International Institute for
Applied Systems Analysis
Schlossplatz 1
A-2361 Laxenburg, Austria

Tel: +43 2236 807 342
Fax: +43 2236 71313
E-mail: publications@iiasa.ac.at
Web: www.iiasa.ac.at

Interim Report **IR-04-009**

A Sustainable Policy Making - Energy System for Colombia

Juan Bernardo Moreno Cruz (be-moren@uniandes.edu.co)

Approved by

Joanne Linnerooth-Bayer
Project Leader, Risk, Modeling & Society Project

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Contents

Abstract

Using a systems approach, this article presents a brief description of the Colombian energy system and shows how a sustainable energy system could be obtained. Particular emphasis has been given to identifying all the stakeholders and the relations between them. This study used an international protocol proposed by the Initiative in Science and Technology for Sustainability (ISTS), which consists of a series of questions that guide the investigation in order to identify and to propose solutions of the problems related to the energy system.

Then, a control model is considered in order to control the decisions of the policy makers and the decisions makers in the energy sector. Using software that allows the inclusion of all the actors involved in the development of the power policy, this model redefines the relations between the actors.

This new system is a useful tool, cradled in the MARKAL family of models. The control system proposed will help to introduce more credibility in the resultant policies and in the model itself and the system outputs would be more sustainable ecologically and provide robust long term solutions.

After examining the Colombian Energy Policy Making System using the ISTS protocol we can identify some problems that should be solved in order to achieve a Sustainable Energy System.

Preface

The Initiative on Science and Technology for Sustainability (ISTS: http://sustainabilityscience.org) is an international, open-ended network with the goal of enhancing the contribution of knowledge to environmentally sustainable human development around the world. The Initiative was founded in late 2000 by an independent group of scholars and development practitioners gathered at the Friibergh Workshop on Sustainability Science. Since that time, it has worked to strengthen cooperation between two communities: practitioners involved in promoting human development and environmental conservation, and researchers involved in advancing science and technology relevant to sustainability.

One of the aims of ISTS is to "foster the next generation" of sustainability scientists. With this goal in mind, ISTS together with the Third World Academy of Sciences (TWAS) and IIASA, invited three young scientists from developing countries to participate in the IIASA Young Scientists Summer Program (YSSP) for three months in the summer of 2003. The competition for fellowships was very strong, with around 100 applicants for the few places that could be funded. The funding was provided from a grant from the Lucille and David Packard Foundation to ISTS.

The aim of this summer initiative was to help the young scientists expand their case studies on environmental issues to consider the issues of sustainable development. This was aided by a protocol developed by David Cash and Vanessa Timmer and others within the ISTS, which raised questions to guide case studies on harnessing science and technology for sustainable development. Obviously, in three short months, it was not possible to answer all of the questions raised in the case study protocol, but it was possible to tackle some of the questions in individual work and group discussions. The three IIASA Interim reports from Sharda Mahabir (Trinidad and Tobago), Juan Moreno Cruz (Colombia) and Riziki Shemdoe (Tanzania) demonstrate very well the progress that was achieved

In addition to presenting the results at the traditional mid-summer YSSP workshop, the ISTS/TWAS scholars also traveled to Trieste and presented and discussed their work at TWAS.

I would like to thank Diego Malpede, ISTS/TWAS Research Fellow, who provided untiring support during the application and selection process and for our visit to TWAS. Thanks also to Leen Hordijk and Joanne Bayer, IIASA, for their support in bring these scholars to IIASA and providing a learning experience for all of us.

Jill Jäger

Vienna, Austria

January 2004

About the Author

Juan Bernardo Moreno Cruz participated in the 2003 Young Scientists Summer Program (YSSP) at IIASA. He is a IIASA/TWAS/ISTS Scholar from the University de Los Andes, Bogota, Colombia.

