STUDY DESCRIPTION OF THE EXTERNE PROJECT AND THE ECOSENSE TOOL APPLIED TO BRAZIL

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ABSTRACT

In the present work an overview of the ExternE Project in Brazil that has been conducted by the Brazilian National Nuclear Energy Commission (CNEN) is presented. To perform part of this evaluation study is used a version of the EcoSense software developed by the Institute for Energy Economy and Rational Energy Application (IER) of University of Stuttgart to be applied to Brazil and other countries of South America and part of Central America. An important feature of this study is to establish a local and regional data bank with environmental and social parameters around Brazil and other countries to estimate the externalities of energy that will be introduced due to the new generation units that are planned to be built during the next years to provide an increase of electricity availability to support the economy growth.

RESUMO

O presente trabalho apresenta uma descrição geral do Projeto ExternE no Brasil que está sendo desenvolvido pela Comissão Nacional de Energia Nuclear (CNEN). Para realizar parte deste estudo de avaliação é utilizado uma versão do software EcoSense, desenvolvido pelo Institute for Energy Economy and Rational Energy Application (IER) da Universidade de Stuttgart, adaptado para o Brasil e outros países da América do Sul e parte da América Central. Uma importante característica deste estudo é estabelecer uma base de dados em escala local e regional com parâmetros ambientais e sociais do Brasil e outros países para estimar as externalidades em energia que serão introduzidas devido às novas unidades de geração elétrica planejadas para serem construídas e operadas nos próximos anos para fornecer um aumento na disponibilidade de eletricidade para sustentar o crescimento econômico.

I. INTRODUCTION

Externality is a concept founded in economic theory. It refers to effects that are not accounted for in the transactions between buyer and seller and hence not reflected in the price of the good or service.

Externalities of energy can be positive as well as negative, although in general, negative externalities tend to dominate. They include damage to the natural and built environment, such as effects of air pollution on buildings, crops, forests and global warming, health, accidents; and reduced amenity from visual intrusion of plant or noise annoyance.

Traditional economic assessment of fuel cycles has tended to ignore these effects. However, there is a growing interest in adopting a more sophisticated approach involving the quantification of these environmental and health impacts of energy use and their related external costs.

In this project, the term environmental externalities is broadly defined and includes all burdens imposed by an activity on the environment that affect our welfare. Hence it is necessary to estimate the impacts of pollution on human health, agriculture and ecosystems and how the resultant changes in ecosystems affect our actual, potential or future possibilities to use it or the importance we may attach to conserving it (biodiversity).

The ExternE Project in Europe was the first comprehensive attempt to use a consistent "bottom-up" methodology to evaluate the external costs associated with a range of different fuel cycles. The European Commission launched the project in collaboration with the US Department of Energy in 1991, and the conceptual approach and the methodology were proposed to a range of fuel cycles [1]. The nature of the work has necessitated a multidisciplinary approach of economists, environmental scientists, health specialists, energy technologists, ecologists, atmospheric chemists and modellers, and computer software specialists.

The main objectives of the ExternE are to apply the methodology to a wide range of different fossil, nuclear, and renewable fuel cycles for power generation and energy conservation options. The methodology is also being extended to address the evaluation of externalities associated with the use of energy in the transport and residential sectors.

II. THE EXTERNE METHODOLOGY

The analysis of the externalities costs begin with the identification of the stages of the fuel cycle under assessment. A comprehensive list of burdens and impacts is then described for each stage. Priority areas for assessment are identified, based partly on the results of earlier studies and partly on expert judgement. Realistic sites and technologies are then selected for the full fuel cycle, in recognition of the fact that they determine the magnitude of many impacts.

The impact assessment and valuation are performed using the "impact pathway" approach. This approach assesses impacts in a logical manner, using the most appropriate models and data available. Methods range from the use of simple statistical relationships, as in the case of occupational health effects, to the use of a series of complex models and databases, as in the cases of acid rain and global warning effects.

