



A Tool for Energy Planning and GHG Mitigation Assessment

Charlie Heaps

LEAP Developer and
Director, U.S. Center



Outline

- What is LEAP?
- How does it Compare to Other Models?
- Structure and Interface
- A Kew Key Concepts and Glossary of Terms
- Who Uses It?

LEAP **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

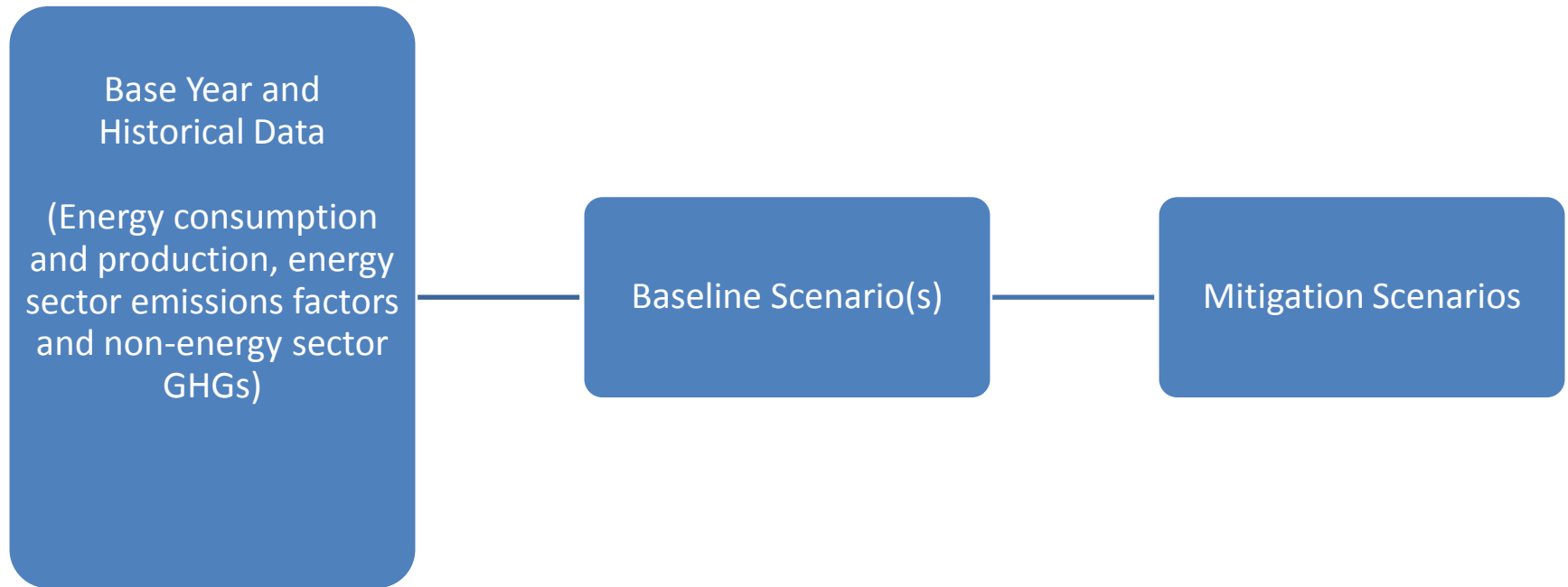
How Does LEAP Compare to Other Energy Models?

- 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).

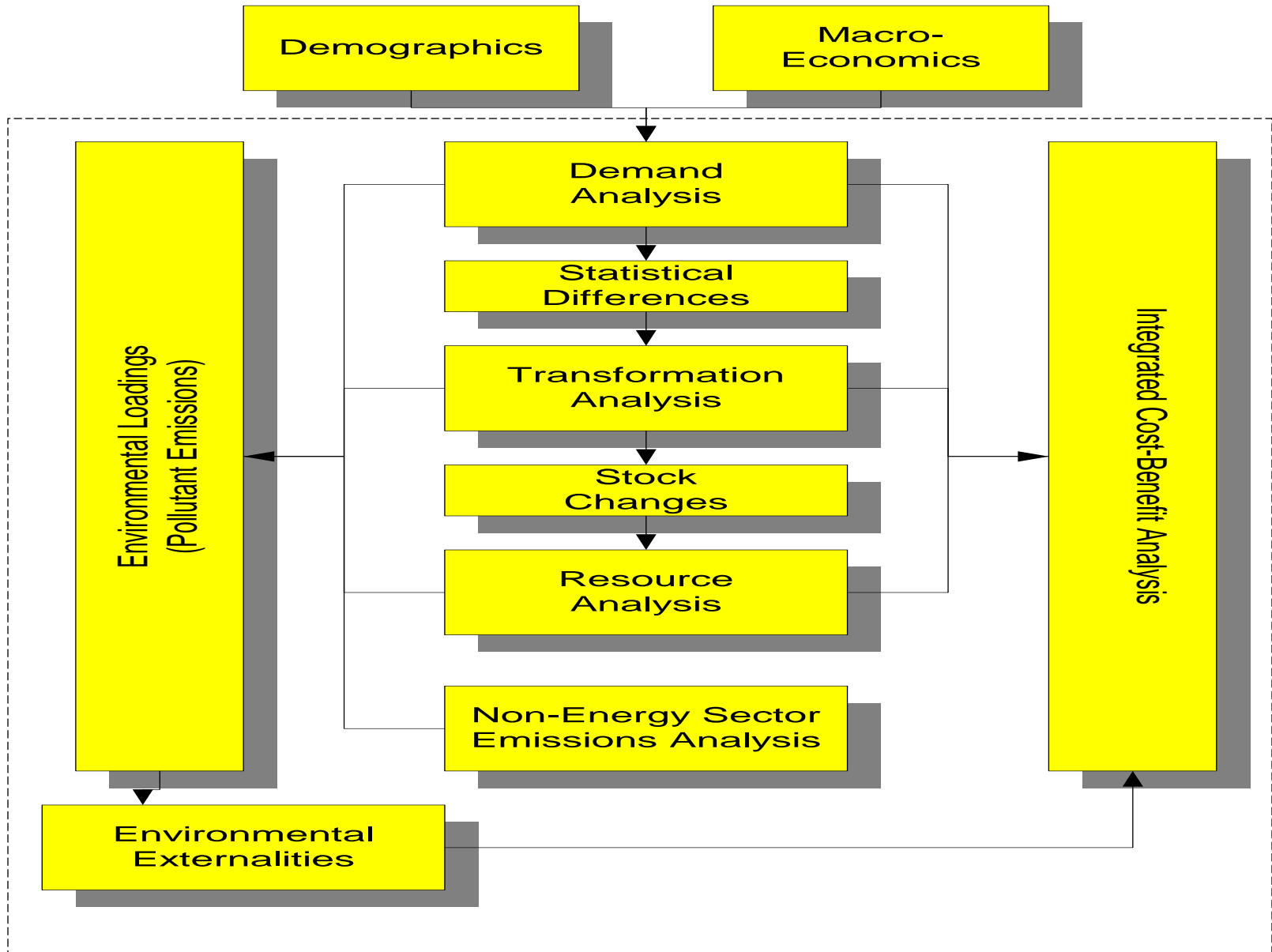
Basic Demand Modeling Philosophy in LEAP

- Other energy models have relatively simple data structures coupled with complex modeling algorithms.
- LEAP relies on building hierarchical data structures that break down the overall problem of projecting energy demand into smaller, manageable pieces.
- EG: the demand for energy use in hybrid gasoline will depend on:
 - A. The growth in national population
 - B. The overall average per capita growth in demand for travel (pass-km/person)
 - C. The share of passenger transport coming from road travel.
 - D. The share of road transport delivered by cars (as opposed to taxis, buses, motorcycles, etc.)
 - E. The market share of hybrid cars (versus standard cars).
 - F. The average load factors of cars (the number of people per car)
 - G. And finally, the energy intensity of hybrid cars.
- $A * B * C * D * E * F$
- Some items can be projected using trend assessments. Others may have to rely on expert judgment or additional modeling efforts.
- Philosophy is to build comprehensive, hierarchical, and transparent data structures, and develop plausible and consistent storylines about how each piece might change.

Key steps in Using LEAP



LEAP Structure & Calculation Flows



LEAP: User Interface

The main menu and toolbar give access to major options.

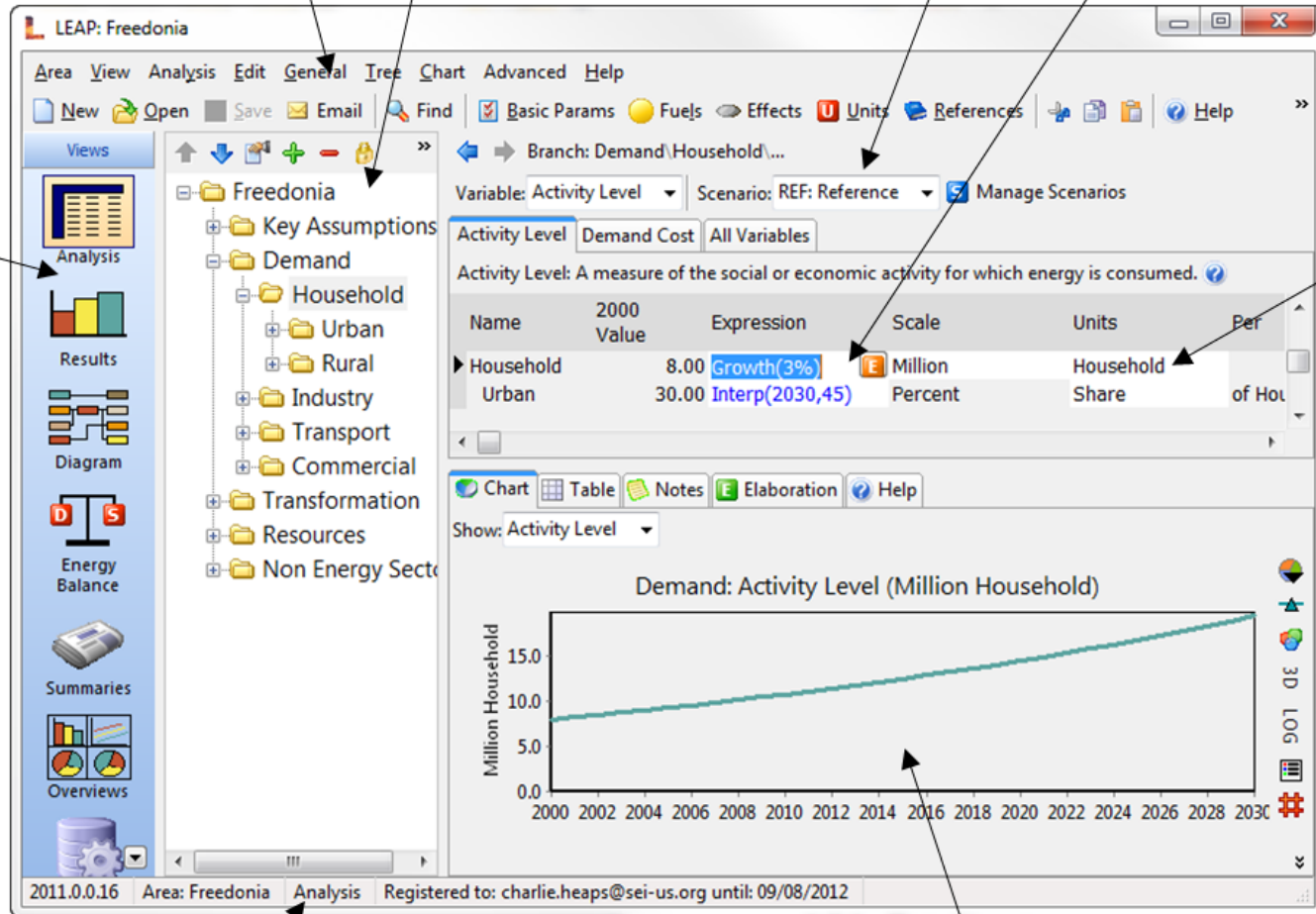
Data is organized in a tree.

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.

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

LEAP 2012: Key New Features

- Energy-Water Nexus: Links to SEI's "WEAP" Water Model for integrated energy/water assessment.
- Flexible region and fuel groupings (used in new global modal).
 - For example, SEI's new global energy model, built in LEAP, modeled 22 global regions, while results were presented aggregated across 22, 10, 6 and 3 macro regions.
- Improved ease-of-use (many screens redesigned and simplified)
- New demand modeling methods.
- More Beautiful Charts that can be exported in high resolution for direct use in reports.
- Improved optimization calculations and better treatment of externality costs.
- Improved Manage Areas screen: better tools for managing data sets.
- Improved API, new modeling functions.

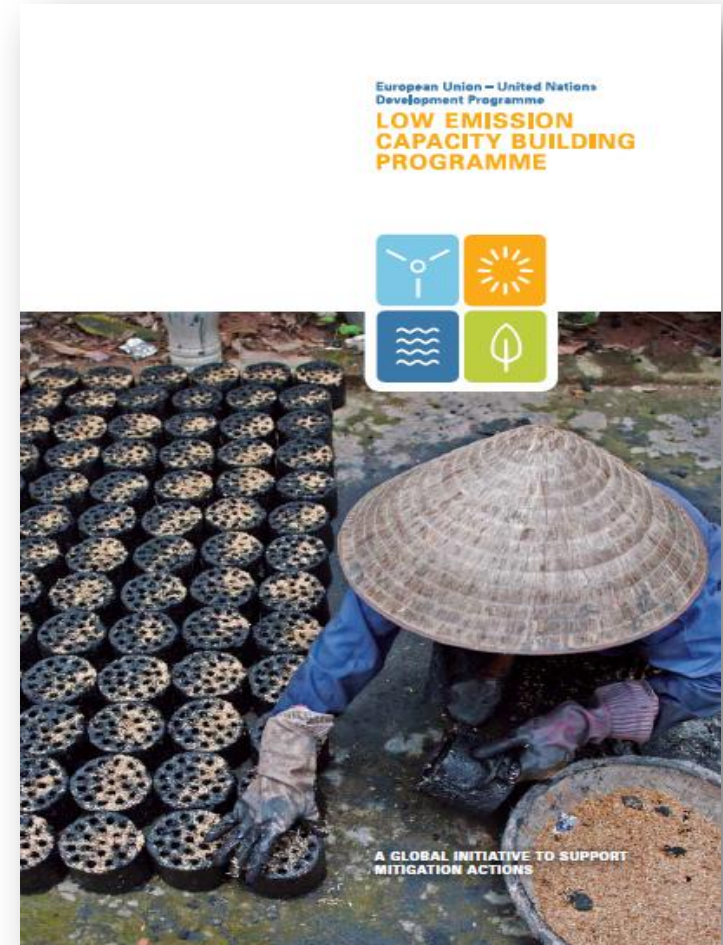
Status and Dissemination

- 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.

