



A Tool for Energy Planning and GHG Mitigation Assessment

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Outline

- LEAP introduction
 - What is LEAP?
 - How does it Compare to Other Models?
 - Structure and Interface
- Demand analysis
- Transformation
- Scenario manager
- GHG calculation

LEAP Introduction

Key Characteristics

- Easy-to-use scenario-based modeling software for energy planning and GHG mitigation assessment.
- Broad scope: demand, transformation, resource extraction, GHG & local air pollutants emissions, social cost-benefit analysis, non-energy sector sources and sinks.
- Not a model of a particular energy system: a tool for modeling different energy systems.
- Support for multiple methodologies such as transport stock-turnover modeling, electric sector load forecasting and capacity expansion, econometric and simulation models.
- Low initial data requirements: most aspects optional.
- Links to MS-Office (Excel, Word and PowerPoint).
- Local (cities, states), national, regional and global applicability.
- Medium to long-term time frame, annual time-step, unlimited number of years.
- Download from: www.energycommunity.org

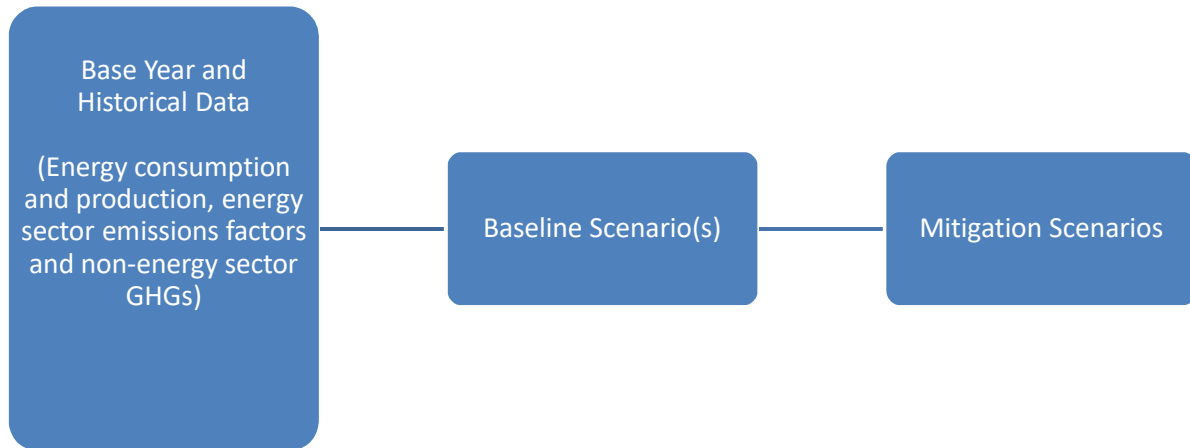
How Does LEAP Compare to Other Energy Models?

- Other tools typically have more sophisticated energy modeling capabilities, but are harder to use, more data intensive.
- LEAP's focus is on transparency of results, ease-of-use, data flexibility, adaptability to different scales, powerful data & scenario management and policy-friendly reporting.
- No other energy modeling tools have such powerful scenario & data management and reporting capabilities.
- LEAP is notable for the degree of methodological choices it provides to users.
- It is also unique in its ability to link to other models and software including WEAP and MS-Office through its powerful API. More such links are being developed (e.g. through SEI's current NOVA research to link to air quality and benefit estimation models).

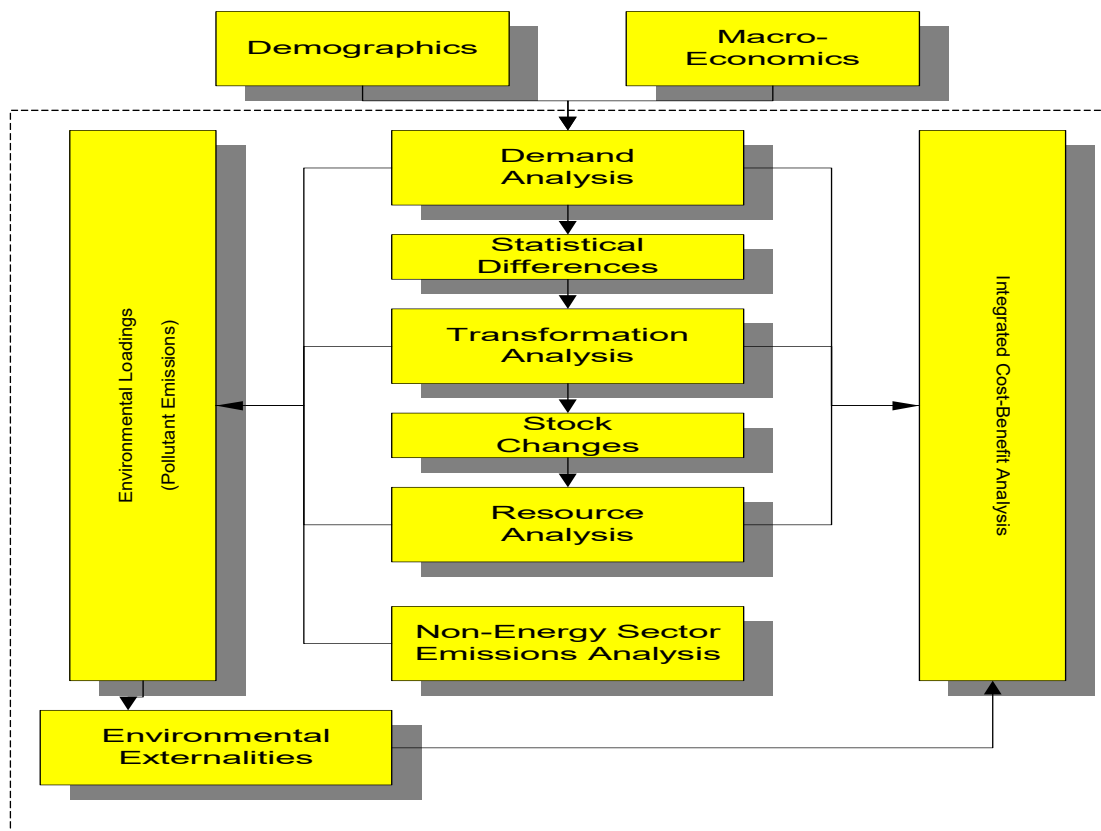
Multi-Regional Analysis

- Areas can optionally be divided into multiple regions.
- Regions appear as an extra data & results dimension.
- Regions can share similar tree structures or tree branches can be selectively hidden in some regions.
- Results can be summed and displayed across regions or aggregated into groups of regions
- Supports inter-regional trade calculations so that import requirements for some regions drives production and exports in other regions.

Key steps in Using LEAP



LEAP Structure & Calculation Flows



Top-Level Tree Categories

- **Key Assumptions:** independent variables (demographic, macroeconomic, etc.)
- **Demand:** energy demand analysis (including transport analyses).
- **Statistical Differences:** the differences between final consumption values and energy demands.
- **Transformation:** analysis of energy conversion, extraction, transmission and distribution. Organized into different modules, processes and output fuels.
- **Stock Changes:** the supply of primary energy from stocks. Negative values indicate an increase in stocks.
- **Resources:** the availability of primary resources (indigenous and imports) including fossil reserves and renewable resources.
- **Non-energy sector effects:** inventories and scenarios for non-energy related effects.

