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OSeMOSYS: The Open Source Energy Modeling System An introduction to its ethos, structure and development

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ABSTRACT

This paper discusses the design and development of the Open Source Energy Modeling System (OSeMOSYS). It describes the model's formulation in terms of a 'plain English' description, algebraic formulation, implementation—in terms of its full source code, as well as a detailed description of the model inputs, parameters, and outputs. A key feature of the OSeMOSYS implementation is that it is contained in less than five pages of documented, easily accessible code. Other existing energy system models that do not have this emphasis on compactness and openness makes the barrier to entry by new users much higher, as well as making the addition of innovative new functionality very difficult. The paper begins by describing the rationale for the development of OSeMOSYS and its structure. The current preliminary implementation of the model is then demonstrated for a discrete example. Next, we explain how new development efforts will build on the existing OSeMOSYS codebase. The paper closes with thoughts regarding the organization of the OSeMOSYS community, associated capacity development efforts, and linkages to other open source efforts including adding functionality to the LEAP model.

1. Introduction

1.1. Rationale

OSeMOSYS[1] is designed to fill a gap in the analytical toolbox available to the energy research community and energy planners in developing countries (UK ERC (United Kingdom Energy Research Centre), 2010). At present there exists a useful, but limited set of accessible energy system models. These tools often require significant investment in terms of human resources, training and software purchases in order to apply or further develop them. In addition, their structure is often such that integration with other tools, when possible, can be difficult.

OSeMOSYS is a full-fledged systems optimization model for long-run energy planning. Unlike long established energy systems (partial equilibrium) models (such as MARKAL/TIMES (ETSAP (Energy Technology Systems Analysis Program), 2010), MESSAGE (IAEA (International Atomic Energy Agency), 2010), PRIMES (NTUA (National Technical University of Athens), 2010), EFOM (Van der Voort, 1982) and POLES (Enerdata, 2010)), OSeMOSYS potentially requires a less significant learning curve and time commitment to build and operate. Additionally, by not using proprietary software or commercial programming languages and solvers,OSeMOSYS requires no upfront financial investment. These two advantages extend the availability of energy modeling to the communities of students, business analysts, government specialists, and developing country energy researchers.

Enabling graduate students to build and iteratively develop formal energy models will impart this knowledge base to very wide range of energy market roles and positions. Extending the

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[1] This effort is based on proof of concept work presented at the International Energy Workshop (IEW) (Howells et al., 2008). That work demonstrated the potential for such an effort focusing on objectives summarized in the acronym "SOFT" (Simple, Open, Free and Transportable).

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human capacity of private and public policy makers to use and understand energy models is a key step in the effective use and interpretation of formal analytical tools (Strachan and Pye, 2009). And growing human capacity in energy modeling in developing countries – whose institutions have relatively fewer research resources – is particularly important, given the growth of developing countries in energy related emissions, resource use, and demand for energy services. However at the most recent International Energy Workshop – the preeminent international energy modeling conference – held in Stockholm in June 2010, less than 10% of participants were from developing countries.

For experienced energy researchers, the OSeMOSYS code is relatively straightforward, elegant and transparent and allows for simple refinements and the ability to conduct sophisticated new analyses. As modeling is designed to generate insights (Huntington et al., 1982), OSeMOSYS allows a test-bed for new energy model developments.

1.2. Paper outline

This paper is divided into two parts. Part 1 discusses the structure of OSeMOSYS, including its division into functional component-'blocks', each representing different levels of abstraction. In part 2, a simple application of OSEMOSYS is presented to provide verification of the model formulation. It goes on to indicate how model development take places by adding a functional 'block' – within each level of abstraction – to the model. Finally, capacity building efforts, including a description of a link to the energy model LEAP, are followed by a description of anticipated next steps.

The paper also includes two appendixes. Consistent with the multiple levels of abstraction used for the model development, including: the algebraic formulation and the implementation in the form of model source code.