Some Recent Applications of LEAP

UNDP Low Emission Capacity Building Programme

- Five year initiative to support GHG mitigation efforts, low emission development strategies (LEDS) and enhanced MRV of GHGs in developing nations.
- 25 developing countries are participating in the programme, which is led by UNDP and funded by the EC and the Governments of Germany and Australia.
- SEI has developed LEAP data sets for 22 countries, which will serve as first draft baseline scenarios and a suggested structure for mitigation assessment in those countries.

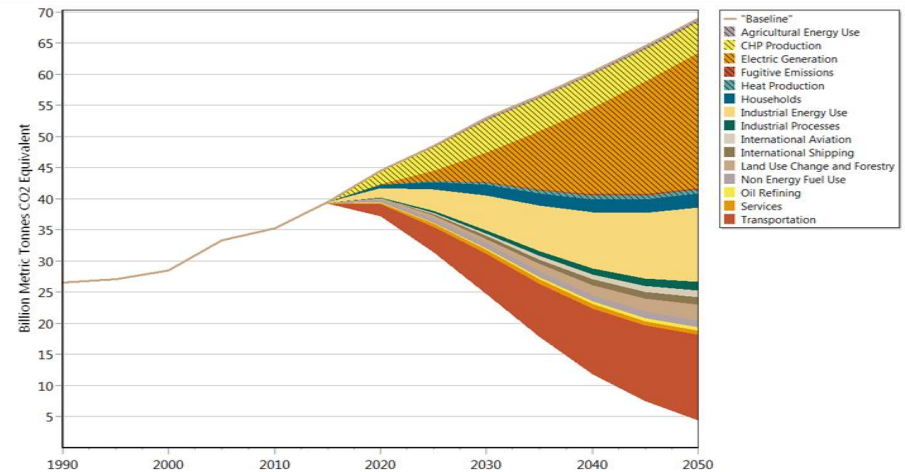




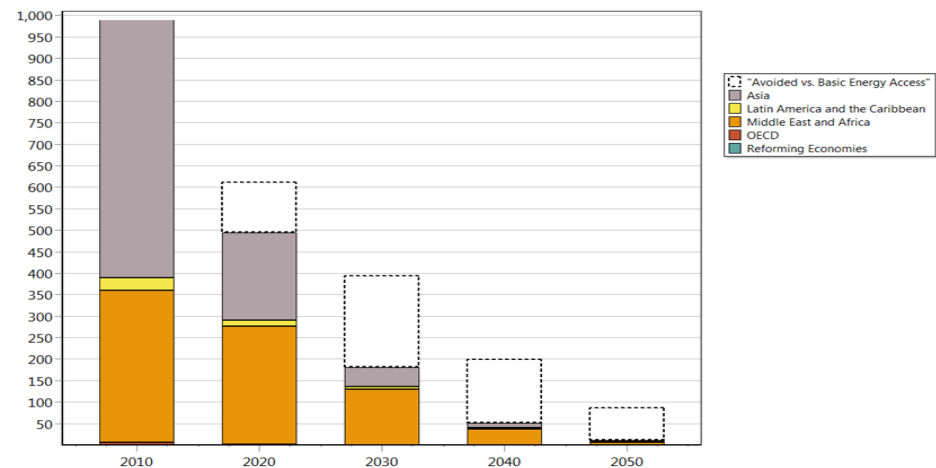
Energy for a Shared Development Agenda: A Global Assessment for Rio+20, 2012

- Explores how global energy systems can be reconfigured to address sustainability whilst also providing meaningful development and poverty alleviation.
- Conducted by SEI with IIASA, PBL, TERI and WRI.
- Energy and emissions scenarios to 2050 developed in LEAP for 20 global regions.
- Three scenarios:
 - Baseline
 - Basic Energy Access
 - Shared Development Agenda
- Report to be published at Rio+20
- Will also result in new open source, freely accessible global data set for LEAP.

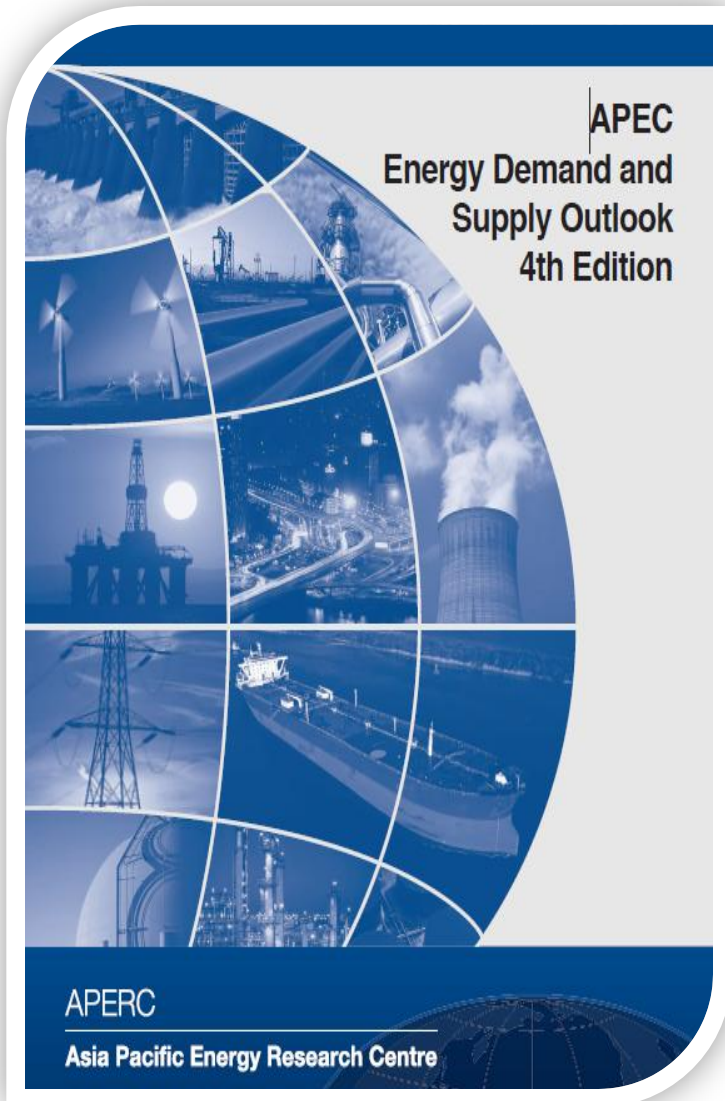
Emissions



Poverty



APEC: Energy Demand and Supply Outlook 2009, 2006, 2002



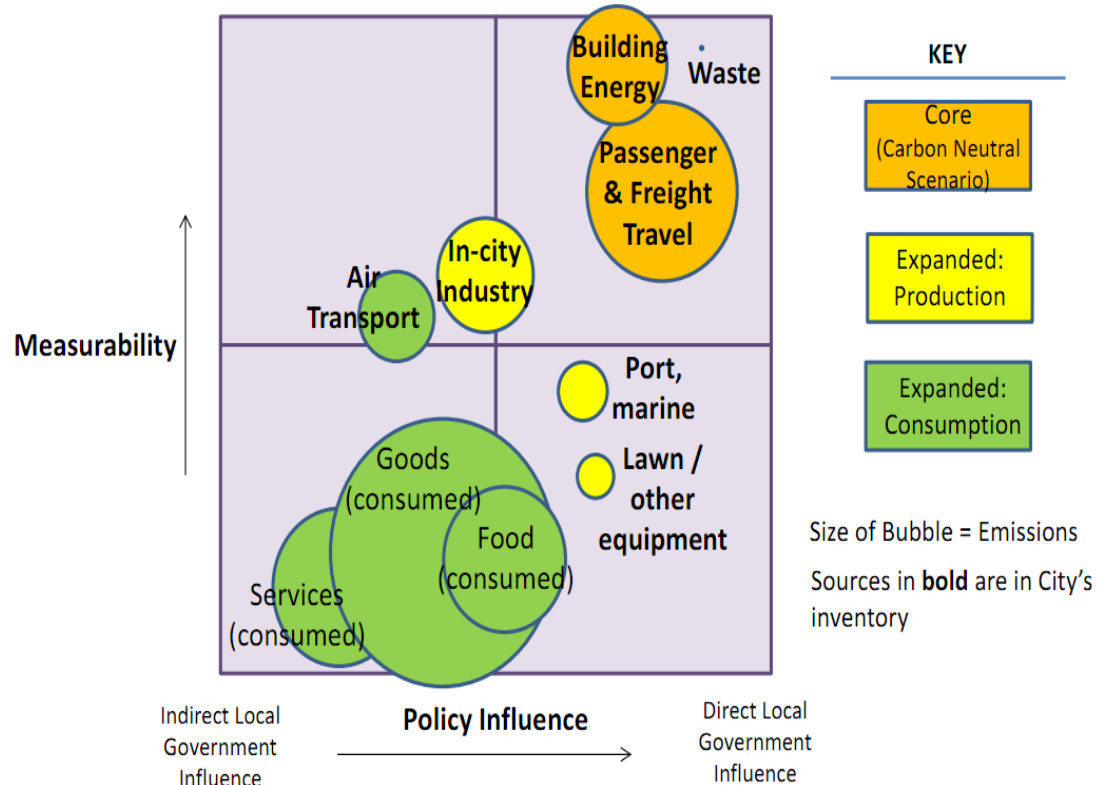
- Forecasts demand and supply for each APEC economy. Updated every 3-4 years
- Examines key technical and socio-economic drivers in APEC such as urbanization, aging of populations, relocation of industries towards less developed economies, technology development.
- Draws policy implications regarding the future energy demand and supply in the APEC region.

Data and Methods:

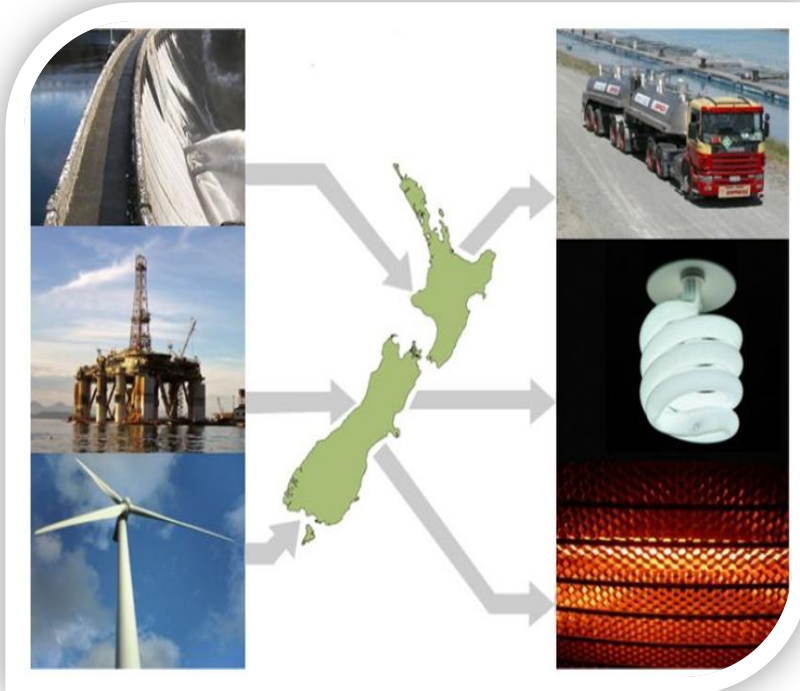
- Key time-series from IEA supplemented by national & APEC statistics, and World Bank indicators.
- Top-down econometric approach used to project energy demands. Microfit used to develop econometric equations, which are then entered in LEAP.
- LEAP used to model Transformation, to create scenario projections and to generate supply and demand balance tables.

Getting to Zero: A Pathway to a Carbon Neutral Seattle

- 2010: Seattle City Council adopts vision of becoming nation's first carbon-neutral city.
- 2011: Seattle Office of Sustainability and Environment (OSE) develops a scenario showing how this might be achieved.
- In October 2011, Seattle City Council adopts zero net emissions by 2050 as the goal for its Climate Action Plan and begins to develop a detailed Climate Action Plan.
- tinyurl.com/SeattleZeroReport



New Zealand's EnergyScape, 2009



- An initiative of the New Zealand National Institute of Water and Atmospheric Research (NIWA) .
- Designed to help citizens understand and visualize the flow of energy in NZ, making information about energy systems more accessible to scientists, businesses and policy makers.
- EnergyScape project explores what New Zealand's energy system might look like in 2030 and 2050.
- LEAP scenarios test out current and emerging technologies such as electric vehicles, thin film photovoltaic cells, fuels from forests, pedestrianized cities, and smart electricity metering.

Europe's Share of the Climate Challenge, 2009

- Joint project of SEI and Friends of the Earth International, presented at COP15 in Copenhagen and at the European Parliament in 2010.
- LEAP used to create a detailed sector-by-sector mitigation scenario for all 27 EU countries, which examines how to achieve GHG reductions of
 - 40% in 2020 and
 - 90% in 2050 vs. 1990 levels.
- Examines radical improvements in energy efficiency, accelerated retirement of fossil fuels and a dramatic shift toward renewables.
- Also examines the role of sufficiency and greater equity among EU nations in helping promote a transition to a low GHG future.