Three important principles need to be followed in the ExternE methodology:

- Transparency: to show how the work was done, what was assessed and what was not.
- Consistency: to allow valid comparisons to be made between different fuel cycles and different types of impact within a fuel cycle.
- Comprehensiveness: all impacts of a fuel cycle should be considered, even though many of them are not investigated in detail.

A typical impact pathway approach is shown in the Fig. 1 below.

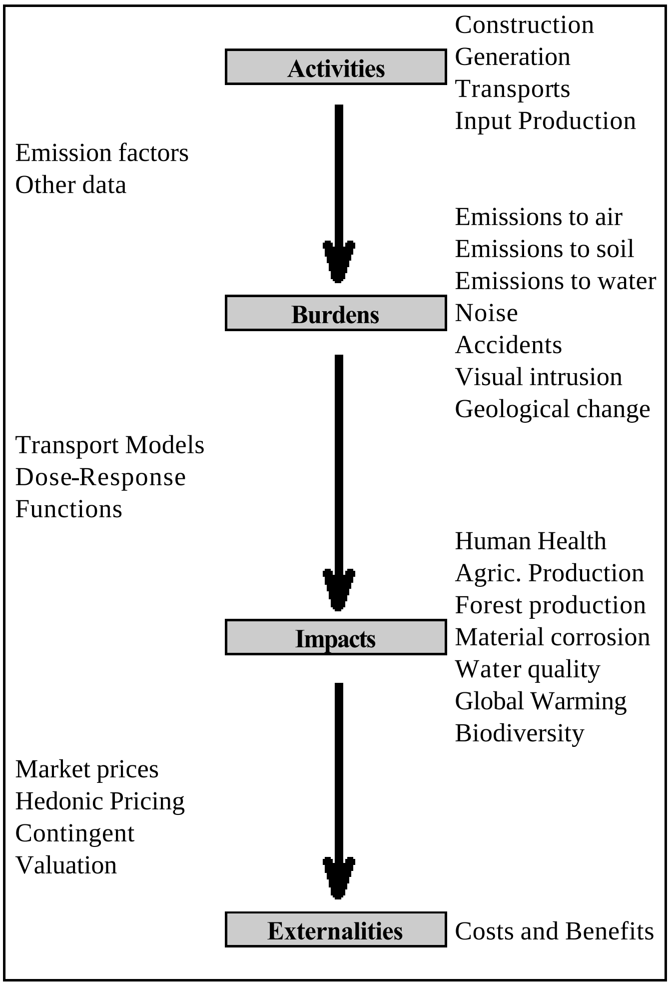

Figure 1. Impact Pathway to Evaluate the External Costs of Different Fuel Cycles

Using this impact pathway scheme it is possible to determine the dose that various receptors will be exposed to the emissions. It is considered a receptor anything that may be affected by a pollutant from a particular emission site, such as population, crops, and buildings. The impacts of these pollutants on the receptors are determined by means of dose-response functions. Finally, the cost of the damages is assessed, using market prices for market goods and WTP (willingness-to-pay) for non-market goods. As a further step of the economic analysis one may want to distinguish which portion of the cost is external, i.e., not yet taken into account in current market transactions.

In practice, there is a huge amount of data which must be collected, organized and correlated before and during the calculations. Some of the necessary data for the impact pathways estimate can be summarized as:

Determining the type and capacity of the plant and related activities. The plant capacity can be considered as either the design or actual capacity. The design capacity is what the plant was built to accommodate, whereas the actual capacity is what the plant produces. Normally, the latter value is used when performing environmental cost calculations.

Collecting Emission and Employee Data. The type and release rates of the pollutants will depend on the plant type, the capacity, the age of the plant, the pollutant control schemes, the quality of the fuel used, etc. It will need to know exactly what pollutants are released, how much (tons/MWh or tons/year) and whether the pollutant is in a gaseous form (released to the air), liquid form (released to rivers, oceans), or solid bulk (generally for a storage location). There will be also a number of employees who work in the plant or for the utility in general. These employees will eventually have work-related problems, both minor and major. One will need to know how many people worked in the construction of the plant, how many work in the plant, and how many will be needed for the eventual decommissioning. In addition, one should have statistics on the accidents and death rates of these workers.