A Sustainable Policy Making – Energy System for Colombia

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1. Introduction

To contribute to solutions of sustainability problems, the scientific community must find ways to ensure that knowledge is effectively communicated and translated for the policy community. In particularly controversial areas, mediation will also be necessary (Cash et al, 2003). The future of the world could be changed if the communication process improves substantially in the near future and thus enhances the linkage between knowledge and action.

The case study presented in this paper looks at the electricity sector of Colombia and the linkages between knowledge and action. Colombia's electricity sector relies heavily on hydropower, which depends on water availability that exhibits a huge variability in the equatorial region. Due to the prolonged electricity rationing in Colombia during 1992, the country began to install thermo-electric plants to provide more reliability to the generation system. According to current plans, thermal generation should reach 50% of the total installed capacity by 2010. The use of new and cleaner technologies to contribute to a reduction of the domination of hydropower is important but at the same time Colombia has to concentrate on technologies that will not increase emissions of greenhouse gases. Electricity generation technologies based on biomass, wind, small hydro plants and in general distributed generation technologies have become an interesting alley to be explored.

This report attempts to explain how the Colombian Energy Policy Making System can be improved, if all the stakeholders are involved in the definition of the energy policies. Using a simple control system that controls the decision and translates all the data for the stakeholders, the system could be more robust and more flexible because the introduction of new "relations" can improve the capacity of response of the system and make the right adjustments on time.

In the first part (Chapter 2) of the paper a definition of sustainability is introduced. The chapter also considers the question of the sustainability of the system as a whole.

The second part (Chapter 3) includes the description of the Colombian Energy Policy Making System and the explanation of the properties of this system from the point of view of a sustainable system. The third part (Chapter 4) explains the integrated system proposed for including the control system and all the relations between the stakeholders in this new integrated system.

2. A Working Definition of Sustainable Development

An important definition of Sustainable Development was given by the World Commission on Environment and Development in the report known as Brundtland Report. The definition of sustainable development was "meets the needs of the present without compromising the ability of future generations to meet their own needs"(WECD, 1987). On the basis of this general framework, a diverse set of definitions of sustainable development was made for different groups, which project their own goals in a more accurate definition for their own work. This section presents the definition of sustainability and sustainable development used during this research.

2.1 Definition of Sustainable Development

There are three important aspects that have to be considered, depending on what issues of sustainable development are being considered (Schrattenholzer et al, 2002).

I. The sustainability of the economic benefit from natural assets, that is the need to preserve the economic benefit of natural assets for current and future generations. In order to accomplish this first idea, there is a possibility of substitution between man-made assets and natural assets.

II. The maintenance of the physical properties of the environment; this is trying to keep the ecological properties of natural assets as high as possible.

III. The need for a non-declining utility; which includes "quality of life" in the widest sense, and "man-made" assets in the narrow sense. This idea includes interregional equity, reduction of poverty, and human capital in the definition of sustainable development.

2. 2 Quantification of Sustainable Development

In trying to convey the concept of Sustainable Development to policy makers, there is the need for quantification of the concept in order to make it operational.

There are many possible approaches but the definition used here is the definition of the paper "Targeting Technological Progress Towards Sustainable Development" (Schrattenholzer et al, 2002). They defined this quantification in a multi-criteria approach, that is, all the future scenarios that satisfy these criteria are called sustainable scenarios.

- Economic growth (GDP per capita) is sustained throughout the whole time horizon.

- Socio-economic inequity among regions is reduced over the 21st Century, which means that the per-capita income ratios between all world regions are reduced to ratios close to those prevailing between OECD countries today (interregional equity).

- The reserves to production ratios of exhaustible primary energy carriers do not decrease substantially from today's values (interregional equity).

• Long-term environmental stress is mitigated successfully. In particular, carbon emissions at the end of the 21st century are near or below today's emissions levels.

2.3 Sustainability of a System

In order to describe some general characteristics of the concept of sustainability, it is useful to take a systems approach.

