LEAP

Training Workshop on Using LEAP for Energy and Climate Change Mitigation Assessment

TECHNICAL TRAINING

JANUARY 28—FEBRUARY 1, 2013

Hotel Kimberly
Tagaytay, Philippines

Analysis and Investment for Low-Emission Growth (AILEG)

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January 28 – February 1, 2013 ● Hotel Kimberly, Tagaytay City, Philippines

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Background

In November 2011, a Memorandum of Understanding (MOU) was signed between the U.S. Government (USG) and the Philippine Climate Change Commission (CCC) to further cooperation under the Enhancing Capacity for Low Emission Development Strategies (EC-LEDS) program with the goal being to support LEDS development in the Philippines. Three priority areas of cooperation were outlined in the MOU:

I. GHG Inventories
II. Analytical Tools for Decision Making
III. Measurable Implementation Progress

A workshop on the EC-LEDS partnership was held on January 25-26, 2012, and it included members from Government of Philippines (GPH) agenciesas well as several USG agencies, including US Agency for International Development, State Department, US Department of Agriculture (USDA), US Environmental Protection Agency, and the US Department of Energy. This workshop was intended to: (i) define a detailed plan of work for the EC-LEDS partnership; (ii) discuss a monitoring plan for implementing the EC-LEDS work program; and (iii) build further understanding of LEDS development and GPH institutional arrangements and facilitate GPH interagency coordination around LEDS.

The approved work plan emerging from this workshop has four major pillars:

1. Enhanced Coordination and Support to the LEDS Process
2. Development of the (or Enhancement of the) National GHG Inventory System
3. Analytical Decision Making
4. Measurable Implementation Progress in areas such as renewable energy policy planning; climate-resilient, low-emission land-use planning; national energy policy implementation and monitoring; and a monitoring, reporting and verification (MRV) system for landscape mitigation actions

The role of the Analysis and Investment for Low-Emission Growth (AILEG) program is to largely support the third pillar above – analytical decision-making.

During the course of meetings with NEDA and DOE, staff expressed the need for national capacity building through training in economic assessment models, in particular, models in the energy sector. DOE explicitly mentioned that, while they do have some capacity in the Long-range Energy Alternatives Planning System (LEAP) energy model, it has waned over time.

Objective: AILEG and SEI are organizing this workshop to demonstrate how the LEAP tool can be applied to energy and environmental analysis.

Targeted Participants: About 25 representatives from academic institutions, governments, regulatory agency, electric cooperatives and development partners

Expected Outcome: Shared information and practical knowledge on LEAP for addressing climate change impacts

Draft Agenda

TECHNICAL SESSIONS (To be Attended by Technical Staff from the Different Agencies and Institutions)	
January 29, Tuesday	
9:00 – 9:15	Welcome, Agenda, Introductions
9:15 – 12:30	**Hands-On Exercises, Part 1: Screening Mitigation options** A simple exercise using a spreadsheet to screen mitigation options by evaluating the costs ($/Tonne CO2) and mitigation potential (Tonnes CO2) of various options. The screened options will be plotted on a marginal abatement cost curve (MAC)
Lunch Break	
13:30 – 15:45	**Hands-On Exercises, Part 2: A Simple GHG Mitigation Scenario** The options developed in the morningwill be used to construct a simple GHG mitigation scenario in LEAP using a data set prepopulated with a baseline scenario.
Break	
16:00 – 17:00	**Hands-On Exercises, Part 3: An Introduction to LEAP** Introduction to Exercise 1 of the LEAP Training Exercises that teach the basic skills required for using LEAP. Participants will learn how to build a LEAP data set from scratch for a single sector (Households)
17:00 – 17:10	Instructions for Day 3
January 30, Wednesday	
9:00 – 12:00	Hands-On Exercises, Part 3 (continued)
Lunch Break	
13:00 – 15:00	**Hands-On Exercises, Part 4: Transformation and Emissions Analysis** In-depth exercises that teach the skills for Transformation and emissions analysis.
Break	
15:30-17.00	Hands-On Exercises, Part 4 (continued)
17:00 – 17:10	Instructions for Day 4
January 31, Thursday	
9:00 – 12:00	**Hands-On Exercises, Part 5: Energy Demand Analysis** Exercises that teach advanced skills for energy demand analysis such as useful energy analysis, as well as advanced techniques for integrating LEAP with spreadsheet analyses.
Lunch Break	
13:00 – 17:00	**Hands-On Exercises, Part 6: Using the Least Cost Optimization Features of LEAP** A new exercise where participants will learn how to use the linear programming features of LEAP, and explore least cost electric generation systems under various assumptions (e.g. with and without inclusion of externality values and CO_2 emissions constraints).
17:00 – 17:10	Instructions for Day 5

February 1, Friday	
9:00 – 12:00	**Hands-On Exercises, Part 7: Using LEAP for Cost-Benefit Analysis of Energy Policies** Participants will learn how to conduct a comprehensive analysis that compares the net present value of alternative scenarios.
Lunch Break	
13.00 – 15:00	Discussion of in-country data development and assignment of tasks to participants ahead of second training workshop
Break	
15.15 - 17:00	Wrap-up, assessment of workshop and presentation of certificates

LEAP Technical Training Section 3: An Introduction to LEAP

Outline

- What is LEAP?
- How does it Compare to Other Models?
- Structure and Interface
- A Few 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

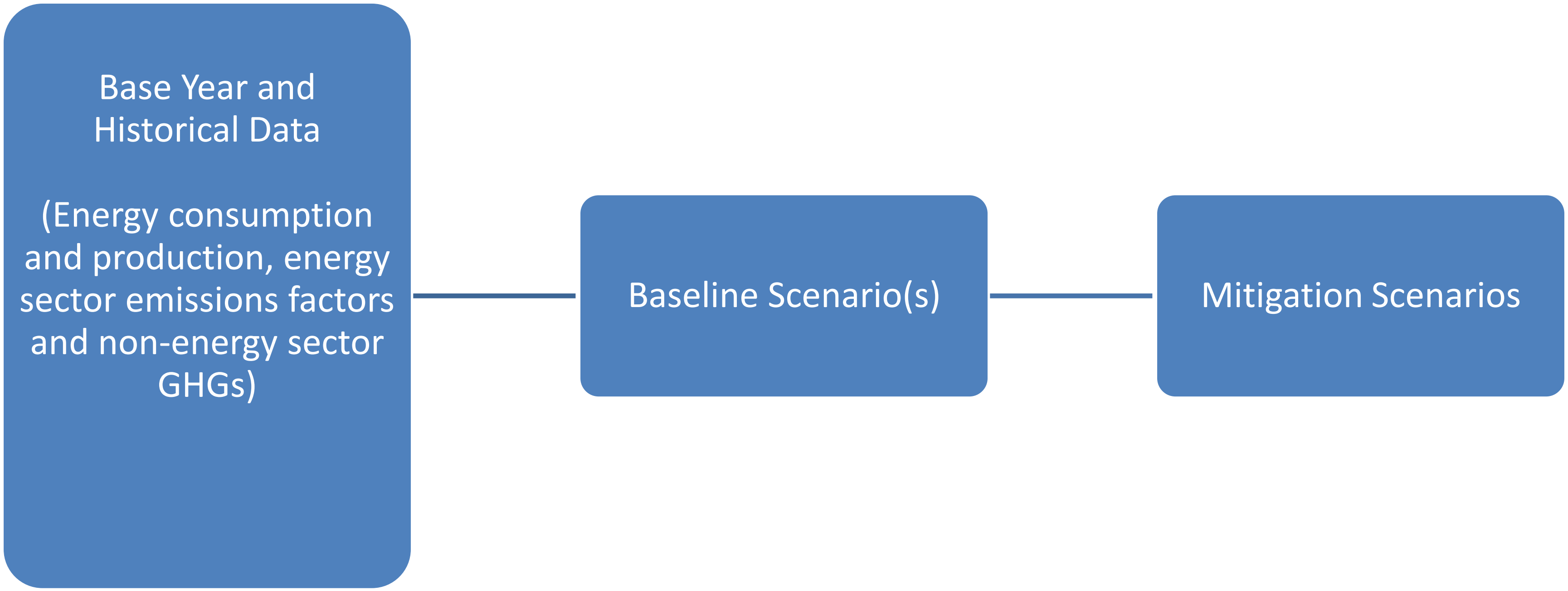
How Does LEAP Compare to Other Energy Models?

- 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).

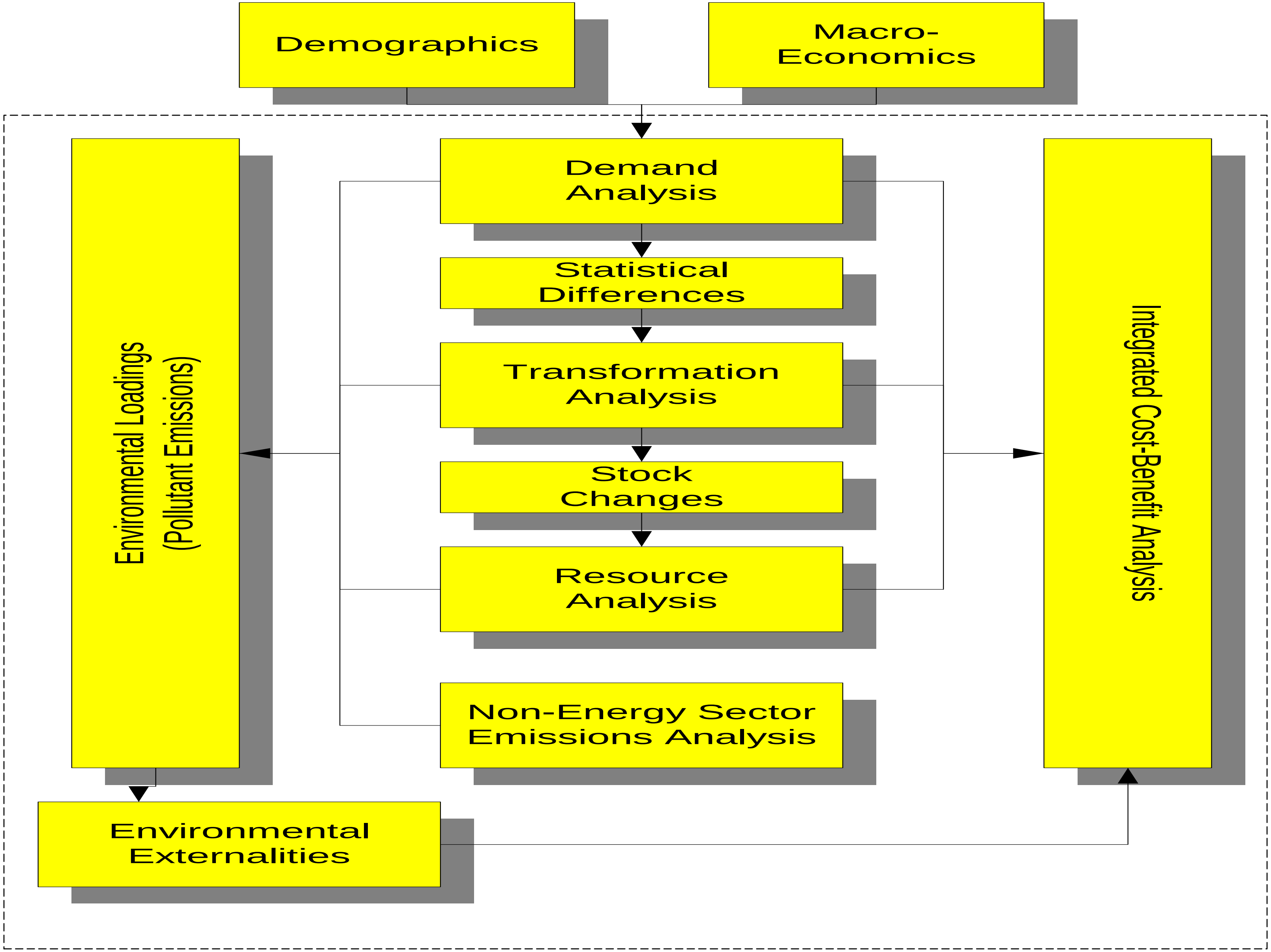
Basic Demand Modeling Philosophy in LEAP

- 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.

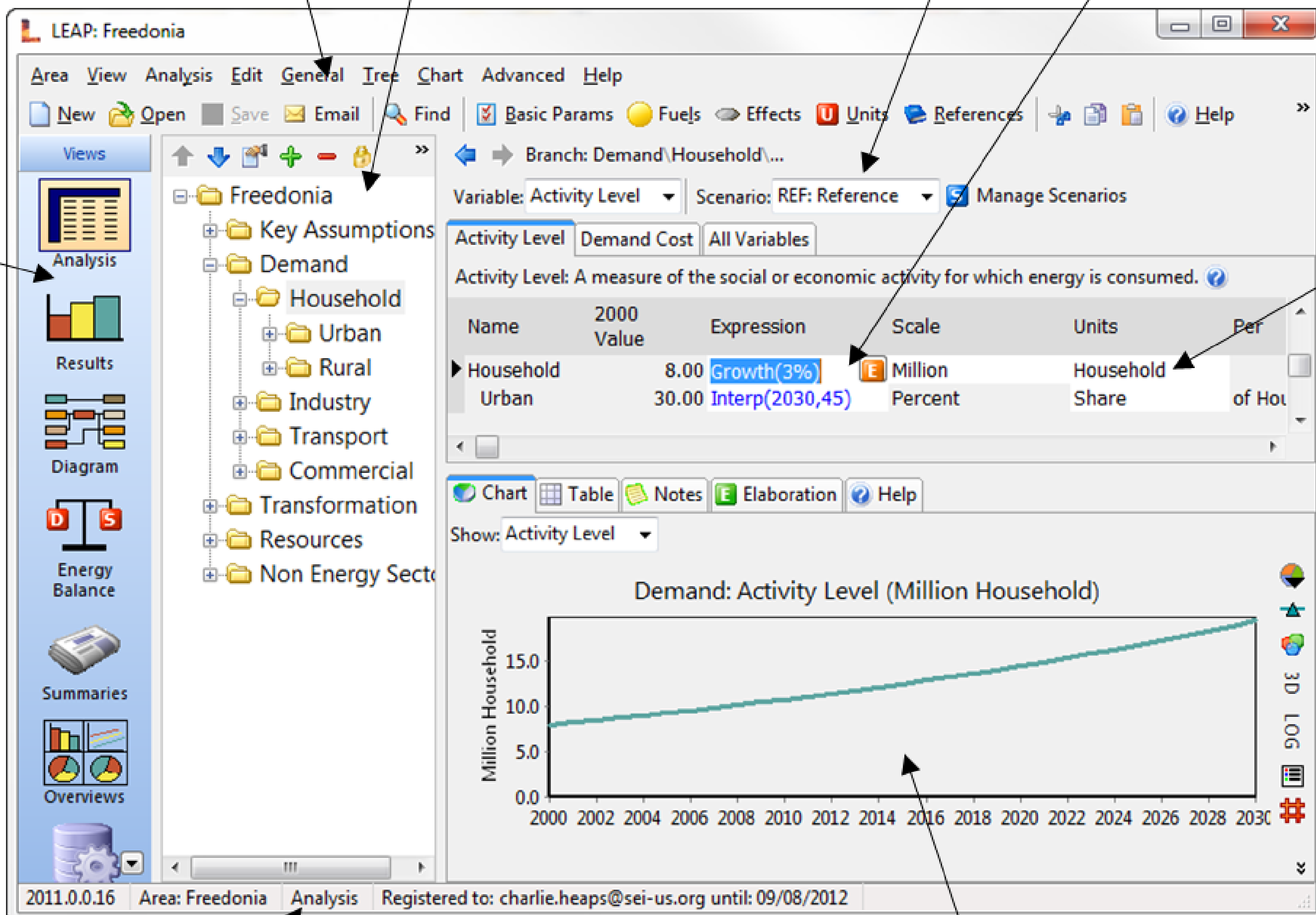
Data is organized in a tree.

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

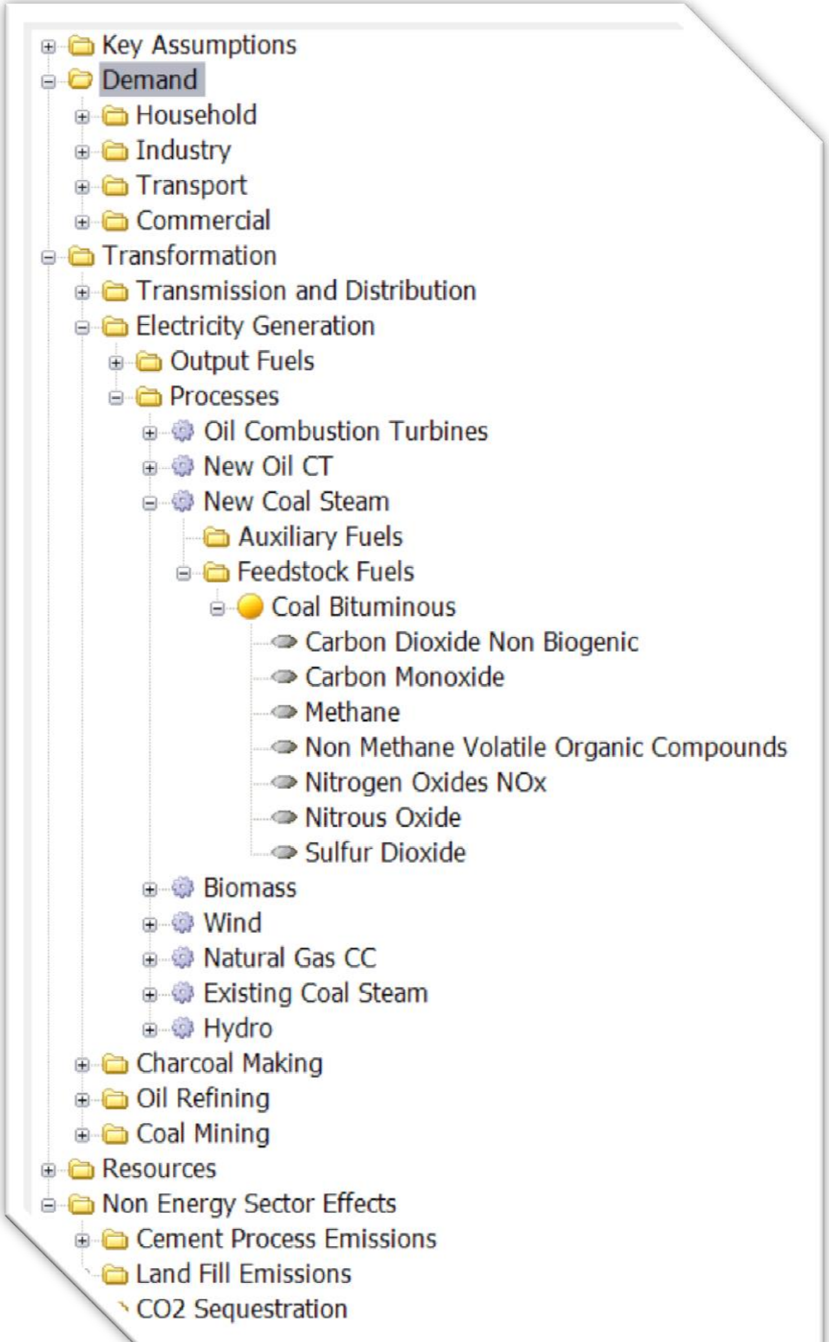
- Energy-Water Nexus: Links to SEI's "WEAP" Water Model for integrated energy/water assessment.
- Flexible region and fuel groupings (used in new global modal).
  - For example, SEI's new global energy model, built in LEAP, modeled 22 global regions, while results were presented aggregated across 22, 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.

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.



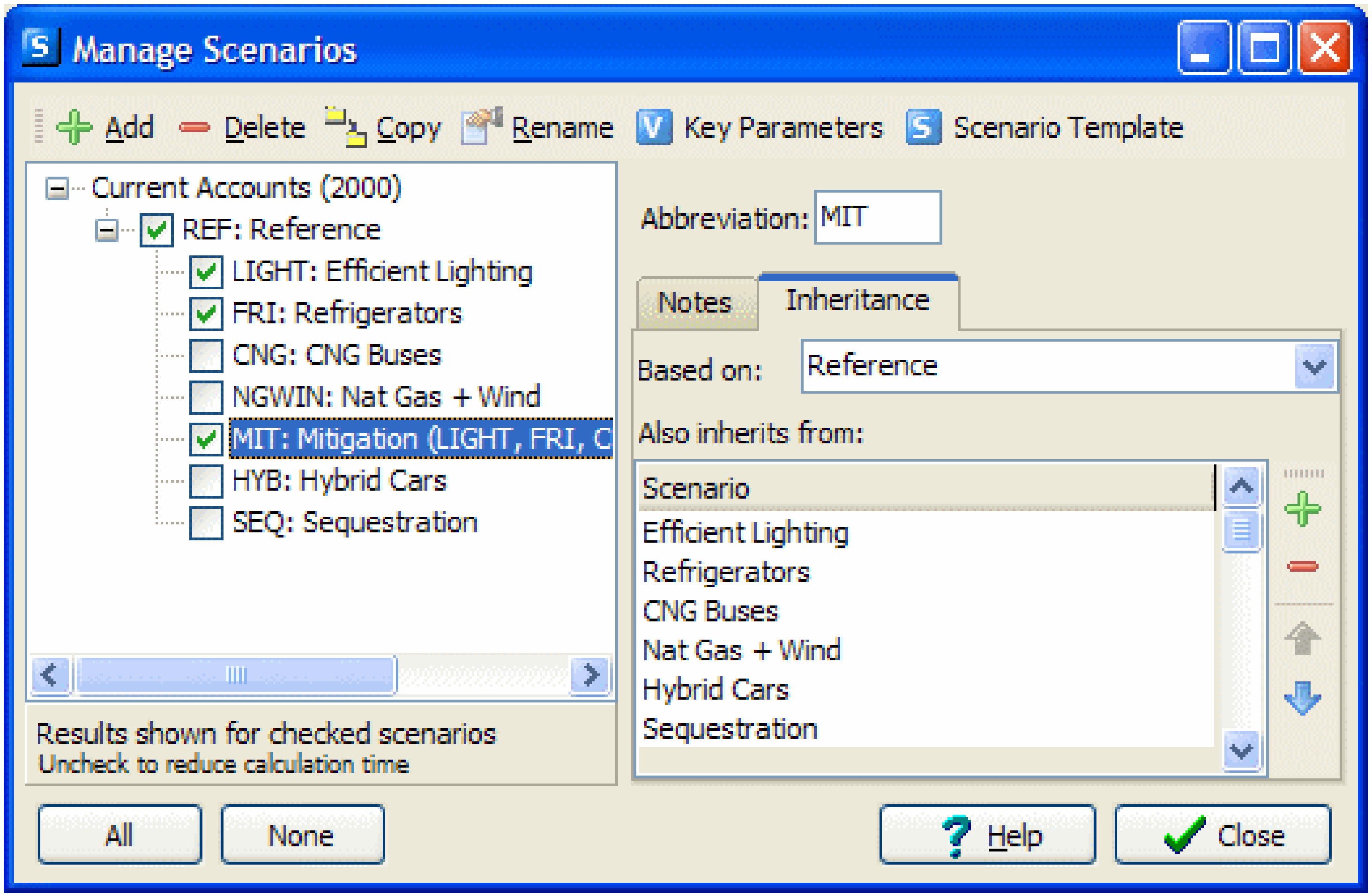
The Tree

- 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)

