# *ADAPTATION PLAN FOR THE ENERGY SECTOR: PARTICIPATIVE METHODS FOR DEVELOPING COUNTRIES*

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## Overview

Climate change is causing alterations in the both natural and socio- economic systems. Thus, it is a fact the need for adaptation to the new climate conditions. Energy sector is particular, is vulnerable to such changes, where there are potential climate negative impacts on energy systems associated to resources endowment, energy supply and energy sector vulnerability (Ebinger & Vergara, 2011). Such adaptation comes from the selection of a portfolio of possible actions and measures.

Adaptation actions come from different kinds: structural, social, and institutional. The actions have associated features such as investment costs, diverse degrees of effectiveness to reduce impacts, short- and long-term effects, etc. Such features serves as selection criteria to be used in decision-making methodologies for a proper, and in the best case optimal, action plans and periodization based on the needs of adaptation of the energy sector. In order to build an optimal portfolio of adaptation actions, we propose and implement a participative decision methodology for energy sector. Such methodology includes the stakeholders associated with the sector. The method is actually being used for other sectors such as hydrocarbons and mining in Colombia.

The paper is organized as follows. After the introduction, there is a brief overview about the climate impacts on energy systems and emerging adaptation responses and practices. Thereafter, we address the requirements for the decision-making problem: preferences regarding decision criteria and restrictions on interdependence between measures and available investment budget. In section four, we describe the proposed decision model and results. In the final section policy implications for energy sector adaptation are derived.

## Methods

We develop a methodological process composed with two stages: 1) A sector analysis to identify climate risks and potenatial impacts in the energy sector; 2) It was developed a decision model based on multi-criteria technique AHP (Saaty, 2008) and combinatorial optimization (Grötschel & Lovász, 1995). There were considered decision criteria in the dimensions of infrastructure, economy, environment and society. Preferences for decision criteria are established through participatory methods, with the consensus of expert judgments, as well as the assessment of effectiveness of the measures to evaluate. We consider two types of restrictions the model, first the dependency relations among measures, such as precedence or contradiction; and second, different budget constraints.

## Results

The application of the methodology in the energy sector allowed to obtain the following results:

First, climate impacts on energy systems and adaptation responses are identified with literature review, and more importantly with the stakeholders that work on the field and have directly faced the impacts of climate chage. Effectiveness of adaptation measures are valued with expert judgement.

Second, preferences on decision criteria for adaptation on energy systems are stablished with expert judgement. Given that we are dealing with firms (focus on financial profitability), economic criteria are prefered, but also long term sustainability of the business

Third, we found an optimal packages of measures for different budget amounts. The measures that prove to be more robust according to the preferences in the decision criteria and the adaptation needs are also identified.

## Conclusions

There is a clear need for adaptation to climate change in economic sectors, in particular, the energy sector could be affected by changing trends in climate parameters. Climate change has (uncertain) impacts on energy supply and demand, resource endowment and infrastructure. In this regard, decision-making methodologies for the optimal selection of actions for climate changeadaptation, involving decision preferences based on expert consensus, are useful. The proposed methodology allows to build an optimal selection of a set of measures that meet the decision preferences established with the participation of experts. Additionally, the methodology considers to comply different constrains such as investment budget, which can vary according to the availability of financial resources.

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