Here an elemental definition of the system is taken (Figure 1), in which, the system is a set of interrelated elements or subsystems. In this definition, what the system does is not only the response to the interaction of the elements of the system and the interaction between them, but also the responses to the interactions with the elements of the environment (input variables). In response to this interaction, the system generates a set of variables that goes to the environment (output variables).

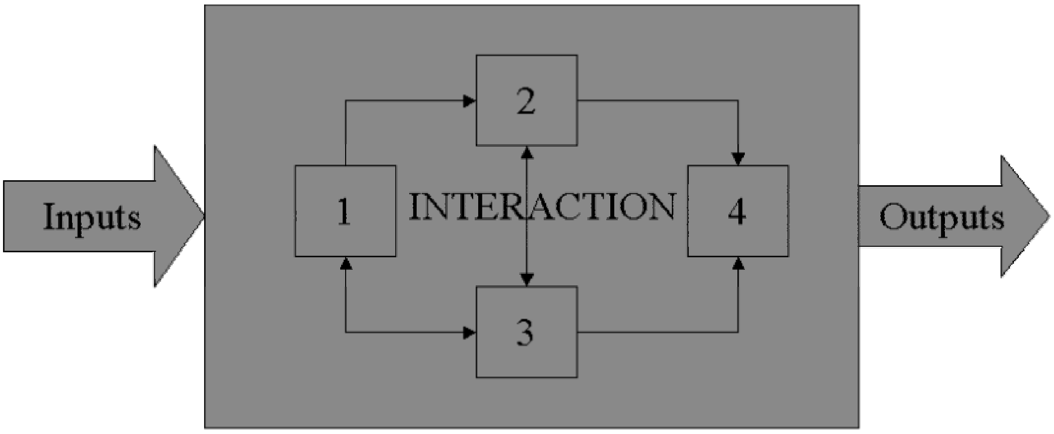

Figure 1: Definition of a System

2.4 Sustainability of the System and the Outputs of the System

When we talk about sustainable development, we are talking about change, sometimes we can refer to the change of the system, and in other cases, we are just talking about improving the system in order to change the outputs of the system.

In order to know if we are trying to change the system, or the outputs of the system, we have first to understand the difference between the sustainability of a system, and the sustainability of the outputs of the system.

Sometimes we are interested in the sustainability of the system itself (e.g. the maintenance of the reserves to production ratio); in this case, the output variables are the same as the state variables, i.e. we are interested in the sustainability of the system itself. When the output variables are different from the state variables, we are referring to the sustainability of the outputs of the system (e.g. the CO_2 emissions of the energy system) (Gallopin, 2003).

2.5 Properties of a Sustainable System

In order to identify whether a system is sustainable or not, this section introduces some of the different attributes that can define a sustainable system. It is known that each system is different and unique, but here some special characteristics are extracted that can be generic in a sustainable system.

The properties that we are going to use in the definition of sustainability are:

• Availability of Resources.

This is an obvious attribute, and it can include natural, financial and human resources like water, energy, money, assets and entitlements

• Adaptability and Flexibility (as opposed to Rigidity).

The system needs to be flexible in order to detect and understand the changes that are occurring outside the frontiers[1] of the system.

• General Homeostasis. Stability, Resilience and Robustness (as opposed to vulnerability, fragility).

This refers to the capacity of the system to maintain or preserve the values of essential variables around a given trajectory or state (stability), a given domain of attraction (resilience), or a given system structure (robustness).

• Capacity of response.

This refers to the capacity of a system to cope with change and the ability to switch strategies according to condition. Capacity of response is built upon adaptability and homeostasis. Two principal characteristics belong to the definition of this property, these are:

o Self-reliance (as opposed to dependency). This refers to the capacity of a system to regulate its interaction with its environment, in that way, the system has to exercise a control over its own interaction with the outside world.

o Empowerment. This attribute denotes the capacity of the system to innovate and induce change in other systems in order to achieve its own goals.