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



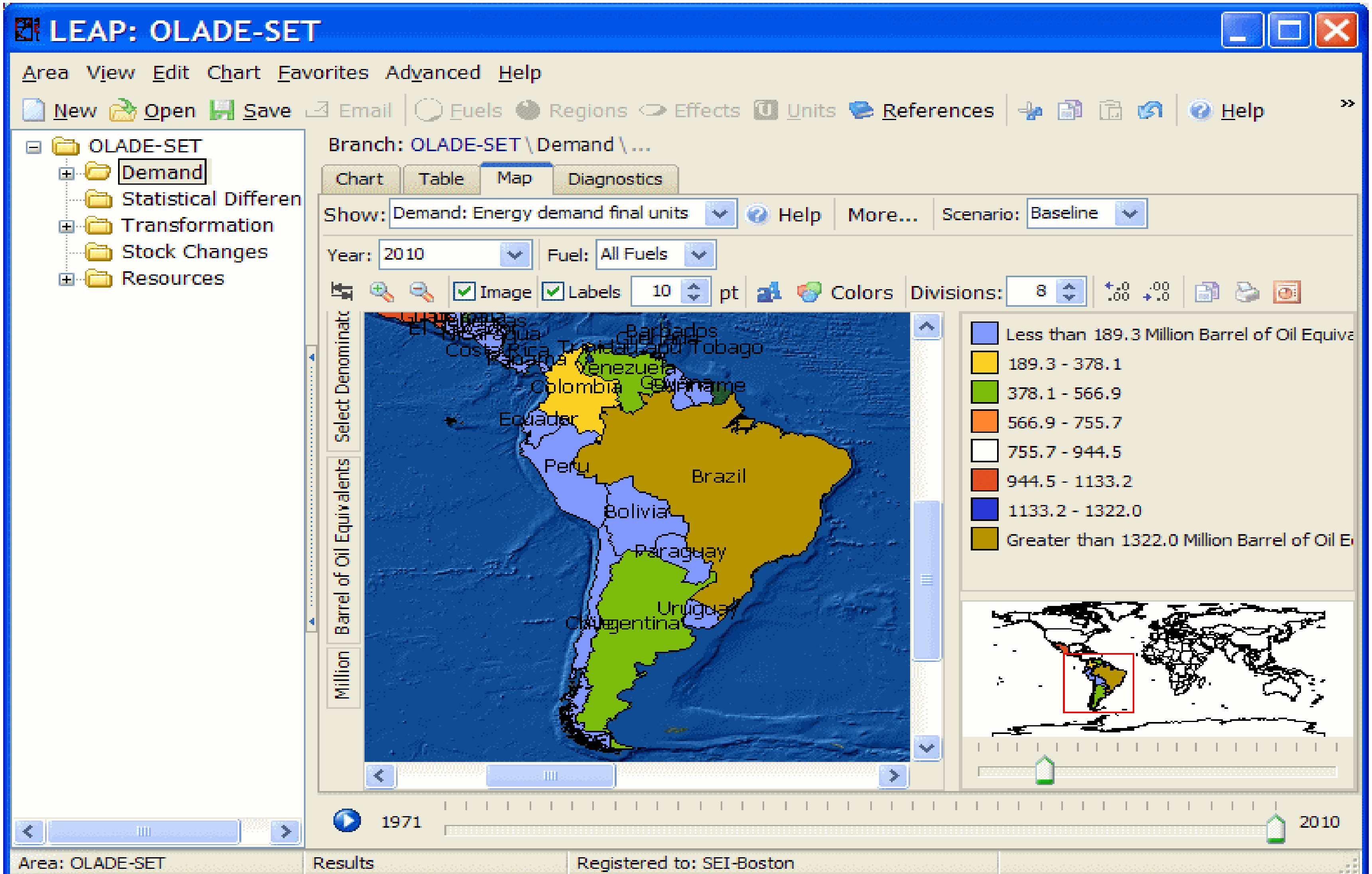
Modeling at Two levels

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.

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

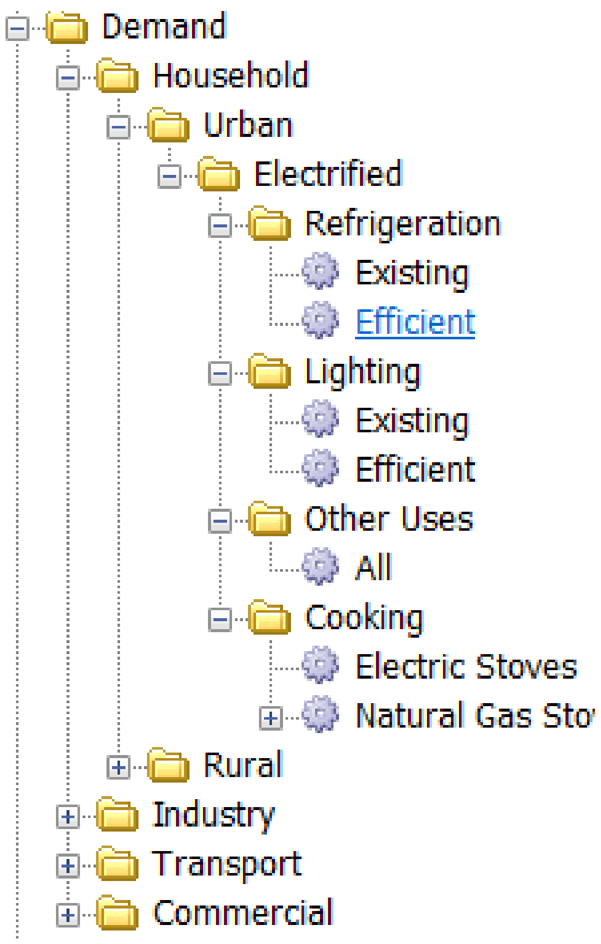


Three Approaches for Demand Modeling in LEAP

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

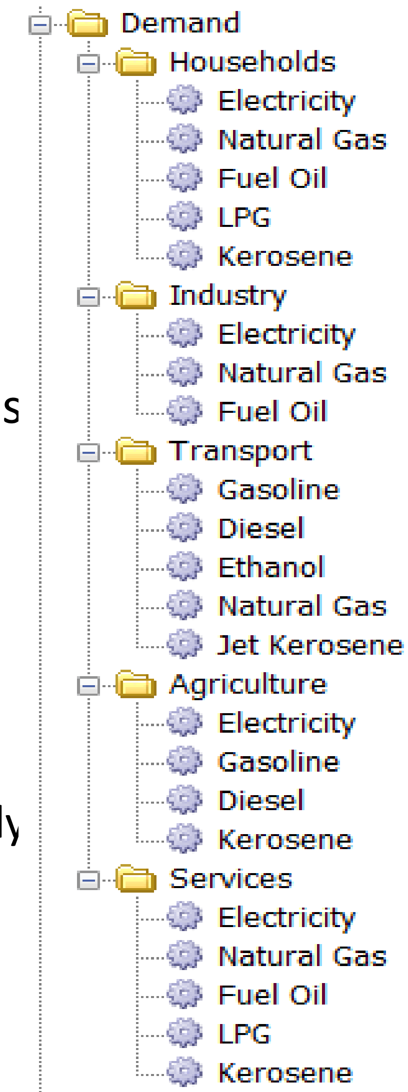
Bottom-Up/End-Use

- 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).



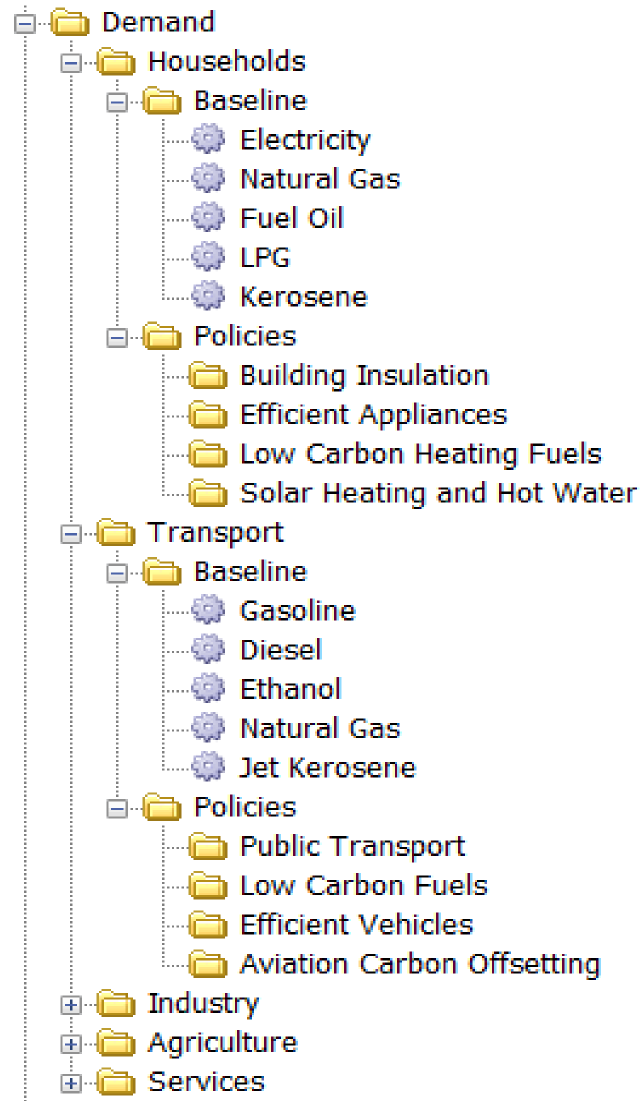
Top-down/Econometric

- 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.



COMMEND

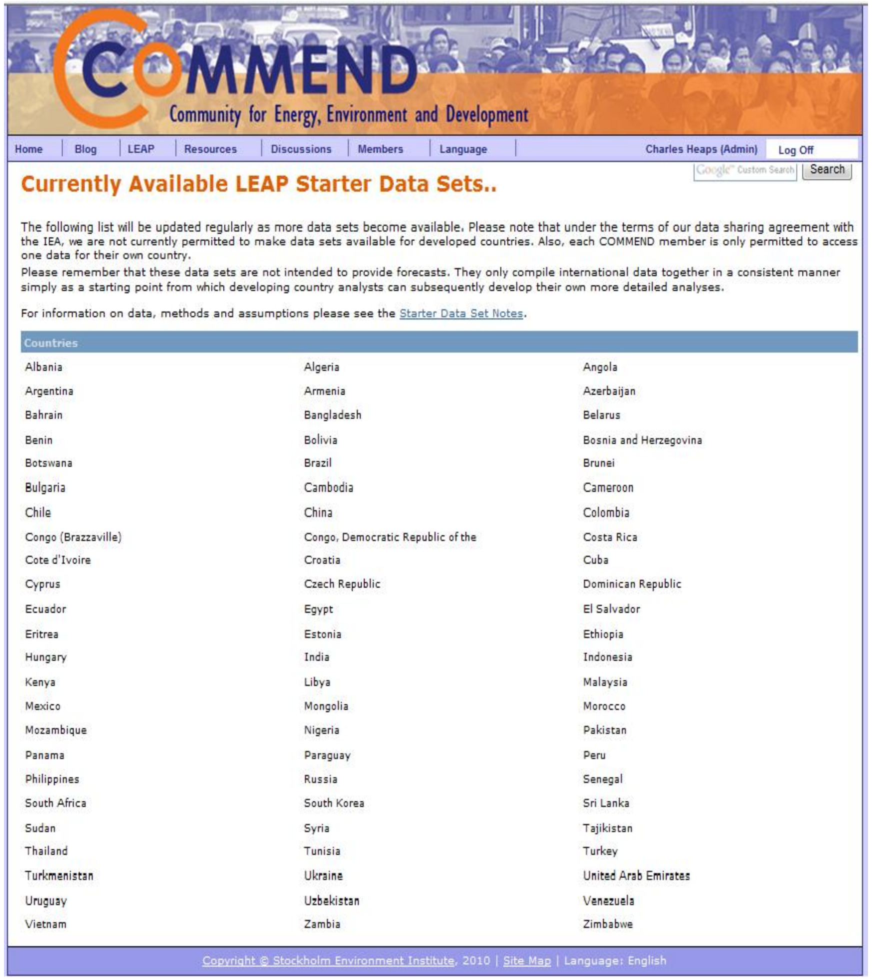
Community for Energy, Environment and Development

- 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

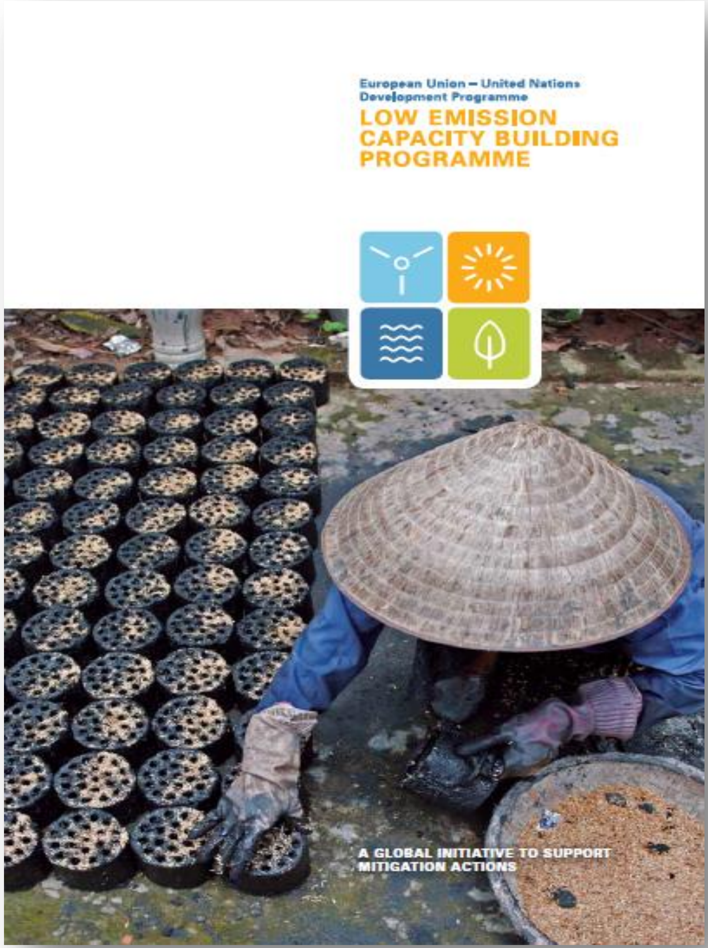


- Now available for free download for 105 countries (1 data set per user).
- Compiles international data as a **starting point** for more detailed analyses.
- Includes IEA energy data (1971-2009), IPCC emissions factors, UN population projections, World Bank development indicators, Non-energy sector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

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.

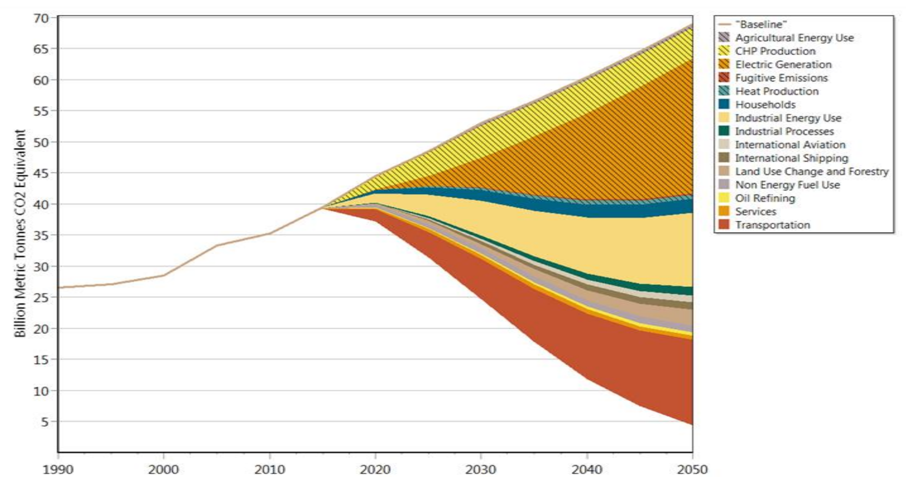


Energy for a Shared Development Agenda: A Global Assessment for Rio+20, 2012

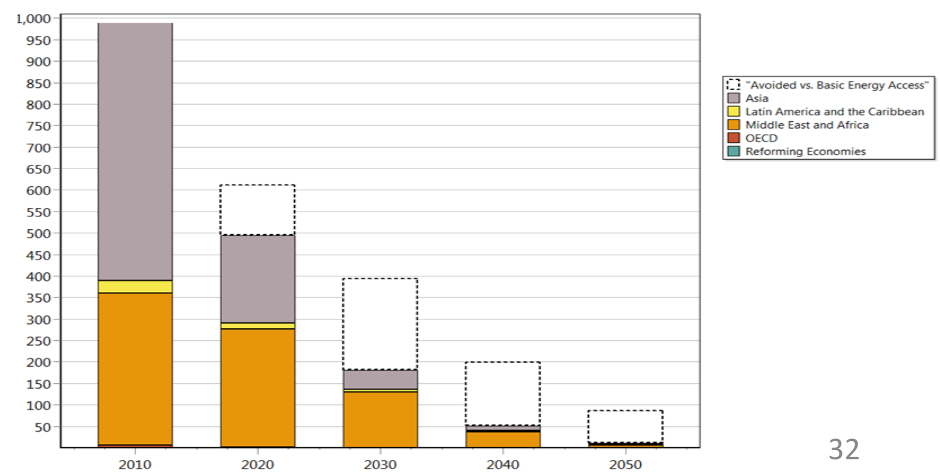
RIO+20

- 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.

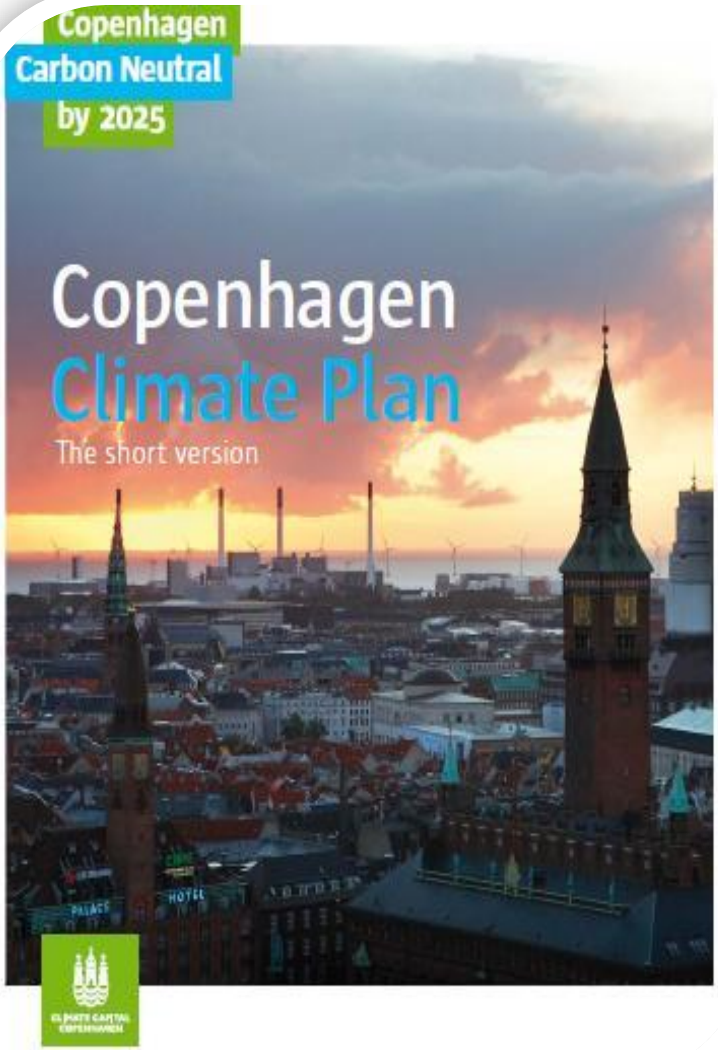
Emissions



Poverty

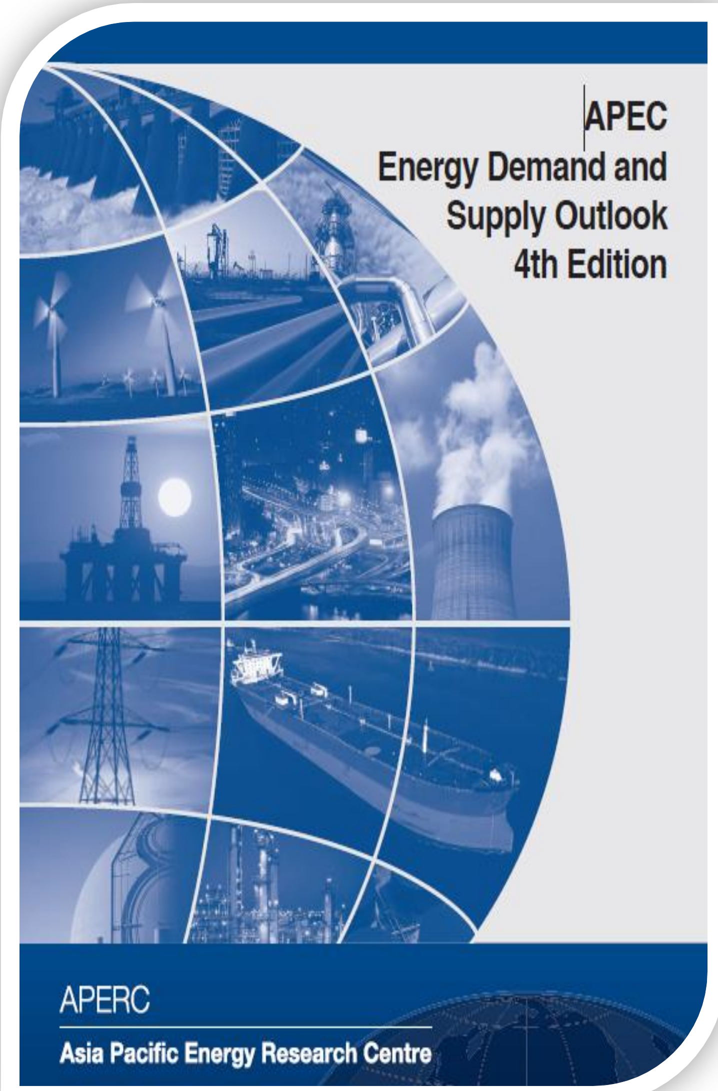


Copenhagen Climate Plan, 2009



- The Consulting Company RAMBOLL used LEAP to prepare a plan for the city of Copenhagen to become CO2 neutral by 2025.
- Copenhagen is already perhaps the most energy efficient city in the World, in part due to its widespread use of CHP systems for district heating and huge investments in wind power, and because nearly 40% of its citizens cycle to work or school every day.
- This study formed the basis for Copenhagen setting a target of 20% reduction in CO2 emissions by 2015 compared to 2005 and becoming completely CO2 neutral by 2025.