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Energy Balances in LEAP

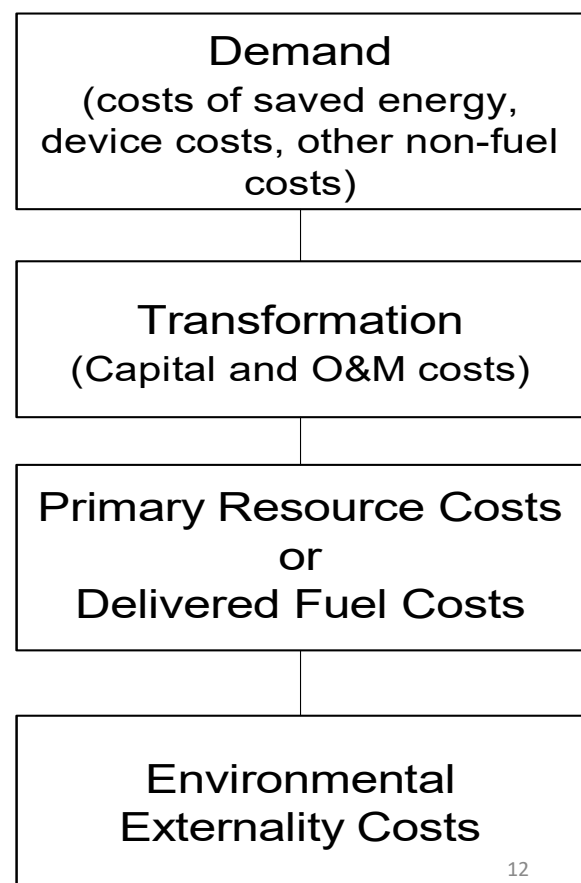
- Results automatically formatted as standard energy balance tables.
- Balances can be viewed for any year, scenario or region in different units.
- Balance columns can be switched among fuels, fuel groupings, years, and regions.
- Balance rows are the Demand and Transformation sectors. Optionally can show subsectoral results
- Displays results in any energy unit.
- Results in table, chart, or energy flow diagram formats.

Emissions Accounting

- Emission factors for any GHG or local air pollutant can be entered in LEAP and used to calculate emissions loadings.
- Can be specified in any physical unit and can be denominated by units of either energy consumption or production (e.g. kg/ton of coal) or distance driven for transport factors (e.g. grams/mile).
- Can also be specified in terms of the chemical composition of fuels (e.g. sulfur): automatically adjusts standard emission factors based on specific fuels used in the study area.
- Includes default IPCC “Tier 1” emission factors for GHG inventories.
- Results can be shown for individual pollutants or summed to show overall Global Warming Potential (GWP).

Social Cost-Benefit Analysis in LEAP

- Societal perspective of costs and benefits (i.e. economic not financial analysis).
- Avoids double-counting by drawing consistent boundary around analysis (e.g. whole system including).
- Cost-benefit analysis calculates the Net Present Value (NPV) of the differences in costs between two scenarios.
- NPV sums all costs in all years of the study discounted to a common base year.
- Optionally includes externality costs, decommissioning costs and costs of unserved demands.



LEAP: User Interface

The main menu and toolbar give access to major options.

Data is organized in a tree.

Select scenarios here.

Edit data by typing here.

Switch between views of the Area here.

Select units and scaling factors here.

The status bar notes the current Area and View.

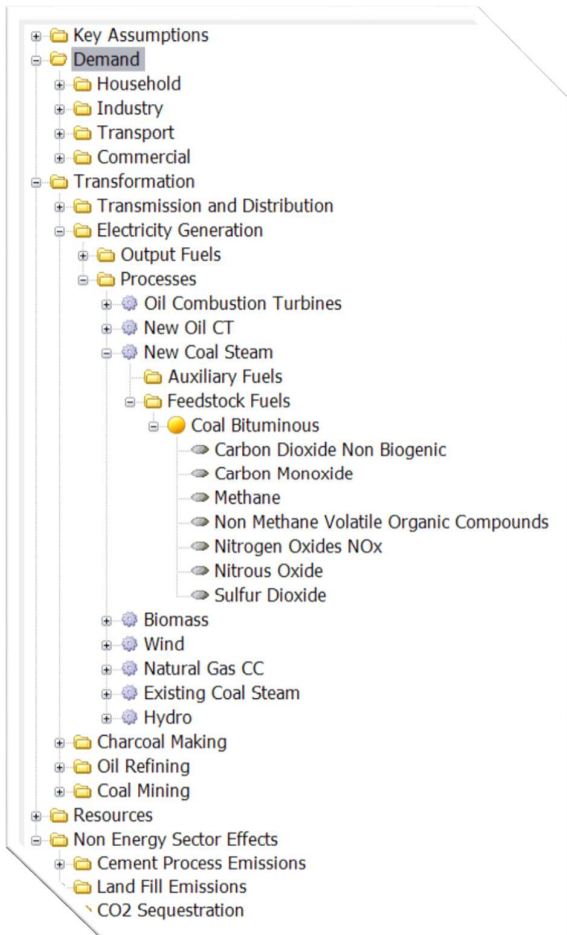
Data can be reviewed in chart or table format.

The screenshot shows the LEAP: Freedonia interface. The menu bar includes Area, View, Analysis, Edit, General, Trees, Chart, Advanced, and Help. The toolbar contains icons for New, Open, Save, Email, Find, Basic Params, Fuels, Effects, Units, References, and Help. The left sidebar has buttons for Views, Analysis, Results, Diagram, Energy Balance, Summaries, and Overviews. The main window displays a tree structure for 'Freedonia' with folders for Key Assumptions, Demand, Household, Urban, Rural, Industry, Transport, Commercial, Transformation, Resources, and Non Energy Sectors. The 'Demand' folder is expanded to show 'Household' and 'Urban'. The 'Household' folder is selected, showing a table of variables. The table has columns for Name, Value, Expression, Scale, Units, and Per. The 'Household' row has a value of 8.00 and an expression of 'Growth(3%)'. The 'Urban' row has a value of 30.00 and an expression of 'Interp(2030,45)'. Below the table is a chart titled 'Demand: Activity Level (Million Household)' showing a line graph from 2000 to 2030. The y-axis is 'Million Household' ranging from 0.0 to 15.0. The x-axis is years from 2000 to 2030. The status bar at the bottom indicates '2011.0.0.16 Area: Freedonia Analysis Registered to: charlie.heaps@sei-us.org until: 09/08/2012'.

Terminology

- **Area:** the system being studied. May be divided into multiple regions.
- **Current Accounts:** the data describing the base year of a study or multiple years of historical data.
- **Scenario:** a consistent set of assumptions about the future. LEAP can have any number of scenarios.
- **Tree:** the main organizational data structure in LEAP.
- **Branch:** an item on the tree: can be organizing categories, technologies, modules, processes, key variables, etc.
- **Variable:** Branches may have multiple variables. Available variables at a branch depend on the type of branch. Displayed as “tabs” on screen.
- **Expression:** a mathematical formula that specifies the time-series values of a variable for a given branch, scenario and region.