3. Colombian Policy Makers System

To identify the state of the Colombian Energy Policy Making System, this study followed the ISTS Protocol in order to find all the stakeholders and to identify the relations between them, and be able to analyze the characteristics of this system and to conclude if the system is a sustainable system or not.

3.1 Stakeholders in the System

The structure of the Colombian Energy Policy Making System includes several agents who have a specific function within the system and contribute to the operation of the energy sector that is quite complicated. This operation must be clear and

[1] Frontiers being understood as the limits of the system of study, this is usually called “the outside world”.

transparent to be able to maintain the activity that is fundamental for the Colombian economy.

Who are the Stakeholders? An analysis of the system results in the following list of actors:

- Ministry of Mines and Energy
- Energy and Mining Planning Unit
- Ministry of Environment
- Energy and Gas Regulatory Commission
- Public Services Supervisor
- National Council of Operation
- Decision Makers:
    - Energy Utilities
    - ISA (Colombian Electric Network Company.)
    - ECOPETROL (Colombian Oil Company)
    - ECOGAS (Colombian Gas Company)
    - Mining (COAL) Office
- Civil Society

3.2 Relations between Stakeholders

This section explains the relations between the actors within the system in order to get a good description of the system that can allow us to identify the characteristics of the system. The Colombian Energy Policy Makers System is shown in Figure 2:

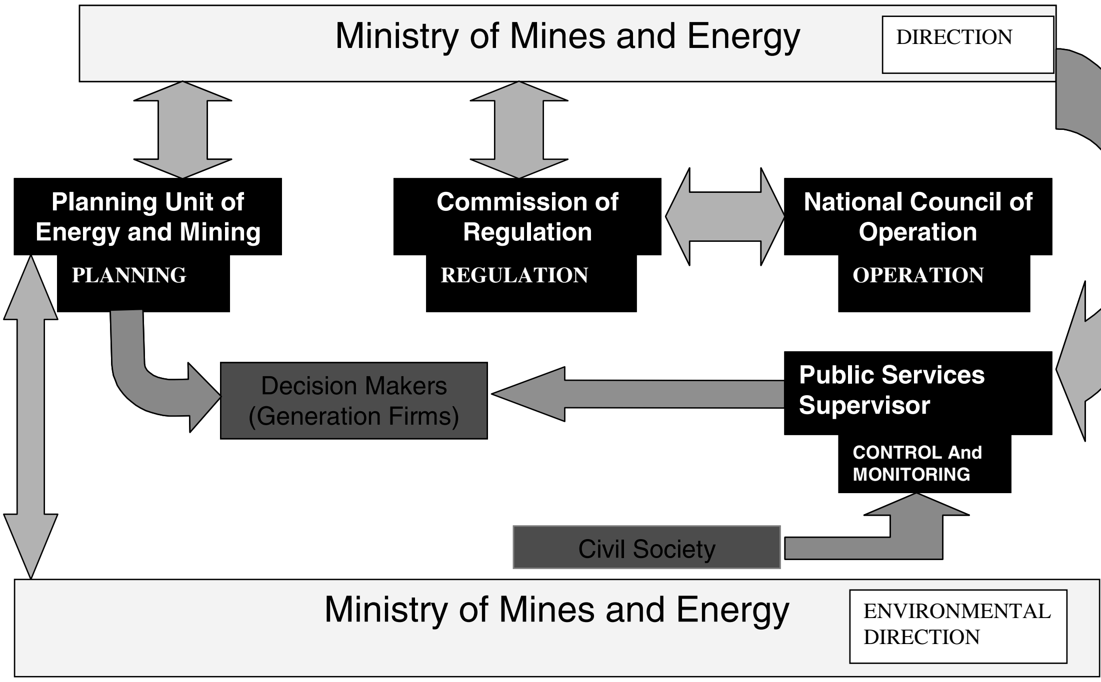

Figure 2 : Colombian Policy Makers System.