Collecting Site Specific Data. The site-specific data refers to all the information about the site which will let one model perform the dispersion of the pollutants and their effects on whoever and whatever becomes contaminated.

Weather Data. The majority of pollutants from power plants are emitted in gaseous form and spread out over the terrain by wind patterns, specifically, the prevailing directions and associated speeds. Some of the pollutants may be deposited on the ground by the action of precipitation, so it will be needed to know how often rain occurs. If the pollutants give rise to secondary pollutants (e.g. ozone and acid rain), it will be important to collect information about the driving functions of these chemical reactions, including such things as temperature distribution and the intensity of sunlight.

Agricultural and Demographic Data. As a pollutant plume spreads out, it will encompass areas of agricultural activities and population centers. The types of activities and the size of population will be needed to enter into the models. This is most often accomplished through the use of grid systems, where each cell of the grid is assumed to have a uniform receptor density. A grid system can be natural, such as a breakdown by countries, by states, or by cities, or it can be artificial, such as a rectangular grid laid out with the same dimensions for each grid cell. In whichever method used, it will be necessary to know the coordinates of the edges of each cell (in latitude and longitude) and the amount of people, animals, trees, etc., which are in the cell.

Economic values. Finally, for determining the economic costs of any damages to the receptors it will be needed to know how much they cost. This can be trivial in the cases of commodities such as agricultural products, but is less clear in the case of existence values and human uneasiness and suffering.

Gathering Necessary Models. As any scientific study, there are a variety of computer models which must be chosen. These models are used to estimate the dispersion of pollutants after release and to gauge the effects of the pollutants on the receptors.

Atmospheric Dispersion and Deposition. The atmospheric models can vary from simple Gaussian plumes to complex dispersion and chemistry simulations. Typically, such a model will allow the user to specify the location and release rate of a pollutant and then calculate the concentrations in the surrounding area. At the very least, these models will require as input some kind of statistics about the frequency of specific wind directions and speeds. More complex models may also require such inputs as the diurnal air temperatures, solar radiation, vertical and horizontal wind velocities, concentrations of reactive substances such as volatile organic compounds, etc. Many models also take into account terrain and local effects due to topography. When working with such a model, it becomes necessary to define some kind of coordinate system with respect to the release point. This often consists of a simple overlaid grid, radial or rectangular, in which the concentration in each cell is assumed to be constant.

Dose-Response Functions. The last set of models needed are the relationships between exposure to the pollutant and the resulting effects on health, crops, building materials, etc. The models are called dose-response or exposure-response functions. These functions can be simple linear relations, e.g., the number of incidents of cough which result from a certain concentration of particulate matter in the air. They can also be quite complex, e.g., when the pollutant passes through several stages before imposing a direct effect, such an intake by a plant or animal which is in turn eaten by humans.

Determining Impacts of the Plant. The overall impacts of the plant emissions are determined by tracing the pollutants as they travel from the plant and into humans, plant, and the infrastructure.

Impacts from Pollutants. The pollutants released by a plant into the natural environment will cause damage to the surrounding region as well as propagate through the food chain to produce health effects in humans. In the case of air emissions the path is the dispersion through the air and deposition on the ground, whereas in water the path originates in a river or ocean. The effects of the pollutants are estimated by applying a dispersion model and dose-response models in sequence. In some cases, the pollutants affect much more than a local region. This is the case with greenhouse gases and certain radioactive wastes.