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



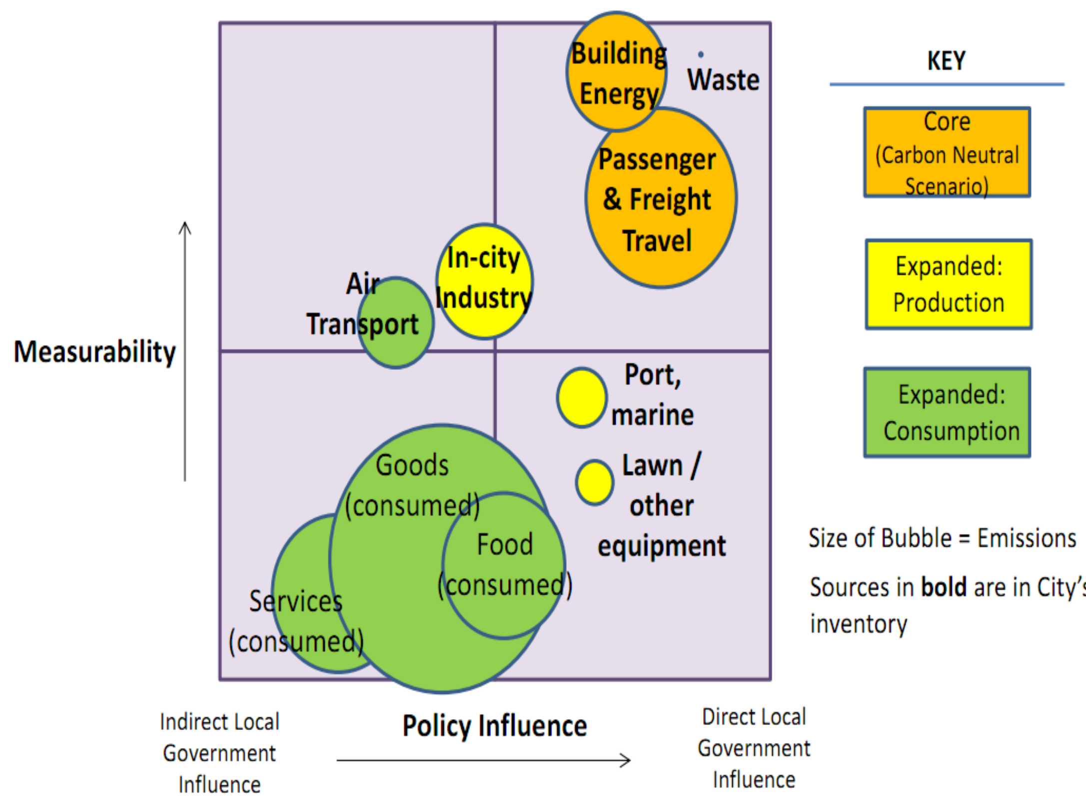
- Forecasts demand and supply for each APEC economy. Updated every 3-4 years
- Examines key technical and socio-economic drivers in APEC such as urbanization, aging of populations, relocation of industries towards less developed economies, technology development.
- Draws policy implications regarding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

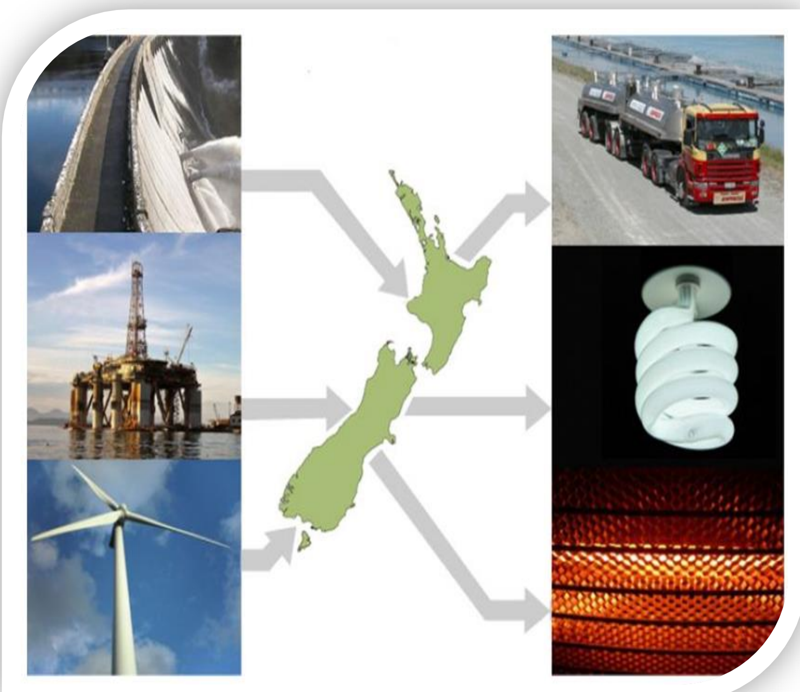
Getting to Zero: A Pathway to a Carbon Neutral Seattle

- 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

NIWA
Taihoro Nukurangi



www.niwa.co.nz

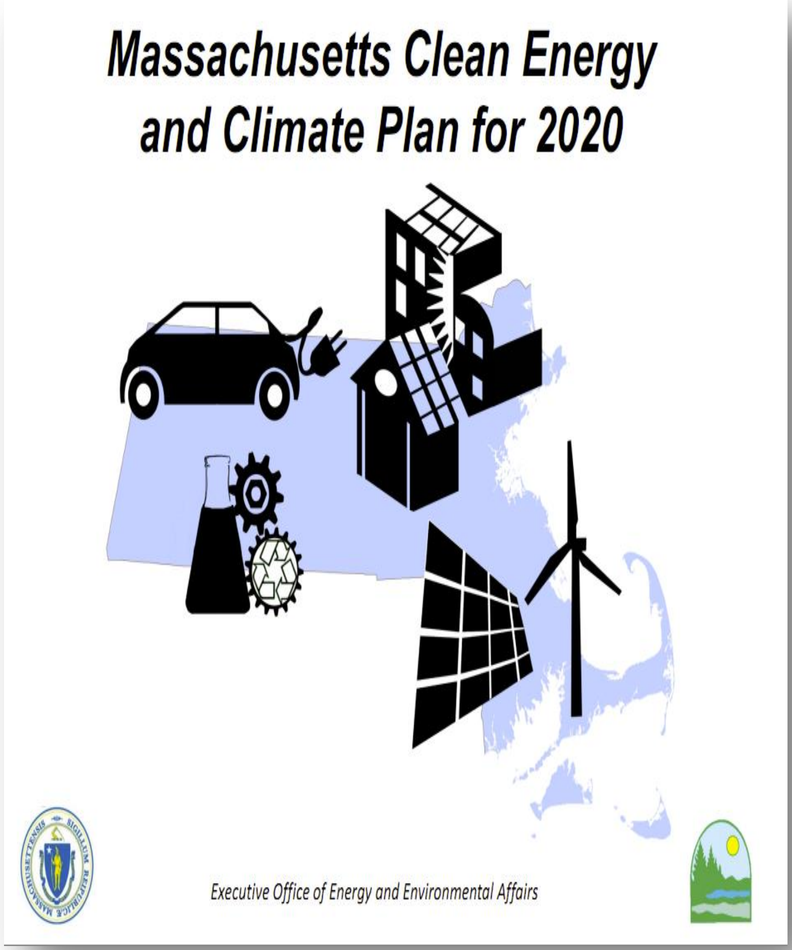
- An initiative of the New Zealand National Institute of Water and Atmospheric Research (NIWA) .
- Designed to help citizens understand and visualize the flow of energy in NZ, making information about energy systems more accessible to scientists, businesses and policy makers.
- EnergyScape project explores 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.

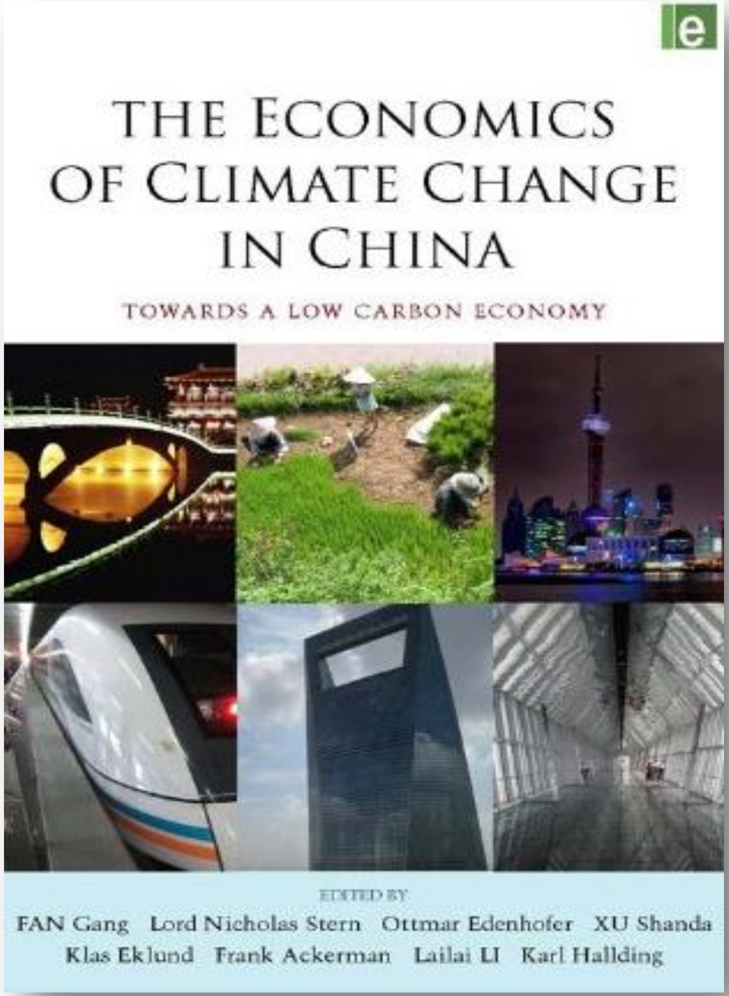
The Massachusetts Clean Energy and Climate Plan (CECP)

- 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

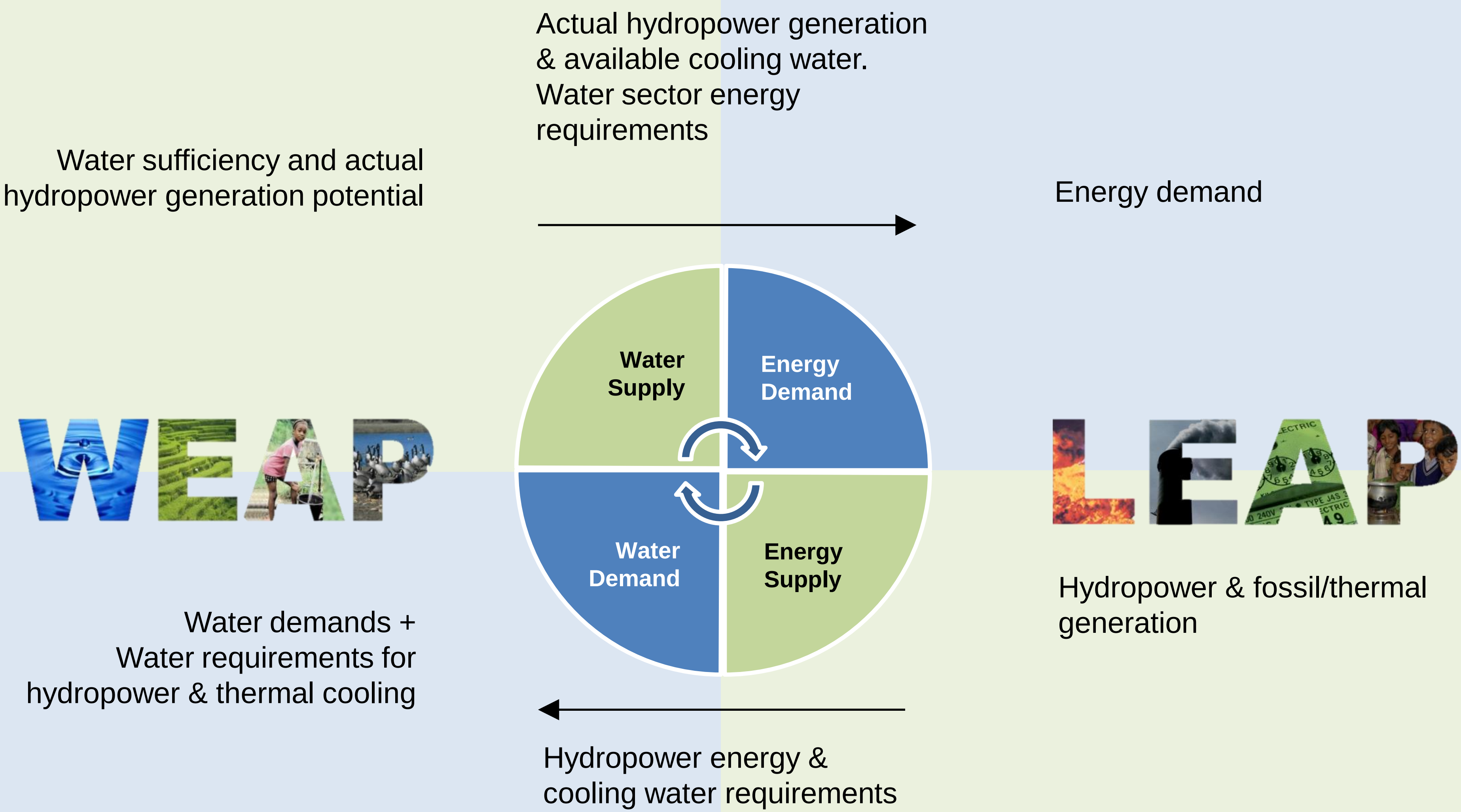


The Economics of Climate Change in China, 2009

- 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.

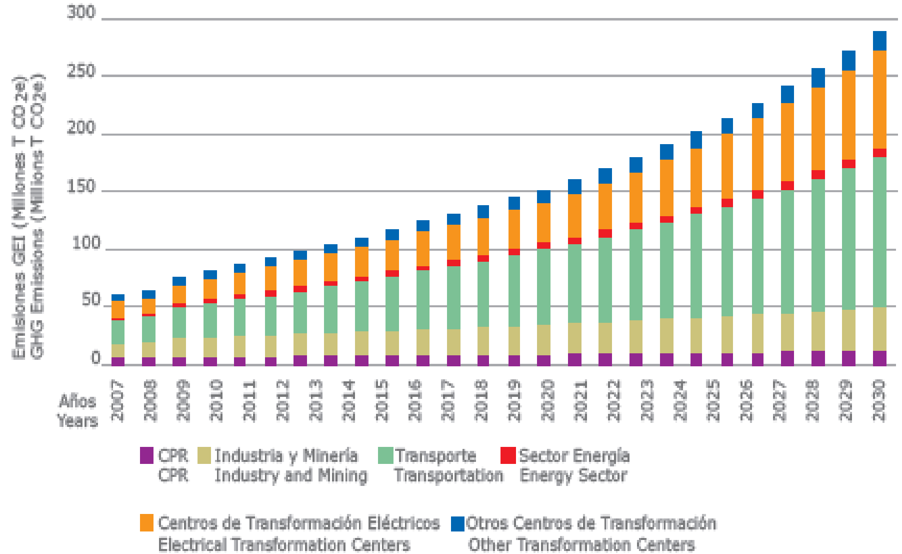
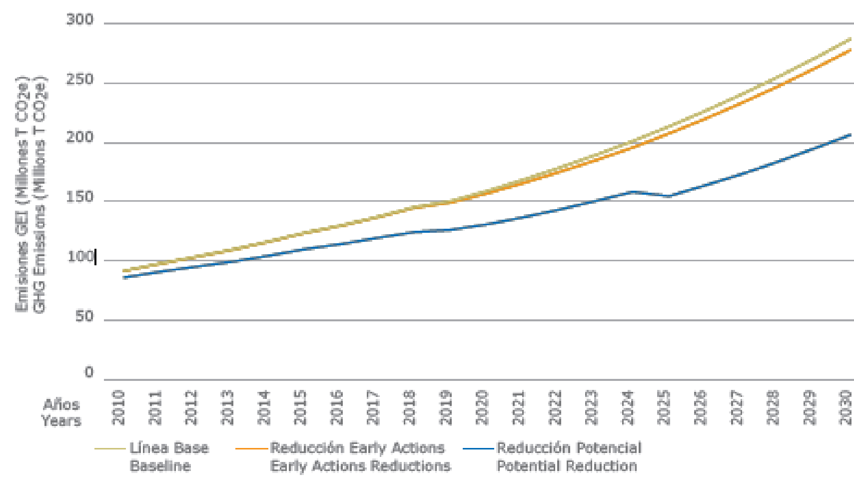


Figura 27: Potencial Máximo de Reducción de GEI en Chile

Figure 27: Maximum GHG Emission Reduction in Chile



More examples at:

www.energycommunity.org/apps

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

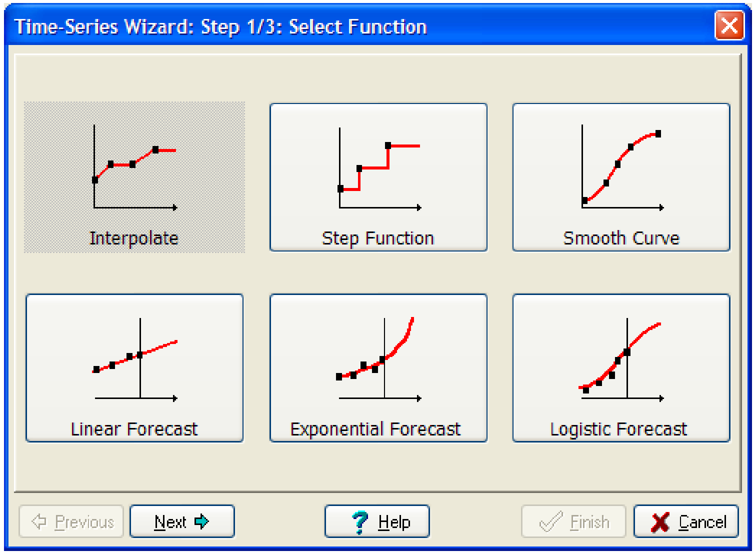
- Similar to expressions in spreadsheets.
- Used to specify the value of variables.
- Expressions can be numerical values, or a formula that yields different results in each year.
- Can use many built-in functions, or refer to the values of other variables.
- Can be linked to Excel spreadsheets.
- Inherited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

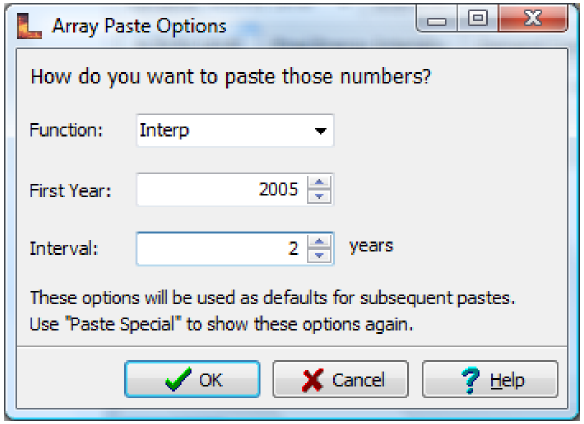
3. Transport Stock Turnover Analysis: *e = s . m / fe*
   - Where: s= number of vehicles (stock),
     m = vehicle distance, fe = fuel economy
   - Allows modeling of vehicle stock turnover.
   - Also allows pollutant emissions to be modeled as function of vehicle distance.
   - Example: model impact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

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:
  1. Export a blank Excel template containing the LEAP data structures and all variables.
  2. Add your own data to this spreadsheet.
  3. Import this spreadsheet into LEAP. LEAP will automatically import scaling factors, units, data and expressions.