The Ministry of Mines and Energy must fulfill the following three functions:

Planning: The organization in charge of the planning is the Energy and Mining Planning Unit (UPME).

The UPME has to recommend policies and strategies for the development of the energy sector to the Ministry of Mines and Energy.

Regulation: The organization in charge of regulating the energy market is the Energy and Gas Regulatory Commission (CREG).

The CREG has to create the conditions to assure a reliable and efficient energy supply that is able to supply the demand under social, economic, environmental (this is a function of the Ministry of Environment) criteria and ensuring financial viability.

Coordination, control and monitoring of all the activities related to the national energy system: The organizations in charge of the supervision of the system are:

(1) Public Services Supervision whose functions are:

Control of efficiency and quality of the public service of electricity and the control, inspection and monitoring of the organizations that serve the public with electricity.

(2) National Council of Operation whose main function is to decide on the technical aspects to guarantee that the integrated operation of the national energy system is safe, reliable and economic, and to be the organization that implements the operation of the system.

(3) The energy policies are given to the companies of the private sector, who analyze the policy from the point of view of financial viability. If the project is not viable, the government must look for the resources so that the energy policy can be developed.

(4) These private sector companies are supervised by the Supervision of Public Services, which receives information from the users (or Civil Society) about the received service, such as, quality of service, cost and efficiency.

(5) The Ministry of the Environment has to create the conditions to assure an energy supply that is able to supply the demand given environmental criteria.

3.3 Analysis of the Properties of the Colombian Policy Makers System

- Availability of Resources.

When we talk about resources in the Colombian Energy Policy Making System, we are talking about human resources, understanding them as the policy maker's knowledge about the energy system and the implications of decisions that are taken by the policy makers.

From that point of view, the most important thing to note is that the people involved in the energy system do not know about the entire problem, they just know about a single process. This creates difficulties, because if you try to optimize a subset of a bigger set, you are going to find different optimal results, and in several cases, you are missing information that can allow you to find the global optimal point.

In Colombia there is an Unit Energy Planning, and this can be more successful that in other countries because the people involved in the Unit are mostly experts. As a result the decisions reached by the Unit are good, but communication from the Unit to other stakeholders is weak.

• Adaptability and Flexibility (as opposed to Rigidity).

The energy system was created by the Colombian Constitution, and was regulated by other laws than those that govern the energy sector, so, this sector is not adaptable nor flexible, because any change requires that the entire process must be revisited, and this process could be as long as 2 or more years and even when the final decision comes out, the problem could be changed again.

• General Homeostasis. Stability, Resilience and Robustness (as opposed to Vulnerability, Fragility).

This system is neither stable nor robust. It is a system full of rigidities that prevent the system from coming back to the original state and in some cases the system would never come back to the original position. Maybe with some time the system will come to a stable and resilient state, but in this time the robustness of the system could experience a breakdown.

• Capacity of response.

As a result of the previous characteristics, this system does not have the capacity of response. It is a system that depends completely on the results of other parts of the Colombian Energy Policy Making System, and cannot induce change in other parts of the system, because there is no direct relation with other political sectors, and there is not enough power to produce changes in order to improve this political system.

After analyzing these properties we can answer the question; is this system a sustainable system? And the answer would be NO.

However, it should be noted that Colombian Energy Companies and Utilities have been leading together with the Ministry of Environment the process of implementing Environmental Codes and Standards, and have tried to implement different measures to introduce rational energy use and last but not least to implement a Plan to use natural gas. There are a lot of problems to be solved but the changes are in the right direction given the difficulties that Colombia has to overcome to get financial investments.

4. Integrated System Proposed

In order to make the Colombian Energy Policy Making System more sustainable, this section proposes the introduction of some new special subsystems that can improve the performance of the system, integrate the Colombian Energy Policy Making System with the Colombian Energy Technological System, and create more interaction between the actors in the system. This would create a new set of relationships that could make the system into a more sustainable system.