Impacts from Other Effects. There are other effects that apply to the external costs routines which are not associated directly with the emission of pollutants. These include the damages from transportation, employees injuries, and any perceived loses. The transport of raw materials, fuel and waste can cause damage to the infrastructure which should be accounted for an environmental cost analysis. This includes road damage and maintenance of railways and waterways. In any large construction process there is a risk of injuries and deaths associated with the construction, operation and maintenance, and decommissioning. In some cases, these incidents can be considered internalized costs since the workers have agreed to the risks of the job. In ohter cases, however, these values will be included as external costs. Finally, there are the "existence" values of things. This can be applied to the value of a park or wood used for recreational purposes which will be flooded by the construction of a dam. Another example would be the loss of historical monuments due to acid rain or other pollutants. The cost of clearing and repairing these sites would be included.

III. THE EXTERNE PROJECT IN BRAZIL

Considering the ExternE Project used in Europe and its methodology as a interesting research opportunity that could be used by under developing countries and where new energy polices have been organized and/or proposed, the Brazilian National Nuclear Energy Commission (CNEN) established in 1999 a cooperation program with the International Atomic Energy Agency (IAEA) and University of Stuttgart to use the EcoSense computational tool [2] to estimate the cost of externalities of energy in Brazil and other countries in Latin America.

A initial study has been conducted by CNEN to evaluate the new version of EcoSense tool [3,4] since the end of 1999. This study will cover in a first step only the Brazilian borders, considering some of the power plants that are candidates to be built and operate in the next few years, meteorological data and population data for the region. At the same time, CNEN is looking for additional technical cooperation with other Latin American research institutes to extend the externality cost study in energy to other countries in Latin America.

IV. ECOSENSE VERSION TO BRAZIL

The new version of EcoSense tool that will be used by CNEN to perform the external costs studies for Brazil and Latin America area will cover the South America region and part of the Central America region and the Caribbean Islands with resolution of 0,5° in latitude and longitude. For the air quality modeling domain, EcoSense will cover a grid system with 133 grid cells in latitude and 151 grid cells in longitude. For the impact assessment modeling domain, EcoSense will cover a grid system with 108 grid cells in latitude and 99 grid cells in longitude, as shown in Fig.2.

Environmental and Population Data. To provide initial environmental data for this EcoSsense version, the CNEN´s team has been making efforts to get the release scenario for each power plant candidate, population data, meteorological data and emission (background) data for the whole country.

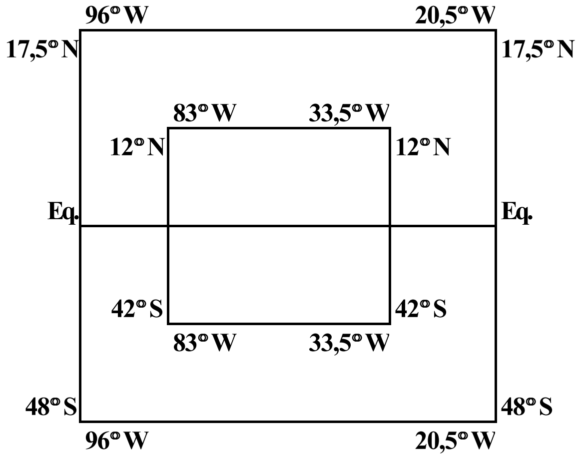

Figure 2. Grid Domain Used by EcoSense to Perform the Atmospheric Transport and Impact Assessment

Population Data and Administrative Units. There is a great job looking for the characterization of the Brazilian population structure including the age distribution, relative percentage of male and female being, main risk groups for acute levels of particulate and specific pollutants (ozone, SO_x, and NO_x) for every administrative unit in Brazil (State level and district level). At the same time, every boundaries of administrative units in Brazil and its population data were put together in a database using a geographical information system (GIS) to handle with these data in a digital way. Fig.3 shows the population distribution around Brazil and Latin American countries that is implemented in the EcoSense population database. The population of other Latin America countries has not been defined in a high level of details. So it is assumed a regular distribution of the population based on official statistics of each country over its area. The Fig. 3 shows the population distribution used by this EcoSense version.