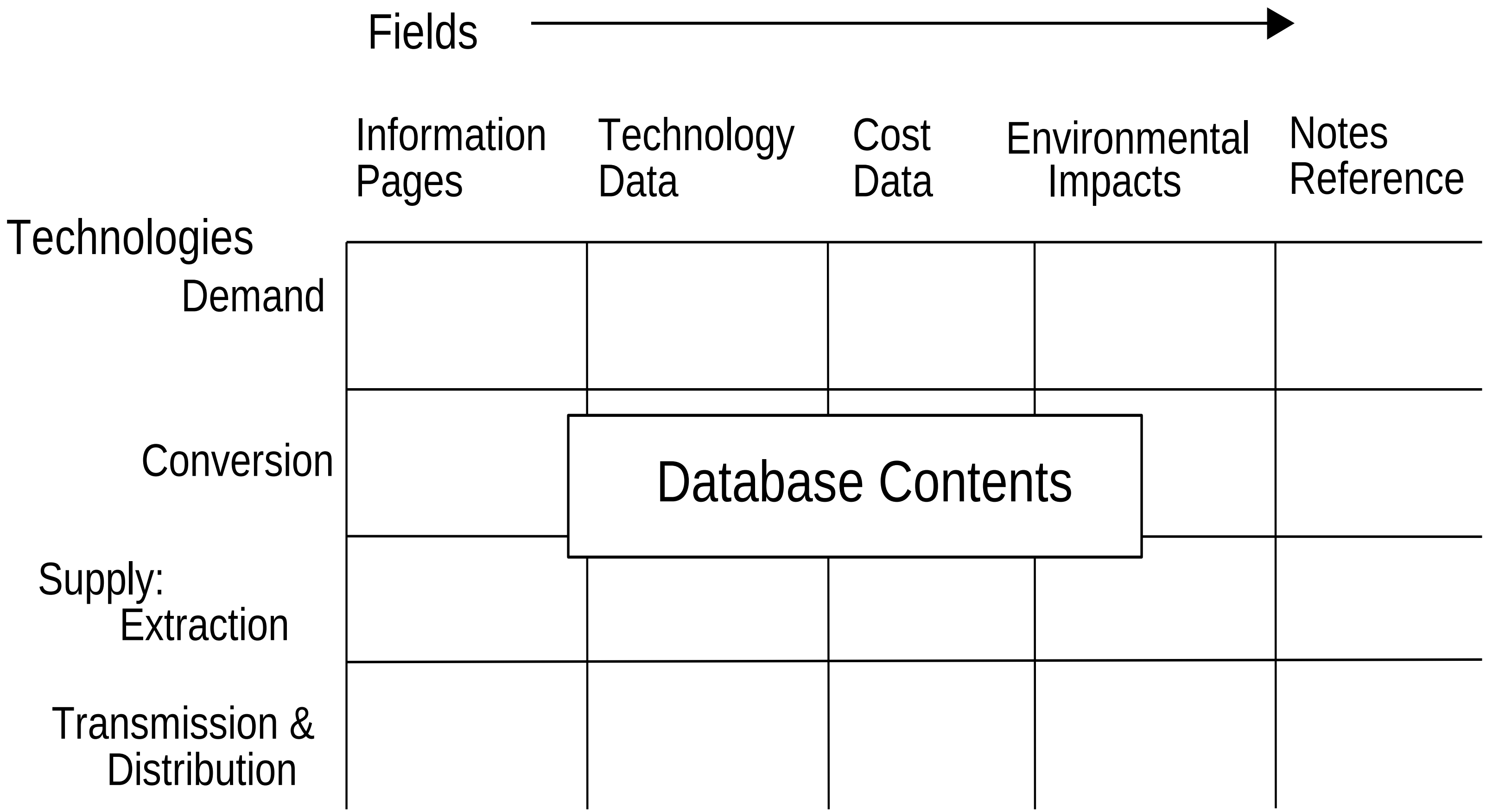
Oil Refining Simulation

- 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



Energy Balances

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

$$P + I - X = L + C_F + C_{NE} + DS$$

- P: Total Primary Energy Produced
- I: Imports
- X: Exports
- L: Transformation Sectors Losses and Consumption
- C_F: Total Final Energy Use in Consuming Sectors
- C_{NE}: Non-energy consumption (e.g. petrochemical feedstock, fertilizers)
- DS: Net Changes in Stocks

Sample IEA Energy Balance

Breakdown by Sector and Activities

Breakdown by Energy Source

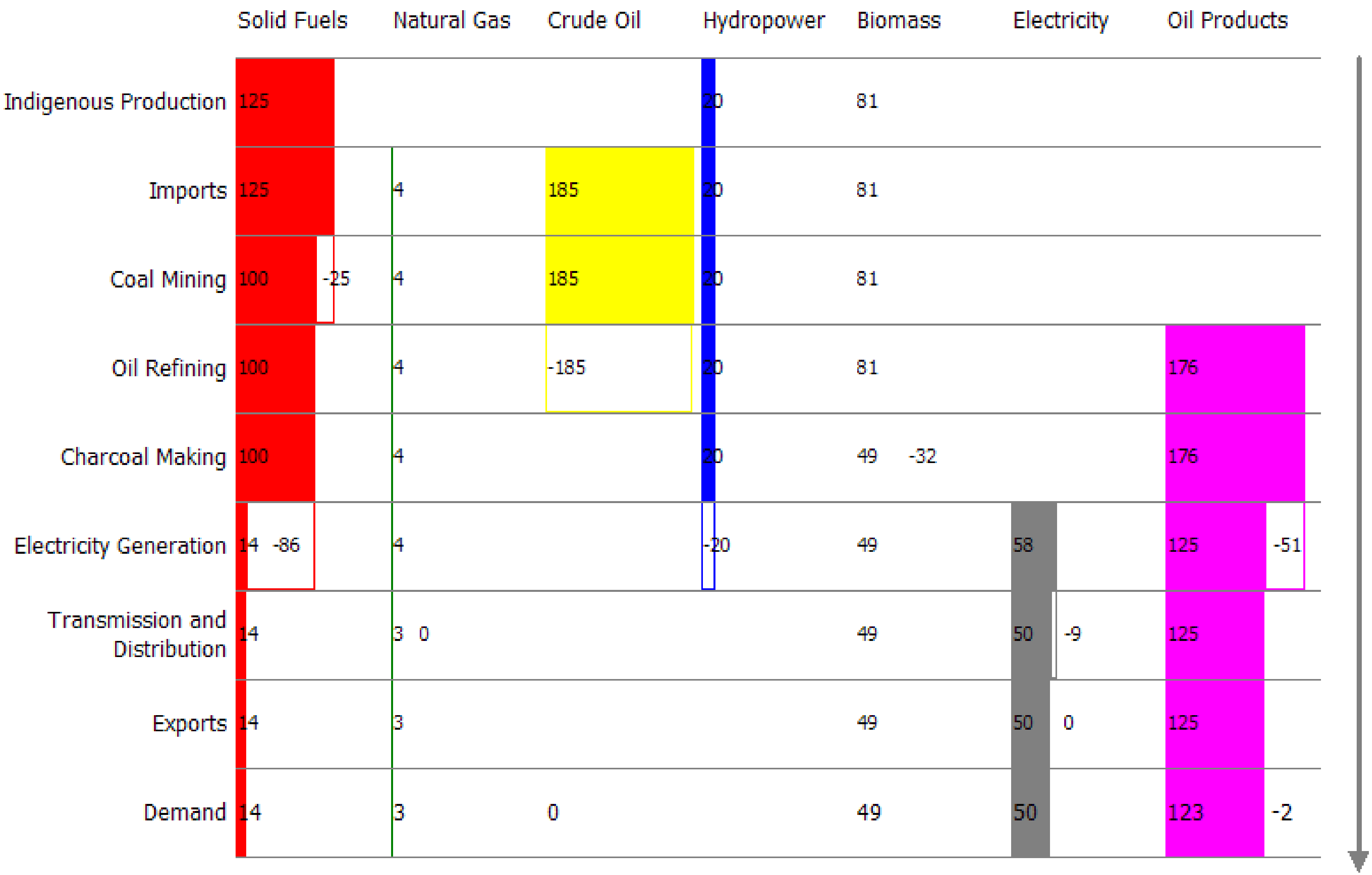
Thailand Energy Balance, 1983 (Thousand TOE)

	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*	*1860*	*0*	*8289*
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*	*2980*	*0*	*5695*
Agriculture			1628				11		1640
Public/Commerce							1890		1890
Residential			1086				1026		2113
Non-specified Other							52		52
Non-Energy Use			340						340

LEAP Energy Balance Table

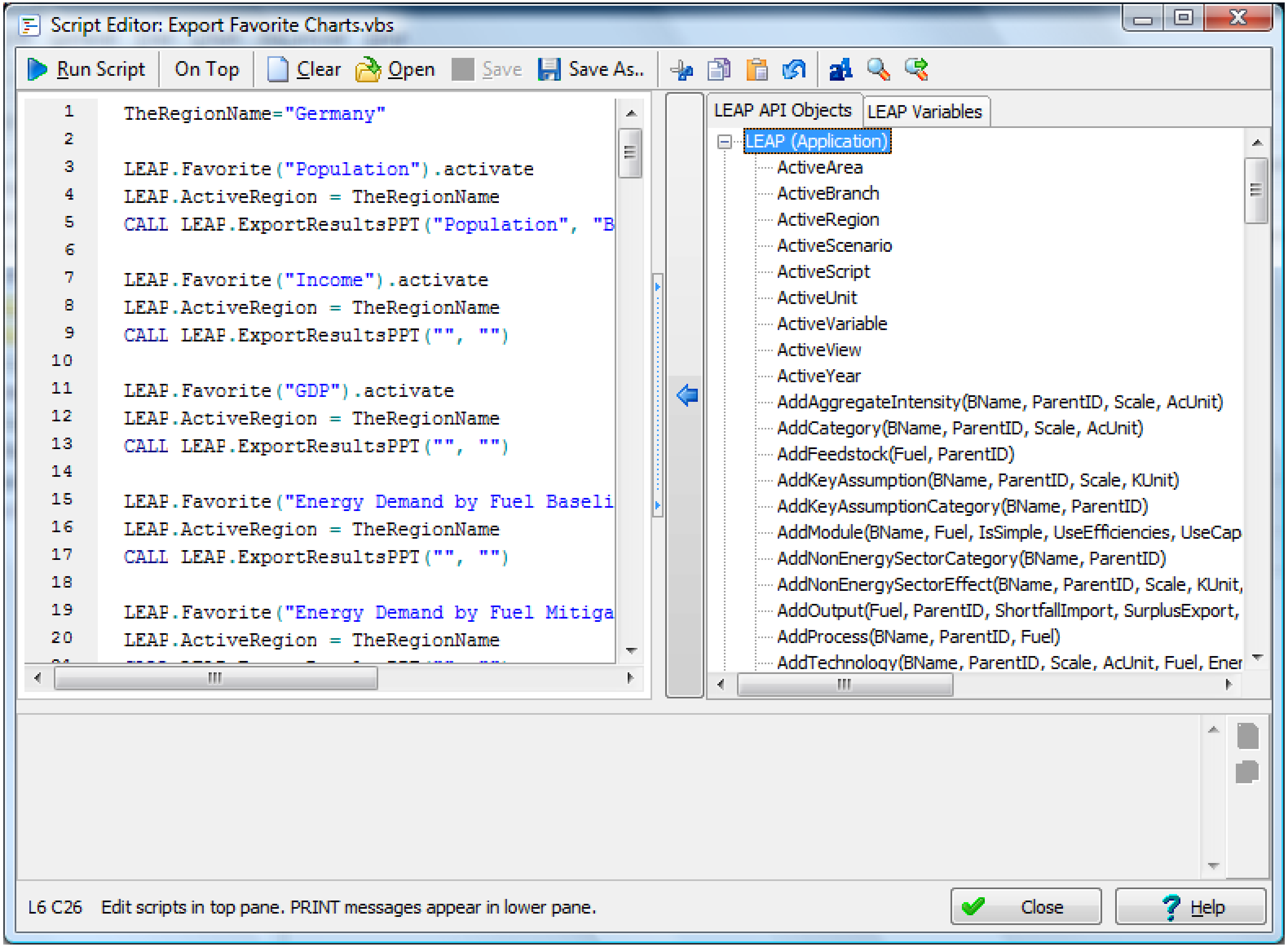
Energy Balance for: Freedonia Scenario: Reference. Year: 2000 (Million Gigajoule)								
	Solid Fuels	Natural Gas	Crude Oil	Hydropower	Biomass	Electricity	Oil Products	Total
Production	125	0	0	20	81	0	0	226
Imports	0	4	185	0	0	0	0	189
Exports	0	0	0	0	0	0	0	0
From Stock Change	0	0	0	0	0	0	0	0
Total Primary 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.


Script Editor: Export Favorite Charts.vbs
Run Script
On Top
Clear
Open
Save
Save As..
TheRegionName="Germany"
LEAP.Favorite("Population").activate
LEAP.ActiveRegion = TheRegionName
CALL LEAP.ExportResultsPPT("Population", "B
LEAP.Favorite("Income").activate
LEAP.ActiveRegion = TheRegionName
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LEAP.ActiveRegion = TheRegionName
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LEAP API Objects
LEAP Variables
LEAP (Application)
ActiveArea
ActiveBranch
ActiveRegion
ActiveScenario
ActiveScript
ActiveUnit
ActiveVariable
ActiveView
ActiveYear
AddAggregateIntensity(BName, ParentID, Scale, AcUnit)
AddCategory(BName, ParentID, Scale, AcUnit)
AddFeedstock(Fuel, ParentID)
AddKeyAssumption(BName, ParentID, Scale, KUnit)
AddKeyAssumptionCategory(BName, ParentID)
AddModule(BName, Fuel, IsSimple, UseEfficiencies, UseCap
AddNonEnergySectorCategory(BName, ParentID)
AddNonEnergySectorEffect(BName, ParentID, Scale, KUnit,
AddOutput(Fuel, ParentID, ShortfallImport, SurplusExport,
AddProcess(BName, ParentID, Fuel)
AddTechnology(BName, ParentID, Scale, AcUnit, Fuel, Ener
L6 C26
Edit scripts in top pane. PRINT messages appear in lower pane.
Close
Help

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.

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).

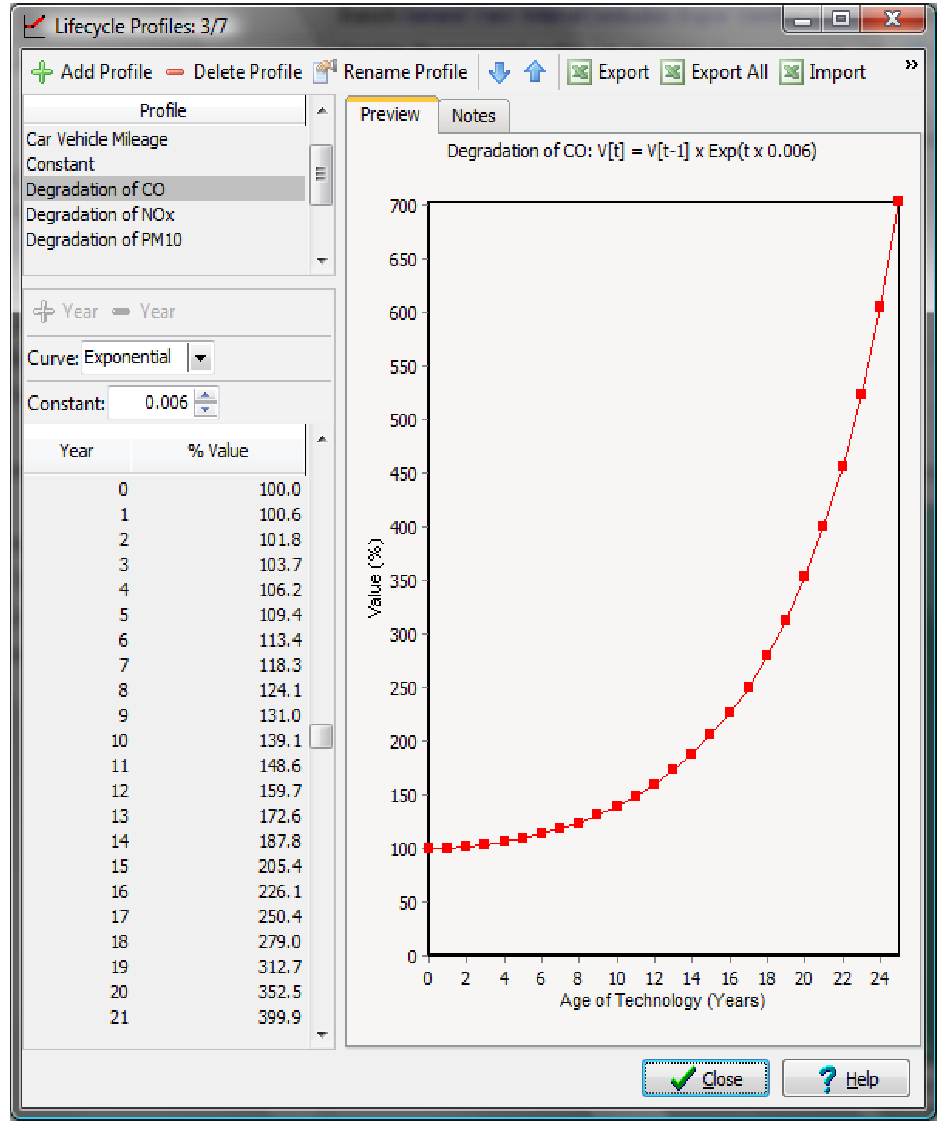
   These changes are specified from year to year using LEAP's standard expressions (interp, growth, etc.)

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.



LEAP Technical Training Section 4: Transformation and Emissions Analysis

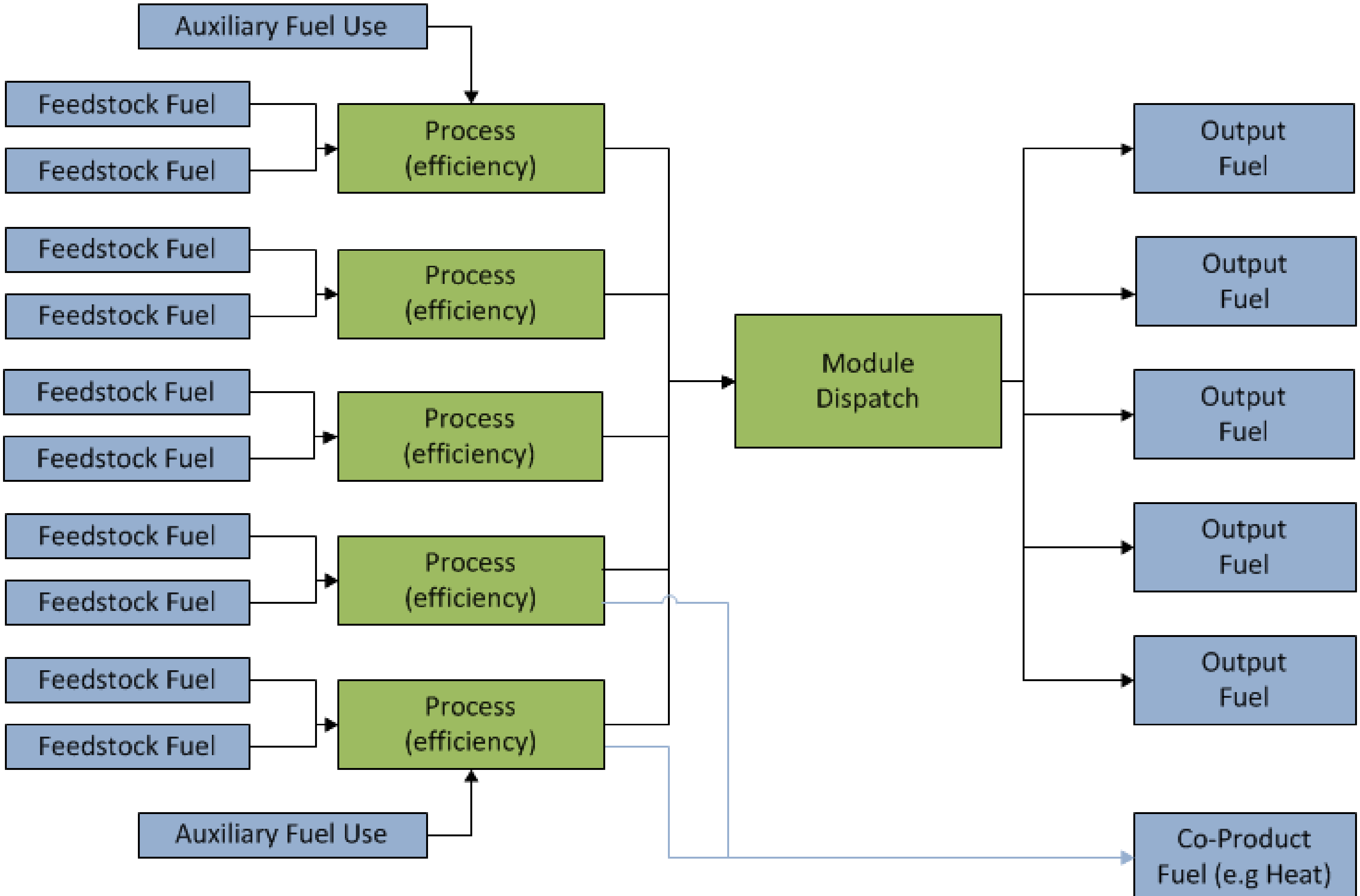
Transformation Analysis in LEAP

- 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**.

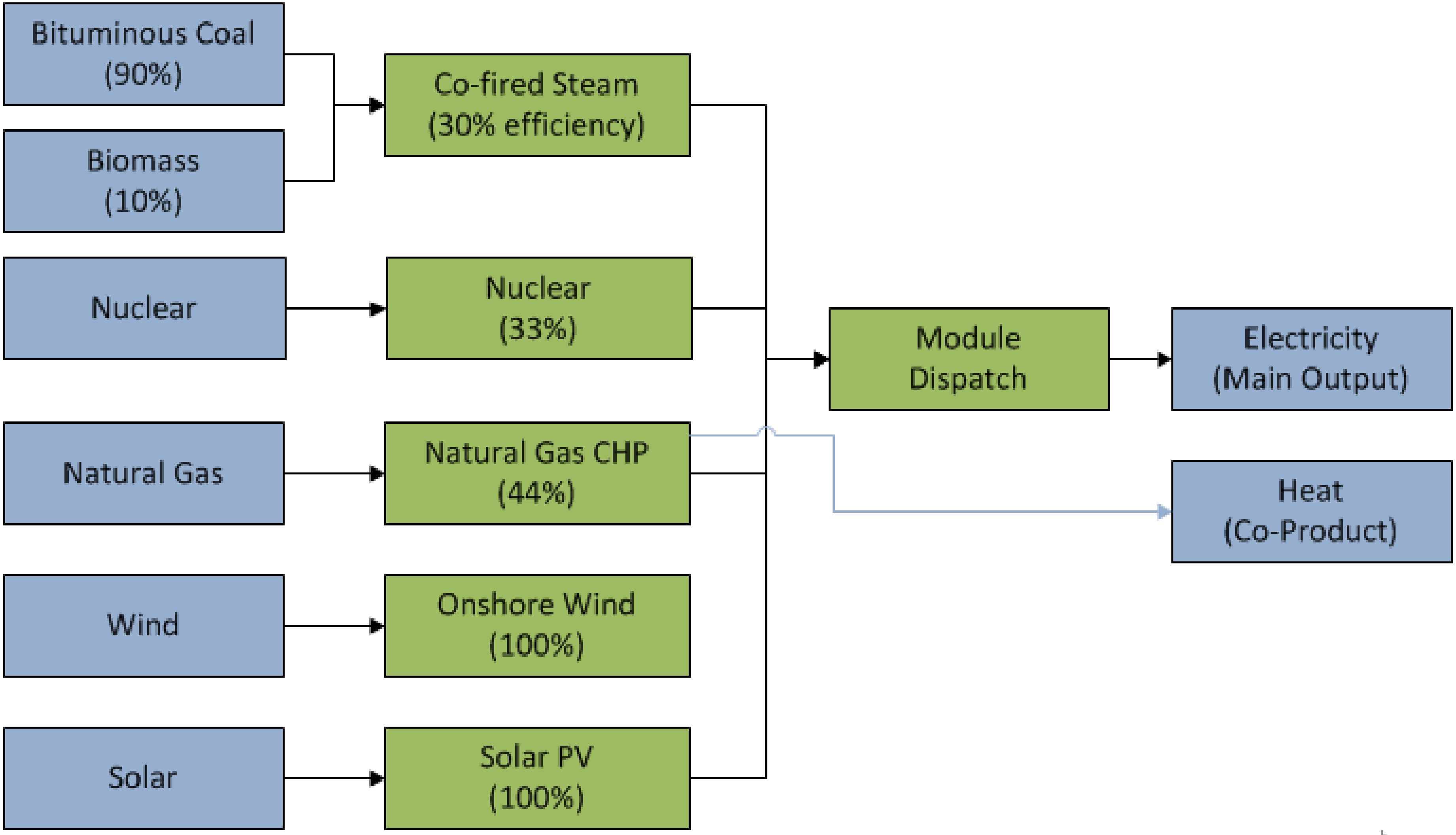
Choice of Methods: to Match Data Available

- **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 peek 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.)