In order to make a sustainable energy system for Colombia, it will be necessary to:

- Remove accumulated rigidities and impediments
- Increase the communication between the policy makers and the experts
- Include all the stakeholders in the process of the creation of the policy. For that, UPME undertook a one-year Scenario Analysis Process (A sustainable energy system) 5 years ago, with around 70 people coming from all sectors that are guiding the Planning Process. In fact, the last National Energy Plan considers some future demand and supply scenarios out of the recommendations of the Scenario Analysis
- Stimulate innovation, experimentation and use of new technologies.

4.1 Control Subsystem

Looking at the original system, and taking into account that we need to introduce a special subsystem in order to make the system more sustainable, here we propose the creation of a control system that can help in the decisions of the policy makers and the decision makers, and finally create a new set of links in order to make the system more robust from the point of view of sustainability.

The Control System is shown in the Figure 3 and its components are:

MKL: This refers to the MARKAL Model (MARKet ALlocation).

EGT: This refers to the Scenarios Generator created for helping the policy makers to make decisions.

COM: This refers to one of the functions that is needed to compare the scenario with the requirements of the policy makers.

TRL: This agent is the translator of the results and is the one in charge of making all the translation that the policy makers need in order to understand the results of the model.

PMK: This is the Policy Makers System explained in the previous chapter.

4.1.1 MARKAL Model

The most important agent of the control system is the MARKAL Model that allows us to analyze the energy system and produces results that are useful for the policy makers:

- Emissions,
- Cost of the System and
- Optimal share of technologies installation and operation, between others.

