Making Energy System Optimization Methodologies Accessible and Affordable: Incorporating the Open Source Energy Modeling System (OSeMOSYS) into the Long Range Energy Alternatives Planning System (LEAP).

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Abstract

In the world of energy planning software a number of tools exist that include powerful optimization methods based on linear and non-linear programming. However, these tools tend to be expensive to purchase and implement for many classes of users, particularly students, academics and non-profit organizations. This in turn has limited the degree to which these models have been applied. In contrast, the Long-range Energy Alternatives Planning system (LEAP) developed and disseminated by the Stockholm Environment Institute is notable for its ease-of-use, transparency, low initial data requirements and affordability -- being free of charge for most classes of users. Up until now however, LEAP's calculation methodologies have been limited to simpler accounting and simulation methodologies.

This paper describes the new version of LEAP, to be released in early 2011, which for the first time gives users the chance to use optimization techniques through a tight coupling with the new Open Source Energy Modeling System (OSeMOSYS). OSeMOSYS is a fully-fledged energy systems optimization model similar in scope to models such as MARKAL, TIMES and MESSAGE, which substantially extends LEAP's existing accounting framework. LEAP 2011 is intended to help national, regional and local energy analysts conduct energy planning and Greenhouse Gas (GHG) mitigation assessments.

A key reason for developing the new version of LEAP is to provide a structured pathway for energy analysts to build analyses in a gradual and cost-effective fashion, and which allows them to get started in situations where limited amounts of data are available and the technical capacity to use complex models is in short supply. This is typically the case in many developing countries where data is sparse and of poor quality, where the number of highly qualified energy modelers is very limited, but where decisions on key energy planning issues nonetheless need to be taken. In these situations, simple physical accounting models like LEAP have tended to be more suitable than complex optimization tools. Optimization models not only require more data in order to be able to calculate solutions but also tend to be less user-friendly and require more expertise to be used properly. The intention with the new version of LEAP is to preserve the ability to use its simpler and less data intensive methodologies whilst also providing a simple transition pathway that let's its users "graduate" to using more sophisticated and data intensive methods when they (and the supporting data) are ready to do so.

The new version of LEAP achieves this goal by providing basic optimization capabilities as an additional technique that can simply be chosen by the user, whilst preserving all of the previous data and modeling efforts already entered into their LEAP model.

Paper Structure

- The paper will start by providing a brief overview of why the new version of LEAP was developed. We will summarize the capabilities of existing energy modeling tools and explain why we feel that this new version of LEAP with optimization capabilities is needed.

- **Section two** of the paper will introduce LEAP– its structure, methodology, interface and capabilities, a brief overview of its history and an outline of some of the recent applications of the system. The section includes information on how LEAP is developed and supported by SEI and provides information on where readers can go to get more information.

  LEAP is an integrated modeling tool that can be used to track energy consumption, production and resource extraction in all sectors of an economy. It can be used to account for both energy sector and non-energy sector greenhouse gas (GHG) emission sources and sinks. In addition to tracking GHGs, LEAP can also be used to analyze emissions of local and regional air pollutants, making it well-suited to studies of the climate co-benefits of local air pollution reduction.

  LEAP is one of the most widely-used software tools for energy policy analysis and climate change mitigation assessment. It has been adopted by many hundreds of organizations in more than 190 countries worldwide. Its users include government agencies, academics, non-governmental organizations, consulting companies, and energy utilities, and it has been used at many different scales ranging from cities and states to national, regional and global applications.

  See also: http://www.energycommunity.org

- **Section three** of the paper will introduce the OSeMOSYS energy model – an open source energy sector optimization model developed by a coalition of organizations including the International Atomic Energy Agency (IAEA), the Stockholm Environment Institute (SEI), the UK Energy Research Center, the Royal Technical University (KTH) in Sweden and the Energy Research Center of the University of Cape Town.