The Tree



- The main data structure used for organizing data and models, and reviewing results
- Icons indicate types of data (e.g., categories, technologies, fuels and effects)
- User can edit data structure.
- Supports standard editing functions (copying, pasting, drag & drop of groups of branches)

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Tree Branches

-  **Categories:** used mainly for organizing other branches.
-  **End-Use** branches indicate situations where energy intensities are specified for an aggregate end-use, rather than with a specific fuel or device. Primarily used when conducting useful energy analysis.
- **Technology** branches represent final energy consuming devices. Three basic types:
 -  **Activity Level Analysis**, in which energy consumption is calculated as the product of an activity level and an annual energy intensity (energy use per unit of activity).
 -  **Stock Analysis**, in which energy consumption is calculated by analyzing the current and projected future stocks of energy-using devices, and the annual energy intensity of each device.
 -  **Transport Analysis**, in which energy consumption is calculated as the product of the number of vehicles, the annual average distance traveled per vehicle and the fuel economy of the vehicles.
-  **Key Assumptions:** independent variables (demographic, macroeconomic, etc.)
-  **Fuels.**
-  **Effect** branches: environmental loadings (emissions).

Expressions

- Similar to expressions in spreadsheets.
- Used to specify the value of variables.
- Expressions can be numerical values, or a formula that yields different results in each year.
- Can use many built-in functions, or refer to the values of other variables.
- Can be linked to Excel spreadsheets.
- Inherited from one scenario to another.

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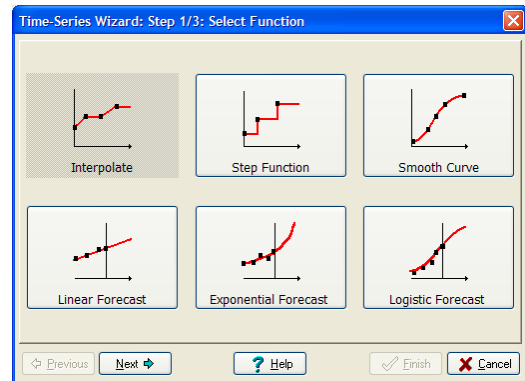
Some Expression Examples

- Simple Number
 - Calculates a constant value in all scenario years.
- Simple Formula
 - Example: "0.1 * 5970"
- Growth Rate
 - Example: "Growth(3.2%)"
 - Calculates exponential growth over time.
- Interpolation Function
 - Example: "Interp(2000, 40, 2010, 65, 2020, 80)"
 - Calculates gradual change between data values
- Step Function
 - Example: "Step(2000, 300, 2005, 500, 2020, 700)"
 - Calculates discrete changes in particular years
- GrowthAs
 - Example: "GrowthAs(Income,elasticity)"
 - Calculates future years using the base year value of the current branch and the rate of growth in another branch.
- Many others!

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Four Ways to Edit an Expression:

- Type to directly edit the expression.
- Select a common function from a selection box.
- Use the Time-Series Wizard to enter time-series functions (Interp, Step, etc. and to link to Excel)
- Use the Expression builder to make an expression by dragging-and-dropping functions and variables.



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Modeling at Two levels

1. Basic physical accounting calculations handled internally within software (stock turnover, energy demand and supply, electric dispatch and capacity expansion, resource requirements, costing, pollutant emissions, etc.).
2. Additional modeling can be added by the user (e.g. user might specify market penetration as a function of prices, income level and policy variables).
 - Users can specify spreadsheet-like expressions that define data and models, describing how variables change over time in scenarios:
 - Expressions can range from simple numeric values to complex mathematical formulae. Each can make use of
 1. math functions,
 2. values of other variables,
 3. functions for specifying how a variable changes over time, or
 4. links to external spreadsheets.

Minimum Hardware & Software Requirements

Any standard modern PC:

- Windows 2000, NT, XP, Vista, 7 or 8.
 - Not compatible with Windows 95 or 98
 - Can be used on Apple or Linux PCs via WINE.
- 1024 x 768 screen resolution.
- > 128 MB RAM
- Optional:
 - Internet connection
 - Microsoft Office

Status and Dissemination

- Available at no charge to non-profit, academic and governmental institutions based in developing countries.
- Download from: www.energycommunity.org
- Technical support from web site or leap@sei-us.org
- User name and password required to fully enable software. Available on completion of license agreement.
- Most users will need training: available through SEI or regional partner organizations.
- Check LEAP web site for news of training workshops.

Demand Analysis

Demand Analysis in LEAP

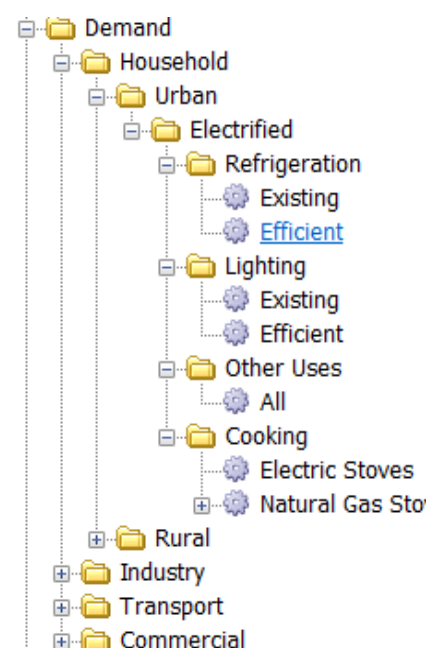
- Analysis of energy consumption and associated costs and emissions in an area.
- Demands organized into a flexible hierarchical tree structure.
- Typically organized by sector, subsector, end-use and device.
- Supports multiple methodologies:
 - End-use analysis: $\text{energy} = \text{activity level} \times \text{energy intensity}$
 - Econometric forecasts
 - Stock-turnover modeling

Three Approaches for Demand Modeling in LEAP

- Bottom-Up/End-Use
- Top-down/Econometric
- Hybrid/Decoupled

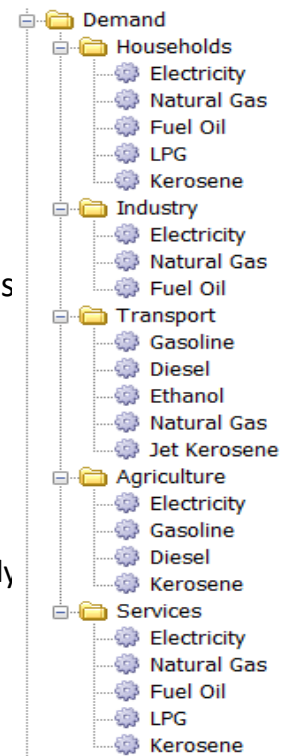
Bottom-Up/End-Use

- Detailed accounting for all the various sectors/subsectors/end-uses/devices that consume energy.
- Pros:
 - Provides a more fundamental understanding of why energy is used in an economy: probably the best approach for thinking about long-term transitions.
 - Captures impacts of structural shifts and from technology-based policies such as energy efficiency.
- Cons:
 - Data intensive.
 - Reliant on expertise of analyst for many trends and assumptions.
 - Hard to capture impacts of fiscal policies (e.g. Carbon tax).