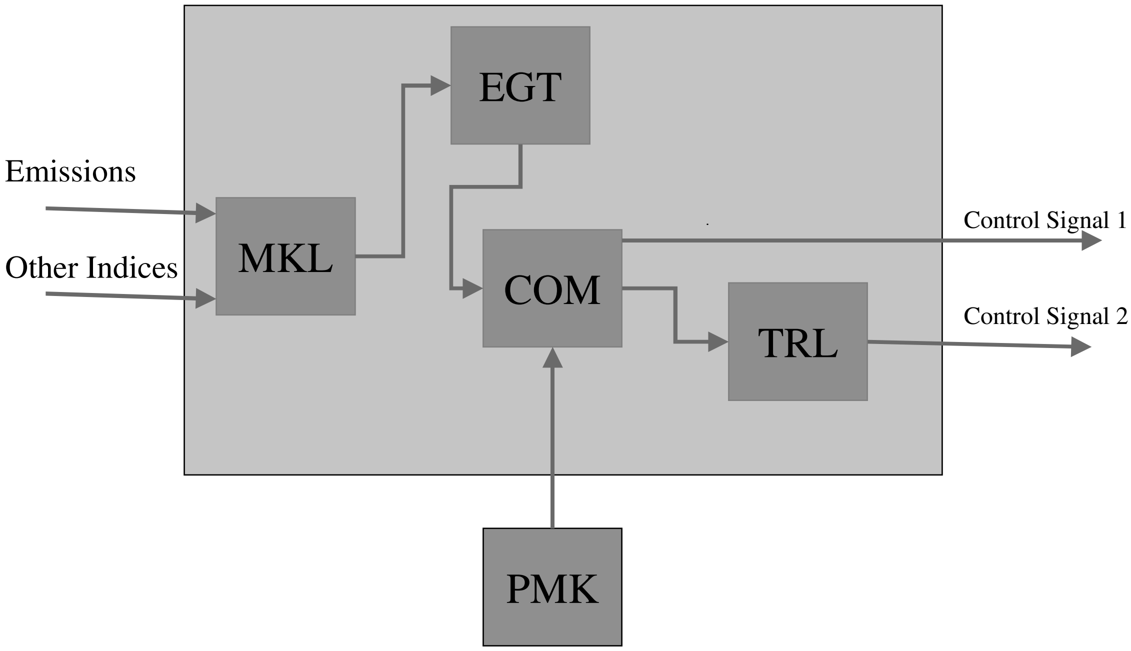

Figure 3 : Control System Proposed for the Policy Makers System

MARKAL takes the emissions and other indices from the present energy system to model the behavior of the system throughout the forecast period. After the first simulation MARKAL gives the results to a scenarios generator that in an iterative form finds a scenario. By comparing the latter with the scenario proposed by the policy makers, it is easier to fulfill the sustainable development goals more quickly and in a better way, because the model finds a more robust solution. The results obtained by the model, that is the newly generated scenario, will produce the output signals from the control system. The first signal will be sent directly to the Planning Unit for Energy and Mining, whereas the second passes through a process of translation that provides the policy makers more clear results that finally can increase the credibility of the model. In addition this will be a tool that ensures communications between the experts, the decision makers and the policy makers.

4.1.2 Scenario Generator

Analyses that guide standard policy assessments usually do not consider important goals that should be included in the decision process. The objective will be to apply an established technique, Goal Programming (Goldstein et al, 2003), to a classical linear programming specification of the MARKAL modeling system. The approach proposed allows an analyst to use the GP formulation to develop limits on emission levels that are sensitive to several criteria, not just the least-cost perspective. Then the analysis can use these limits as constraints in a series of sensitivity runs. This enables a robust solution-set to be generated that fosters a broader examination of policy tradeoffs than has traditionally been the case.

4.1.3 Translator for the Policy Makers

This process is the result of the need to make a system more transparent in order to increase the plasticity of the system, creating new relationships between the stakeholders. There are three important issues that we are trying to address here.

- Involve all the stakeholders in the decisions about the system from the beginning of the process, that is, from the definition of the system.
- Create an interaction environment in the definition of the energy policies.

Translate results into maps, colorful graphs, output on computer screen with web-based support.

4.2 Relations between Subsystems

In control engineering when you talk about a control system, necessarily there is a feedback system to be controlled; the relation between the Policy Makers System and the Control System is based upon this kind of theory. The system design is shown in Figure 4, and the actors of the system are explained following the picture.

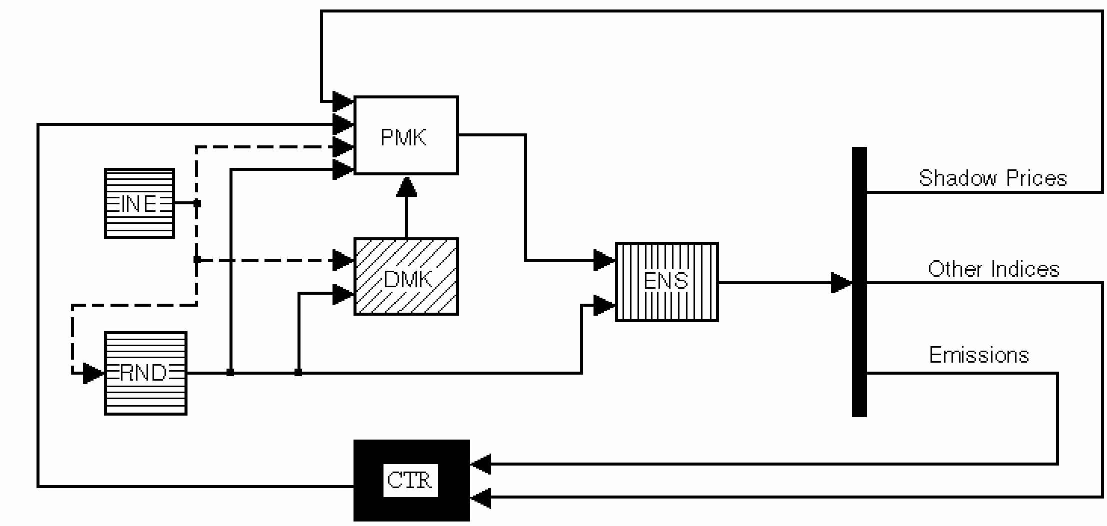

Figure 4 : Relation between subsystems.

