REGIONAL ENERGY PLANNING

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ABSTRACT

The general objective of this paper is to present a method for integral regional energy planning within the frame of national policies on energy and economic development.

A historical database and energy balances of supply and demand allow to analyze and model the dynamics of the sector, and its interaction with other economic sectors and social and technological variables.

This paper contributes to understand how to mix econometric and system dynamics technics. Whenever data is abundant and reliable, statistical analysis and modelling could be useful to reproduce historical behavior, but in order to study possible future scenarios it is required to set hypotheses on parameters evolution, probably based on system dynamics methods.

On the other hand, in order to model interactions among demand, supply, prices and other economic variables, system dynamics is particularly suitable. In this context, technics that seem to be confronted appear to be as each one complementing the other.

The model was implemented by the Departamento of Antioquia in Colombia, which possesses a considerable amount of energy resources, particularly hydroelectricity. Specific methodological aspects for planning energy resources were considered to analyze the feasibility to introduce new elements such as gas.

Recommendations on policy considered integral development of different regional energy resources in accordance with supply potentials, requirements and economic efficiency.

1. INTRODUCTION

The problem related to integral energy planning has troubled the entire world since the mid seventies, mainly due to the oil crisis.

In Colombia in 1982, the Ministry of Mines and Energy produced the National Energy Study (Mejía et al 1982) in which the first thorough synopsis of the national energy situation was presented. This technical report was based on several factors such as: the supply of different energy resources, the demand structure and its determinants, balances between supply and demand, and relationships between the energy sector and many other economic sectors.

One primary aspect in the Study, which has exhibited many great improvements in the last few years, has been the construction of models to forecast the future levels of demand in accordance with the type of energy and the corresponding sector in which it is consumed. Nevertheless, the models used have led to great excesses in the installed capacity of the electricity subsector, causing dangerous consequences to the payment capacity of the external debt and even to the Country macroeconomic balance. This, and other problems are mainly due to the following facts:

Estimated parameters are held constant during large historic periods, supported on arguments that the situation should not vary fundamentally in the future.

In the majority of cases only short time series were available for economic variables, creating great unstabilities in the estimated parameters, from a statistical standpoint.

Although models are complex and take into account large number of variables, they are not integrated in a systemic form as to be able to represent a dynamic economy.

Finally, models do not consider some important interactions between the supply and demand of different energy resources.

2. REGIONAL ENERGY STUDIES IN COLOMBIA

In spite of the fact that the Colombian energy sector has been predominantly developed through government monopoly and that the decision making is heavily centralized, there is a regional concern for regaining a relative control in energy management.

One example of the question mentioned above is presented in the Antioquia Energy Study (Valencia et al 1989), in which, following the scheme presented in the National Energy Study, the former approaches such themes as the balance between regional supply and demand. and relationships between costs and prices from a regional standpoint.

The importance of the Departamento of Antioquia is recognized throughout the Country, given that its installed electricity capacity amounts to 30% of the national level and that it produces 8% of Colombian oil. Also, Antioquia possesses abundant coal fields, with potentials not yet completely established, but which have been exploited for many decades. These resources, and their comparative cost advantages, stimulated investments and creation of new factories, which led to industrial development and economic growth in the region.

Information limitations and the need to evaluate regional policies on prices and energy supply, led to revise the models presented in the Antioquia Energy Study. System Dynamics was then used to complement the econometric technics previously used, offering a global view point on energy supply and demand within a regional scope. Additionally, it was used as a simulation tool allowing a clear observation of feedback and delay effects on the system, which permitted to analyze possible policy changes on prices and energy supply, as well as variations on parameters and exogenous variables.

In order to accomplish the desired effects, besides the econometric technics used to estimate historical price elasticity coefficients of demand, models were implemented in Professional DYNAMO with appropriate feedback loops of supply and demand as in Managing the Energy Transition (Naill 1979). The elasticity functions maybe easily incorporated to the model.

As an example of this technic to explore different demand scenarios, with changing policies on prices and supply, this paper presents the case of a possible replacement program of electricity by gas within the Metropolitan Area of Medellín (departamental capital of Antioquia and second largest city of Colombia, in terms of population and economic activity).

3. REPLACEMENT OF ELECTRICITY BY NATURAL GAS

In the future, the increment on electricity prices may contribute to the competitiveness of other energy resources because of the possibility to use energy substitutes at lower costs or because of planning strategies on energy supply.