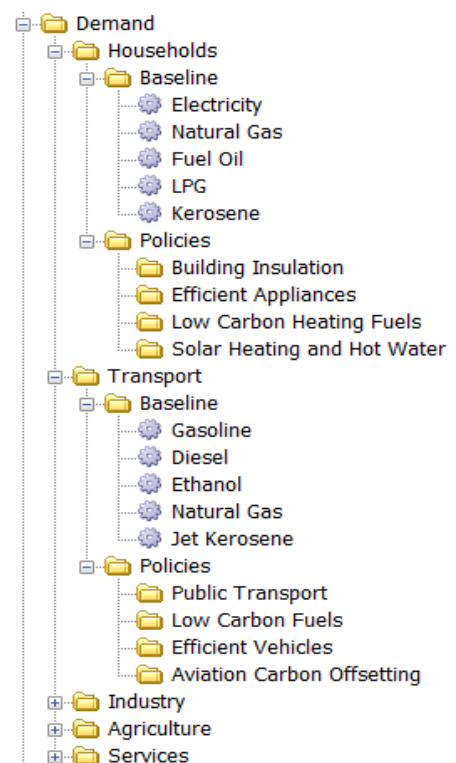
Top-down/Econometric

- A more aggregate approach often with energy consumption broken down only into sectors and fuels.
- Less data intensive
- Relies on good historical time-series data.
- Consumption trends forecast into future using simple historical trends or aggregate econometric relationships (GDP, fuel prices, etc.)
- Pros:
 - Captures impacts of fiscal policies (e.g. C tax)
- Cons:
 - Not well suited to long-range scenarios since the exogenous variables (e.g. prices) are themselves so poorly known.
 - Not well-suited for examining technology-based policies.



Hybrid/Decoupled

- Baseline scenario forecast using top-down approach. Alternative scenarios modeled as policy measures that reduce energy consumption over time.
- In LEAP, these are entered as negative “wedges” of consumption: subtracted from baseline energy use in each sector.
- Pros:
 - Less data intensive than end-use approach, but able to capture technology-based policies.
- Cons:
 - Not a full end-use model, so does not give insights into how energy system structure might change in long-run. Limited to situations where measures are small vs. baseline.



Demand Modeling Methodologies

1. Final Energy Analysis: $e = a \cdot i$
 - Where e=energy demand, a=activity level, i=final energy intensity (energy consumed per unit of activity)
 - **Example:** energy demand in the cement industry can be projected based on tons of cement produced and energy used per ton. *Each can change in the future.*
2. Useful Energy Analysis: $e = a \cdot (u / n)$
 - Where u=useful energy intensity, n = efficiency
 - **Example:** energy demand in buildings will change in future as more buildings are constructed [+a]; incomes increase and so people heat and cool buildings more [+u]; or building insulation improves [-u]; or as people switch from less efficient oil boilers to electricity or natural gas [+n].

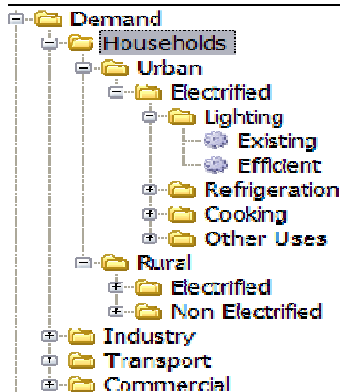
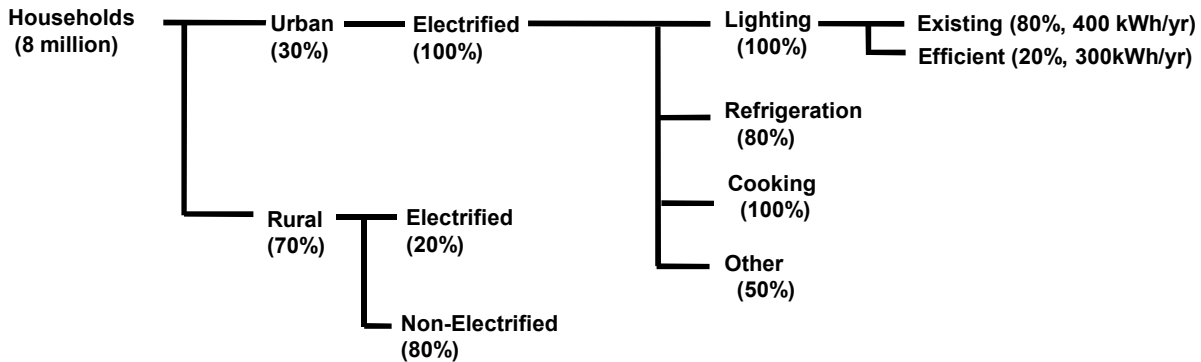
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Demand Modeling Methodologies (2)

3. Transport Stock Turnover Analysis: $e = s \cdot m / fe$
 - Where: s= number of vehicles (stock), m = vehicle distance, fe = fuel economy
 - Allows modeling of vehicle stock turnover.
 - Also allows pollutant emissions to be modeled as function of vehicle distance.
 - Example: model impact of new vehicle fuel economy or emissions standards.

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A Simple Demand Data Structure



- The tree is the main data structure used for organizing data and models, and for reviewing results.
- Icons indicate the types of data (e.g., categories, technologies, fuels and environmental effects).
- Users can edit the tree on-screen using standard editing functions (copy, paste, drag & drop)
- Structure can be detailed and end-use oriented, or highly aggregate (e.g. sector by fuel).
- Detail can be varied from sector to sector.

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Saturation and Share

- **Saturation:** Similar to a market penetration. When using this unit all values must be between 0% and 100%, but neighboring values need NOT sum to 100%. For example, 100% of households may use and electric stove and 20% may also use a gas stove.
- **Share:** Use this unit to tell LEAP that all immediately neighboring branches must sum to 100%. For example, the sum of urban and rural percentages should equal 100%. In calculations, if branches do not sum to 100% LEAP will halt the calculations and show an error message.
- When there is only one branch either saturation or share can be used.

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Transport Stock-Turnover Modeling

Transport Stock-Turnover Modeling

- In earlier activity level analysis we were always dealing with the average characteristics of all devices (averaged across new and old).
- In a stock-turnover analysis we want to reflect the different characteristics of vehicles of different ages (vintages).
- Vehicle characteristics will change as vehicles get older (emissions profiles, km driven, fuel economy, etc.)
- We also want to reflect how transport policies affecting new vehicles (e.g. new fuel economy standards and emissions standards) will have a gradual impact as older vehicles are retired and newer vehicles are purchased. So we need to model how long vehicles survive on the road.
- Ability to examine fuel switching and multi-fueled vehicles independently of transport stock turnover,

Transport Stock-Turnover Modeling

Energy calculated as follows:

$$e = s \times m / fe$$

- Where: s = number of vehicles (stock),
 m = vehicle distance, fe = fuel economy
- (NB: fuel economy can be defined as either l/100 km or MPG)
- Emissions can be specified per unit of energy consumed or per unit of distance driven (which reflects how vehicle emissions are generally regulated).

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Two Dynamics to Consider...

Two dynamics to consider:

1. How characteristics of new vehicles might evolve (e.g. due to new regulations).

These changes are specified from year to year using LEAP's standard expressions (interp, growth, etc.)