2. Part 1: The OSeMOSYS model

OSeMOSYS is designed to be easily updated and modified to suit the needs of a particular analysis. To provide this capability, the model is being developed in a series of component 'blocks' of functionality. A collection of the functional component blocks combines to form a customized model. Further, each block is divided into different levels of abstraction as follows:

I. A plain English description of the model sets, parameters, variables, constraints, and objectives as well as how they are related.
II. An algebraic formulation of the plain English description.
III. The model's implementation in a programming language.
IV. The application of the model, which depends on how it is being used in a study.

Each of these levels is individually important, and by separating them, we hope to facilitate independent and simultaneous additions or refinements.

It is noted that these levels are a simple abstraction of how much model development takes place. However, in existing energy system models, such strata are not neatly identified, nor are they separated. We suggest this lack of separation is conducive to organic and perhaps inefficient model development.

At present the model is disaggregated into seven functional component 'blocks' (Fig. 1). Added together they define the current version of OSeMOSYS. They are compatible and potentially replaceable with new blocks (containing different or improved functionality) with careful and consistent set, variable and parameter definitions. Each block is defined within three levels of abstraction (I–III). The blocks include specifications of the objective (1), costs (2), storage (3), capacity adequacy (4), energy balance (5), constraints (6) and emissions (7).

A full 'Plain English' description, algebraic formulation, and implementation for each 'block' in the current formulation is given in appendix. Under the section "Model Development", the process of adding the storage block (highlighted in Fig. 1) is described. Next we outline the levels of structure (I–V) in more detail, with selected examples extracted from the appendix.

2.1. I. Plain English description

A clearly articulated 'plain English description' is the first level of OSeMOSYS abstraction and represents good practice for any code documentation (McConnell, 2004). This is particularly useful to help match the policy maker and energy system analyst's expectations—a noted downfall of many modeling efforts (Munson, 2004). The full description for each block of the current model is given below.

The objective (block 1 of Fig. 1) in the current version of OSeMOSYS calculates the lowest net present cost (NPC) of an energy system to meet given demand(s) for energy carriers, energy services, or their proxies. (From this point on, 'energy carriers' will be taken to include 'energy services' and 'proxies'). The system is represented by technologies. Most technologies both use and produce energy

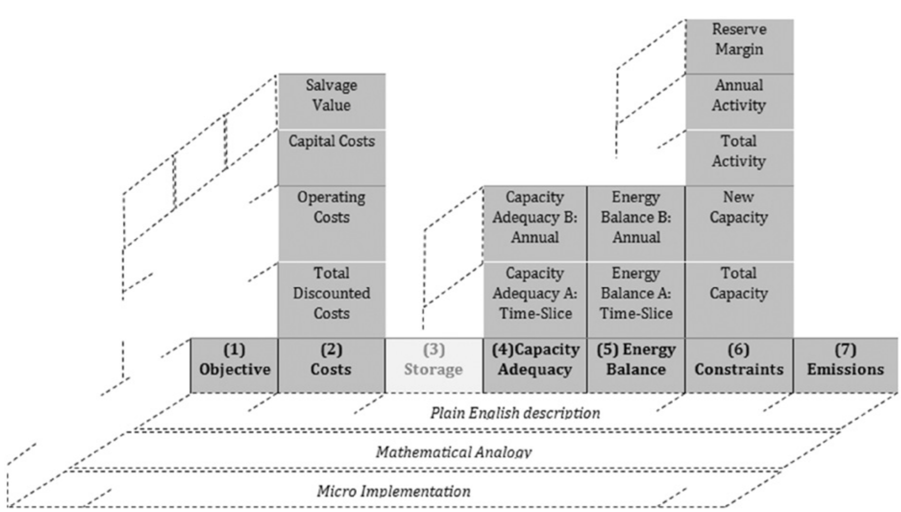

Fig. 1. Current OSeMOSYS 'blocks' and levels of abstraction.