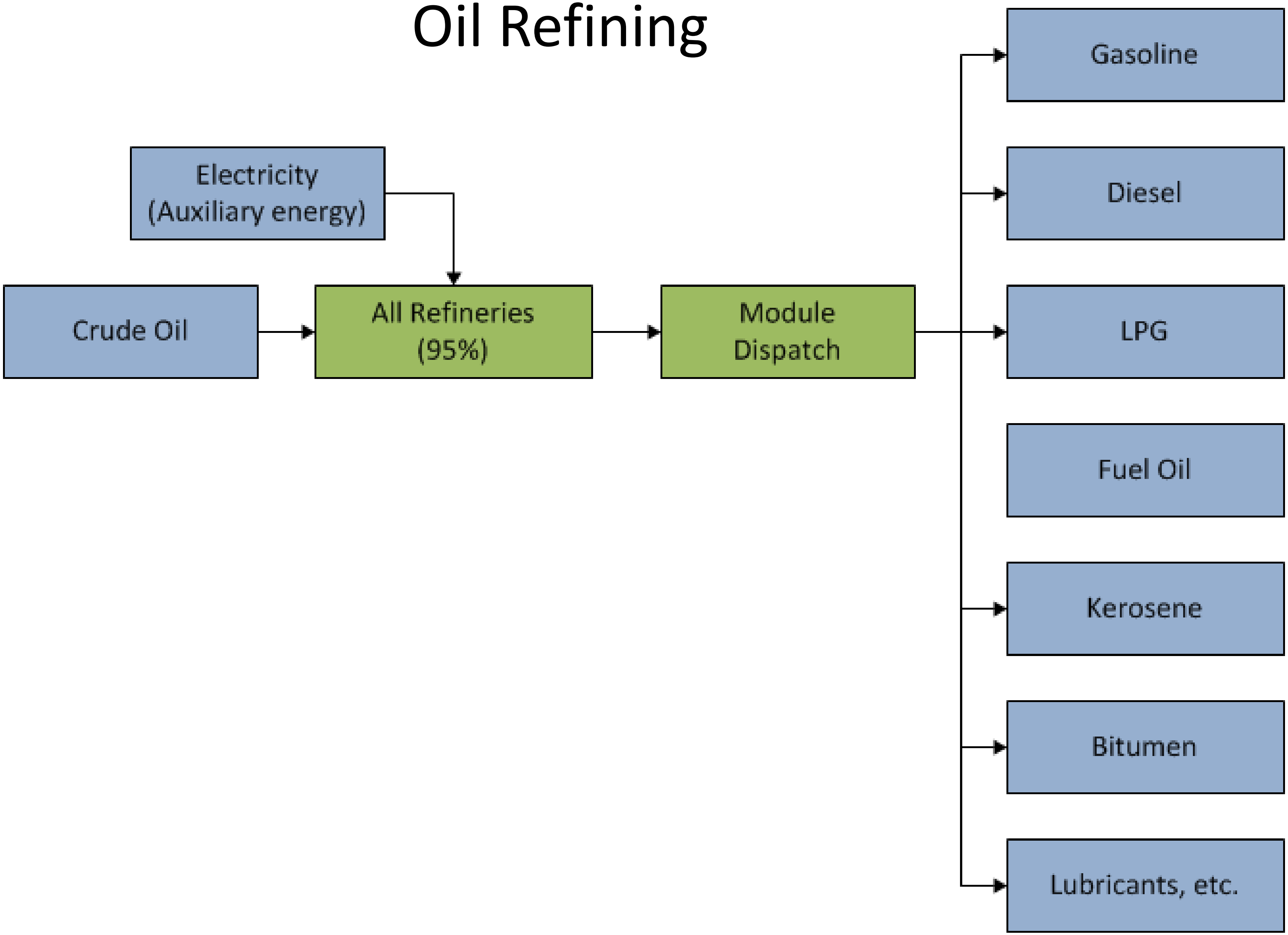
General Transformation Module Layout



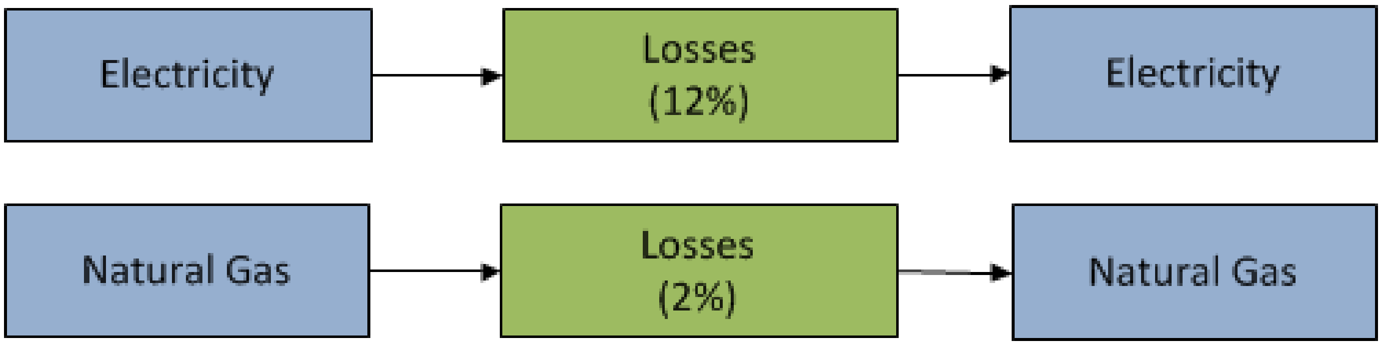
A Transformation Module for Electricity Generation



A Transformation Module for Oil Refining



A Simple, Non-Dispatched Transformation Module

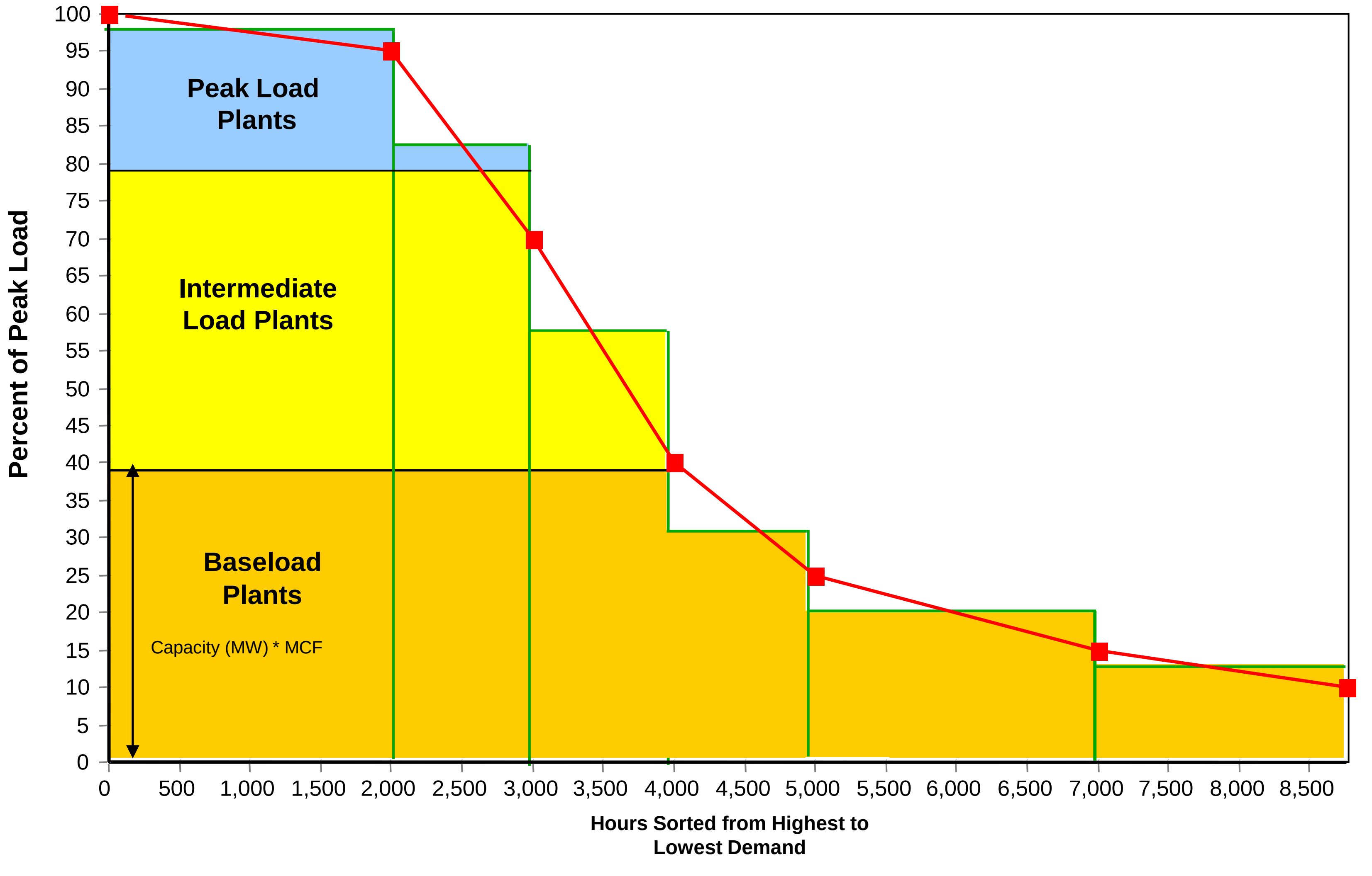


Electric Generation

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



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.

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.

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).

Emissions Accounting

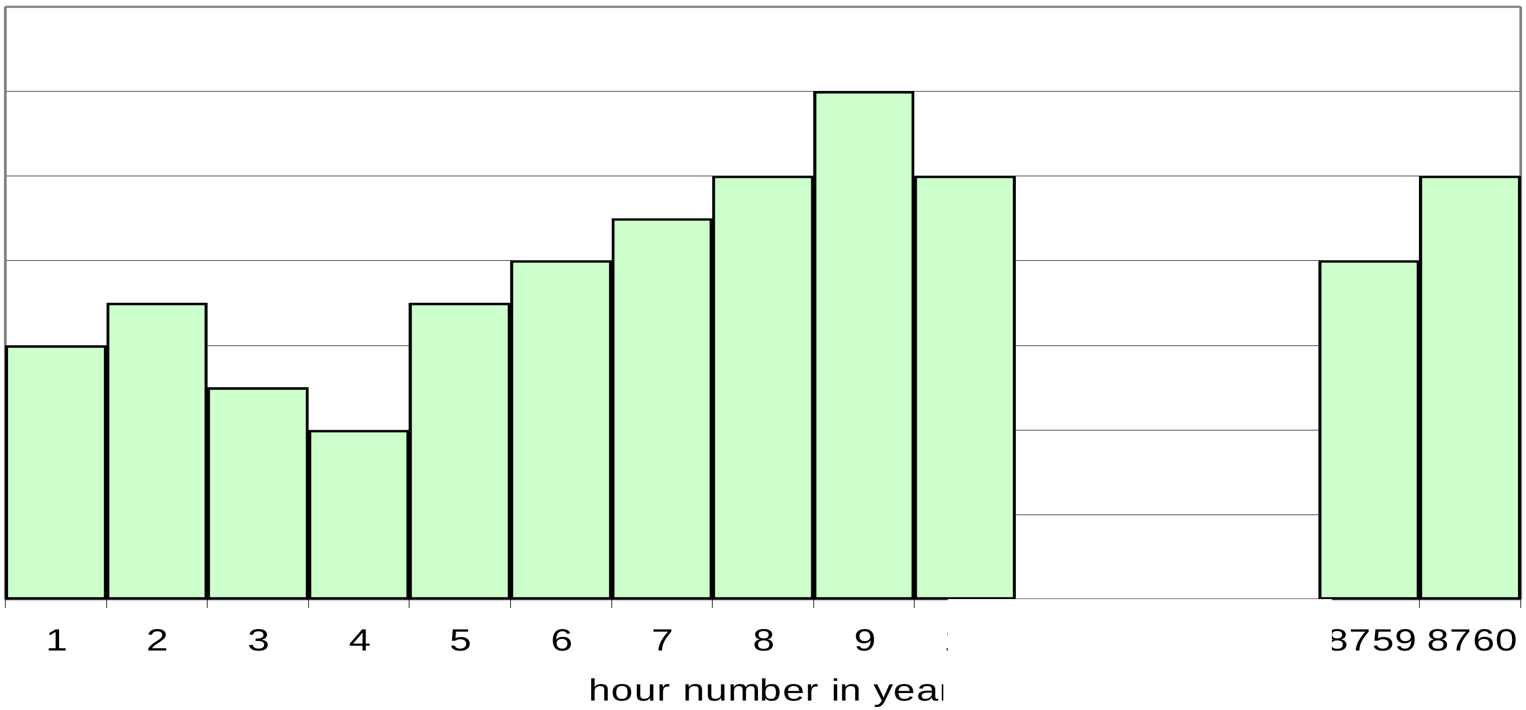
- Emission factors for any GHG or local air pollutant can be entered in LEAP and used to calculate emissions loadings.
- Can be specified in any physical unit and can be denominated by units of either energy consumption or production (e.g. kg/ton of coal) or distance driven for transport factors (e.g.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

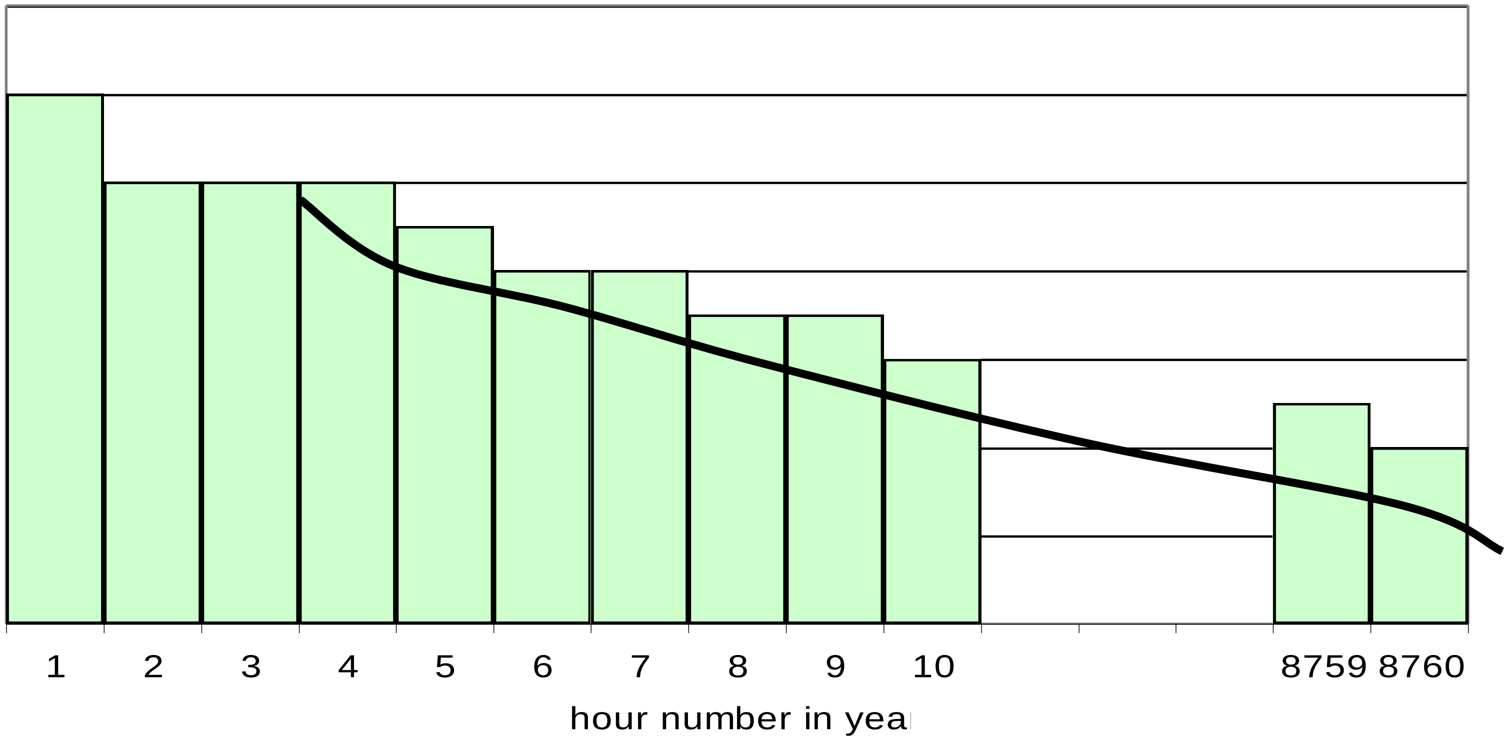
Hourly Demand Curve

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

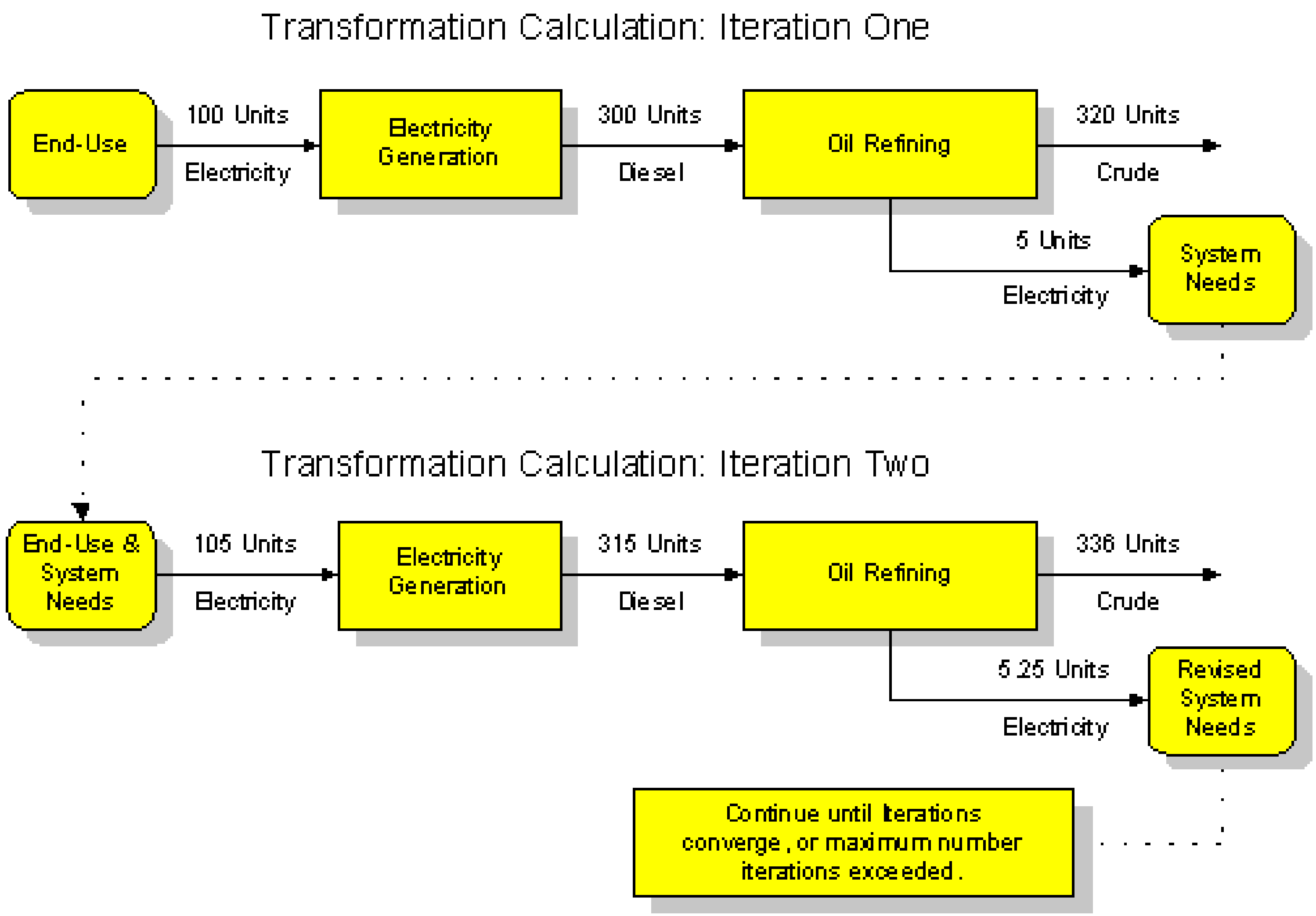


Load Duration Curve

- 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



LEAP Technical Training Section 5: Energy Demand Analysis

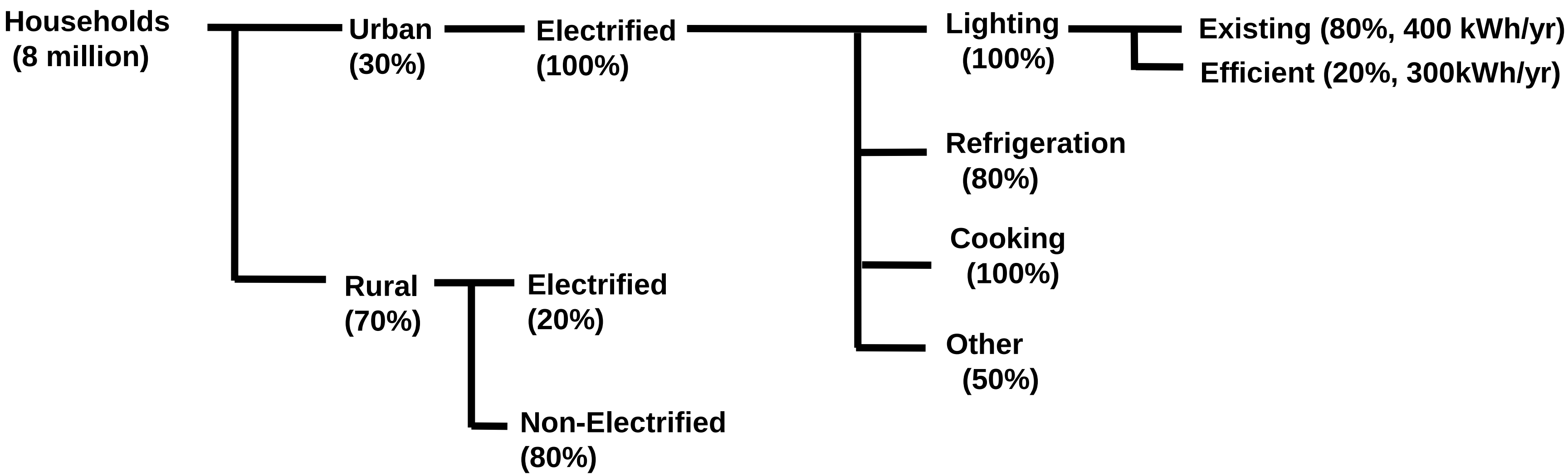
Tree Branches

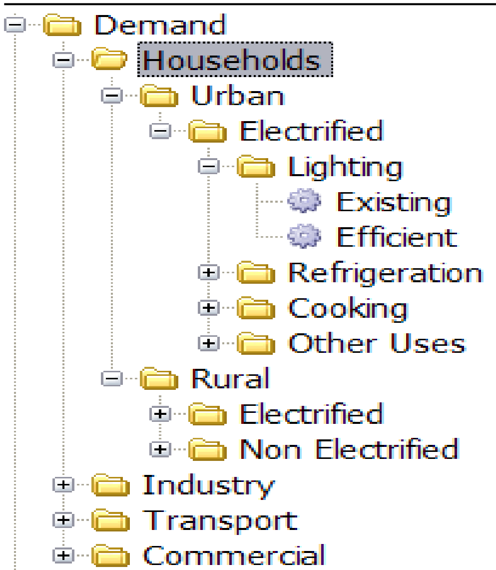
- **Categories:** used mainly for organizing other branches.
- **End-Use** branches indicate situations where energy intensities are specified for an aggregate end-use, rather than with a specific fuel or device. Primarily used when conducting useful energy analysis.
- **Technology** branches represent 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).

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: energy = activity level x 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.

