Project Title: Feasibility Study of Developing Hybrid Hard- Link Energy Planning Models

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Keywords:

Hybrid Models- MESSAGE- Energy Planning- Soft-link- Hard-link- Top-down Model- Bottom-up Model, Computable General Equilibrium

Project Necessity:

Models used for the analysis of impacts of energy policies in the past years were only divided into two categories: engineering models (bottom-up) and macroeconomic (top-down). In engineering models like MESSAGE, the details of energy supply technologies and energy resources, as well as interactions between technologies, and also their economic-technical specifications determine the optimal energy mix. However, in macroeconomic models, the effects of price changes on the energy balance in different markets are simulated. In other words, DCGE models are equilibrium top-down tools that apply macroeconomic data to determine energy prices and demands. Recently, hybrid models have been developed to take advantage of both approaches. Hybrid models address the different mechanism of the energy sector and the rest of economy interactions because they include features of both bottom-up and top-down approaches. Since hybrid modeling efforts combine technological explicitness of bottom-up models with the economic comprehensiveness of top-down models, we aim to provide completely integrated models based on developments of solution algorithms with respect to the characterization of technology options and associated input substitution possibilities in production.

Project Goals:

The main goal of this project is developing a hybrid model, in which the features of MESSAGE ix can be applied. We can categorize the different goals of this project as follow:

Objectives:

- Identifying MESSAGE ix and its features
- Applying MESSAGE ix for energy planning (In this phase a simple RES was defined and the optimal energy mix was calculated by MESSAGE ix)
- Developing a hybrid energy planning model on the basis of MESSAGE ix

Abstract:

In the first phase, we reviewed different hybrid energy models. Moreover, the differences between different approaches were explored, and they were categorized into three groups as follows:

- Soft-link
- Hard-link
- Integrated Models

In the second phase, the main features of MESSAGE-ix model were identified. MESSAGE-ix is a versatile, open-source, dynamic systems-optimization modelling framework. It was developed for strategic energy planning and integrated assessment of energy-engineering-economy-environment systems. In this project, MESSAGE-ix model was used to simulate the operation of given energy-system to supply a given set of demands, with focus on analyzing specific energy technologies and the associated investment options. In addition to Python environment, the equations of MESSAGE-ix were implemented in the mathematical programming system GAMS for numerical solution of a model instance. We worked with MESSAGE-ix model using Python and GAMS to model RES in MESSAGE-ix using the two following approaches:

- The MESSAGEix framework is fully integrated with ’s ix modeling platform (ixmp), a data warehouse for high-powered numerical scenario analysis. The platform supports an efficient workflow between original input data sources, the implementation of the mathematical model formulation, and the analysis of numerical results. We accessed this platform to simulate the reference energy system of Iran via a web-based user interface and application programming interfaces (API) to the scientific programming language Python.
- Moreover, the platform also includes a generic data exchange API to GAMS for numerical computation. We used the GAMS formulation directly to simulate the Iran’s energy system.

In the third phase, the optimization model was linked to the general equilibrium model to incorporate feedback between prices and demand levels for energy and commodities. To achieve this goal, the electricity column in social accounting matrix was decomposed into different electricity production technologies. We laid out the complementarity features of economic equilibrium and demonstrate how we can integrate bottom-up activity analysis into a top-down representation of the broader economy using a stylized numerical example of an integrated model.

Steps and Methodologies

The project includes the following phases:

- Identifying the characteristic of hybrid energy models, especially hard-link energy models
- Identifying MESSAGE-ix features, and developing a simple bottom- up model by using MESSAGE-ix
- Developing a hybrid energy model by adding top-down features to MESSAGE-ix in Python environment and GAMS formulation

Main Results (technical outputs, patents, papers, books, reports, etc.):

Scientific Reports for each phase