of 2 m/s at 10 m of height and a level of solar radiation around the 4.0 kW/m2 during 6 hours a day.

As for agricultural production: bananas (85.7%), for self-consumption; corn (68.3%), of these, 60% are sold inside the community and the rest for self-consumption. More than 65.1% of cultivate frijol and yucca, are in general for self-consumption; 58.8% sugar cane, of these, a third is sold inside the community and the rest is for self-consumption.

More than half of cultivated fruits and medicinal plants are for self-consumption, 36.51% vegetables for self-consumption; and 20% cultivates potatoes, also for self-consumption. In all the cases the productions are inferior to 5 sacks for crop.

PHYSICAL CAPITAL

Infrastructure construction has been undertaken but due to inconveniences such as budget limitations, lack of technical skills, climatic conditions, most works have not been concluded (DNP, 2003a).

In the department of the Cauca the main communication road is the Pan-American Highway that crosses municipal heads. However, most of the territory is isolated as it is located in the high mountains or deep depressions.

As for sewerage system, none of the interviewees have access to this service. More than 90% of those interviewed believed that it is very necessary to have access to this service.

The municipality of Jámbalo has in their urban zone a hospital. The rural zones lack medical services and the first aids scarcely are given in the schools. The indigenous communities rarely use hospital services, as they prefer to use their traditional medicine (Díaz, 2003).

In Jambaló the families with own housing is 70%, 10% live at leased homes, 10% in houses of the family and other 10% at homes of the community. The housings of two rooms prevail (63%), although 23% has between 3 and 5 rooms. The floor is in soil (80%) and in cement (19%); 63% of the houses have walls of bahareque, while 27% are made of brick or concrete. The roof is of eternit (33%), zinc (25%), tiles of mud (25%) or straw (9%); 49.2% of the interviewees says to be neither very satisfied nor very unsatisfied with its housing and 40.7% say to be unsatisfied.

Near half of those interviewed have radio-sets, 97.4% of these use batteries for their operation; less than 10% possesses lamps or bulbs, irons, televisions but none of the interviewees in this municipality has a refrigerator or a telephone.

Interviewed people consider that the most important services are energy and drinkable water, followed by health and sewerage systems and lastly, and with a very low grade of importance, education.

FINANCIAL CAPITAL

The interviewed families conduct agricultural activities. There is some commercial activity; the necessary food is cultivated for the family and the rest of the land is not used.

The commercial products are coffee and fique, for other products are frijol, corn, yucca, banana etc., and the surpluses are exchanged. All these products have unstable prices and they are not well paid for the merchants; the natives take their agricultural products and smaller species, to the municipal, very few take their products to the big cities (Díaz, 2003).

Near 90% of the interviewees do not have credit; they lack accesses to banks or cooperative. All the interviewees say that they require energy for some activities. The main use would be illumination (98.4%), followed by radio (66.7%), television (47.6%), education (33%) and health (33%). Less than 10% require energy for cooking and the demand for other uses is inferior to 3%.

Note that 92.1% of the interviewees use candles for the illumination, spending around $2 USD a month for this concept; 98.4% uses firewood to cook.

The third part of those interviewed agrees with using the river to produce electricity, because they consider that it would bring benefits to the community. Those that oppose say that the river would be contaminated, and it is their main water source.

Regarding the cost of power-infrastructure acquisition, maintenance and repair, around 90% of the interviewees believe that the government should pay the costs associated to the energy infrastructure; 46% believe that the users should pay for the energy consumption, 30% believes that it should be paid by the Government, and 17% that should be shared between the Government and the users.

VI. MODEL RESULTS

Based on the above, the initial community capitals are established. A simulation is conducted to determine the evolution of these capitals if a small hydroelectric plant of 40 kW is installed. Figure 4 shows the initial and final states of capitals after 25 years.

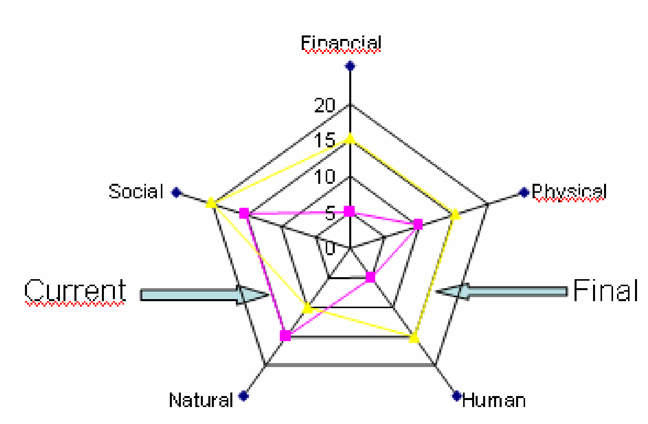

Figure 4. Current and Final Pentagon of capitals for Janbaló.

Figure shows the evolution of some of the modelled variables. The installed power capacity is sufficient for the first 17 years.

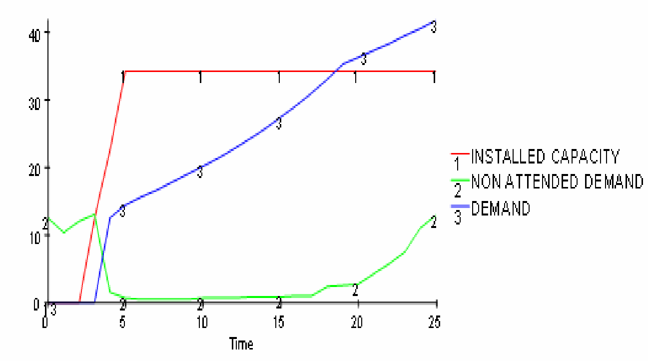

Figure 5. Supply and demand of Energy.

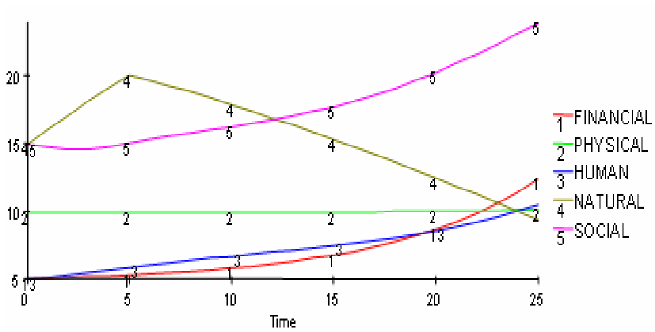

Figure 6. Capitals Evolution

Figure 6 show a simulation of the evolution of the community's assets that can be helpful for policy assessment, before implementation of solutions.

VII. CONCLUSIONS

The integration of livelihood capitals and systems dynamics proves to be an adequate framework for evaluating energy policies.

Energization has significant impacts on the community.

Energization should convey with other development programs in order to be sustainable.

It is required that the energization process consider developing human capabilities to operate, and maintain the corresponding technology.

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