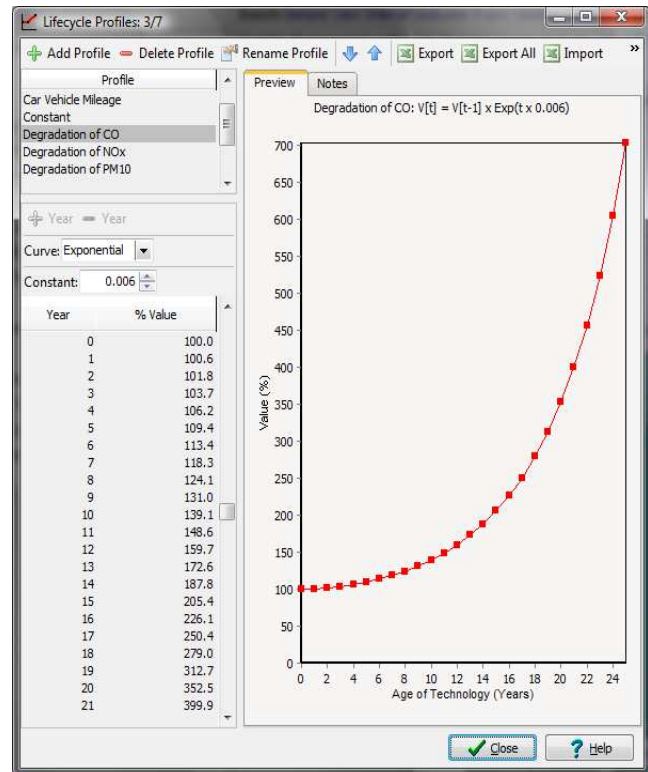
2. How characteristics of existing vehicles change as they get older (so need to keep track of number of vehicles of each vintage).

These changes are specified by vehicle age (vintage) from new to old (0, 1, 2, years, etc.) using a special lifecycle profile screen.

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Lifecycle Profiles

- Describe how vehicle characteristics change as they get older.
- Used to describe:
 - Emissions degradation
 - Mileage degradation
 - Fuel economy degradation
 - Survival of vehicles
- Typically start from value of 100% (the characteristic of a new vehicle).
- Can be specified using data values, or an exponential curve or imported from Excel.



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Transformation Analysis

Transformation Analysis in LEAP

- Analysis of energy conversion, transmission and distribution, and resource extraction.
- Demand-driven engineering-based simulation.
- Basic hierarchy: “modules” (sectors), each containing one or more “processes”. Each process can have one or more feedstock fuels and one or more auxiliary fuels.
- Allows for simulation of both capacity expansion and process dispatch.
- Calculates imports, exports and primary resource requirements.
- Tracks costs and environmental loadings.
- Choice of two solution methodologies: **simulation** or **optimization**.

Choice of Methods: to Match Data Available

- **Level 1 (Simplest):** Ignores capacity limits, assume sufficient capacity available: dispatch simply specifies shares of each process.
- **Level 2:** User controls **what** to build and **when** it will be built (capacity expansion). User also fully controls the dispatch of processes (e.g. by percentage share or in proportion to available capacity).
- **Level 3 (Intermediate):** User controls **what** to build but LEAP decides **when** (so as to meet some minimum planning reserve margin). Dispatch by merit order to meet peak demands varying along a load duration curve.
- **Level 4 (Most detailed):** LEAP decides both **what** to build and **when**, using optimization modeling (LP). Plant availability and dispatch vary by season and time-of-day according to detailed load shapes. Load shapes specified for system as a whole or may be built-up for system based on load shapes of different devices (e.g. A/Cs, fridges, lighting, industrial demands, etc.)

Capacity Expansion

Different ways to specify current and future capacity:

Simulation:

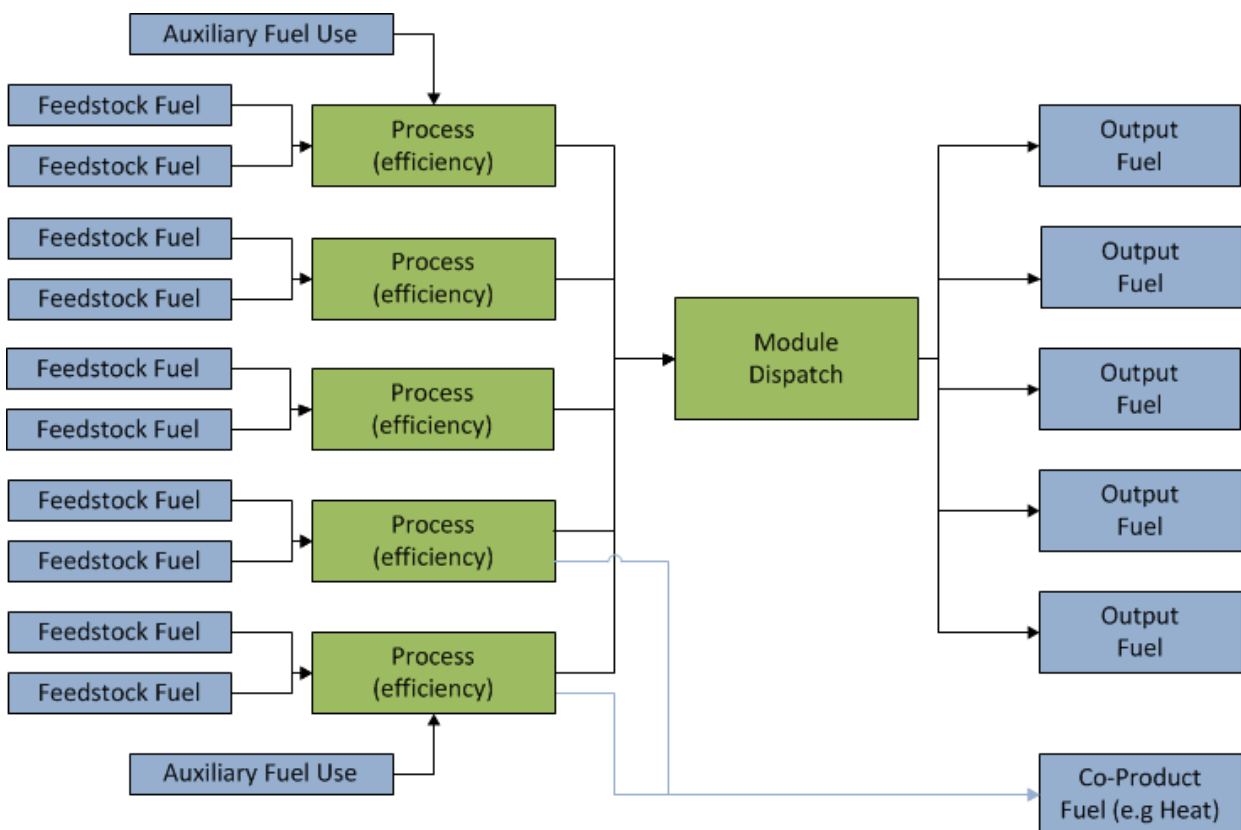
- **Exogenous Capacity:** User specifies current and future capacity of plants including retirements.
- **Endogenous Capacity:** User specifies types of plants to be built but LEAP decides *when* to add plants to maintain a specified planning reserve margin.

Optimization

- LEAP decides both what to build AND when to build.
- Uses the OSeMOSYS model to calculate optimal capacity expansion – then reads the results back into LEAP's **Exogenous Capacity** variable.