The system is integrated by the following actors:

- ENS: Energy System
- PMK: Policy Makers
- INE: International Economy
- RND: Research and Development
- CTR: Control System

The following paragraphs explain how the different actors interact. First we have the energy system, which is influenced by the energy policies of the policy makers.

The Policy Makers (White Box) takes the international statistics and the international economic influences as well as technological advances (Horizontal Lined Boxes). These provide the background for decisions about the energy policies.

The Decision Makers (Diagonal Lined Box), also influenced by the international economy and the advances in the technology, propose new strategies that are attractive from the financial point of view and decide if they want to invest in the energy policy proposed by the policy makers.

Once the energy policy is selected, it is applied to the energy system (Vertical Lined Box) which, considering the new and available technologies, produces results that affect the RND, INE, and PMK.

In order to avoid that policy makers must decide completely without information about the power policy, the idea is to implement a control system (Black Box) that emits two signals, the first one goes directly to the Planning Unit for Energy and Mining and second one is for the other policy makers so that they can think jointly about the proposed energy policy, and the final policy is generated by all the policy makers and not only by the Planning Unit for Energy and Mining.

5. Conclusions

After examining the Colombian Energy Policy Making System using the ISTS protocol we can identify some problems that should be solved in order to achieve a Sustainable Energy System.

The use, or partial use, of the ISTS protocol helps to identify all the stakeholders and the relations between them and in this way understand the behavior of the system and the possible failures of the topology of the system itself.

The problem of the system can be resolved by introducing the control signal proposed in this paper, in order to add more flexibility and more capacity of response to the system. This should contribute to enhancing the sustainability of the system.

The use of the MARKAL family of models is very helpful because it is already developed for analyzing the impacts of the energy policies on the environment, but if we introduce the analysis for other aspects than CO2 emissions, like health or land use, we can get a more accurate model for helping the policy makers to decide on the policy and the decision makers to take a right decision. In particular for sustainable development, it is important to consider that any system is subject to multiple stresses

The control system proposed will help to introduce more credibility in the resultant policies and in the model itself and the system outputs would be more sustainable ecologically and provide robust long term solutions.

The Colombian Energy Policy Making System is a good system and is working really hard to improve their performance, for example, UPME undertook a Scenario Analysis (one year) Process (A sustainable energy system) 5 years ago, with around 70 people coming from all sectors that are guiding the planning process. In fact, the last National Energy Plan considers some future demand and supply scenarios resulting from the recommendations of the Scenario Analysis, but they need to keep working on involving stakeholders, because there is no relation between the policy makers and the civil society yet.

6. Further Work

We have to begin the design of the scenario generator, including most of the indicators related to the energy sector. Until now MARKAL has developed the scenario generator only for the CO_2 emissions level, and other GHG emissions, but there is no development of indicators related to land use or health.

The process of translation is really crude as well, and there are a lot of topics to work on. For example, for mapping we need to take the results database of MARKAL and process the data in order to do the mapping using GIS. The results of analyses must be effectively translated using graphics and statistical data processing. This will require the development of new tools and will provide a strong basis for the communication process between the policy makers and the experts.

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Acronyms

ISA	Colombian Electric Network Company
ECOPETROL	Colombian Oil Company
ECOGAS	Colombian Gas Company
UPME	Energy and Mining Planning Unit
CREG	Energy and Gas Regulatory Commission
MARKAL	Market Allocation Optimization Model
MKL	MARKAL
EGT	Scenarios Generator
COM	Comparator
TRL	Translator
PMK	Policy Makers Subsystem
ENS	Technical Energy System
INE	International Economy
RND	Research and Development
CTR	Control System