Quick Start Guide
for Using Optimization in LEAP

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> **Important note:** Currently the optimization features in LEAP2011 are still experimental and should be used for testing purposes only. While we believe that the optimization calculation work well, we also welcome feedback from users on any issues they may identify. The optimization calculations should not yet be relied upon for the preparation of any final analyses or reports. We expect to finalize these aspects in the coming few months.

Introduction

LEAP 2011 includes new capabilities to automatically calculate least cost capacity expansion and dispatch of supply-side Transformation modules. This new capability works through integration with the new Open Source Energy Modeling System (OSeMOSYS), which has been developed by a coalition of organizations including SEI, the International Atomic Energy Agency (IAEA), the United Nations Industrial Development Organization (UNIDO), the UK Energy Research Center, and the Royal Technical University (KTH) in Sweden. OSeMOSYS in turn depends on the GNU Linear Programming Kit (GLPK), a software toolkit intended for solving large scale linear programming problems by means of the revised simplex method. Both OSeMOSYS and GLPK are open source freely distributed tools. Both are included as part of LEAP's standard installation and both are fully integrated into LEAP's user interface. No additional software is needed to use optimization in LEAP.

Typically you will use this new capability 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 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, SO_x, NO_x, 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.

The connection between LEAP and GLPK/OSeMOSYS is completely transparent, so that users of LEAP need never interact directly with OSeMOSYS or GLPK or any of their data or results files. LEAP automatically writes the data files required by OSeMOSYS making use of the same data you already input into LEAP including process efficiencies, availability rates, emission factors, unit capital costs, fixed and variable O&M costs, fuel costs and externality values.   The results of the optimization are then read back into LEAP so that all relevant results can be viewed in LEAP in its standard Results, Energy Balance and Cost-Benefit reports.

Using optimization in LEAP is straight-forward. Optimization can optionally be used in one or more scenarios for calculating capacity expansion, whilst other scenarios can continue to use the previous accounting and simulation calculations in which the user specifies the expansion pathway.   The optimization method calculates both capacity expansion (how many future megawatts of power plants will be built) and process dispatch (how many megawatt-hours of each power plant will be dispatched in each time slice of each year).

You can choose to use the optimal dispatch information from OSeMOSYS back into LEAP, or you can override the OSeMOSYS dispatch calculations and continue to use one of LEAP's built-in dispatch rules (e.g. merit order or running cost dispatch).

One thing to remember with optimization calculations is that the *model tells the user* what future configuration of the energy system will yield the lowest overall cost to society. Such pathways may not necessarily represent realistic policy options in a particular country for many different reasons such as the social and environmental acceptability of certain technologies or the need to preserve diversity and energy security. On the other hand, with LEAP's simpler accounting calculations *the user tells the model* what energy system you want to see built. That is, you have to use your expert judgment to assess what pathways are feasible. These pathways are not necessarily optimal in the sense of being least cost.

Note that the optimality of a given pathway may be very sensitive to input assumptions such as future capital costs, future efficiency assumptions, future fuel costs or future GHG mitigation targets. A system

that is optimal for a country under one set of assumptions (e.g. low growth in fuel prices) may be far from optimal under another set of assumptions (e.g. high growth in oil prices). Generally, the goal in energy planning is not to identify a single optimal solution, but rather to identify robust energy policies that work well under a range of plausible input assumptions. You can easily use LEAP's scenario capabilities to calculate explore different optimal solutions under different sets of input assumptions[1].

Key Steps for Using Optimization in LEAP

The following are the key steps for setting up optimization in LEAP:

- **Step 1:** Check that OSeMOSYS is properly installed by visiting the Optimization tab of LEAP's General: Basic Parameters screen. Here you can also specify whether you wish to specify any emissions constraints and whether you wish to have LEAP make use of its optimal dispatch calculations. If not, LEAP will use one of its own dispatch rules.
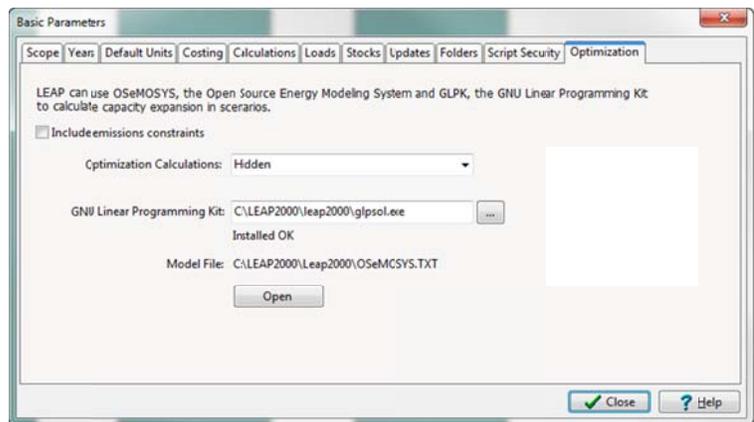
- **Step 2:** Select the Transformation module for which you wish to calculate an optimal capacity expansion pathway. Typically this will be the module in your LEAP data set that deals with electricity generation. Transformation modules are listed immediately below the top level Transformation branch in the LEAP tree structure (visible in the Analysis View).