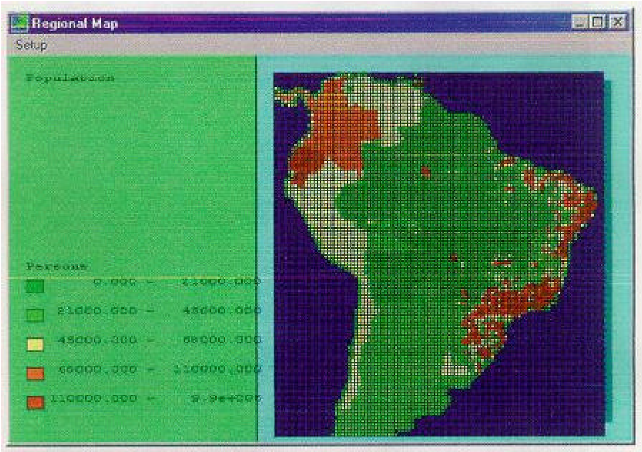

Figure 3. Map of Population Distribution. This Picture is a Output Window of EcoSense for Brazil / Latin America

Meteorological data. Meteorological data required by the Windrose Trajectory Model (WTM) are annual wind direction frequencies, wind speed, and precipitation for each grid cell. For a first run of the EcoSense, IER introduced a meteorological database based in global meteorological database available at the National Center for Atmospheric Research (NCAR). The wind speed and wind direction are available on a 2,5°x2,5° grid, and precipitation data is available on a 1°x1° grid.

Emission Data. The emission data are required for SO_2, NO_x, PM_{10} and NH_3, and they are required on the grid format as an input into the air quality modeling, but the user should access the data via a user interface that is based on administrative units and industry sectors. For a first run of EcoSense, IER introduced a data from the RIVM EDGAR-1990-Emission Database for Global Atmospheric Research as a reference value. The global annual emissions are available for SO_2, NO_x, and NH_3 on a 1°x1° grid per source category. Fig. 4 shows the SO_2 background concentration using EDGAR 1990 database.

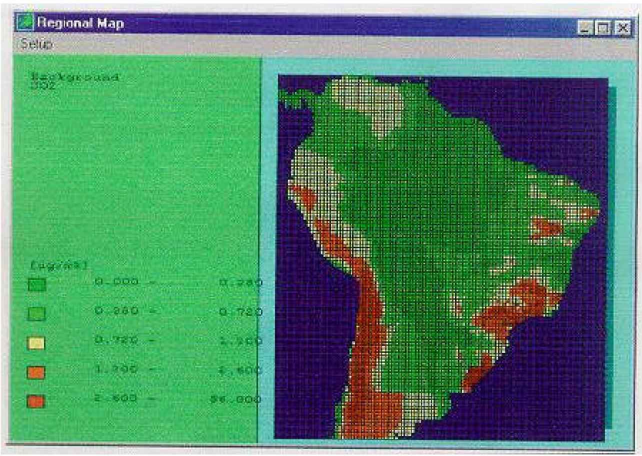

Figure 4. Map distribution of SO_2 background concentration scenario over South America according to EDGAR 1990 database. This picture is a output window of EcoSense for Brazil / Latin America.

Receptor Data. ExternE results show that about 95 % of the external costs from fossil fired power plants result from human health effects. Taking into the overall uncertainties of the approach and the limited resources available, the study will primarily focus on the human health impact category. Data on crop production and material stock will need to be provide in a second stage of the externalities study for Brazil and Latin America, keeping in mind that external costs from crops losses and material damage are small compared to health impacts. In addition, the transference of dose-response functions for crops and materials from American and European context to Brazil and other countries seems to be much more uncertain than for health impacts. Fig. 5 shows a EcoSense window that allows the user to define the emission scenario, the reference scenario and the receptor.

Dose-Response Functions The EcoSense version for Brazil and Latin America include a set of extensively reviewed ExternE dose-response functions in the model. As far as possible, the CNEN´s team need to discuss the feasibility of the transfer of these dose-response functions to the local population. Fig. 6 shows the results for a YOLL based dose-response function.