LEAP Technical Training Section 6: Using Least Cost Optimization Features in LEAP

LEAP 2011

- May 2011: SEI released major new version of LEAP. Adds new capabilities and is also easier to use.
- Includes **Least-Cost Optimization** for capacity expansion and dispatch modeling - works with the new Open Source Energy Modeling System (OSeMOSYS) developed by SEI, IAEA, UNIDO, KTH, and UKERC. Based on linear programming approach.
- Improved modeling of seasonal and time-of-day variations in demand and supply.
- New more robust file format and faster operation encourages more interactive use.
- Cleaner user interface: easier to use.

Introduction to Optimization in LEAP

- LEAP 2011 includes least-cost optimization of capacity expansion and dispatch for individual Transformation modules.
- Works through integration with the Open Source Energy Modeling System (OSeMOSYS) a new tool developed by the IAEA, SEI, UK ERC, KTH (Sweden), and others.
- www.osemosys.org
- OSeMOSYS in turn depends on GLPK, a freeware software toolkit for solving large-scale linear programming problems by the revised simplex method.
- Both OSeMOSYS and GLPK are open source and freely available.
- Both are fully integrated into LEAP's user interface. No additional software is needed.

How Optimization Works in LEAP

- All data specified in LEAP.
- Optimization calculations done in a separate model called OSeMOSYS
- OSeMOSYS developed jointly by SEI, and KTH/IAEA. Open source and free of charge.
- OSeMOSYS has no user interface – relies on LEAP for all data entry and reporting.
- LEAP does a partial calculation (demand and all of supply up to the module to be calculated). It then pauses and writes the data file required by OSeMOSYS.
- After OSeMOSYS calculates, LEAP reads back key results (mainly capacity expansion). These are written back to the Exogenous Capacity variable. LEAP then resumes its calculations using this capacity data.
- For now dispatch continues to be calculated in LEAP.
- LEAP is still used for all results reporting.

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 calculation optimal capacity expansion – then reads the results back into LEAP's **Exogenous Capacity** variable.

Treatment of Costs

In calculating an optimal system LEAP takes into account all relevant costs and benefits in the system including:

- Capital costs,
- Salvage values (decommissioning costs),
- Fixed and variable operating and maintenance costs,
- Fuel costs,
- Externality costs (i.e. pollution damage or abatement costs).

Least-cost systems can optionally consider additional constraints such as caps on any given pollutant (CO_2, SO_x, NO_x, PM_{10}, etc.) and minimum or maximum capacities for certain types of power plants.

Current Limitations

<u>Limited Scope</u>

- Currently optimization only operates on a single LEAP Transformation module (e.g. Electricity Generation).
- Calculates least-cost capacity expansion and dispatch for one module but not least-cost configuration of the system as a whole.
- Use Linear Programming: so cannot properly examine large discrete capacity additions (important in smaller energy systems)
- Thus, does not look at proper balance between investments in efficiency and supply augmentation.

<u>Limited Ability to Import Detailed Dispatch from OSeMOSYS Back into LEAP</u>

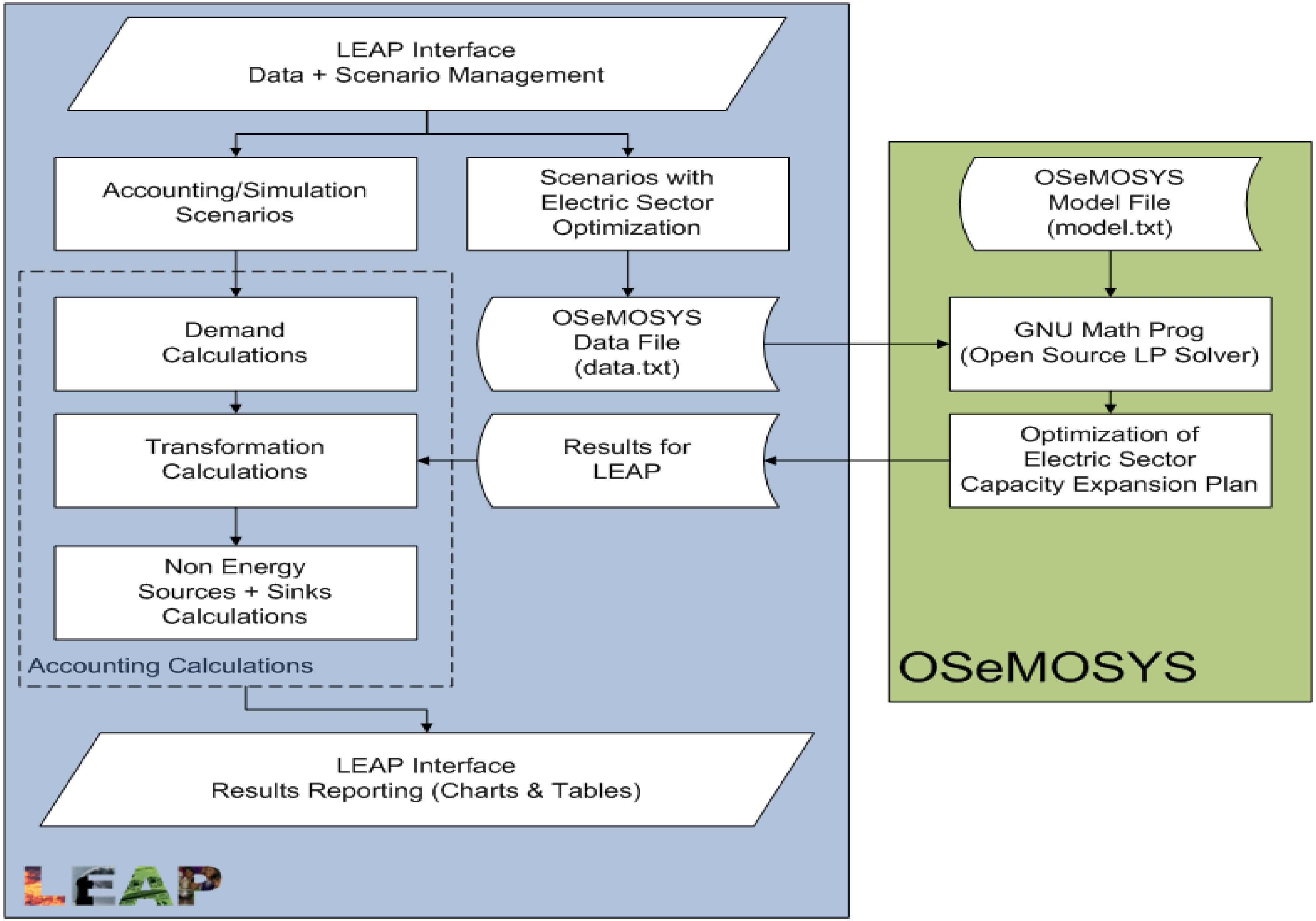
- The dispatch patterns calculated in OSeMOSYS cannot currently be fully imported back into LEAP
- For best results in data sets with complex load shapes, use LEAP's own dispatch rules to simulate dispatch by running cost.

<u>Some known issues in OSeMOSYS</u>

- E.g. Does not support zero discount rate.

We hope to address these in a second phase of integration.

Calculation flows



LEAP Technical Training Section 7: Using LEAP for Cost/Benefit analysis of energy policies

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.

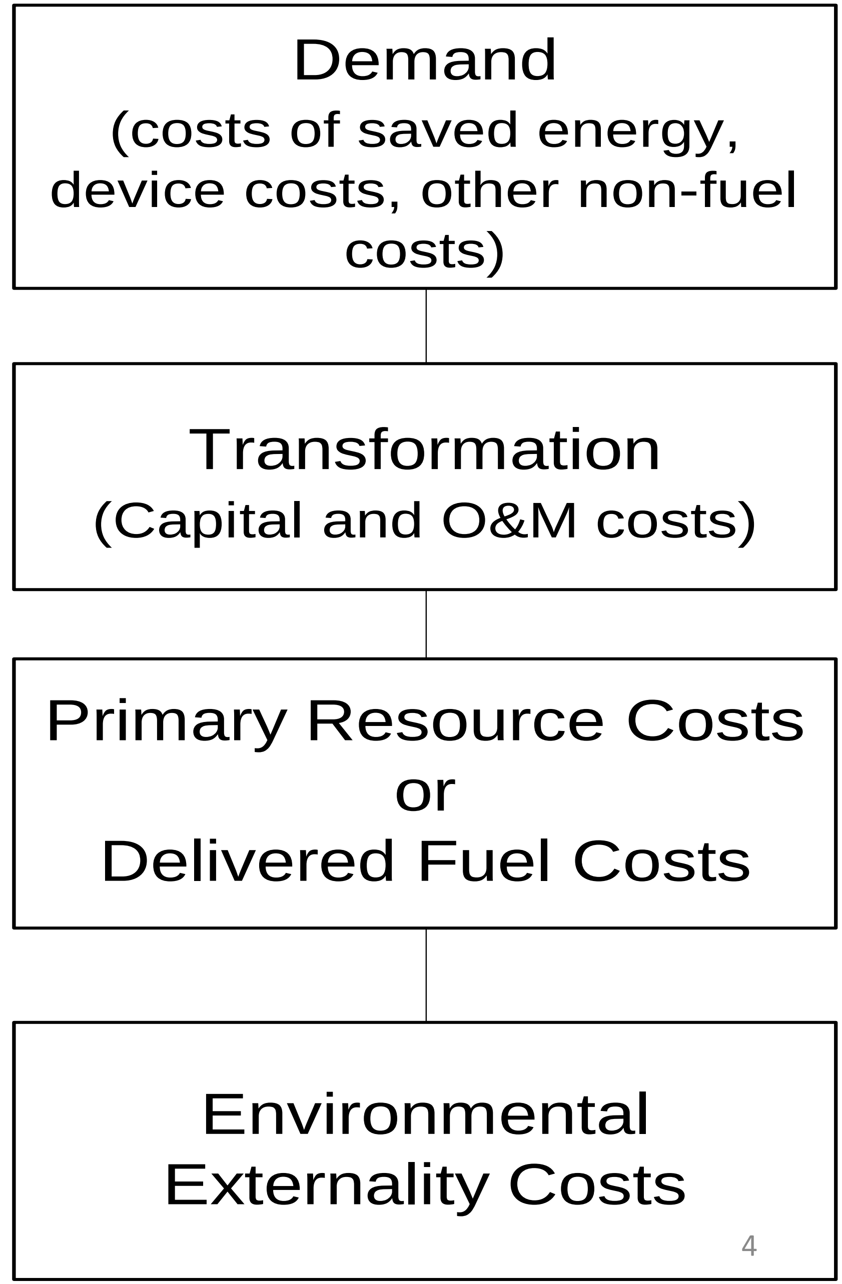
2. **Alternative Case**
   - **Demand:** DSM programs increase the penetration of efficient (but more expensive) fluorescent lighting.
   - **Transformation:** Slower growth in electricity consumption and investments to reduce transmission & distribution losses mean that less generating capacity is required.

Simple Cost-Benefit Analysis (cont.)

- **<u>The Alternative Case…</u>**
- …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)*

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.



Long-range Energy Alternatives Planning System

TRAINING EXERCISES

August 2012
Updated for LEAP 2012

STOCKHOLM ENVIRONMENT INSTITUTE

These exercises are for use with LEAP2012 for Windows.
Download the latest version of LEAP from www.energycommunity.org before using these exercises.

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TRAINING EXERCISES FOR LEAP

Introduction

These training exercises will introduce you to LEAP, the Long-range Energy Alternatives Planning system, and how it can be applied to energy and environmental analysis. The exercises are normally used as part of LEAP training courses. They assume that you have some background in energy issues and familiarity with Windows-based software, including spreadsheets (such as Microsoft Excel).

The training exercises are designed in a modular fashion. If you only have a few hours and want to get a general impression of how LEAP works then complete Exercise 1.

- **Exercise 1** will introduce you to the basic elements of energy demand and supply analysis, of projecting energy requirements and calculating environmental loadings. You must complete Exercise 1 before beginning Exercise 2.

- **Exercises 2 and 3** allow you to develop a basic energy (and emissions) analysis, to create scenarios, and to evaluate a handful of individual policy and technical options, such as cogeneration, energy efficiency standards, and switching power plants from coal to natural gas. The exercises cover demand, supply, environmental loadings, and scenario analysis, and can be done individually or together. Altogether they will take about to 2 to 4 days to complete fully.

  All of the exercises use the backdrop of a fictional country called "Freedonia". The exercises present you with data that is similar to the information you will encounter in the real world. As in the real world, in some cases you will need to convert the data into a format suitable for entry into LEAP. We provide you with hints to assist you and to help ensure that your approaches are consistent. In order for the exercises to work well, exercises 1-3 have a "right answer", and you will need to check your results against the provided "answer sheets". Notice that your data structures can vary, but your projected energy requirements should match the answer sheets. You can import the results of individual exercises if you wish to skip them. For instance, users interested only in supply analysis (Exercise 3) can import a data set that corresponds to the results of Exercise 2 (demand analysis).

- **Exercise 4** lets you explore alternative scenarios in an open-ended fashion (for which there are no "answer sheets"). In these exercises, working groups adopt roles (e.g. energy supplier, environmental NGO, rural development agency) and use LEAP to construct, present, and defend energy policy scenarios that reflect different interests and perspectives.

- **Exercise 5** lets you use LEAP's transportation analysis features to construct a range of scenarios that examine different policies for reducing fuel use and pollution emissions from cars and sport utility vehicles (SUVs). You can use Exercise 5 without having completed any of the previous exercises.

- **Exercise 6** lets you use LEAP's optimization features to explore least-cost optimization of energy systems. You also explore how to model a cap on CO2 emissions – including how a cap might alter the set of technologies chosen and the overall costs of a scenario.

In order to complete these exercises you will need a Pentium class PC (400 MHz or higher clock speed recommended) with at least 256 MB of RAM with Microsoft Windows XP, Vista or Windows 7 running LEAP. You will also need pens, paper and a calculator, such as the one built-in to Windows. Exercise 6 also requires that you have access to Microsoft Excel.

Getting Started in LEAP

If LEAP is installed, start **LEAP** from the **Start/Programs/LEAP** menu. If not, run the setup program directly from the setup.exe file or download and run LEAP from the Internet (www.tinyurl.com/LEAPDownload), following the on-screen instructions. Once started, LEAP will display a title screen, and then the main screen will be shown.

NB: To complete these exercises you must be using a registered version of LEAP. The Evaluation version of LEAP does not allow you to save data and so cannot be used for these exercises. To learn more about licensing, please go to www.tinyurl.com/LEAPLicensing.

The main screen consists of 8 major "views", each of which lets you examine different aspects of the software. The **View Bar** located on the left of the screen, displays an icon for each view. Click on one of the View Bar icons or use the **View Menu** to change views,

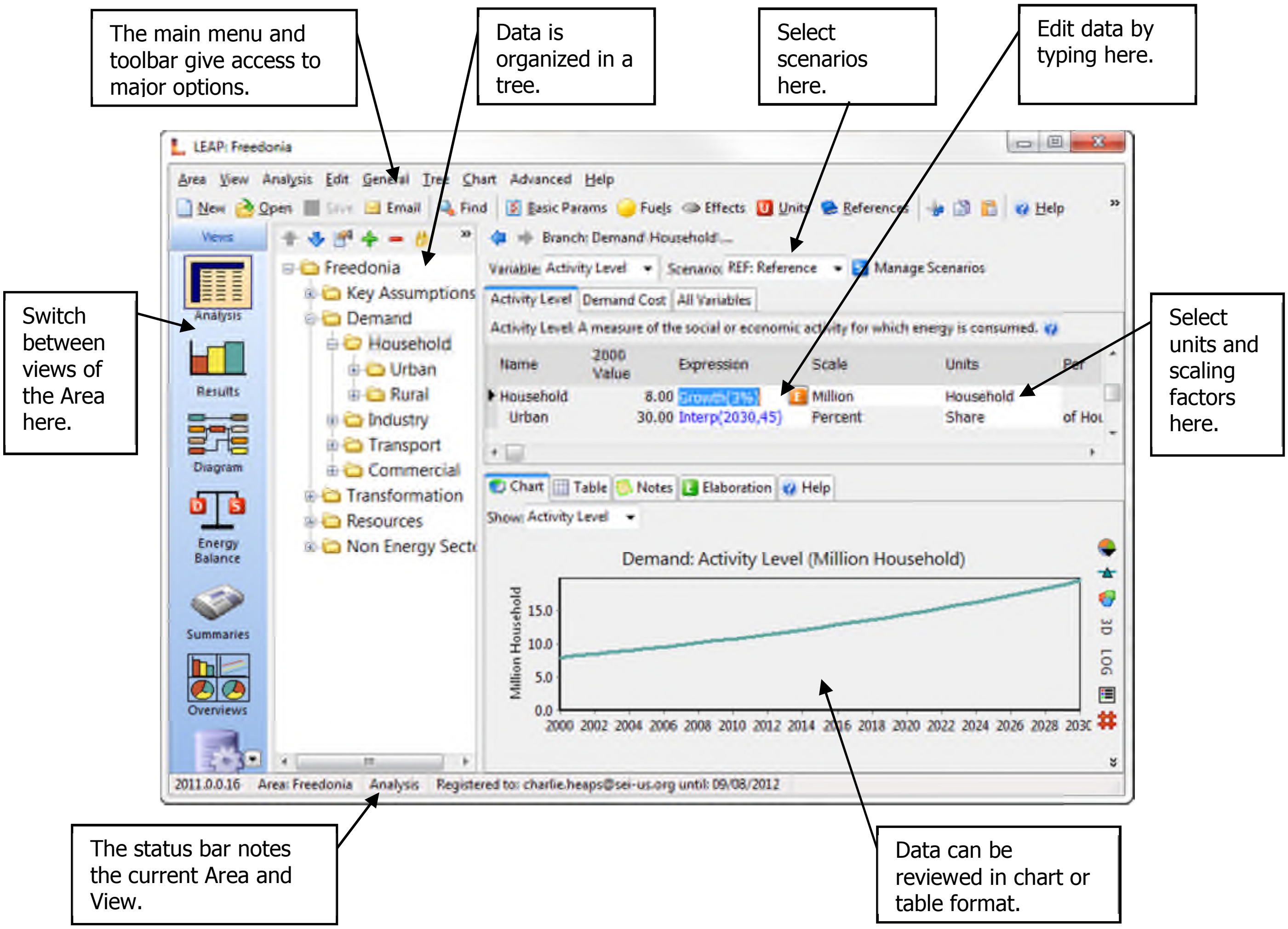
> *Hint: If you are working on a lower resolution screen, you may want to hide the View Bar to make more space on the screen. Use the menu option* ***View: View Bar*** *to do this. When the View Bar is hidden, use the View menu below the tree to switch views.*

- The **Analysis View** is where you enter or view data and construct your models and scenarios.
- The **Diagram View** shows you your energy system depicted as a Reference Energy System Diagram.
- The **Results View** is where you examine the outcomes of the various scenarios as graphs and tables.

For information on the other views, click on **Help.**

The Analysis View

The **Analysis View** (shown below) contains a number of controls apart from the view bar mentioned above. On the left is a tree in which you view or edit your data structures. On the right are two linked panes. At the top is a table in which you edit or view data and create the modeling relationships. Below it is an area containing charts and tables that summarize the data you entered above. Above the data table is a toolbar that lets you select the data you want to edit. The topmost toolbar gives access to standard commands such as saving data, creating new areas, and accessing the supporting fuels, effects and references databases.



The main parts of the **Analysis View** are described in more detail below:

- **Tree:** The tree is the place where you organize your data for both the demand and supply (Transformation) analyses. In most respects the tree works just like the ones in standard Windows tools such as the Windows Explorer. You can rename branches by clicking once on them and typing, and you can expand and collapse the tree outline by clicking on the +/- symbols. Use the right-click menu to expand or collapse all branches or to set the outline level.

  To edit the tree, right-click on it and use the **Add ( ), Delete ( )** and **Properties** ( ) buttons. All of these options are also available from the **Tree** menu option. You can move selected tree branches by clicking and dragging them, or you can copy parts of the tree by holding down the **Ctrl** key and then clicking and dragging branches.

  The tree contains different types of branches. The type of a branch depends on its context (for example whether it is part of your demand or Transformation data structure, or whether it is one of your own independent variables added under the

"Key Assumptions" branch. Different branch icons indicate different types of branches. The main types of branches are listed below:

Category branches are used mainly for the hierarchical organization of data in the tree. In a demand analysis, these branches only contain data on activity levels and costs. In a supply analysis, category branches are used to indicate the main energy conversion "modules" such as electric generation, oil refining and resource extraction, as well as groups of processes and output fuels.

Technology branches contain data on the actual technologies that consume, produce and convert energy. In a supply analysis, technology branches are shown with the icon. They are used to indicate the particular processes within each module that convert energy (for example a particular power plant in an electric generation module). In a demand analysis, technology branches are associated with particular fuels and also normally have an energy intensity associated with them. Demand technology branches can appear in three different forms depending on the type of demand analysis methodology chosen. These methodologies are activity analysis ( ), stock analysis ( ) and transport analysis ( ). This latter methodology is described in more detail in Exercise 5.

Key Assumption branches are where you create your own independent variables such as macroeconomic or demographic indictors. These variables can then be referred to in expressions under other branches.

Fuel branches are found under the Resources tree branch. They also appear under each Transformation module, representing the **Output Fuels** produced by the module and the **Auxiliary** and **Feedstock Fuels** consumed by the module.

Environmental loading branches represent the various pollutants emitted by energy demand and transformation technologies. Effect branches are always the lowest level branches. In a demand analysis they appear underneath demand technologies, while in a transformation analysis they appear underneath the feedstock and auxiliary fuel branches. They can also optionally be created for non-energy sector emissions analyses.

- **Data Table:** The Analysis View contains two panes to the right of the tree. The top pane is a table in which you can view and edit the data associated with the variables at each branch in the tree. As you click on different branches in the tree, the data screen shows the data associated with branches at and immediately below the branch in the tree. Each row in the table represents data for a branch in the tree. For example, in the sample data set click on the "Demand" branch in the tree, and the data screen lists the sectors of your demand analysis, then click on "Households" in the tree and the data screen summarizes the household subsectors (in this case urban and rural).

  At the top of the table is a set of "tabs" giving access to the different variables associated with each branch. The tabs you see depend on how you specified your data structures, and on what part of the tree you are working on. For example, when editing demand sectors you will normally see tabs giving access to "Activity Level" and "Demand Costs"; while at the lowest levels of the tree you will also see tabs for "Final Energy Intensity" and "Environmental Loading" data.

- **Chart/Table/Notes:** The lower pane summarizes the data entered above as a chart or a table. When viewing charts, use the toolbar on the right to customize the chart. Graphs can be displayed in various formats (bar, pie, etc.), printed, or copied to the clipboard for insertion into a report. The toolbar also allows you to export the data to Excel or PowerPoint.

- **Scenario Selection Box**: Above the data table is a selection box, which you can use to select between **Current Accounts** and any of the scenarios in an area. Current Accounts data is the data for the base year of your study. Different scenarios in LEAP all begin from the base year. This box also shows you the basic *inheritance* of each scenario. In LEAP, scenarios can *inherit* modeling expressions from other scenarios. All scenarios ultimately inherit expressions from the Current Accounts data set. In other words, unless you specifically enter scenario data for a variable, its value will be constant in the future.