- **Step 3:** Make sure you have input the minimum level of data required for an optimization calculation. Optimization calculations require more supporting data than LEAP's basic accounting calculations. In particular you need to specify process efficiencies and availability rates, unit capital costs, fixed and variable O&M costs, and (where appropriate) fuel costs. If you are analyzing GHG or local air pollution emissions and wish to consider an optimal system that takes into account pollution damage costs then you will also need to specify emission factors and pollutant externality values. Most of these data values are specified for the processes listed under the selected Transformation module. Unit fuel costs must be specified within the **Indigenous Cost** variable in the fuel branches located under the **Resources** tree branch. If you wish to specify an emission constraint, do so under the top level **Emission**

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[1] This process could even be automated by integrating a Monte Carlo modeling approach with LEAP using LEAP's API. Monte Carlo simulation is used to help identify by taking into account randomness and investigating thousands of different input assumptions.

Constraints tree branch.

- **Step 4:** Create a scenario in the Manage Scenarios screen that will be calculated using the optimization methodology.

- **Step 5:** While editing this scenario in Analysis View set the **Optimization** variable located at the Transformation module branch to **Yes** or **True**.

- **Step 6:** Optionally, You can also specify additional constraints for the **Minimum Capacity** and the **Maximum capacity** for each process within the optimized Transformation module.

Note that you can set up multiple scenarios, one or more of which can calculate an optimized expansion pathway with different assumptions. For example, different pathway may make different assumptions about economic growth, fuel price inflation and mitigation targets.

Viewing Results

Once you have followed the above steps you may now go to the **Results** view to see results for this scenario. LEAP will first attempt to calculate the scenario, invoking OSeMOSYS as needed to calculate the least cost expansion pathway and the least cost pattern of dispatch for the processes within the optimized Transformation module. LEAP will appear to pause for a few moments each time OSeMOSYS is called. Once the optimization calculations are complete, LEAP's own calculations will continue. If the OSeMOSYS calculations fail to solve (i.e. they fail to find an optimal pathway) then LEAP's calculations will be halted, an error message will be displayed and you will be given an opportunity to review the detailed debugging messages from OSeMOSYS.
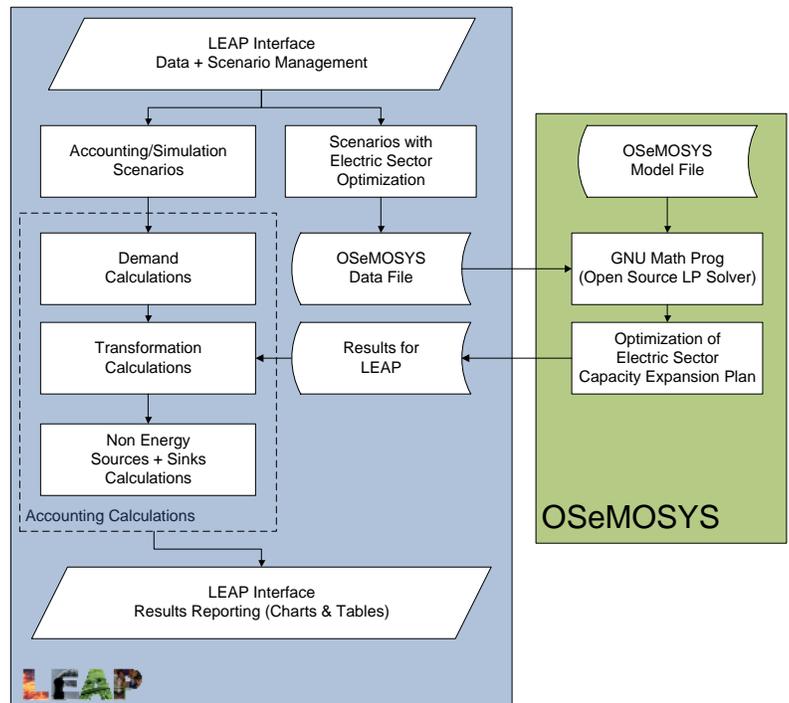
Getting More Information

Visit the following resources to get more details about the algorithms in the OSeMOSYS model, and the operation of the GLPK toolkit.

- OSeMOSYS web site:
  www.osemosys.org
- OsEMOSYS Documentation
  http://osmosys.yolasite.com/resources/OSMOSYS%202009_1_1.pdf
- GLPK web site:
  http://www.gnu.org/software/glpk/

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