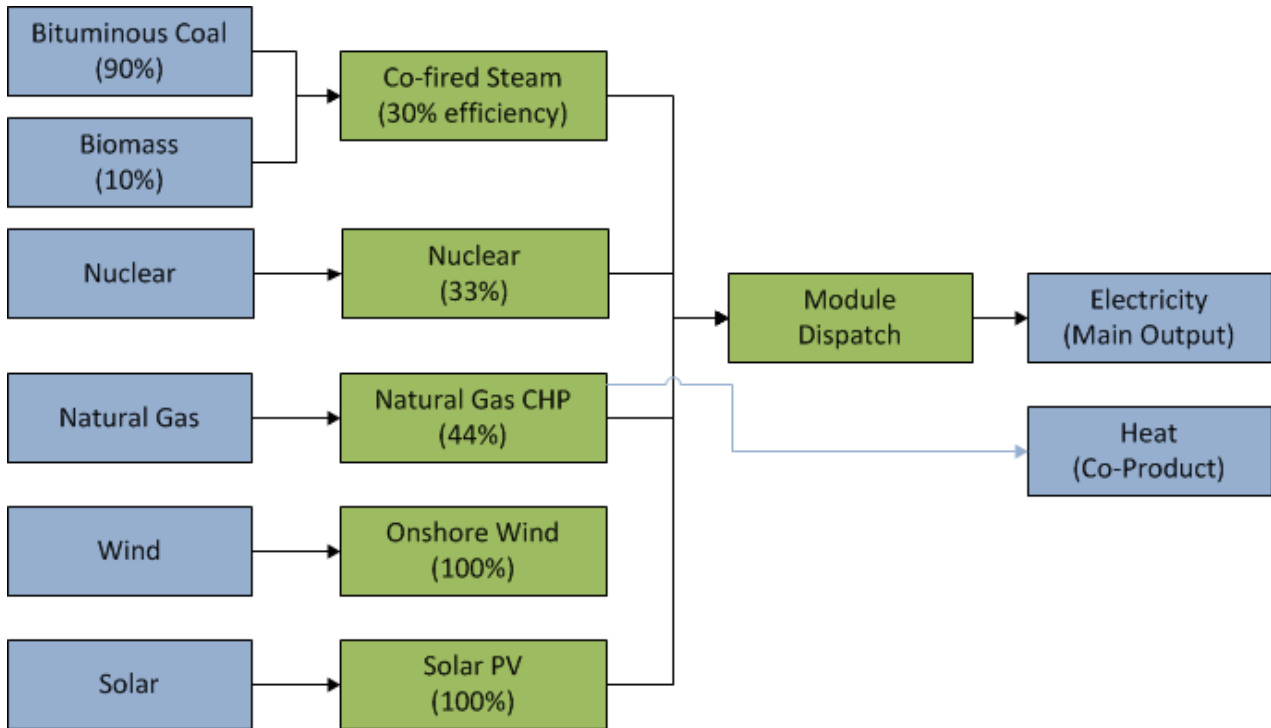
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General Transformation Module Layout



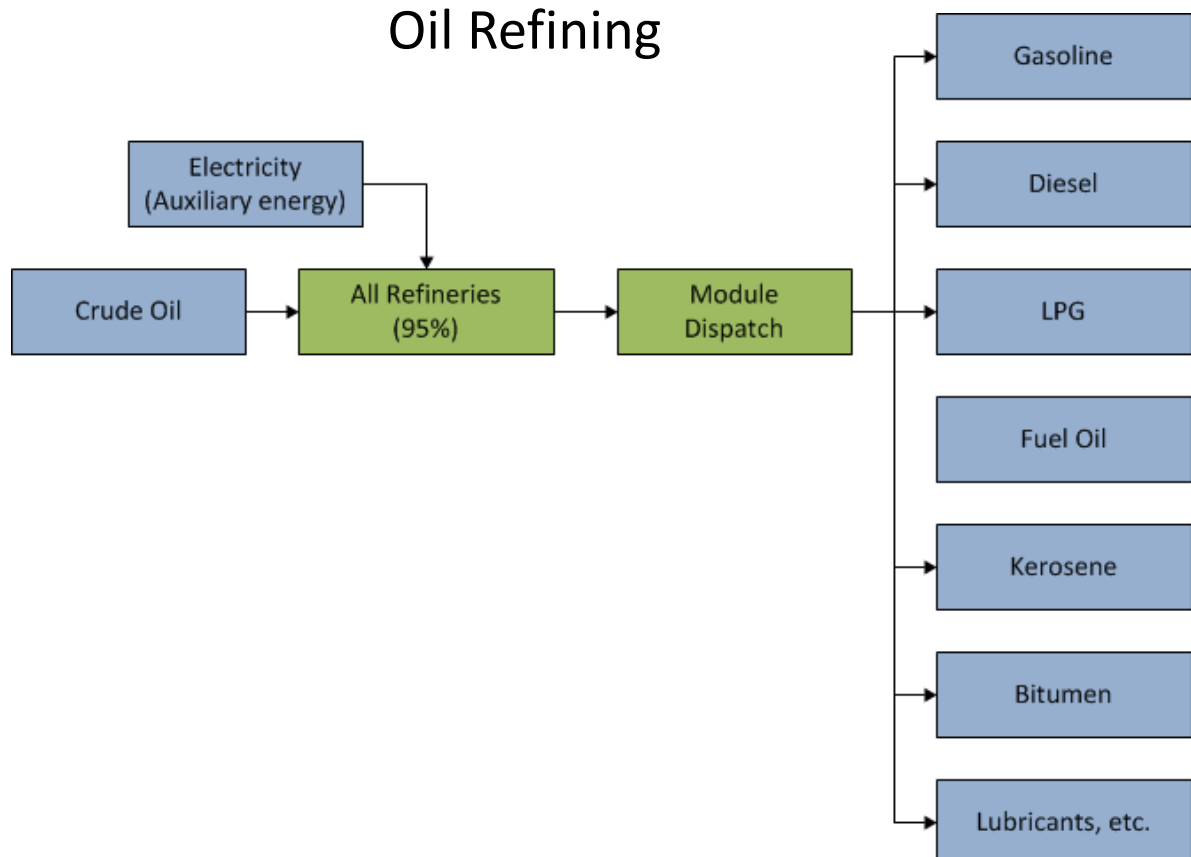
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A Transformation Module for Electricity Generation

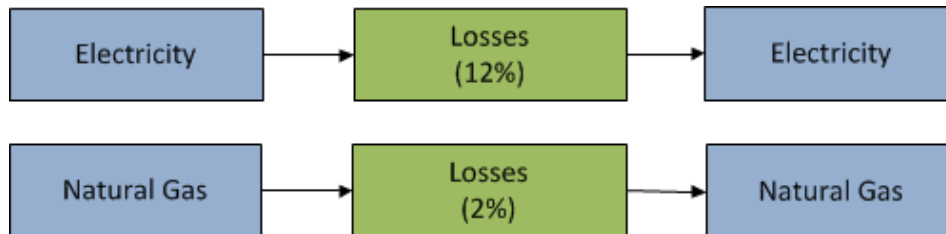


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A Transformation Module for Oil Refining



A Simple, Non-Dispatched Transformation Module



Two Dispatch Modes

- **Mode 1:** Historical: LEAP simply dispatches plants based on historical generation.
- **Mode 2:** Simulation: plants dispatched based on various dispatch rules ranging from very simple (% of total generation) to more sophisticated (dispatch by merit order or in order of running costs)
- Set the **First Simulation Year** variable for each process to determine when to use historical mode and when to use simulation mode.
- You *can* mix modes and dispatch rules in neighboring processes. (e.g. dispatch wind by percentage to meet a renewable portfolio standard, but dispatch other processes by merit order).