  To create a new scenario, click on **Manage Scenarios ( )**. When you create a new scenario, you can specify that it be based on (i.e. inherits from) another scenario. Until you change some expressions in the new scenario, it will give exactly the same results as its parent scenario. Expressions displayed in the data table are color-coded so you can tell if they were explicitly entered in the scenario (colored blue) or if they are inherited from the parent scenario (colored black).

How to Get Support for LEAP

We have tried to make LEAP as robust and easy to use as possible so we hope you will not encounter too many problems. However, should you have any questions or problems, please try and address them in the following order:

1. Check to make sure that you have the most up-to-date version of LEAP. Use the Help: Check for Updates feature. If available, this will automatically install a newer version of LEAP on your PC. Your existing data will be preserved. Each new version of LEAP contains new features and bug fixes, so this may help solve any issues you are encountering. Note that the update normally requires that approximately 2 MB of data is downloaded, so you will need a reliable internet connection to take advantage of this option. You can also always download the latest version of LEAP from the COMMEND website by going to www.tinyurl.com/LEAPDownload.

2. Next, check the documentation on the COMMEND web site. The two best sources of information are the LEAP user guide (also available as help files within LEAP) and LEAP discussion forum (URLS below). Many questions can be answered by doing a search of these two resources. Check the discussion forums to see if another user has already experienced (and hopefully answered) the same question you have.

LEAP User Guide: www.tinyurl.com/LEAPUserGuide
LEAP Discussion Forum: www.tinyurl.com/LEAPDiscussion

3. If you are unable to get an answer, please create a new post on the LEAP discussion forum. We invite all users to contribute both questions and answers to discussions.

4. If you are encountering an issue with installing or operating LEAP, we invite you to fill out a LEAP Problem Report (URL below) and submit it to leap@sei-us.org.

   www.tinyurl.com/LEAPProblemReport

Exercise 1: Introduction to LEAP

1.1 Overview of Freedonia

In order to illustrate how LEAP can be used in a variety of contexts, we have structured the data in Freedonia to reflect the characteristics of both an industrialized, and developing country. For instance, Freedonia's urban population is fully electrified and living at OECD standards, while its poorer rural population has limited access to modern energy services, and is heavily reliant on biomass fuels to meet basic needs. To simplify the exercises and reduce repetitive data entry, we have deliberately left out a number of common sectors and end uses. For example, exercise 1 considers only a partial residential sector: appliance energy use in Freedonia's urban households, and cooking and electricity use for Freedonia's rural residents. Similarly, in exercise 2, there is no agriculture sector, and the only energy used by commercial buildings is for space heating.

1.2 Basic Parameters

Before beginning the exercises, set the basic parameters of your study. These include the standard energy unit for your study, the standard currency unit (including its base year), and basic monetary parameters.

LEAP comes supplied with a completed Freedonia data set, so for the purpose of these exercises, you will make a new blank data set called "New Freedonia". Start by creating a new area in LEAP called "New Freedonia" that is based only on default data (**Area: New** menu option).

Review the **General: Basic Parameters** screen ( ) and set the base year and end year for the analysis. Choose 2010 as the base year, 2011 as your first scenario year and 2040 for the end year. Also enter 2040 as the only default year for time-series functions (this will save you time later on when specifying interpolated data). For exercises you will do later on, be sure to set the monetary year to 2010 and the first depletion year to 2011. On the scope screen, you can initially leave all of the options unchecked since you will start by only conducting a demand analysis. All other options can be left at their default values. Note: In this exercise you will be using only one year of historical data (2010).

1.3 Demand

This preliminary demand analysis exercise considers only the energy used in Freedonia households. You will start by developing a set of "Current Accounts" that depict household energy uses in the most recent year for which data are available (2010). You will then construct a "Reference" scenario that examines how energy consumption patterns are likely to change in the coming years in the absence of any new policy measures. Finally, you will develop a "Policy" scenario that examines how energy consumption growth can be reduced by the introduction of energy efficiency measures.

1.3.1 Data Structures

The first step in an energy analysis is to design your data structure. The structure will determine what kinds of technologies, policies, and alternative development paths you can analyze. It will be guided by the information you collect (data and assumptions) and by the relationships you assume. For instance, you might consider whether you want to include branches for all possible end-uses or only for major categories of residential energy consumption, you might consider whether residential energy intensities should be developed on a per capita (i.e. per person) or per household basis, or you might consider whether energy demand be a direct function of income or prices. (In this simple exercise you don't need to include these factors).

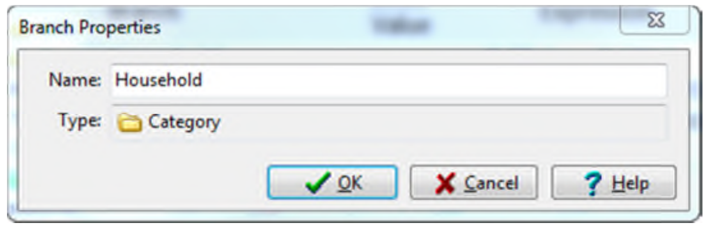
Before using the software, it is therefore important to plan the way you will enter data into the program. Read the following description of the relevant data (in sections 1.3.2 to 1.3.3) to get an idea of the types of data structures that are possible. *Note that there is more than one branch structure that can be created with the data provided.*

It is a good idea to sketch the structure before entering it into LEAP. Use the blank spaces below for your sketch. If you are working as part of a training course, discuss your first sketch with your instructor and revise your drawing if needed.

First Sketch of Demand Tree	Second Sketch of Demand Tree

After reading though the following sections and finalizing a sketch of a demand tree, you should now be ready to create a demand tree structure in LEAP that reflects the organization of household demand data in Freedonia.

> ***Hint:*** *Make sure you have selected the Analysis view in the View Bar before proceeding and make sure you have selected Current Accounts in the scenario selection box. Note that you can only change the structure of the tree (and also select scaling factors, fuels and units) when editing Current Accounts data.*



Create the tree structure using the **Add ( ), Delete ( )** and **Properties** ( ) commands available either by right clicking on the Tree, or on the Tree menu. In this exercise, you will create various sub-sectors, end-uses, and devices beneath the "Households" branch, but, for now, you can ignore the other demand sector branches labeled: Industry, Transportation, etc. As shown below, upper level branches will be created as category branches ( ), while the lower level branches at which you select a fuel and enter an energy intensity will be technologies ( ).

1.3.2 Current Accounts

In the year 2010, Freedonia's 40 million people are living in about 8 million households. 30% of these are in urban areas. The key data is given below.

Urban Households

- All of Freedonia's urban residents are connected to the electric grid, and use electricity for lighting and other devices.
- 95% have refrigerators, which consume 500 KWh per year on average.
- The average urban household annually consumes 400 KWh for lighting.
- Other devices such as VCRs, televisions, and fans annually consume 800 KWh per urban household.
- 30% of Freedonia's urban dwellers use electric stoves for cooking: the remainder use natural gas stoves. All households have only one type of cooking device.
- The annual energy intensity of electric stoves is 400 KWh per household, for natural gas stoves it is 60 cubic meters per household.

> ***Hint 1:*** *In general you can enter the above data as simple numeric values in the Current Accounts "Expression" column. In the scale and units columns, select the units for the activity levels and energy intensities for each branch (scaling factors can be left blank). If you specify "shares" as the unit for stove type (natural gas or electric), then you need only type the percentage value for electric stoves. For gas stoves, enter "Remainder(100)". LEAP will use this expression to calculate the households using gas stoves.*

Hint 2: *When selecting units for activity levels, it is important to select carefully between "saturations" and "shares". Shares should be used only where activity levels for adjacent branches need to sum to 100%, as in the case above of stove fuel shares above. LEAP calculations require that shares always sum to 100% across immediately neighboring branches. Therefore, be sure to use "saturation" for items such as refrigerator ownership that need not sum to 100% to avoid later error messages.*

Rural Households

- A recent survey of all rural households (both electrified and non-electrified) indicates the following types of cooking devices are used:

Cooking in Rural Freedonia

	% Share of Rural HH	Energy Intensity per Household
Charcoal Stove	30%	166 Kg
LPG Stove	15%	59 Kg
Wood	55%	525 Kg

- Only 25% of rural households have access to grid-connected electricity.
- 20% of the electrified rural households own a refrigerator, which consumes 500 KWh per year on average.
- All electrified rural households use electricity for lighting, which consumes 335 KWh per household. 20% of these households also use kerosene lamps for additional lighting, using about 10 liters per year.

Hint: *Use saturation for your activity level units here since some households own more than one lighting device.*

- Other electric devices (TV, radio, fans, etc.), account for 111 KWh per household per year.
- Non-electrified households rely exclusively on kerosene lamps for lighting, averaging 69 liters consumption per household per year.

Hint: *This is a good place to save your data before going on. Do this by clicking the icon or by selecting Areas: Save. It is always a good idea to save your data often.*

1.3.3 Reference Scenario

You are now ready to create your first scenario, analyzing how household energy demands are likely to evolve over time in the Reference scenario. Click the **Manage Scenarios** button ( ) and use the Scenario Manager screen to add a first scenario. Give it the name “Reference” and the abbreviation “REF”. Add an explanatory note to describe the scenario, e.g., “business-as-usual development; official GDP and population projections; no new policy measures.”

Exit the scenario manager and, if necessary, select the “Reference” scenario from the selection box at the top of the screen. Now enter the assumptions and predictions of the future data in Freedonia as described below.

> ***Hint:*** *If you wish to add branches or to edit the base year data you should return to Current Accounts.*

First enter the basic demographic changes that are expected to take place in Freedonia. The number of households is expected to grow from 8 million in the year 2010 at 3% per year.

> ***Hint****: To enter a growth rate, press* ***Ctrl-G*** *or click on the button attached to the expression field and select “****Growth Rate”*** *(you must be in a non-Current Accounts scenario to see this option). You can also type “Growth(3%)” directly as the expression.*

Urban Households

- By 2040, 45% of Freedonia’s households will be in urban areas.

  Hint: *This is an example of a common situation in LEAP, one in which you wish to specify just a few data values (2010, implicitly, and 2040) and then have LEAP interpolate to calculate the values of all the years in-between. You can enter interpolated data in a number of different ways. The simplest way is to click on the button attached to the expression field and select “End Year Value”. Then simply type in the value 45. When you click* ***OK****, LEAP will enter an “Interp” function into your expression. You can also type the “Interp" function directly into the expression field as “Interp(2040, 45)”.*

- Increased preference for electric stoves results in a 55% market share by 2040.
- The energy intensity of electric and gas stoves is expected to decrease by half a percent every year due to the penetration of more energy-efficient technologies.
- As incomes rise and people purchase larger appliances, annual refrigeration intensity increases to 600 kWh per household by 2040.
- Similarly, annual lighting intensity increases to 500 kWh per household by 2040
- The use of other electricity-using equipment grows rapidly, at a rate of 2.5% per year.

  Hint: *To specify a decrease, simply enter a negative growth rate.*

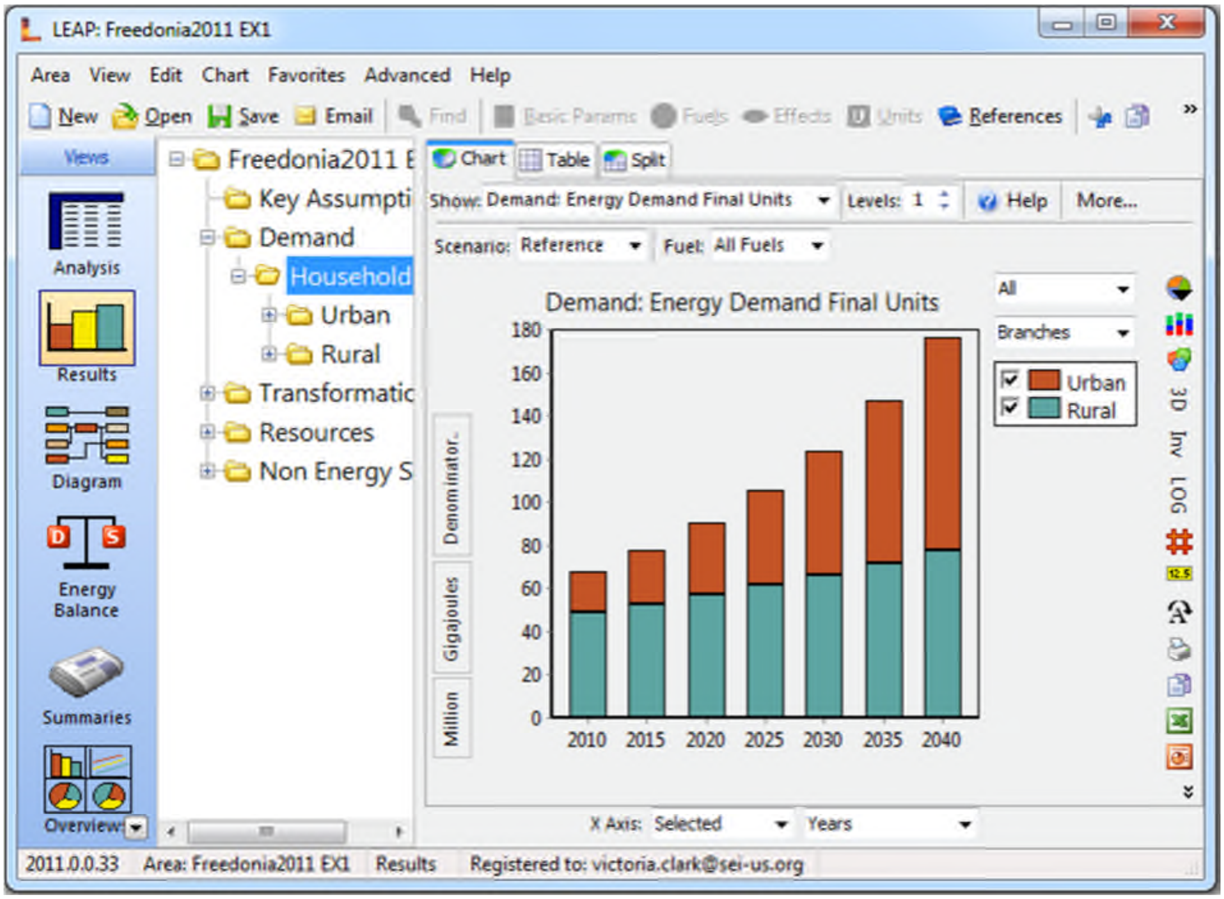
Rural Households

- An ongoing rural electrification program is expected to increase the percentage of rural households with electricity service to 28% in 2020 and 50% in 2040.
- As incomes increase, the energy intensity of electric lighting is expected to increase by 1% per year.
- The number of grid-connected rural homes using a refrigerator is expected to increase to 40% in 2020, and 66% in 2040.
- Due to rural development activities the share of various cooking devices in all households (both electrified and non-electrified) changes so that by 2040, LPG stoves are used by 55% of households, and charcoal stoves by 25%. The remaining rural households use wood stoves.

Hint: *Save your data before going on by pressing the Save button ( ).*

1.3.4 Viewing Results

Click on the **Results** view to see the results of the Reference scenario in either Chart or Table form.



To configure your results:

- On the Chart, use the selection boxes to select which types of data you want to see on the legend and X-axis of the chart. Typically you will select years as the X-axis for many charts and "fuels" or "branches" as the legend (see above).
- On the toolbar above the chart, select Show: "Demand: Energy Demand Final Units", then, using the Tree, select the demand branches you want to chart. Click on the "Demand" branch to display the total energy demands for Freedonia.
- Use the "units" selection box on the Y-axis to change the units of the report. You can further customize chart options using the toolbar on the right of the chart. Use the toolbar to select options such as the chart type (area, bar, line, pie, etc.) or whether the chart is stacked or not.
- Once you have created a chart, click on the **Table** tab to view the underlying results in table format. You can also save the chart configuration for future reference by saving it as a "Favorite" chart (click on the Favorites menu). This feature works much like the Favorite/Bookmark options in Internet browsers.

Now compare your demand projections with the tables and chart shown here (note that the tables in LEAP is formatted differently than the tables shown here). Start by checking results at the highest levels (i.e. start by clicking on "Demand" and then work your way down to more detailed levels to investigate where the problem lies, using the demand answers shown on the right. Adjust your data before proceeding. (Ignore differences of less than 1%).

***Hint**: Always debug the Current Accounts before attempting to correct problems with future year results.*

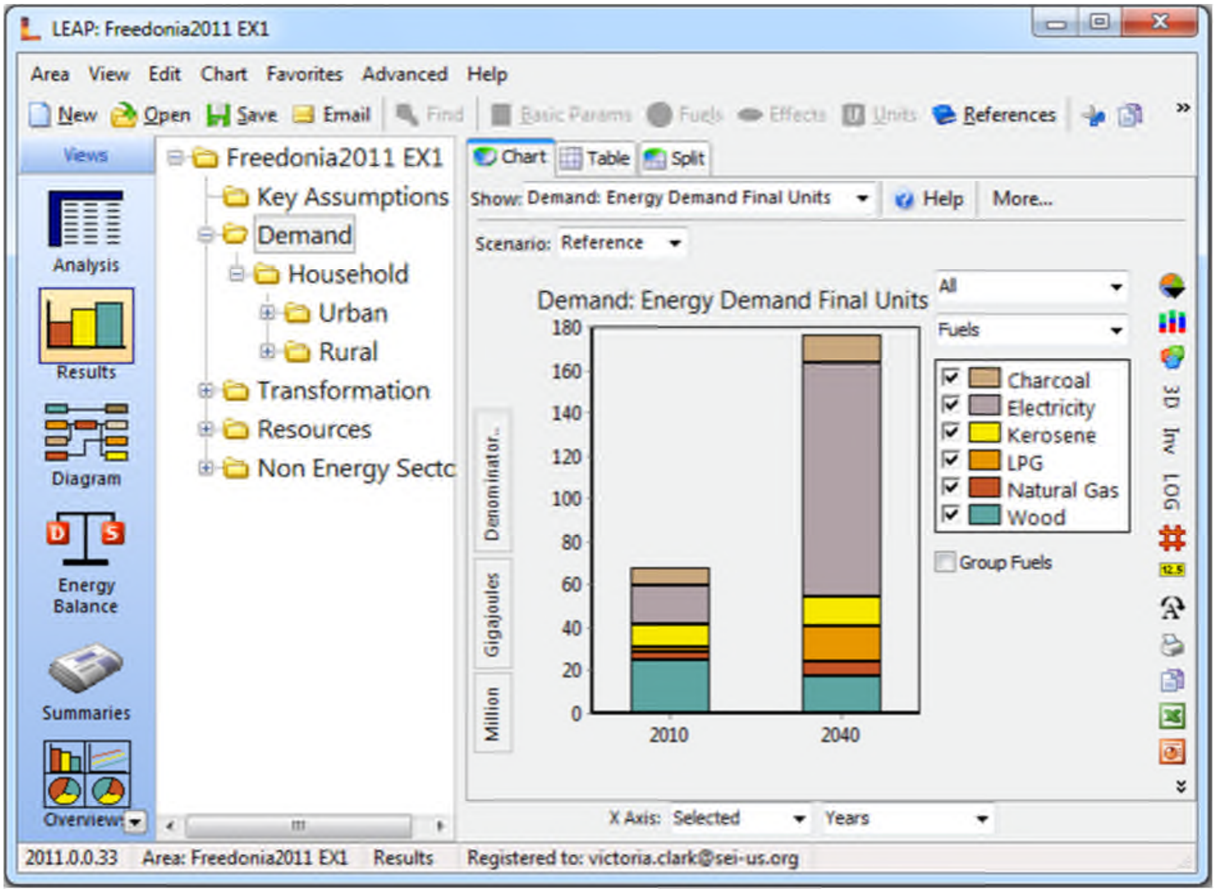
Energy Demand by Fuel (Million GJ)

Fuels	2010	2040
Charcoal	8.1	12.8
Electricity	18.3	109.6
Kerosene	10.6	13.7
LPG	2.3	16.4
Natural Gas	3.4	6.9
Wood	25.1	17.4
Total	**67.8**	**176.8**

Energy Demand by Branch (Million GJ)

Branches	2010	2040
Urban (all electrified)	**19.0**	**99.3**
Refrigeration	4.1	17.9
Cooking	4.5	12.9
Electricity	1.0	6.0
Natural gas	3.4	6.9
Lighting	3.5	15.7
Other Uses	6.9	52.8
Rural	**48.8**	**77.5**
Electrified	**11.7**	**40.8**
Refrigeration	0.5	6.3
Cooking	8.9	23.3
Charcoal	2.0	6.4
Wood	6.3	8.7
LPG	0.6	8.2
Lighting	1.8	9.1
Electric	1.7	8.7
Kerosene	0.1	0.4
Other Uses	0.6	2.1
Unelectrified	**37.1**	**36.7**
Cooking	26.6	23.3
Charcoal	6.0	6.4
Wood	18.8	8.7
LPG	1.8	8.2
Lighting	10.5	13.4
Total Households	**67.8**	**176.8**

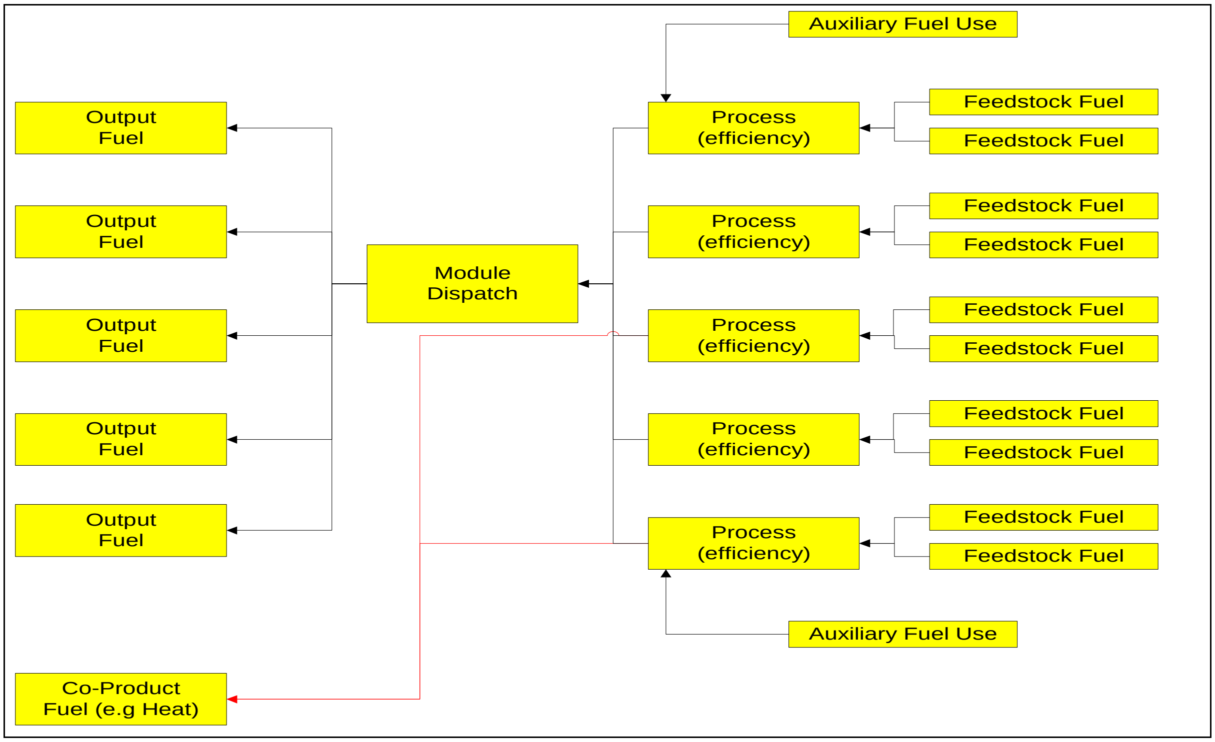
Energy Demand by Fuel (Million GJ)



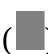
1.4 Transformation

The Transformation sector uses special branches called *modules* to model energy supply and conversion sectors such as electricity generation, refining, or charcoal production. Each module contains one or more *processes*, which represent an individual technology such as a particular type of electric plant or oil refinery, and produces one or more *output fuels. These* represent the energy products produced by the module. The basic structure of a module is shown below:

LEAP Module Structure

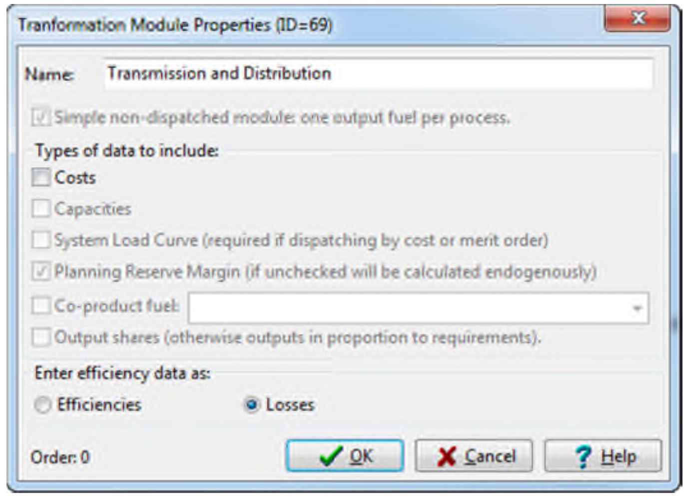


In this exercise you will develop a simplified model of the electricity transmission and generation sectors in Freedonia. This model will be the basis for the more detailed and realistic model you will create in Exercise 3.