The Massachusetts Clean Energy and Climate Plan (CECP)

- The Global Warming Solutions Act (GWSA) requires MA to achieve GHG reductions of 80% by 2050 vs. 1990.
- The Commonwealth of Mass asked SEI to use LEAP to model a portfolio of options capable of meeting that goal.
- For 2050, 40+ policies examined including system and end-use efficiency, electrification, low carbon fuels and lifestyles.
- Results used to inform the State Government's Clean Energy and Climate Protection plan: published in 2010.
- tinyurl.com/CECPMass

Massachusetts Clean Energy and Climate Plan for 2020

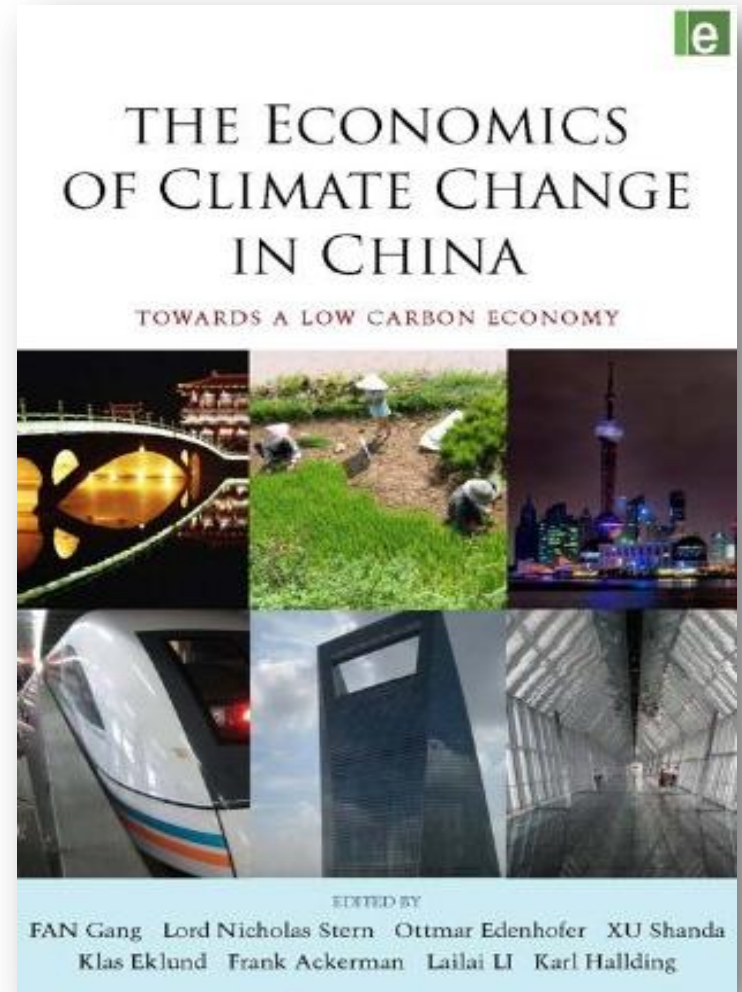


Executive Office of Energy and Environmental Affairs

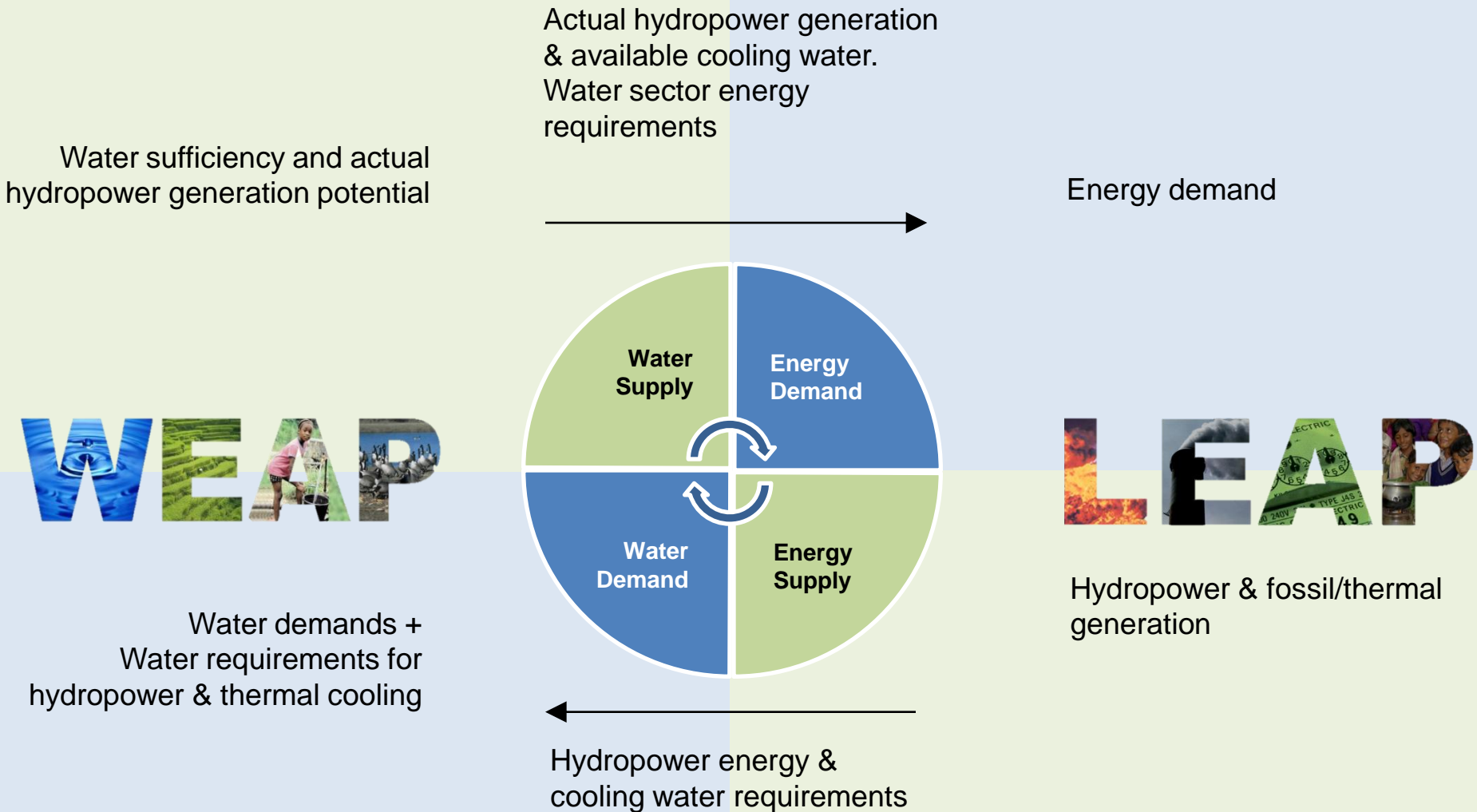


The Economics of Climate Change in China, 2009

- SEI and the China Economists 50 Forum used LEAP to examine how China's energy systems might be changed to allow China to meet ambitious goals for development whilst also keeping GHG emissions within the levels required for climate protection.
- A resulting Deep Carbon Reduction Scenario examines the feasibility of massively reducing China's emissions in 2050: using efficiency, electrification of transport, renewables, CHP and CCS.
- Resulted in a chapter in the book "Economics of Climate Change in China"
- <http://tinyurl.com/3pg6jst>



The Water-Energy Nexus





ECLAC/CEPAL-UN: Strengthening national capacities for sustainable biofuel policies in Latin America and the Caribbean

- The Division of Natural Resources and Infrastructure of the Economic Commission for Latin America and the Caribbean (CEPAL) has organized major capacity building workshops throughout Latin America and Caribbean Region.
- Working with Fundación Bariloche, CEPAL developed LEAP applications for target countries: marking one of the first times that LEAP capacity building efforts have been conducted using real country data.
- Over 300 experts have now been trained in 9 separate workshops in the region.

Greenhouse Gases in Chile: Forecasts and Mitigation Options for 2007-2030

- In 2010, the Program of Environmental Management and Economics at the University of Chile completed the study "Greenhouse Gas (GHG) Emissions in Chile: Background for the Development of a Regulatory Framework and Evaluation of Reduction Strategies.
- The study included projections of GHG emissions in Chile from 2007-2030 and evaluated alternative policy options.
- It defined a realistic Chilean base strategy for greenhouse gas mitigation, while setting the stage for future studies needed on topics such as agricultural sector emissions and sequestration, and clean energy.

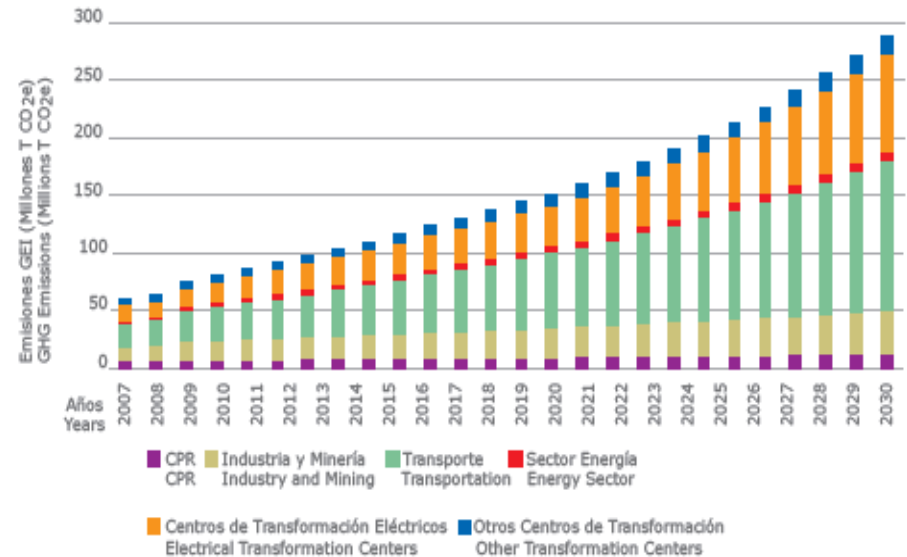
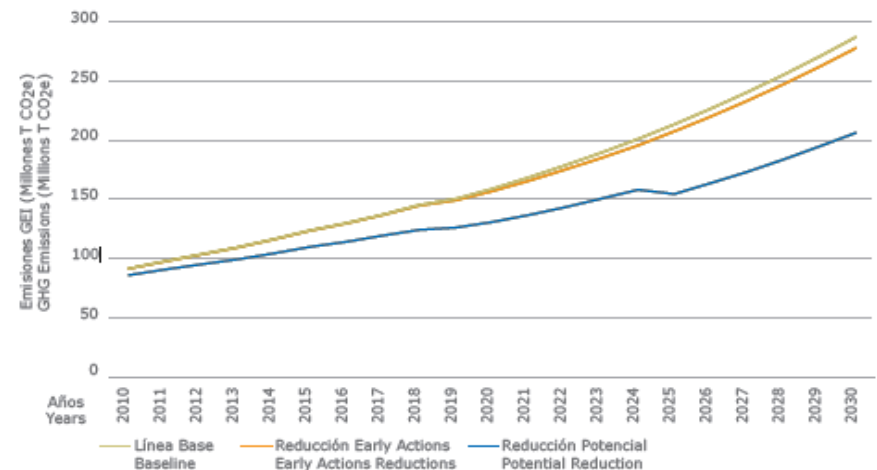


Figura 27: Potencial Máximo de Reducción de GEI en Chile

Figure 27: Maximum GHG Emission Reduction in Chile



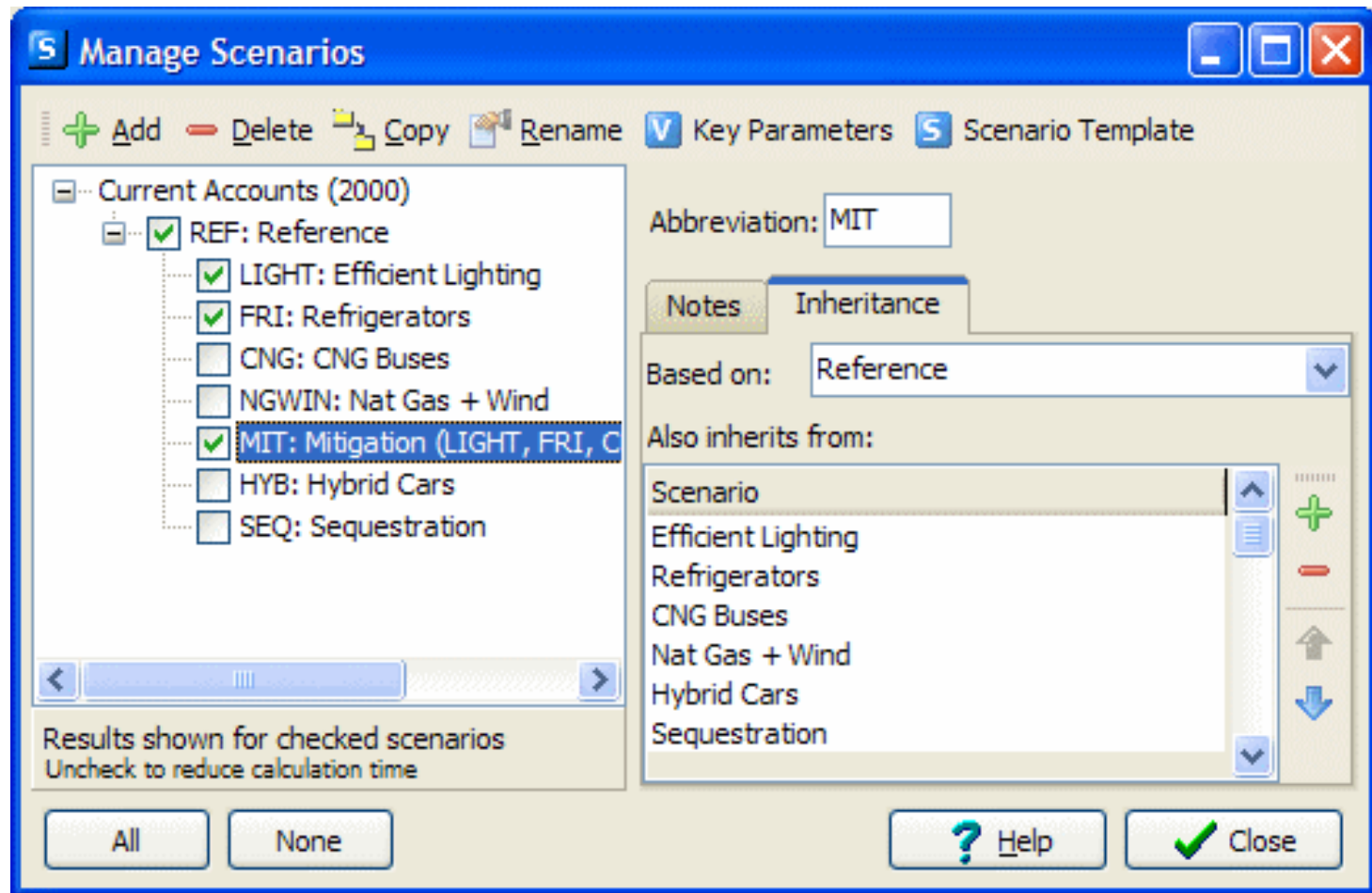
More examples at:

www.energycommunity.org/apps

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).