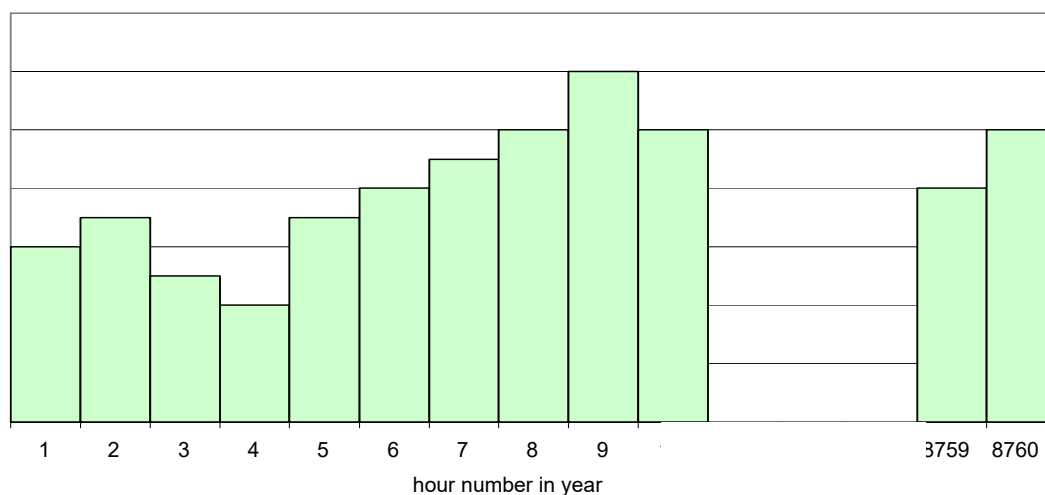
Electric Generation

Two Issues to consider:

- 1. Capacity Expansion:** How much capacity to build and when? (MW)
- 2. Dispatch:** Once built, how should the plants be operated? (MW-Hr)

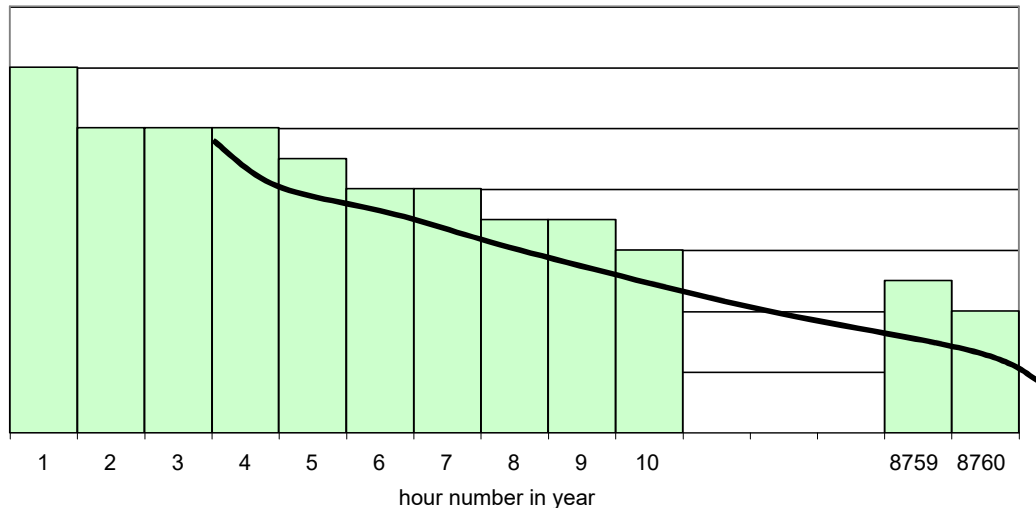
Hourly Demand Curve

- Hour-by-hour load curve
 - Power demand in each hour of the year
 - Area = Power (kW) x time (1 hour) = Energy (kWh)

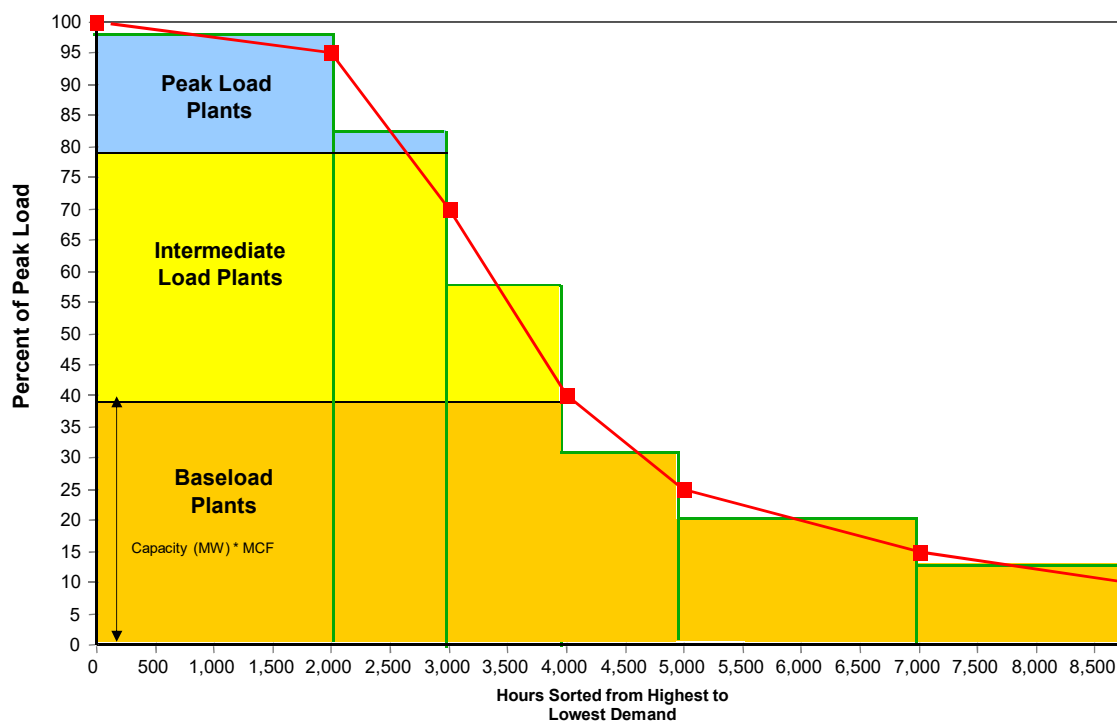


Load Duration Curve

- Rearrange hourly demand curve
 - Hours on x-axis is # of hours/year that demand is greater than or equal to a particular value