The exploited natural gas, as well as those fields expected to be discovered in association with oil exploration programs, constitute in principle a relative economic resource and one more appropriate for house cooking. The benefits gained by switching to natural gas, at least in the residential sector, can materialize in an energy bill reduction to costumers, as well as in a slower expansion of the electricity system, contributing to alleviate the financial burden of the companies in charge of electricity generation and distribution.

The feasibility of constructing a major gas pipe depends on a better knowledge of real natural gas reserves. The utility of the project is also based on reasonable transportation and distribution costs that each user would need to assume, and the opportunity costs for not using natural gas in other profit making alternatives, such as its transformation into products in the petrochemical industries.

As a final aim in studying an alternative program to replace electricity by natural gas in residential use, this paper presents results of simulation exercises performed in order to quantify possible economic effects in terms of: energy cost savings; gas volume required to meet demands, assuming policies on the amount of gas made available to different social strata; and the amount of energy which would be substituted.

This model includes desaggregated variables related to the residential consumption in each of the six social levels in which the population is classified, as well as the potential natural gas substitution in each strata, and the differential increments in electricity price per level. The assumed gas prices were increased considerably with respect to the ones actually applied in Bogotá, Colombia.

The basic scheme of the simulation model is represented in Figure 1. By using information on electricity installations, as well as global residential consumption and its distribution by social levels, it is possible to estimate the average monthly consumption per costumer, as follows:

$$EC/(POP * EI) = a * (GRP/EAP)^{b} * P^{c}.$$

Where,

EC:	**Electricity Household Consumption**
POP:	**Persons per installation**
EI:	**Number of electricity Installations**
GRP:	**Gross Regional Product**
EAP:	**Economically Active Population**
P:	**Electricity Price**
a, b, and c:	**Parameters**

The next step is to determine the monthly cost of electricity per costumer. The substitution alternative is now considered using information of potential electricity that may be substituted.

Using appropriate conversion factors, the equivalent of natural gas needed for substitution is calculated and its corresponding price determined. To evaluate the monthly bill for natural gas, that value is added to the installation charges, which are distributed during a period of fifteen years. The cost of electricity not substituted is now valued depending on the amount consumed. The total average energy bill per user level is then obtained by adding the previous partial costs.

The comparison between the electricity consumption cost alone and that constituted by combining electricity and gas, permits to evaluate the incentive magnitude for a costumer to participate in a substitution program.