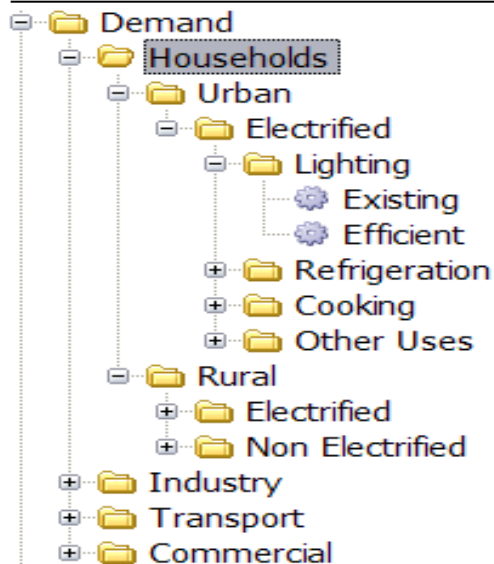
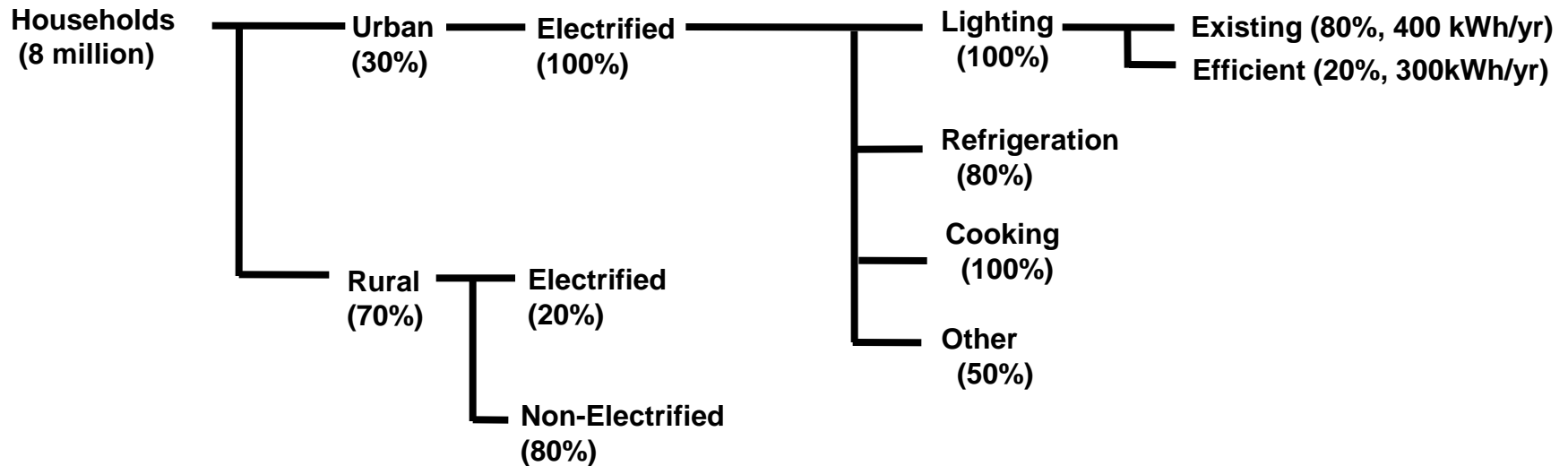
The Scenario Manager



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

A Simple Demand Data Structure

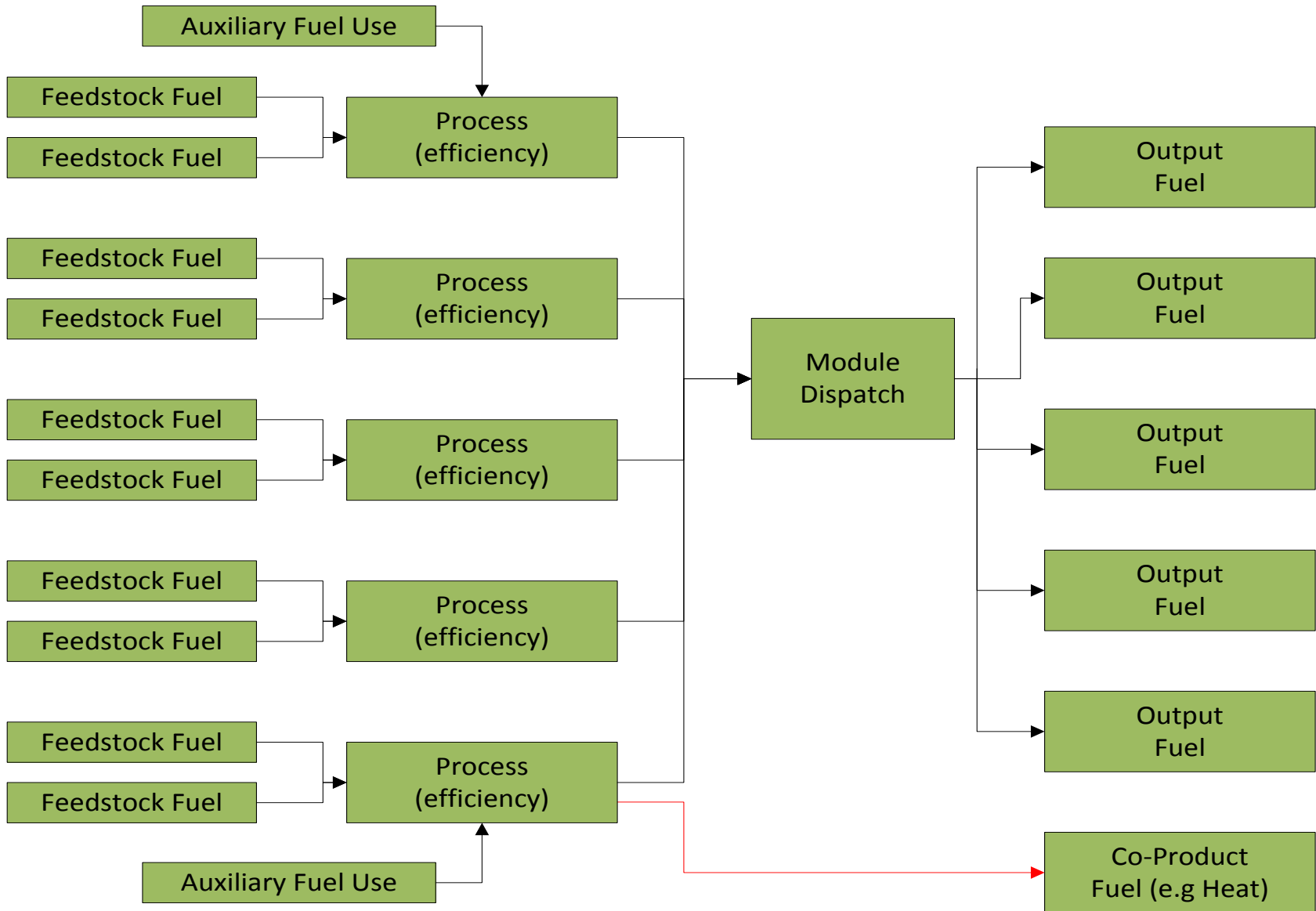


- The tree is the main data structure used for organizing data and models, and for reviewing results.
- Icons indicate the types of data (e.g., categories, technologies, fuels and environmental effects).
- Users can edit the tree on-screen using standard editing functions (copy, paste, drag & drop)
-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

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**.

Standard Transformation Module



Emissions Accounting

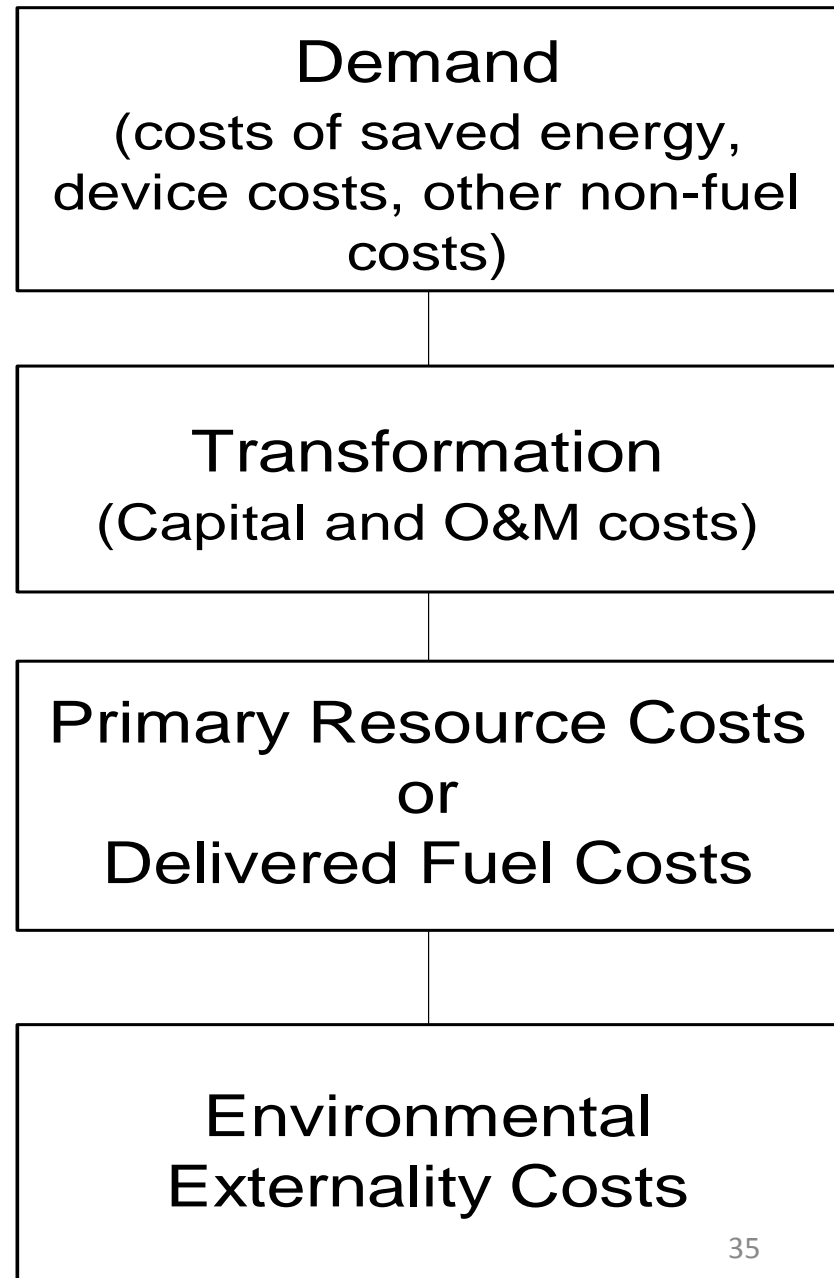
- Emission factors for any GHG or local air pollutant can be entered in LEAP and used to calculate emissions loadings.
- Can be specified in any physical unit and can be denominated by units of either energy consumption or production (e.g. kg/ton of coal) or distance driven for transport factors (e.g. 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).

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.

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.

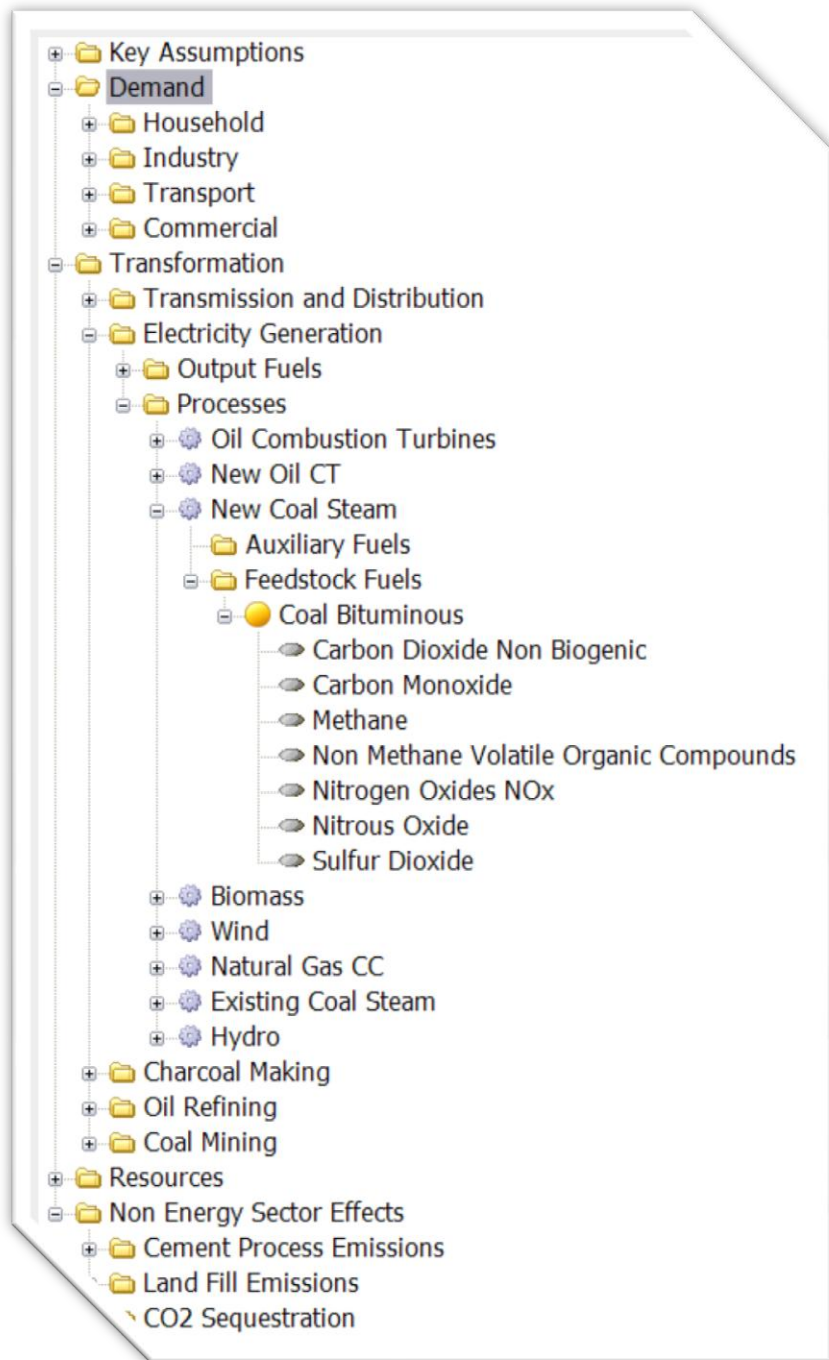


Terminology

- **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)



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).