Load-Duration Curve and System Dispatch in LEAP



Making a Load Shape

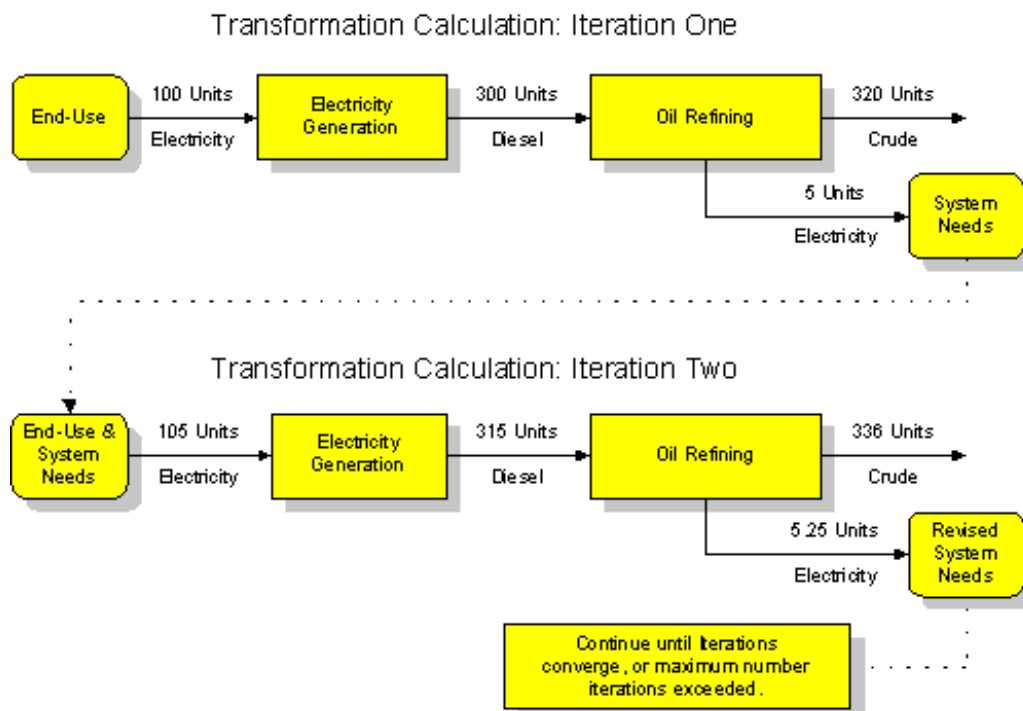
- Step 1: Divide Year into Time Slices
- Step 2: Make a load shape with data for each time slice
- Step 3: Assign the load shape to our electricity system.

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Electric Generation Dispatch

- Plants are dispatched to meet both total demand (in MWh) as well as the instantaneous peak demand which varies by hour, day and season.
- User can exogenously specify a load-duration curve and LEAP will dispatch plants by merit order.
- Alternatively, load shapes be specified for each demand device so that the overall system load is calculated endogenously. Thus the effect of DSM policies on the overall load shape can then be explored in scenarios.
- Plant dispatch can also then be varied by season (e.g. to reflect how hydro dispatch may vary between wet and dry seasons).

Transformation Modules with Feedback Flows



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Oil Refining Simulation

- Uses the same basic module structure as for Electric Generation, but generally has a single input fuel (crude) and multiple output fuels (gasoline, diesel, kerosene, LPG, fuel oil, etc.)
- Outputs produced in specified proportions, and the whole module is run to the point where demands for “priority products” are met (assuming module has sufficient capacity).
- Other products are considered by-products and may or may not be produced in sufficient quantities.
- User sets simulation rules to tell what LEAP to do in situations of surpluses (export or waste) and deficits (import or ignore).
- Alternatively, output fractions can be set to same proportions as requirements so all products produced without shortfalls or surpluses.

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Simple Refinery Simulation Example

Fuel	Production Required	Output Energy Share	Priority Fuel?	Energy Produced	Outcome
Kerosene	400	55%	Yes	660	Surplus
Gasoline	300	25%	Yes	300	Exact
Fuel Oil	300	20%	No	240	Shortfall
Total	1000	100%		1200	

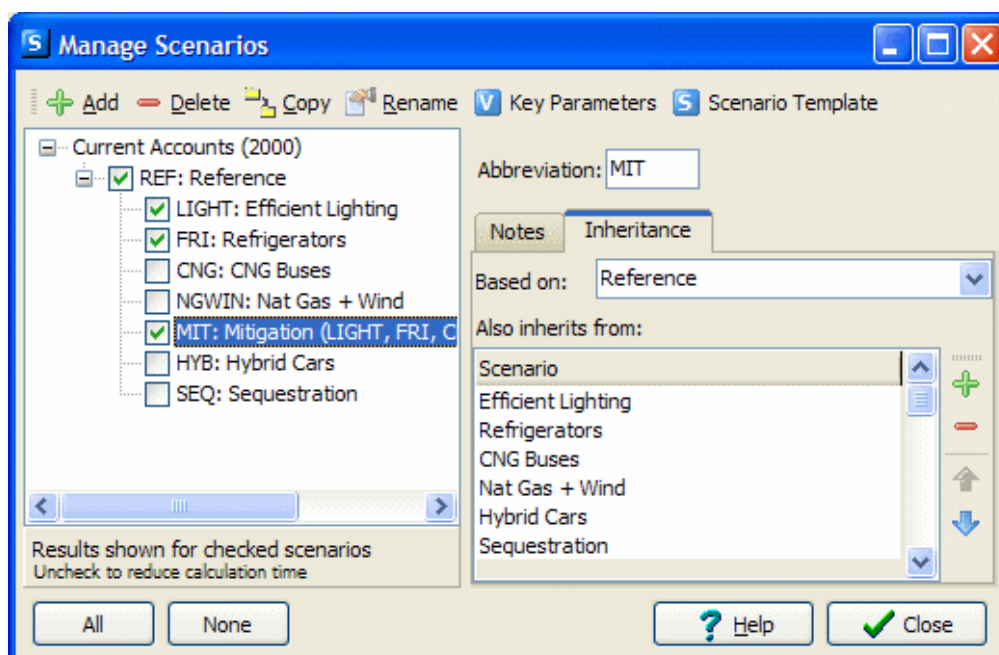
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Scenario Manager

Scenarios in LEAP

- Consistent story-lines of how an energy system might evolve over time. Can be used for policy assumption and sensitivity analysis.
- *Inheritance* allows you to create hierarchies of scenarios that inherit default expressions from their parent scenario. All scenarios inherit from *Current Accounts* minimizing data entry and allowing common assumptions to be edited in one place.
- *Multiple inheritance* allows scenarios to inherit expressions from more than one parent scenario. Allows combining of measures to create integrated scenarios.
- The **Scenario Manager** is used to organize scenarios and specify inheritance.
- Expressions are color coded to show which expressions have been entered explicitly in a scenario (blue), and which are inherited from a parent scenario (black) or from another region (purple).

The Scenario Manager



- Free online community to support analysts:
 - discussion & support forums.
 - online libraries and newsletters.
 - downloadable software.
 - Downloadable national data sets
 - training and reference materials.
- Almost 15000 members in 190 countries.
- www.energycommunity.org

When You Have a Problem...

- Post message on LEAP discussion at www.energycommunity.org or email leap@sei-us.org
- **Be as specific as possible:** Include:
 - Error message (if any)
 - Did problem happen during installation or when running LEAP?
 - What were you doing and what part of LEAP were you using when problem occurred?
 - Is the problem reproducible and what exact steps do I (Charlie) need to take do that?
 - Operating system version (2000, XP, Vista, etc.), language and regional number formatting (e.g. 1,234.56 or 1.234,56)
 - Version of LEAP (check Help: About)
 - If possible include the LEAP.LOG file and attach the problem data set as a .zip or a .leap file.
 - The error reporting screen will do most of this for you automatically.