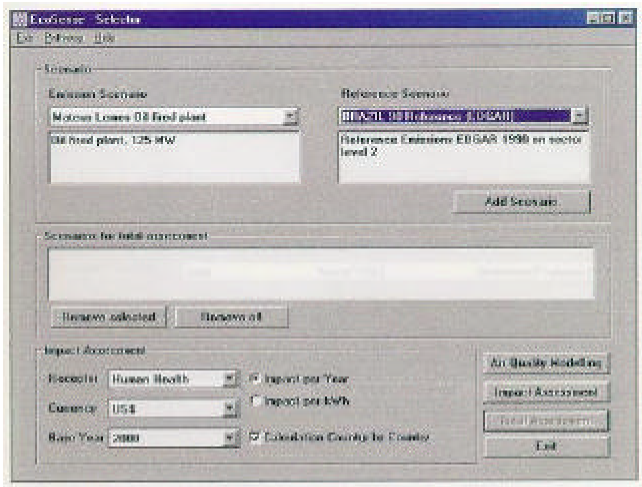

Figure 5. EcoSense window to manage the emission and reference scenario, and the impact assessment (for human health in this example).

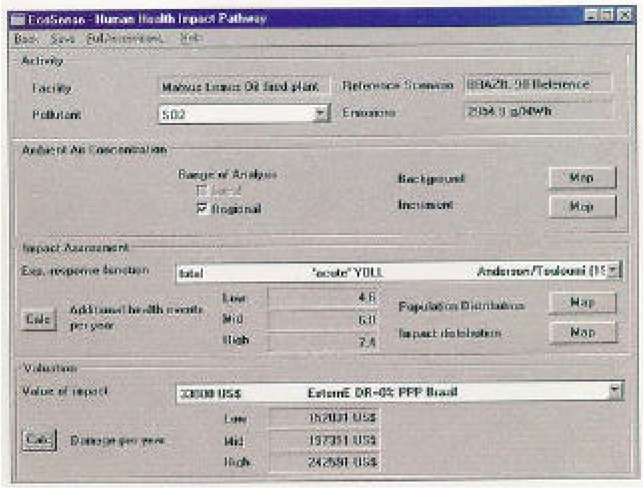

Figura 6. EcoSense window to choose the dose-response function and calculate the economical evaluation of the impact assessment (based on the data introduced in Fig.5).

Monetary Values. The transfer of monetary values from American and European studies into the Brazilian and Latin American context certainly is a problem and a source of major uncertainties. IER´s team has suggested to use the ExternE values, weighted by purchase power parity, as a starting point. The definition of new monetary values within the system will demand new studies and a straight work with economists.

V. CONCLUSION

The ExternE Project in Brazil has shown its great importance as a new tool to estimate environmental damage and economic costs due to the introduction of new sources of pollution by the electrical sector in the atmosphere and the environmental and health consequences associated.

The externalities costs in this case can help the regulatory agencies to define the strategies and the best technological choices for each region of the country based in a comparative study between different fuel cycles and their potential impacts over local and regional population and the environment.

At the same time the opportunity to use a validated methodology to estimate the externalities can reduce time in research development, and focus on more details to check and test the EcoSense tool adapted to Brazil and Latin America region. The most important activities to be done and questions to be solved in the short future for the ExternE Project in Brazil using EcoSense are related to:

- Review the meteorological and concentration databases, and validate the meteorological model used in the EcoSense tool for tropical and equatorial areas
- Define the most important agricultural activities in Brazil and their production for each city/state
- Define the dose-response functions for these cultures and crops, considering that they are not applied for the same cultures that Europe are used to cultivate.
- Review the population database according to the new data to be released by Instituto Brasileiro de Geografia e Estatística (IBGE) in 2001 related to the last decade.
- Review the projection and construction of new power plants that will be installed in the next years around the country to be able to estimate the incremental increases of air concentration and health damages compared to the actual scenario.

It is important to make clear the importance of this project as an additional tool to help the decision makers in the energy area in Brazil, and the necessity to merge and exchange information and research with other research institutes and electrical companies to develop this work.

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