Modeling at Two levels

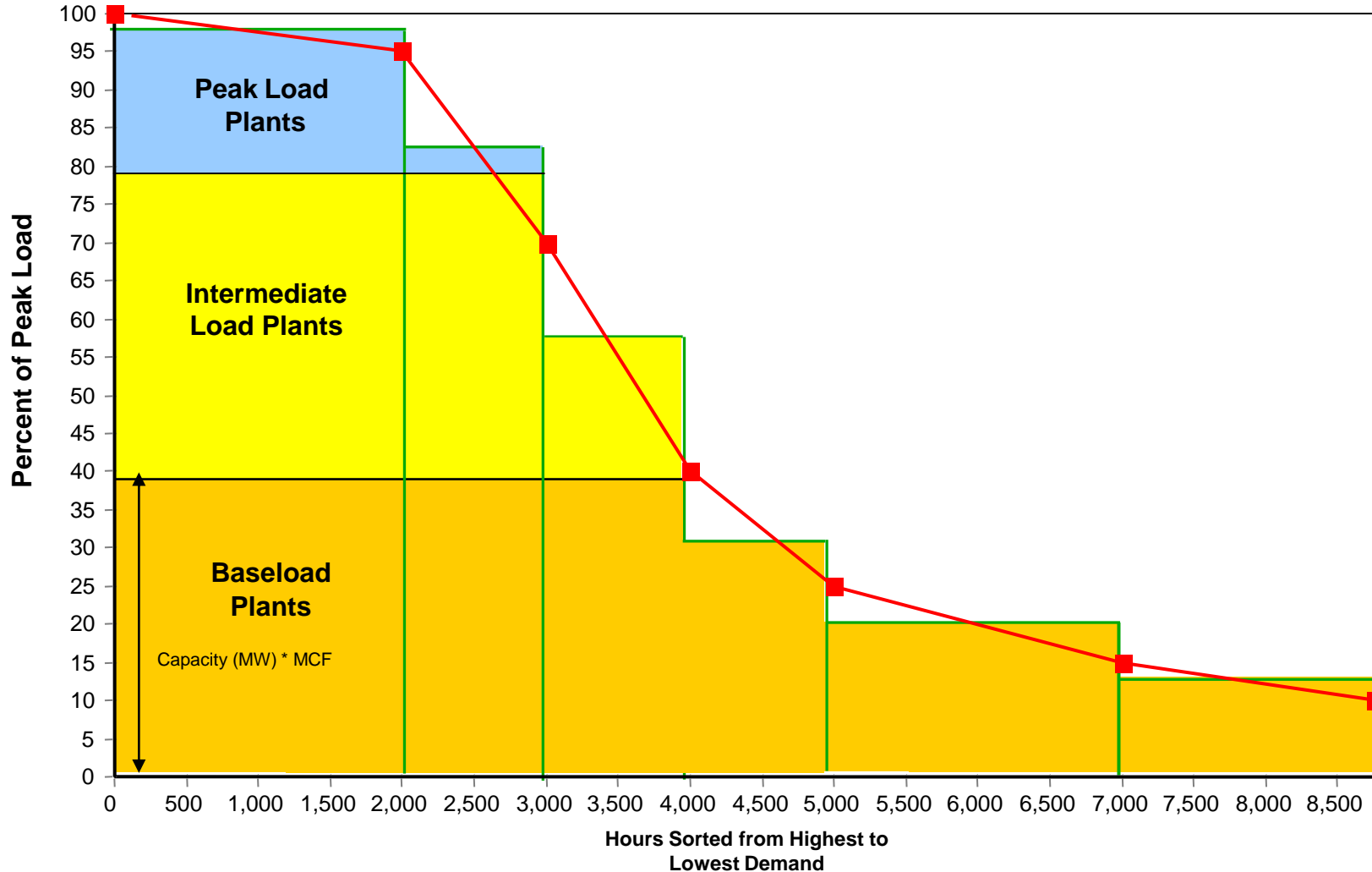
1. Basic physical accounting calculations handled internally within software (stock turnover, energy demand and supply, electric dispatch and capacity expansion, resource requirements, costing, pollutant emissions, etc.).
2. Additional modeling can be added by the user (e.g. user might specify market 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.

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)

Load-Duration Curve and System Dispatch in LEAP



Two Dispatch Modes

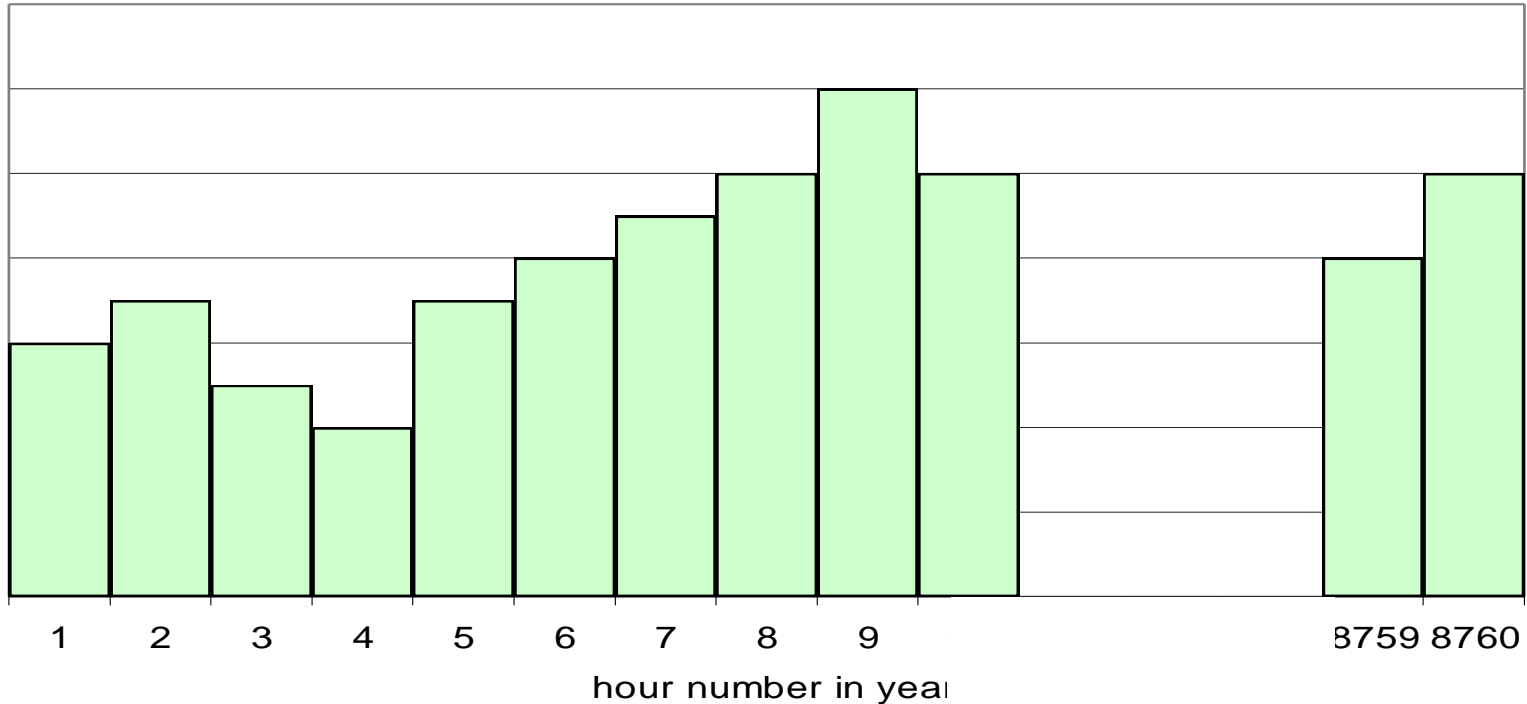
- **Mode 1:** Historical: LEAP simply dispatches plants based on historical generation.
- **Mode 2:** Simulation: plants dispatched based on various dispatch rules ranging from very simple (% of total generation) to more sophisticated (dispatch by merit order or in order of running costs)
- Set the **First 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 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).