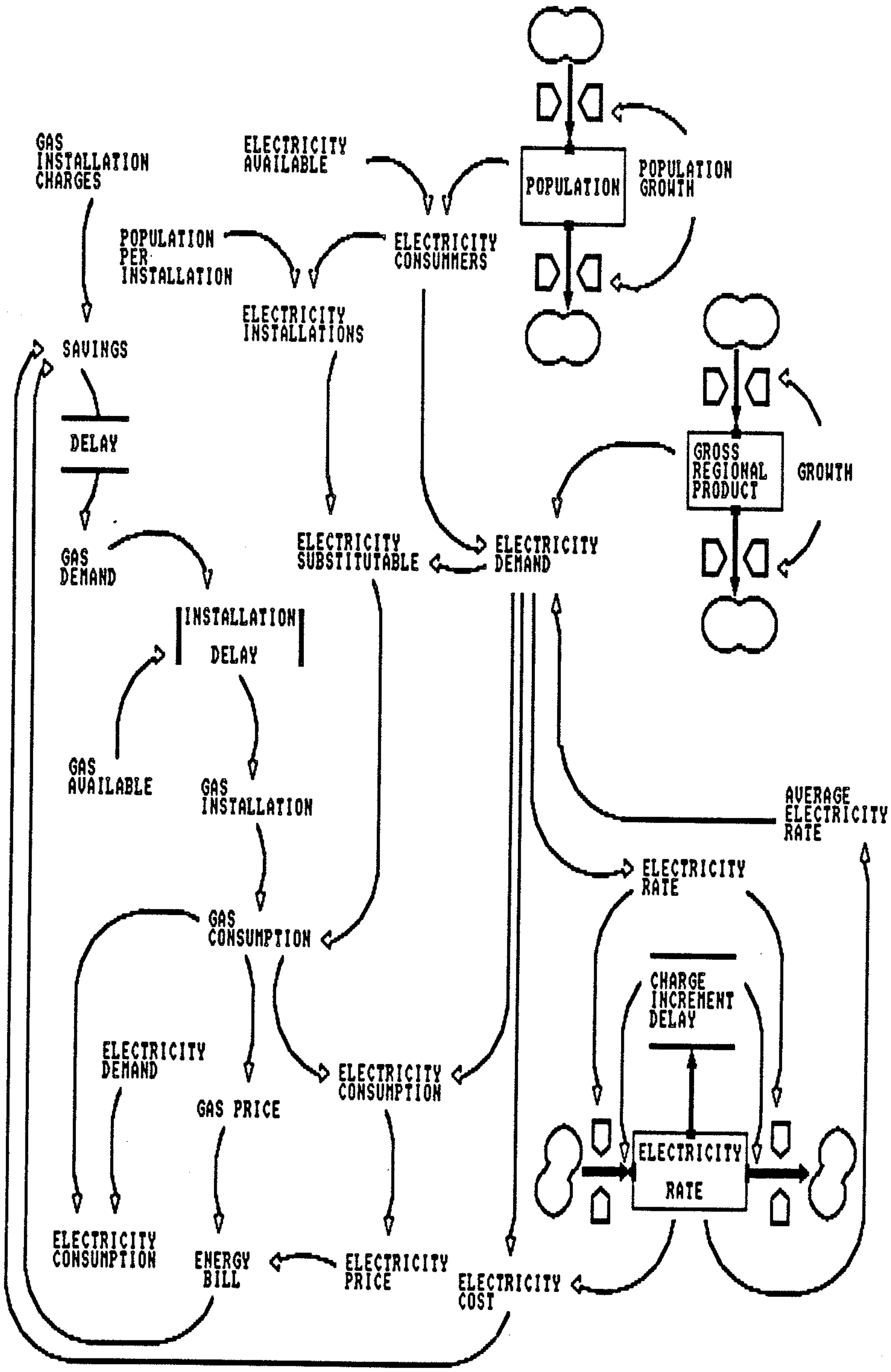

FIGURE 1. CAUSE-EFFECT DIAGRAM OF ELECTRICITY REPLACEMENT BY GAS

Finally, under the assumption of policies for the gas program, it is possible to obtain the magnitude of energy resources required to satisfy the residential sector demand.

Figure 2 shows the results obtained in terms of percentages of energy costs savings per sector of the residential community. These are only observed starting some years ahead, wherein it is assumed that the substitution program will begin.

These results indicate that, under the set conditions, the main beneficiaries of such substitution would be those in the lower social levels.

Figure 3 shows important dynamic changes in electricity and gas consumption during the simulation period. under the hypothesis of gas availability to customers. First, making it available to the poorer sectors of the community, and later, satisfying progressively other sectors.

Table 1, in turn, presents the results in terms of the amount of electricity substituted, which could represent up to 48% of the consumption forecasted in the case of a non-existent substitution program. The magnitude gas demand, which by the end of the simulation is expected to reach 13.9 millions of cubic feet daily (5070.7 millions of cubic feet per year), is relatively modest.

YEAR	1991	1995	2000	2005
ELECTRICITY CONSUMPTION(GWH/YEAR)	1820.4	1332.0	1352.4	1634.4
ELECTRICITY SAVINGS(GWH/YEAR)	255.1	955.3	1267.2	1380.0
GAS CONSUMPTION(MMCF/YEAR)	937.5	3510.8	4659.2	5070.7
SUBSTITUTION PERCENTAGE	12.3	41.8	48.4	45.8

TABLE 1. SIMULATION RESULTS. MMCF: Millions of Cubic Feet.

4. CONCLUSIONS

The simulation results seem to indicate, in principle, the convenience of the substitution program, mainly for the lower income sectors. This program would not only provide great benefits to consumers, but also a considerable reduction in demand for electricity.

Given the fact that other Colombian cities have gas available for household consumption, as well as for industrial use, the Medellín case becomes especially important because its energy competitive advantage could disappear.

In the following issues, the System Dynamics model might become a fundamental tool in the decision making process of a replacement program of electricity by gas:

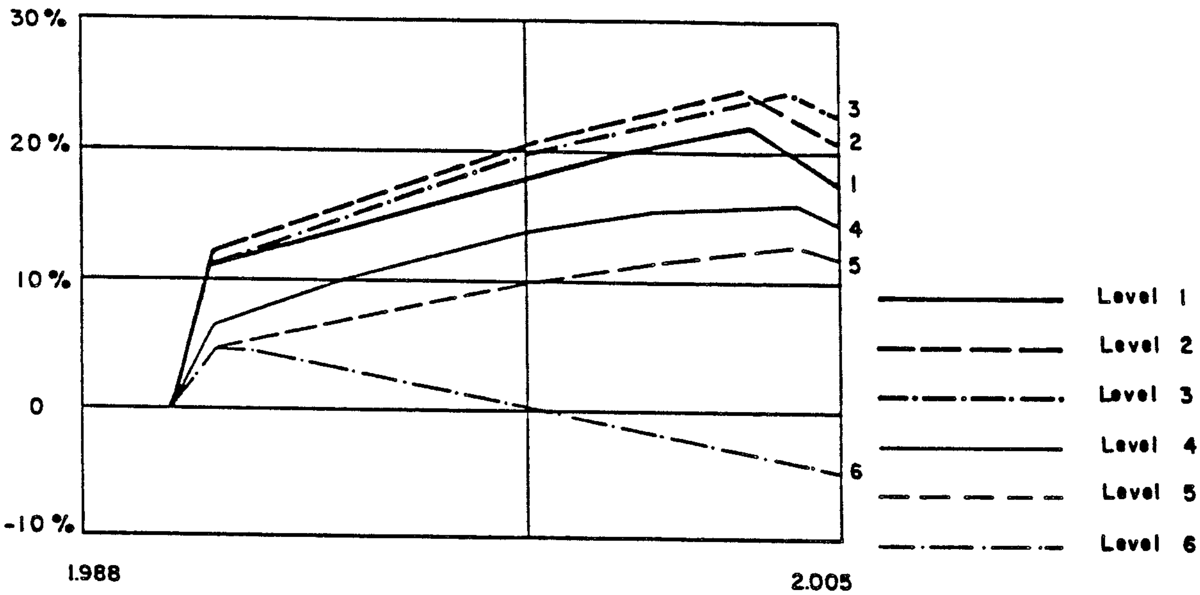

FIGURE 2. PERCENTAGE ENERGY SAVINGS

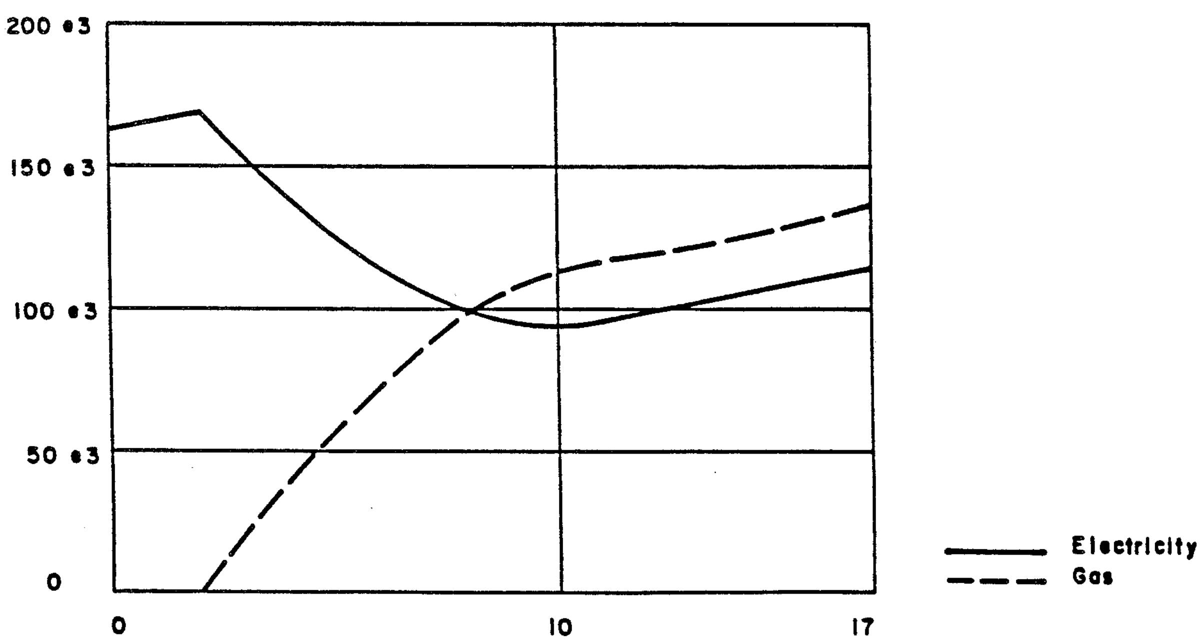

FIGURE 3. ELECTRICITY AND GAS CONSUMPTION SCENARIO. Year 0 corresponds to 1988, and year 17 to 2005.

Aiding to design adequate policies on energy prices, making natural gas competitive with respect to electricity, in order to achieve savings to customers.

And, furthermore, helping to establish goals on gas availability in order not to affect drastically the electricity companies financial situation (due to the loss of a market portion).

5. ACKNOWLEDGEMENTS

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