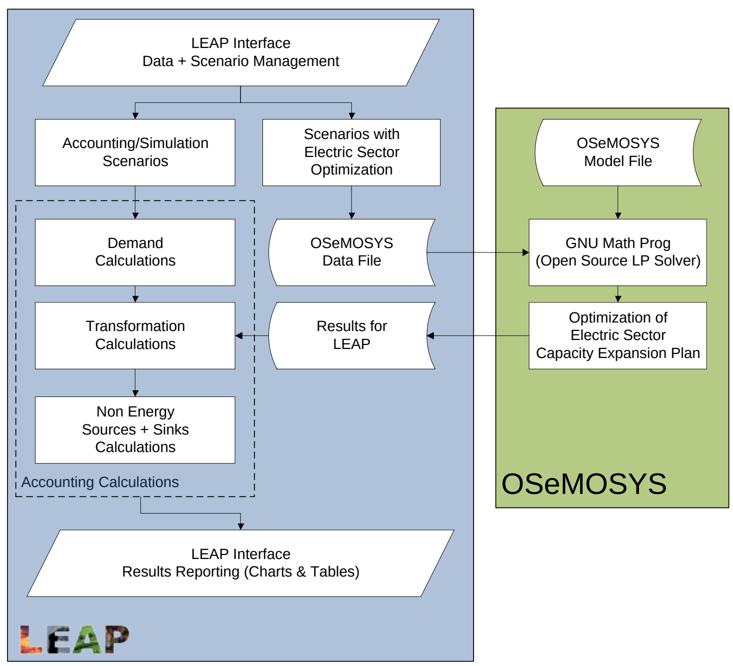
  OSeMOSYS is a full-fledged systems optimization model designed for long-run energy planning. Unlike more established energy modeling systems models such as MARKAL, TIMES, MESSAGE, PRIMES, EFOM and POLES, OSeMOSYS does not require a significant learning curve and time commitment to build and operate. Additionally, it is an open source system and thus requires no upfront financial investment. 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. OSeMOSYS thus provides a test-bed for new energy model developments.

  This section briefly outlines the structure of OSeMOSYS, including its division into functional component blocks. At present, the model is disaggregated into seven blocks, which currently define the objective function, costs, storage, capacity adequacy, energy balance, constraints and emissions calculations in the model. Each of these blocks is potentially replaceable with new blocks (containing different or improved functionality) with careful and consistent set, variable and parameter definitions. A full 'Plain English' description, algebraic formulation, and implementation for each 'block' in the current formulation is provided in a separate paper (Howells et. al., 2011).

As it currently stands, OSeMOSYS has no user-interface. The entire model is defined in a single text file which defines all of the set, variable and parameter definitions of its seven functional blocks. The OSeMOSYS model is made operational through the use of the Open Source GNU Math Program, which solves the equations in the model. All of the data required by the model (such as technology costs, efficiencies, availability factors, emission factors, constraints, etc,) are supplied in a single text file which is processed by the GNU Math Program and used to write a set of results, again to a single text file.

See also: http://osemosysforum.wikispaces.com

- **Section four** of the paper describes the integration of OSeMOSYS into LEAP (see Figure 1). LEAP provides an entire "front-end" and back-end" user interface for OSeMOSYS providing all data management and reporting capabilities. Thus, from the perspective of the user of LEAP, the OSeMOSYS model is invisible – operating entirely behind the scenes. This section provides an overview of how the two models have been integrated both with respect to data management and reporting as well as in terms of the calculations of the two modeling systems.



- **Section five** will provide an overview of the new capabilities of the two newly integrated modeling systems. Typically you the new capabilities will be used to calculate the optimal expansion and dispatch of power plants for an electric system, where optimal is defined as the energy system with the lowest total net present value of the social costs of system over the entire period of calculation (from the base year through to the end year). In calculating the optimal system LEAP (and OSeMOSYS) takes into account all of the relevant costs and benefits incurred in the system including:
  - Capital costs for building new processes.
  - Salvage values (or decommissioning costs) for decommissioning processes
  - Fixed and variable operating and maintenance costs

- Fuel costs
- Environmental externality values (i.e. pollution damage or abatement costs).

The Least cost system can optionally be calculated subject to a number of user specified constraints including maximum annual levels of emissions for any given pollutant (CO_2, SOx, NOx, PM10, etc.) and minimum or maximum capacities for certain plant types. So for example, a pathway for an energy system could be calculated that met a minimum renewable portfolio standard (RPS) whilst also staying within a target for reducing greenhouse gas (GHG) emission.

- **Section six** provides a simple example of the application of the new system, describing a simple model that is currently being constructed of a national energy system.

The paper will conclude with a summary of the potential applications of this new system and information on how the reader can access the new tool.

Reference: *OSeMOSYS: The Open Source Energy Modeling System: An introduction to its Ethos, Structure And Development.* (2011) Howells, M., Rogner, H., Strachan, N., Heaps, C., Huntington, H., Socrates, K., Hughes, A., Silveira, S., DeCarolis, J., Bazillian, M., Roehrl, A. Forthcoming in Energy Policy.

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