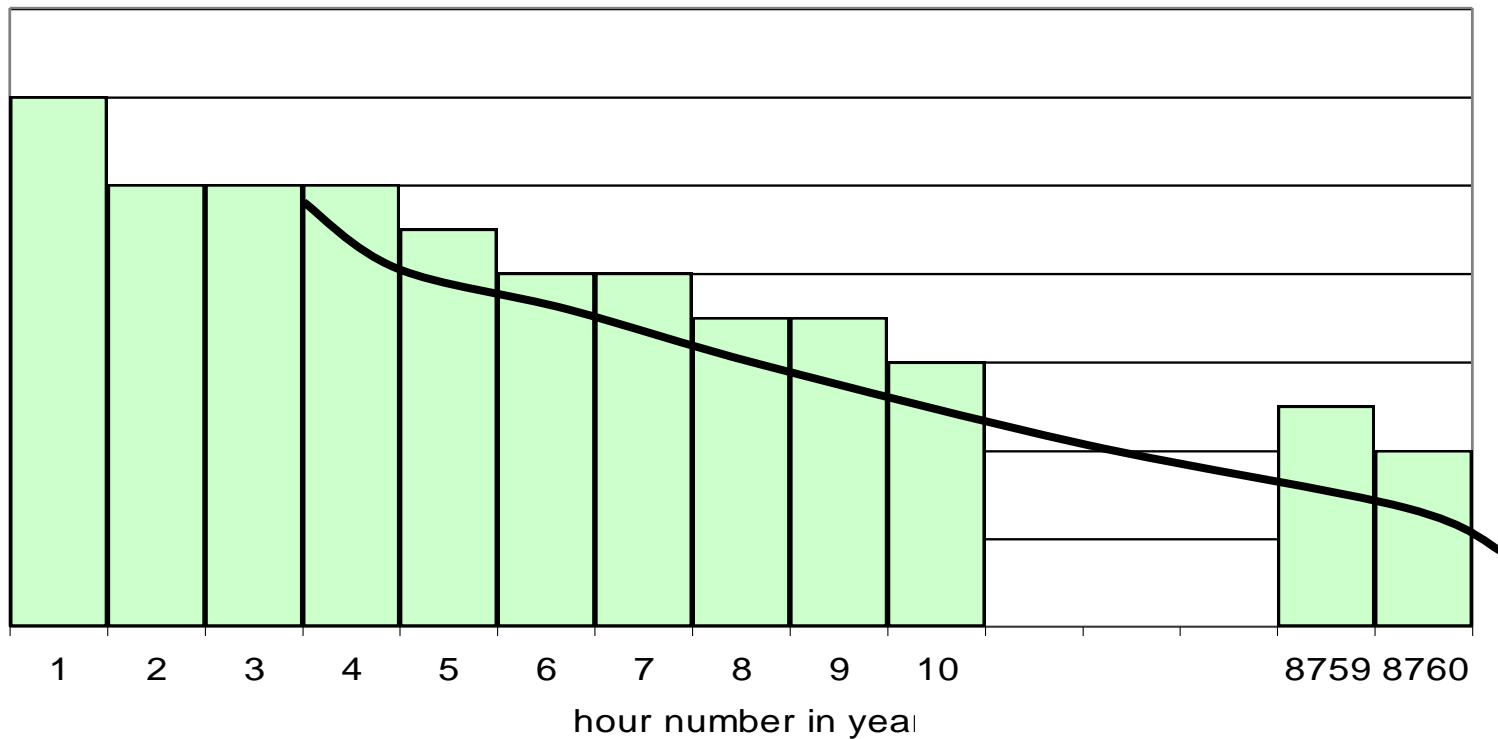
Hourly Demand Curve

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



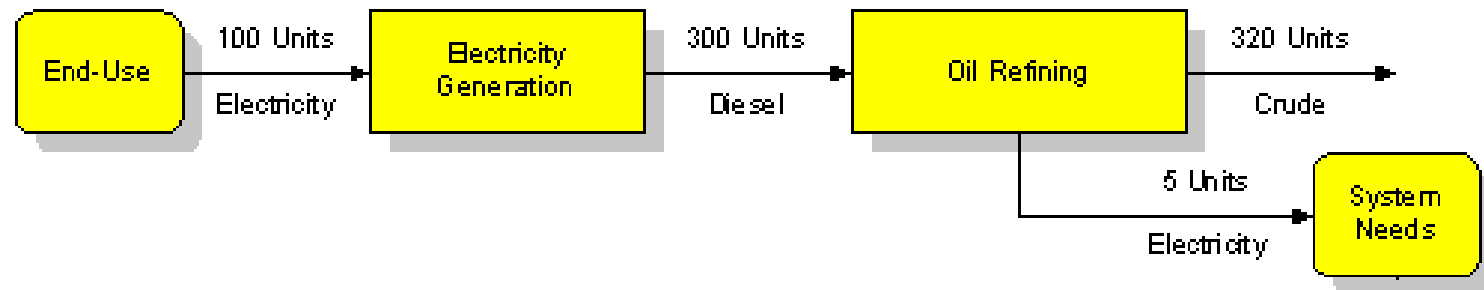
Load Duration Curve

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

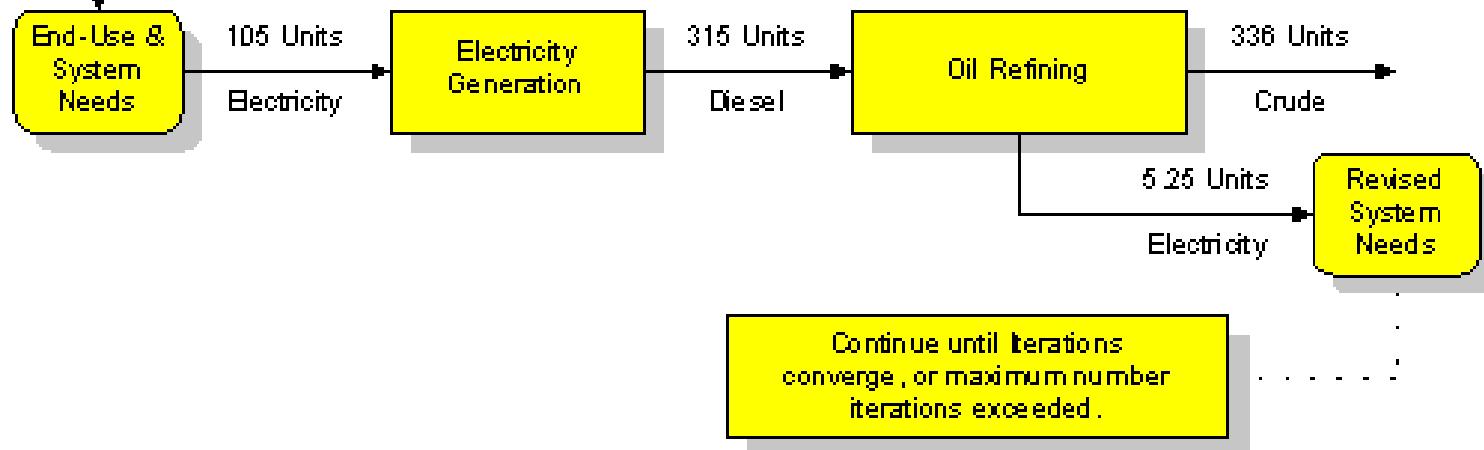


Transformation Modules with Feedback Flows

Transformation Calculation: Iteration One



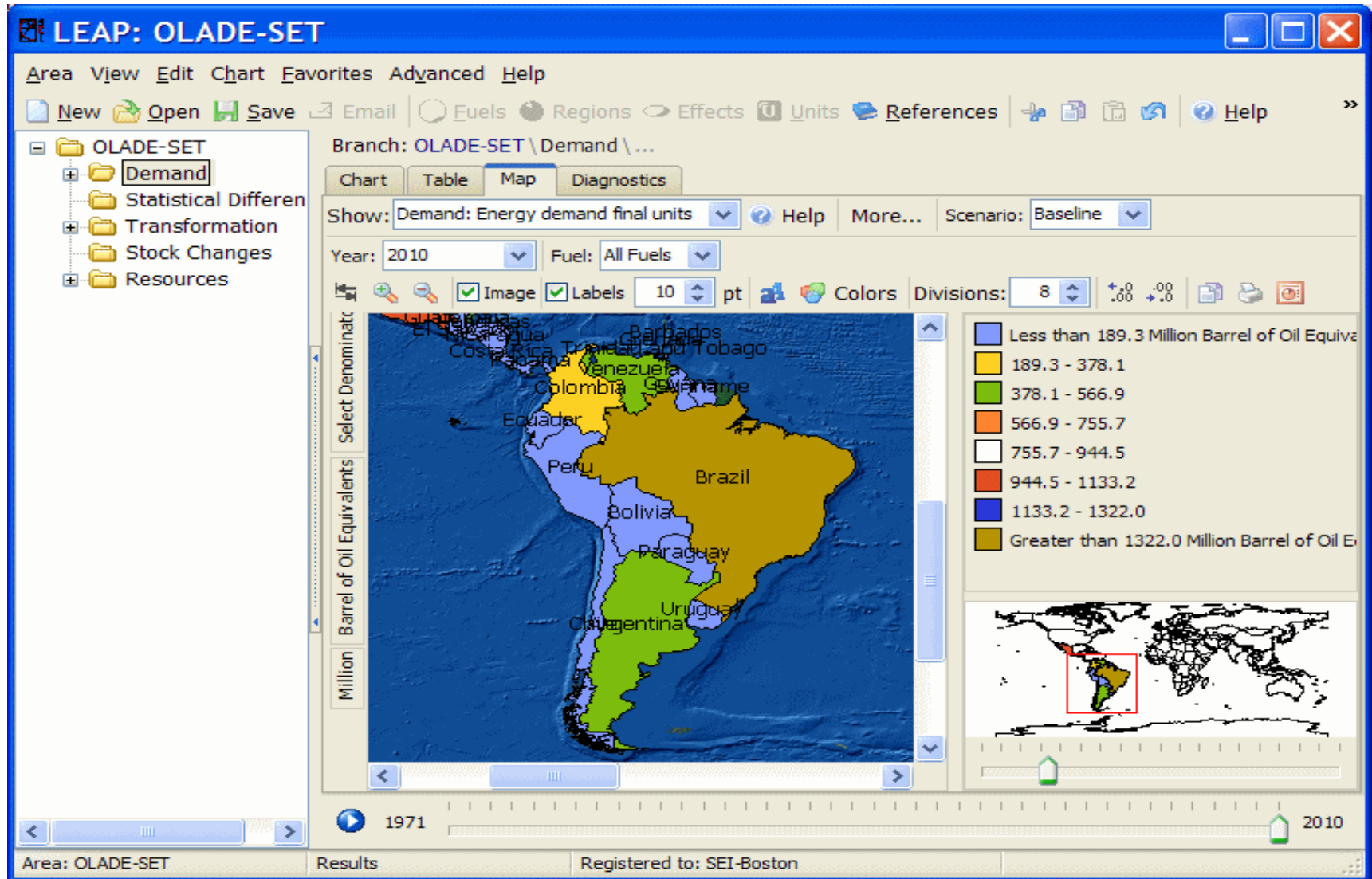
Transformation Calculation: Iteration Two



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.

Showing Results for a Multi-Region Data Set in LEAP



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

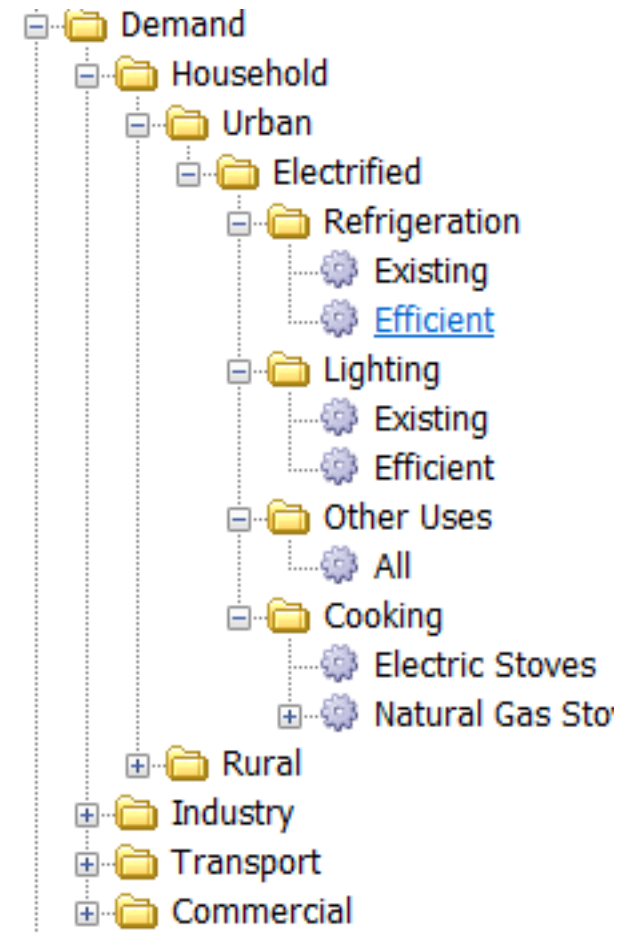
- LEAP decides both what to build AND when to build.
- Uses the OSeMOSYS model to calculate optimal capacity expansion – then reads the results back into LEAP's **Exogenous Capacity** variable.

Three Approaches for Demand Modeling in LEAP

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

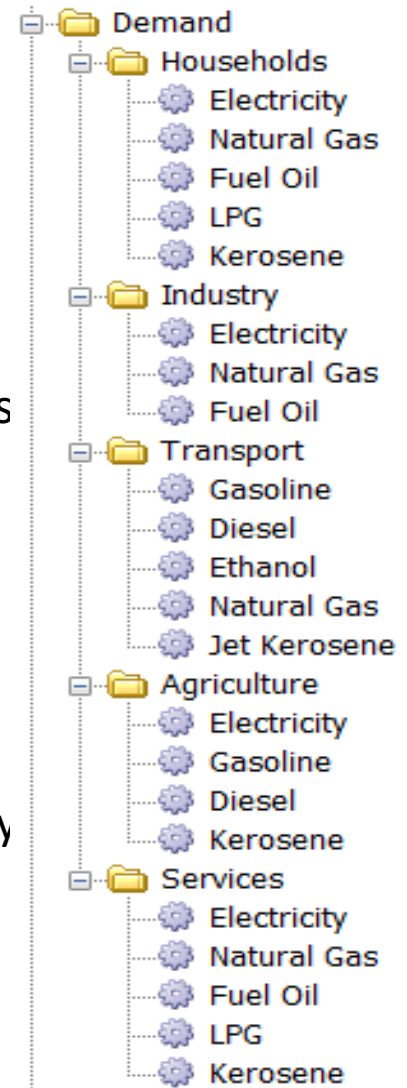
Bottom-Up/End-Use

- 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).



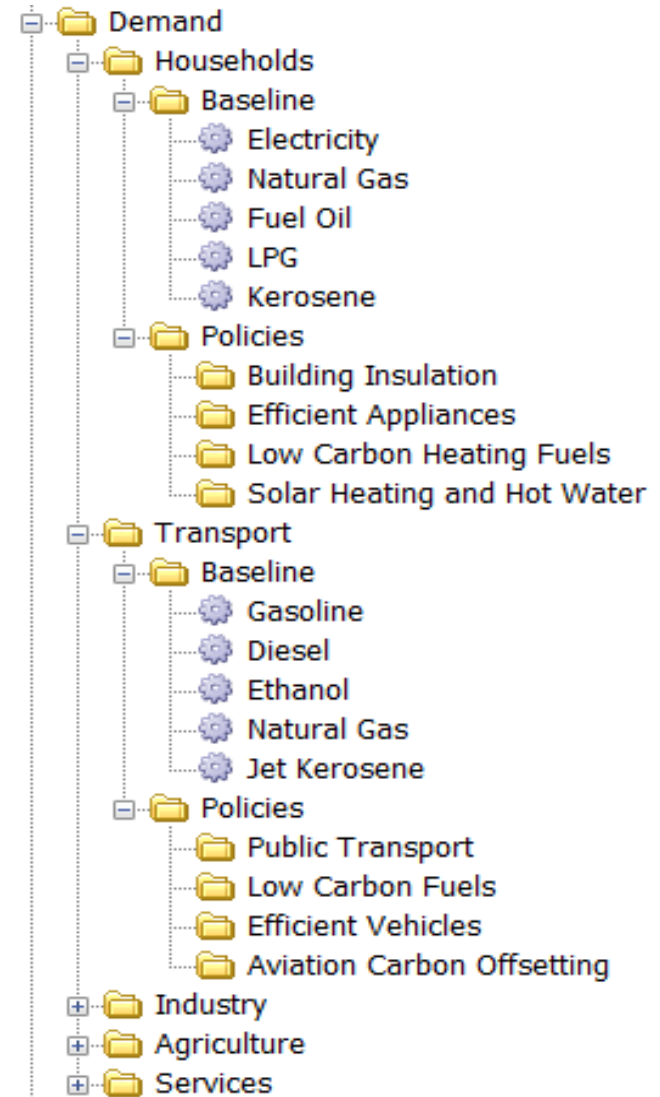
Top-down/Econometric

- 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.



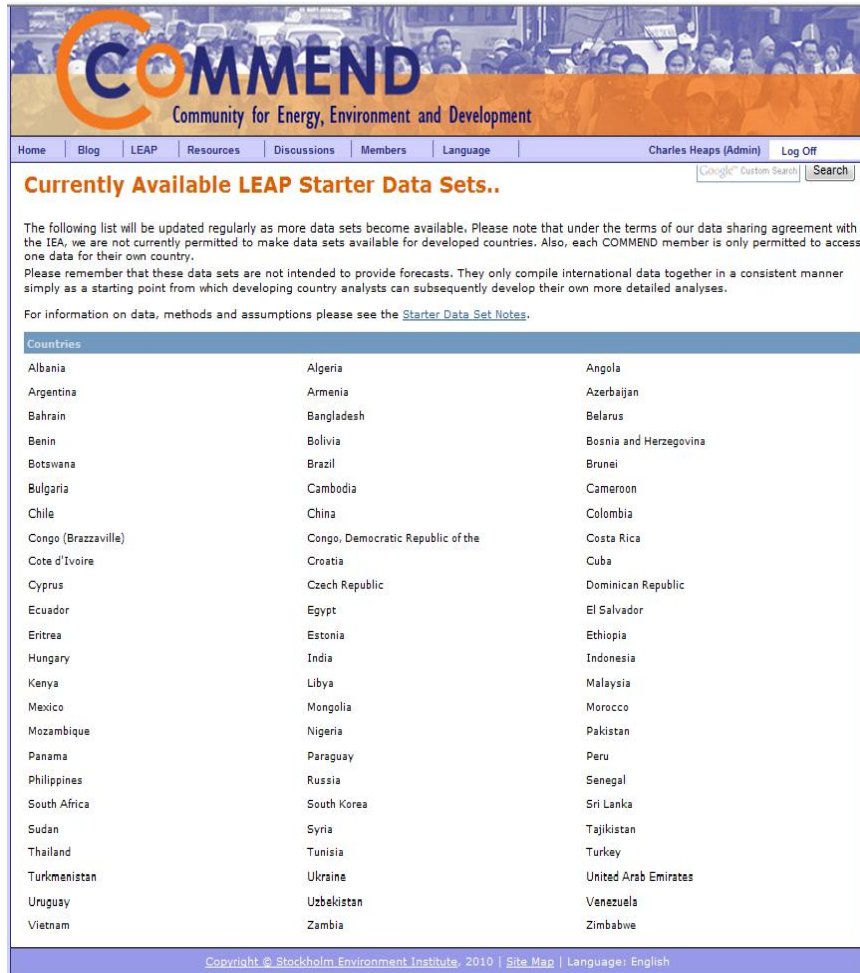


- Free online community to support analysts:
 - discussion & support forums.
 - online libraries and newsletters.
 - downloadable software.
 - Downloadable national data sets
 - training and reference materials.
- Almost 15000 members in 190 countries.
- www.energycommunity.org

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.

“Starter” Data Sets



The screenshot shows the COMMEND website interface. At the top is the COMMEND logo with the tagline 'Community for Energy, Environment and Development'. Below the logo is a navigation bar with links: Home, Blog, LEAP, Resources, Discussions, Members, Language, Charles Heaps (Admin), and Log Off. A search bar is also present. The main heading is 'Currently Available LEAP Starter Data Sets..'. Below this, a paragraph explains that the list is updated regularly and that data is shared under specific terms. It also mentions that the data is not for forecasts and is intended as a starting point for analysis. A link to 'Starter Data Set Notes' is provided. The core of the page is a table listing 48 countries, organized in three columns. The footer contains copyright information for the Stockholm Environment Institute, 2010, and a link to the site map.

Countries		
Albania	Algeria	Angola
Argentina	Armenia	Azerbaijan
Bahrain	Bangladesh	Belarus
Benin	Bolivia	Bosnia and Herzegovina
Botswana	Brazil	Brunei
Bulgaria	Cambodia	Cameroon
Chile	China	Colombia
Congo (Brazzaville)	Congo, Democratic Republic of the	Costa Rica
Cote d'Ivoire	Croatia	Cuba
Cyprus	Czech Republic	Dominican Republic
Ecuador	Egypt	El Salvador
Eritrea	Estonia	Ethiopia
Hungary	India	Indonesia
Kenya	Libya	Malaysia
Mexico	Mongolia	Morocco
Mozambique	Nigeria	Pakistan
Panama	Paraguay	Peru
Philippines	Russia	Senegal
South Africa	South Korea	Sri Lanka
Sudan	Syria	Tajikistan
Thailand	Tunisia	Turkey
Turkmenistan	Ukraine	United Arab Emirates
Uruguay	Uzbekistan	Venezuela
Vietnam	Zambia	Zimbabwe

- Now available for free download for 105 countries (1 data set per user).
- Compiles international data as a **starting point** for more detailed analyses.
- Includes IEA energy data (1971-2009), IPCC emissions factors, UN population projections, World Bank development indicators, Non-energy sector GHG emissions from the PBL EDGAR database, energy resource data from WEC.

A more detailed look at LEAP...

Top-Level Tree Categories

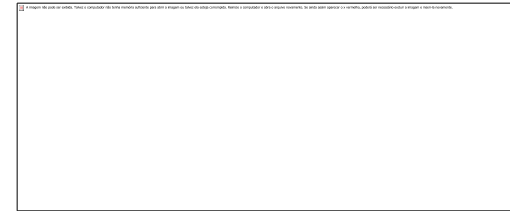
- **Key Assumptions:** independent variables (demographic, macroeconomic, etc.)
- **Demand:** energy demand analysis (including transport analyses).
- **Statistical Differences:** the differences between final consumption values and energy demands.
- **Transformation:** analysis of energy conversion, 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.

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.

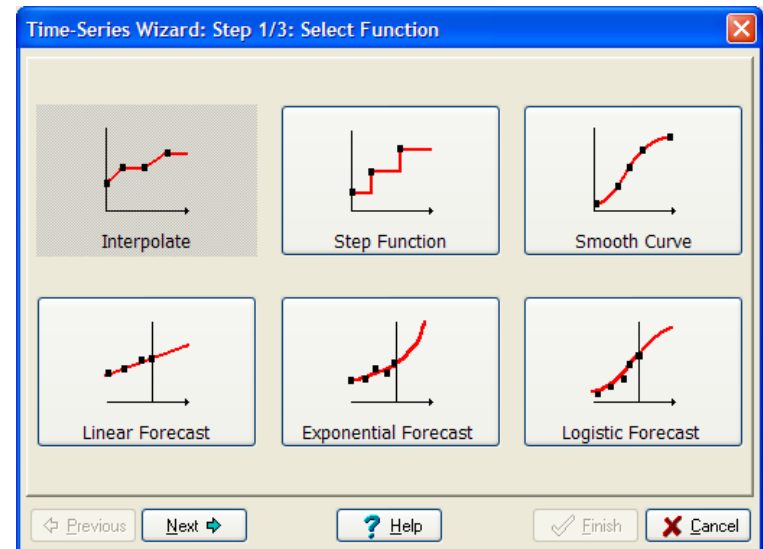
Some Expression Examples

- 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!



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.



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 [$+n$].

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.

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.

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	

TED:

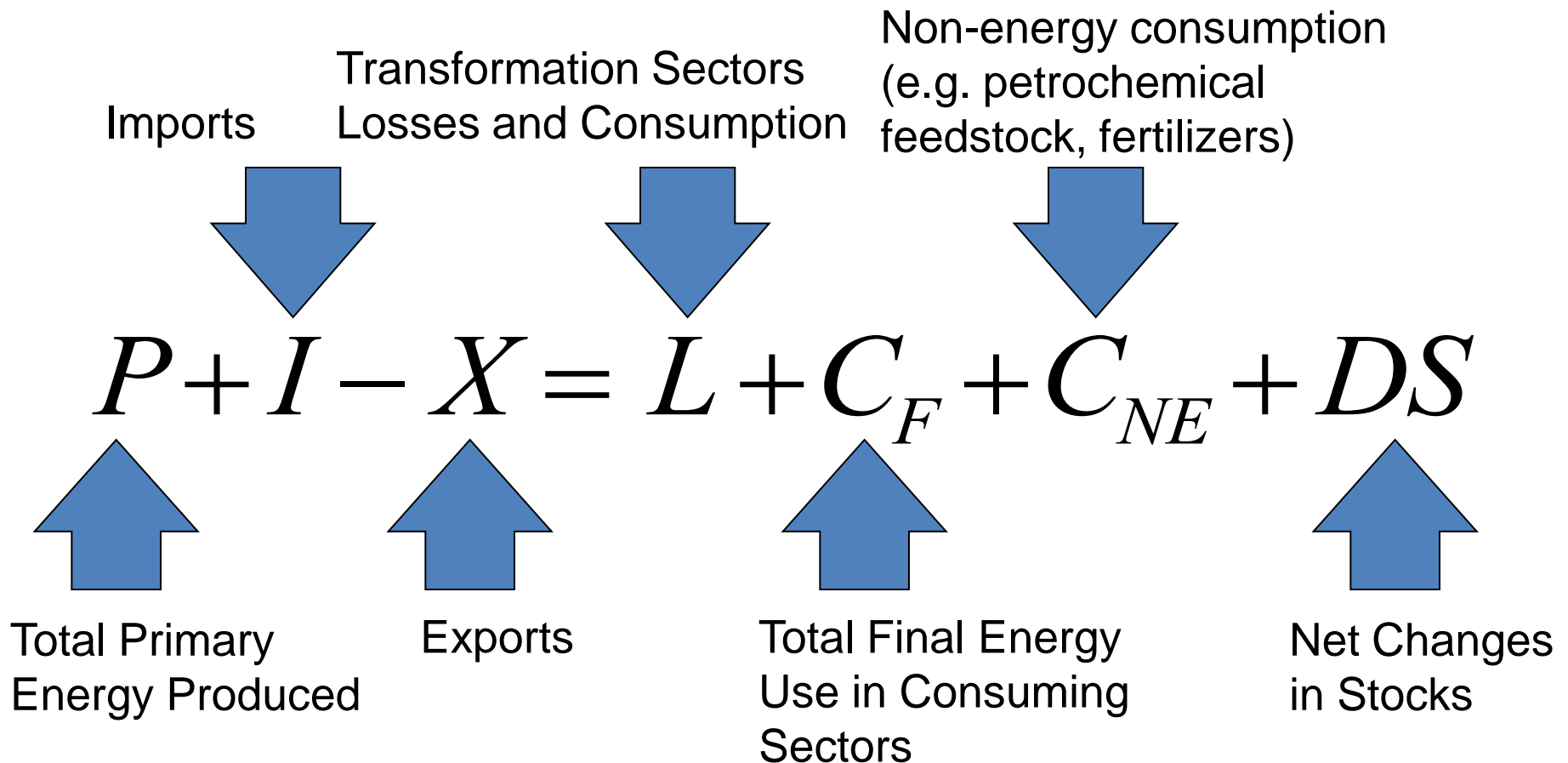
The Technology and Environmental Database

Fields 

	Information Pages	Technology Data	Cost Data	Environmental Impacts	Notes Reference
Technologies					
Demand					
Conversion		Database Contents			
Supply: Extraction					
Transmission & Distribution					

Energy Balances

An accounting system that describes the flows of energy through an economy, during a given period.



Sample IEA Energy Balance

Breakdown by
Sector and
Activities

Thailand Energy Balance, 1983 (Thousand TOE)

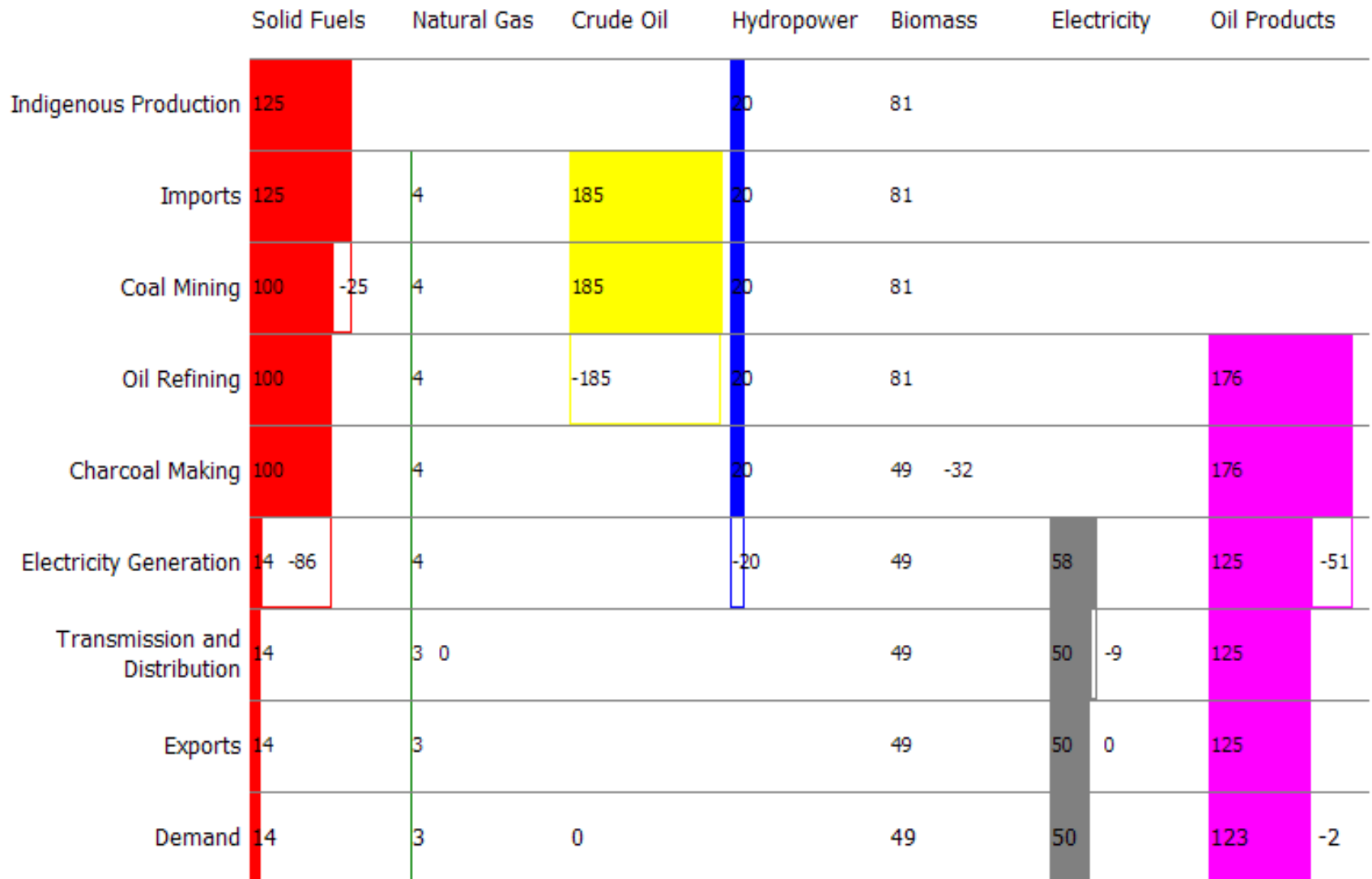
	Coal	Crude Oil	Petroleum Products	Gas	Nuclear	Hydro/ Other	Electricity	Heat	Total
Indigenous Production	4514	3948		8395		319			17175
Import	664	16425	9115				55		26259
Export		-685	-368				-4		-1057
International Marine Bunkers			-812						-812
Stock Changes	65	-304	-729						-969
TPEs	5242	19383	7205	8395	0	319	51	0	40595
Returns and Transfers		-977	986						10
Statistical Differences	254		-47						207
Public Electricity	-2964		-4172	-7795		-319	5453		-9797
Autoproducers of Electricity									0
CHP Plants									0
District Heating									0
Gas Works									0
Petroleum Refineries		-18355	16892						-1463
Coal Transformation									0
Liquefaction									0
Other Transformation									0
Own Use			-34	-294			-220		-548
Distribution Losses							-444		-444
TFC	2532	51	20830	306	0	0	4840	0	28560
Industry Sector	2532	51	3539	306	0	0	1800	0	8269
Iron and Steel			69				172		241
Chemical		51	271	184			336		842
Non-Ferrous Metals									0
Non-Metallic Minerals	1467		933	11			293		2703
Transport Equipment									0
Machinery			300				238		539
Mining and Quarrying			43						43
Food and Tobacco	101		583				313		997
Paper, Pulp, and Printing			145				52		197
Wood and Wood Products			71				44		114
Construction			183						183
Textile and Leather			553				357		910
Non-specified Industry	965		388	111			55		1520
Transport Sector	0	0	14236	0	0	0	0	0	14236
Air			2423						2423
Road			11429						11429
Rail			120						120
Internal Navigation			264						264
Non-specified Transport									0
Other Sectors	0	0	2715	0	0	0	2080	0	5095
Agriculture			1628				11		1640
Public/Commerce							1890		1890
Residential			1086				1026		2113
Non-specified Other							52		52
Non-Energy Use			340						340

Breakdown
by Energy
Source

LEAP Energy Balance Table

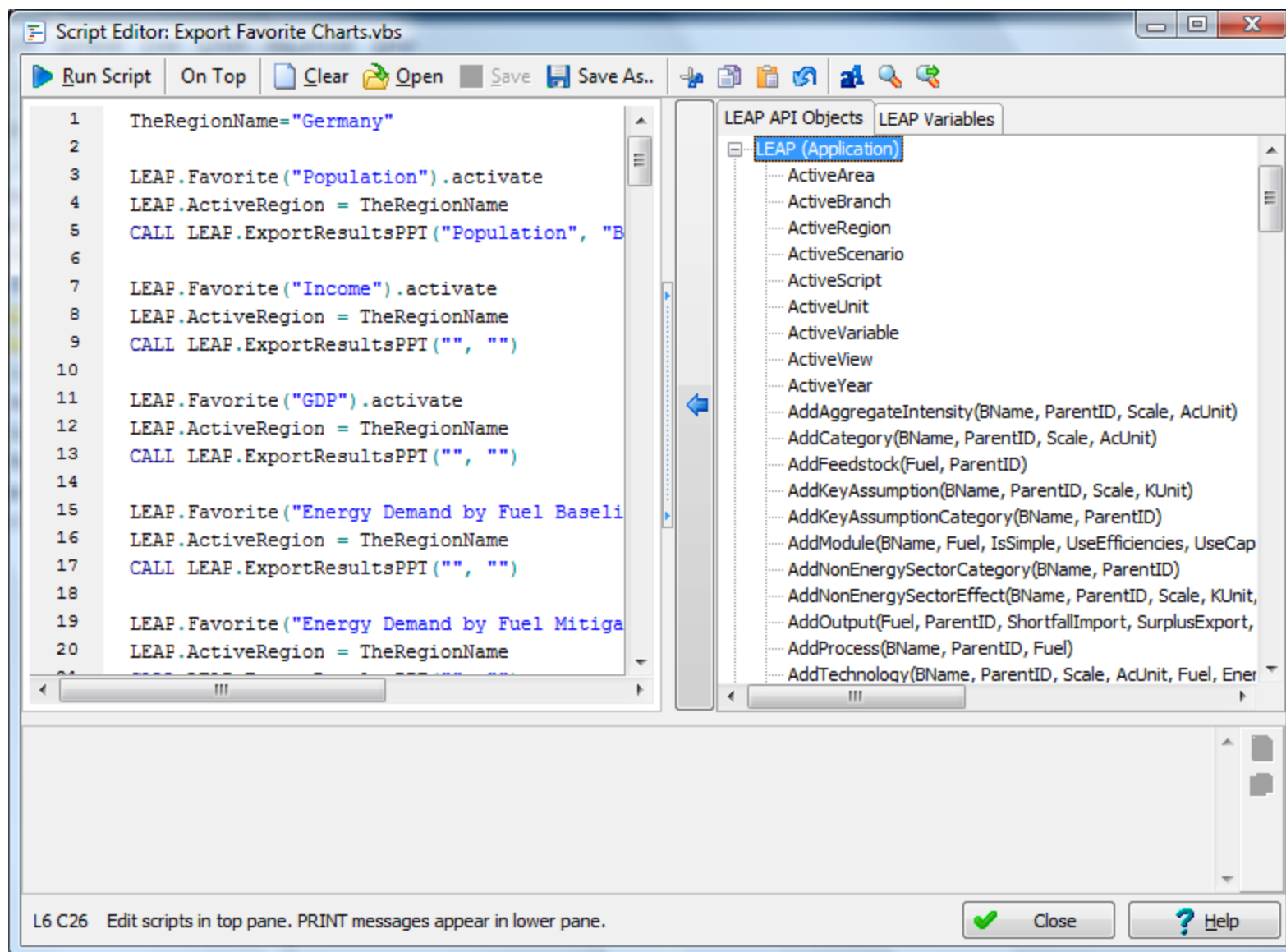
Energy Balance for: Freedonia								
Scenario: Reference. Year: 2000 (Million Gigajoule)								
	Solid Fuels	Natural Gas	Crude Oil	Hydropower	Biomass	Electricity	Oil Products	Total
Production	125	0	0	20	81	0	0	226
Imports	0	4	185	0	0	0	0	189
Exports	0	0	0	0	0	0	0	0
From Stock Change	0	0	0	0	0	0	0	0
Total Primary Supply	125	4	185	20	81	0	0	415
Coal Mining	-25	0	0	0	0	0	0	-25
Oil Refining	0	0	-185	0	0	0	176	-9
Charcoal Making	0	0	0	0	-32	0	0	-32
Electricity Generation	-86	0	0	-20	0	58	-51	-98
Transmission and Distribution	0	0	0	0	0	-9	0	-9
Total Transformation	-110	0	-185	-20	-32	50	125	-174
Statistical Differences	0	0	0	0	0	0	0	0
Household	0	3	0	0	33	18	13	68
Industry	14	0	0	0	16	20	22	72
Transport	0	0	0	0	0	1	78	79
Commercial	0	0	0	0	0	10	10	20
Total Demand	14	3	0	0	49	50	123	239
Unmet Demand	0	0	0	0	0	0	-2	-2

LEAP Energy Balance Diagram



The Application Programming Interface (API)

- LEAP's API is a standard COM Automation Server
- Other programs can control LEAP: changing data values, calculating results, and exporting them to Excel or other applications.
- For example, a script could iteratively run LEAP multiple times revising input assumptions for goal-seeking applications.
- LEAP has a built-in script editor that can be used to edit, interactively debug and run scripts that use its API.
- LEAP uses Microsoft's ActiveScript technology which supports in Visual Basic and JavaScript.



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 an 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.

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).

Two Dynamics to Consider...

Two dynamics to consider:

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

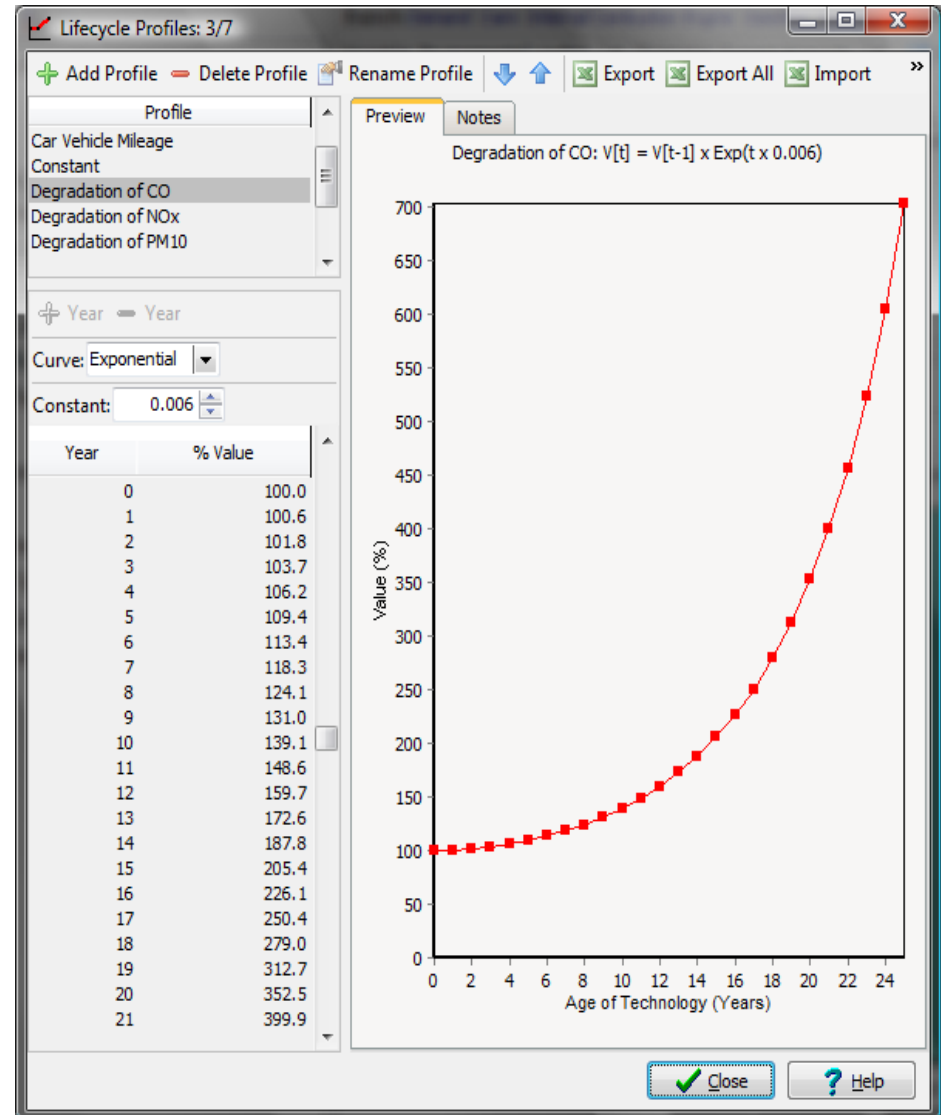
These changes are specified from year to year using LEAP's standard expressions (interp, growth, etc.)

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.

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.





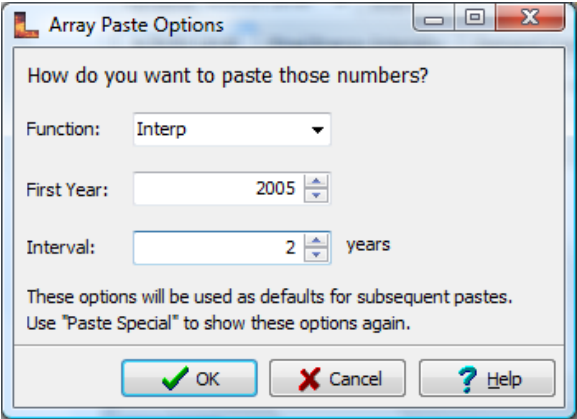
Key Assumptions

- **Key Assumption Variables** are used for creating additional user-defined variables such as macroeconomic, demographic and other time-series variables.
- Can hold exogenous variables (input assumptions) and can also be used to calculate intermediate results using LEAP's expressions.
- You can also add your own **User Variables** which are visible in the Demand, Transformation and Resource branches, and **Indicator Variables**: which are used to calculate additional results after all other LEAP calculations are complete.

Indicators

- Optional additional branches in the tree used to calculate user-defined results variables.
- Just like **Key Assumptions**, they are not used directly in LEAP's calculations.
- Unlike Key Assumptions, Indicators are calculated after all other LEAP calculations are complete, so they can include direct non-lagged references to all other data and results variables.
- Can make use of a series of **Indicator Functions** that calculate normalized comparisons between regions and scenarios, (e.g. scores, rankings, ratios, etc.).

Three Ways to Import from Excel

- **Copy** a range of data from Excel (Ctrl-V) and then **paste** into a LEAP expression (Ctrl-V). If the range has two rows or two columns and includes years in the first row/column, then LEAP will automatically create an “Interp” expression for those years/values. If there is a single row/column, LEAP will prompt you for the years.
- Use the **Time-Series Wizard** to import data or create a dynamic link to a named range in an Excel sheet. If importing as a dynamic link, LEAP will automatically be updated whenever the spreadsheet is changed and saved.
- Use Analysis Menu: **Import from Excel & Export to Excel** functions to:
 - i. Export a blank Excel template containing the LEAP data structures and all variables.
 - ii. Add your own data to this spreadsheet.
 - iii. Import this spreadsheet into LEAP. LEAP will automatically import scaling factors, units, data and expressions.

Simple Cost-Benefit Analysis Example

Two scenarios for meeting future growth in electricity lighting demand:

1. Base Case

- **Demand:** future demand met by cheap incandescent bulbs.
- **Transformation:** growth in demand met by new fossil fired generating capacity.

2. Alternative Case

- **Demand:** DSM programs increase the penetration of efficient (but more expensive) fluorescent lighting.
- **Transformation:** Slower growth in electricity consumption and investments to reduce transmission & distribution losses mean that less generating capacity is required.

Simple Cost-Benefit Analysis (cont.)

- **The Alternative Case...**
- ...uses more expensive (but longer lived) lightbulbs.
 - *Result: depends on **costs**, lifetimes, & discount rate.*
- ...requires extra capital and O&M investment in the electricity transmission & distribution system.
 - *Result: net cost*
- ..requires less generating plants to be constructed (less capital and O&M costs).
 - *Result: net benefit*
- ...requires less fossil fuel resources to be produced or imported.
 - *Result: net benefit*
- ...produces less emissions (less fuel combustion).
 - *Result: net benefit (may not be valued)*