Return to the **General: Basic Parameters** screen () and check the box marked Transformation & Resources, since you are now going to enter data for various Transformation modules.

1.4.1 Transmission and Distribution

You will start by adding a simple module to represent electricity and transmission and distribution (T&D) losses and natural gas pipeline losses. In the base year, electricity T&D losses amount to 15% of the electricity generated in 2010. In the Reference scenario these are expected to decrease to 12% by 2040. Natural gas pipeline losses amount to 2% in 2010, and are expected to decrease to 1.5% by 2040 in the Reference scenario.

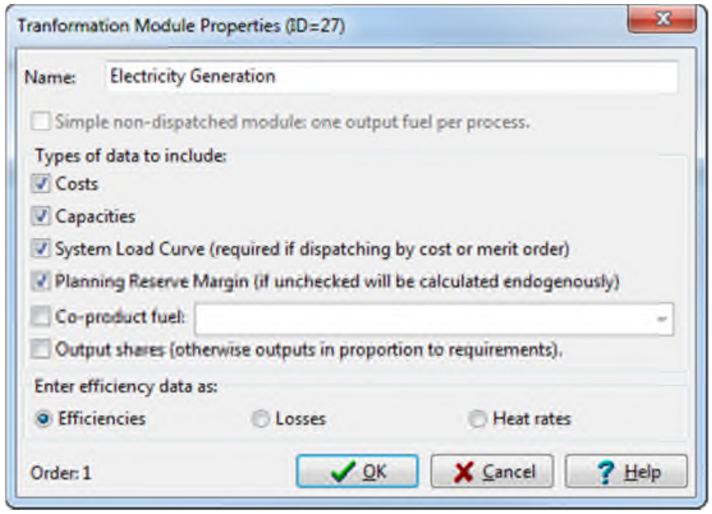


To create a module, right-click on the Transformation branch on the Tree and select the **Add** command ( ). On the resulting Module properties screen (shown right), enter a name "Transmission and Distribution", and use the checkboxes to indicate the types of data you will be entering. Check the box marked "simple, non-dispatched module", and then mark that efficiencies will be entered as losses.

When you click "OK" the module is added. Expand the branches beneath the newly created module and you will see a new branch marked **Processes**. Click on this and add a new process called "Electricity". Select the feedstock fuel (electricity), and then enter percentage share of electricity losses on the **Energy Losses** tab. Repeat this process to add a process for natural gas then enter the data on natural gas pipeline losses.

> ***Hint:*** *Use the same features as in demand to enter time-varying data: switch to the Reference scenario and use the* ***Interp*** *function to specify how electric losses change over time.*

1.4.2 Electricity Generation



Next you will simulate how electricity is generated in Freedonia. The module "Electricity Generation" should already appear on the list. If not you will need to add it.

Make sure that the Electricity Generation module appears below the Transmission and Distribution module in the list of modules. You may need to use the up ( ) and down ( ) buttons to reorder modules. You will need to switch to Current Accounts before you can do this. The sequencing of modules reflects the flow of energy resources from primary/extraction (bottom of the list) to final use (top of the list). Electricity must be generated before it is transmitted and distributed. Similarly a module for mining of coal that feeds electricity generation would need to be added lower down on the list.

Make sure that you set correct properties ( ) for Electricity Generation module (see above). Since you will be specifying data on plant **capacities**, **costs**, **efficiencies**, and a **system load curve**, be sure that these items are checked.

Next you will add three processes to represent the various power plants available in the region. Information on some of the basic characteristics of these plants is supplied in the following table:

Plant Type	Exogenous Capacity (MW)	Efficiency (%)	Merit Order	Maximum Availability (%)
Coal Steam	1000	30	1 (base)	70
Hydro	500	100	1 (base)	70
Diesel Combustion Turbines	800	25	2 (peak)	80

In this exercise you are going to simulate base year operations in a special way, since for that year you have data describing known (historical) operation of power plants. In later future years, for which there is no operational data, you will simulate the dispatch of different power plants by specifying a dispatch rule and various parameters that will allow LEAP to simulate the dispatch of power plants by merit order.

To enable this type of simulation you need to set a few process variables in Current Accounts. First, set the **First Simulation Year** to 2011 (the year after the Base Year) for all processes. Next, set the **Process Dispatch Rules** to "MeritOrder" for all processes. The rules will be obeyed from 2011 onwards. You can select the dispatch rule from the list of available options from the button at the end of the expression box.

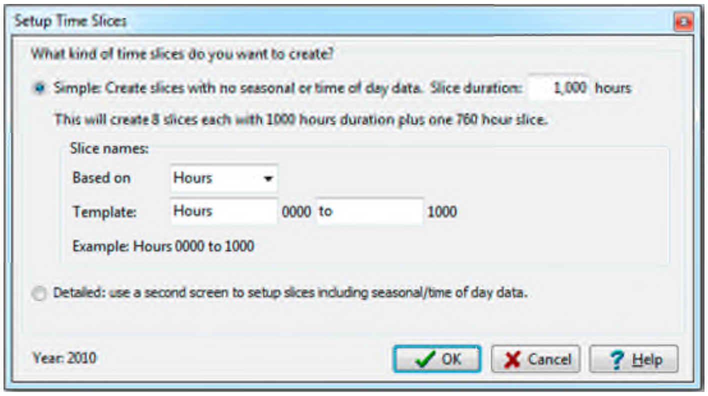
In the base year, total electricity generation (outputs) was 5970 GWh. 29% came from hydro plants. 15% from the Diesel CTs, and the remainder came from the coal plants.

> ***Hint:*** *Enter the formula* **0.29*5970** *to specify the base year generation of the hydro plants. Enter a similar formula for diesel Combustion Turbines. Enter the formula* **Remainder(5970)** *to specify the remaining generation from coal plants.*

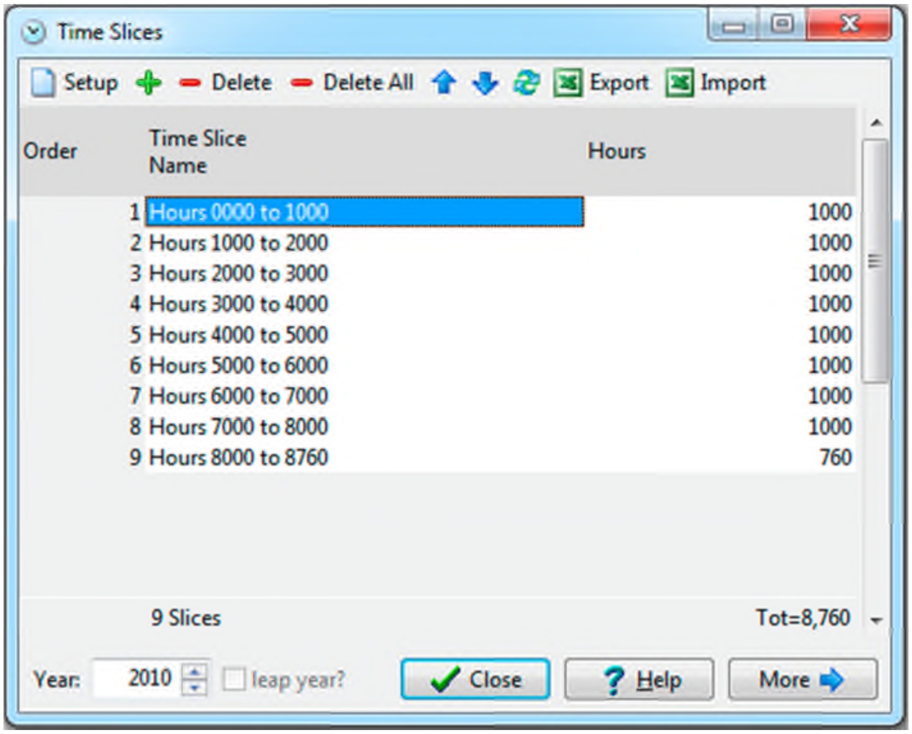
The electricity system operates with a minimum planning reserve margin of 35%. Enter this at the Electricity Generation branch.

You also need to specify a system load shape that describes how the electric load varies from hour to hour within each year. Follow this three-step process for entering a system load shape:

1. First create the set of time slices into which the year will be divided. These are entered on the General: Time Slices screen. Use the setup button to create nine slices as in the screen shown right.

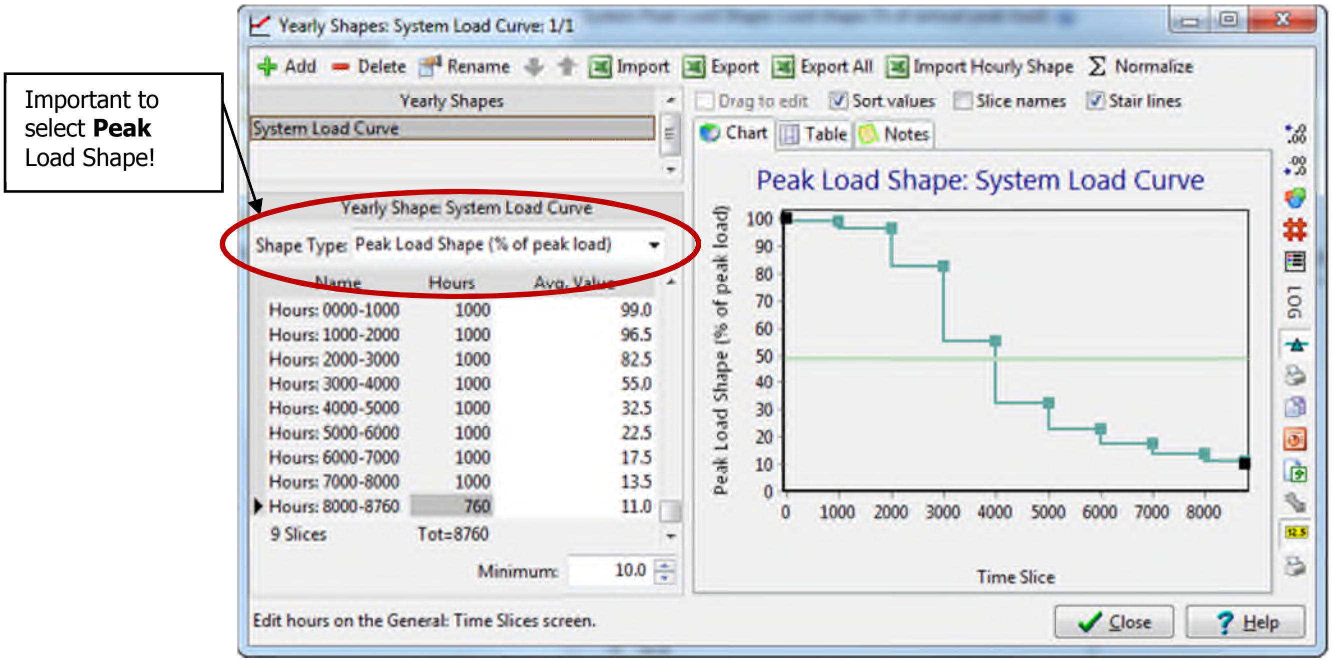


The time slices created should then look like this:



2. Next, you need to create a yearly load shape with values for each of the hourly slices you just specified. To do this, go to the General: Yearly Shapes screen (shown

below) and enter a **Peak Load Shape** for the entire system. Enter the values as shown in the screen below.



> ***Hint:*** *The value in hour 0 implicitly is always 100%. This does need to be entered explicitly. Make sure you enter the minimum value of 10% in the* ***Minimum*** *box at the bottom of the screen, which corresponds to the hour 8760.*

3. Finally, return back to the Analysis View screen and select Current Accounts. Now create a link to this new load shape in the **System Peak Load Shape** variable at the Electricity Generation branch.

   The easiest way to do this is click on the  button attached to the expression field and select **Yearly Shape: System Load Curve** option.

   > ***Hint:*** *If you don't see a variable named System Peak Load Shape, you may need to go to the General: Basic Parameters: Loads screen and make sure that you choose the option* ***"Load Shape for Entire System (Entered as % of Peak Generation").***

1.4.2.1 The Reference Scenario

You can now specify how the electric generation system is likely to change in the future in the Reference scenario.

- No new power plants are currently being built in Freedonia.
- In the Reference scenario, existing coal power plants are expected to be retired. Five hundred megawatts of existing coal-fired steam plants will be retired in 2020 and the remaining five hundred megawatts are retired in 2030.

  Hint: *Try using the BaseYearValue function to model this situation. The resulting expression for coal capacity should appear as:*

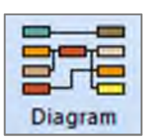
  Step(2020, BaseYearValue-500, 2030, BaseYearValue-1000).

  When entering explicit capacity values to reflect existing capacity and/or planned capacity and retirements, use the ***Exogenous Capacity*** *tab.*

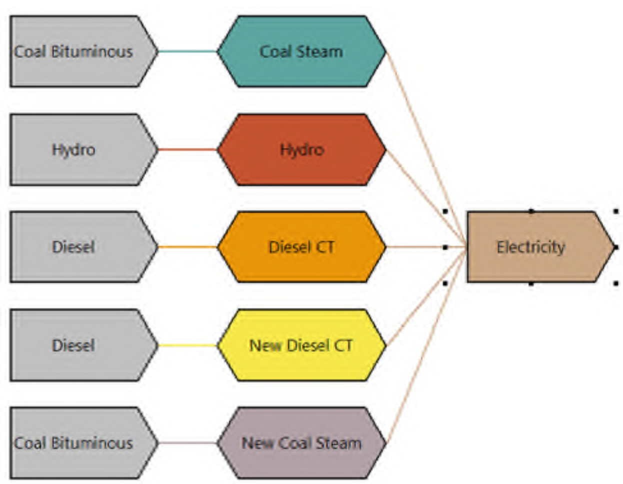
- In the future, to meet growing demands and replace retired plants, new power plants are expected to consist of base load coal-fired steam plants (built in units of 500 MW, with a thermal efficiency of 35%) and new peak load fuel oil-fired combustion turbines (built in units of 300 MW with a thermal efficiency of 30%). Both types of plants have a life expectancy of 30 years and a maximum availability of 80%.

  Hint: *First add new power plant types in Current accounts. Use the button to add a process to this screen (selecting from the list of processes in the tree). Next, enter the information on endogenous capacity additions on the* ***Endogenous Capacity*** *tab in the Reference Scenario.*

  Remember also to set the dispatch merit order of each process. For more information on exogenous and endogenous capacity, please refer to the help file, found in LEAP under Help: Contents.



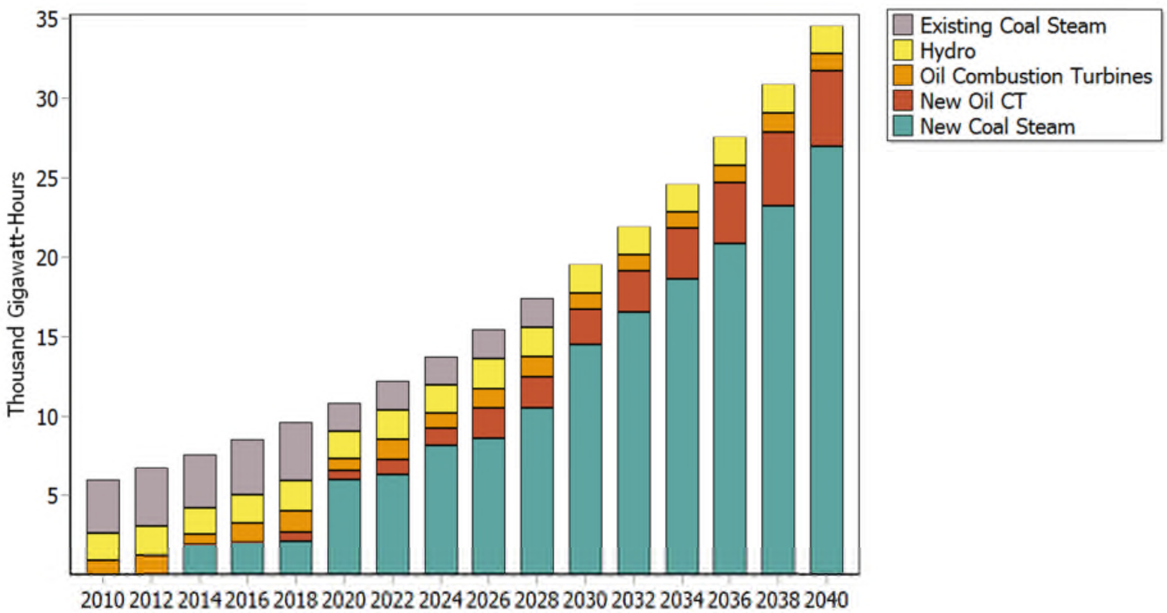
Use the **Diagram View** (Select from the View bar) to review the energy flows in the energy supply system you have created. Your diagram should show the modules you've created. Double-click on the electricity generation module and check that the diagram is similar to the one shown right. If it doesn't look correct, check that you have specified all of the appropriate input fuels (specific to each process) and output fuels (specific to each module).



1.4.3 Viewing Results

Click on the **Results View** to see the results of the Reference scenario. Select the Transformation: Electricity Generation branch and view the results for categories such as capacities, energy outputs, and module reserve margins. Compare your results to the tables and charts provided below.

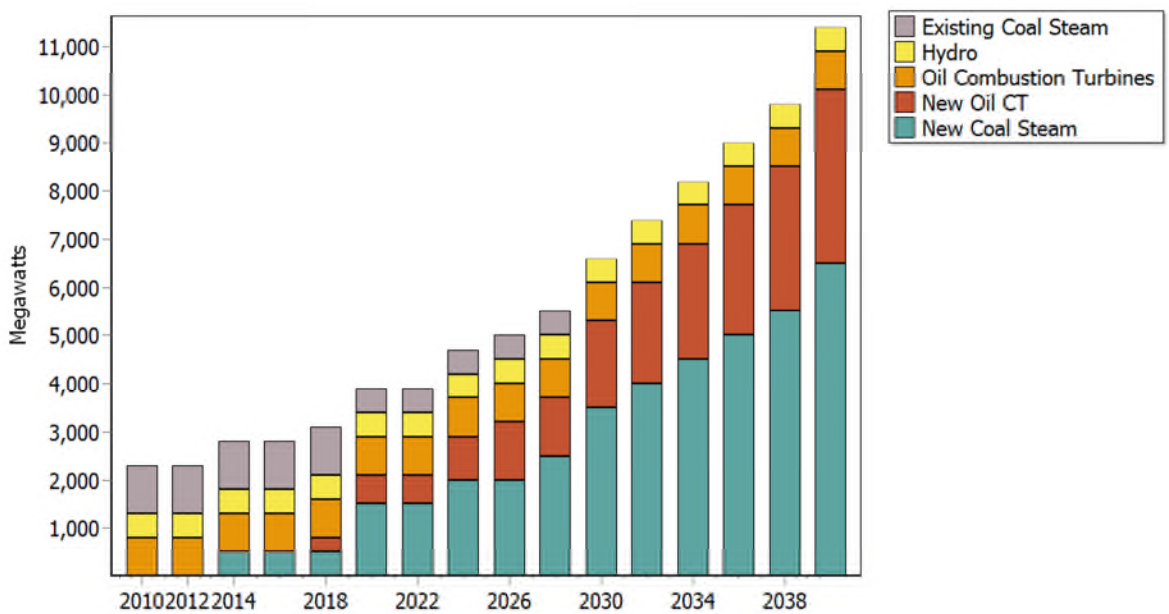
Electricity Generation in Freedonia: Reference Scenario



Notes: base year = 5,970 GWh, 2040 = 34,583 GWh

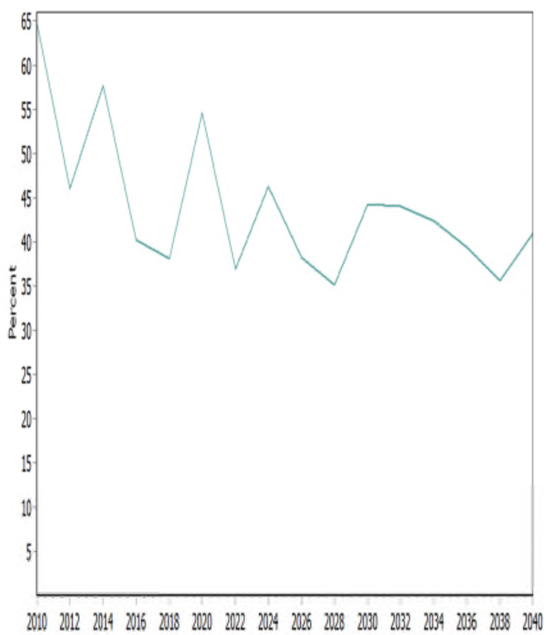
Hint: *To get this chart, click on the Processes under the Electricity Generation module in the Tree, select* ***Show: Transformation: Outputs****. Next, choose* ***Selected Years*** *on the X-axis and choose every 2 years for results. On the chart legend select* ***All Branches****. Use the chart toolbar on the right to select a stacked bar chart. Finally, make sure units are set to Gigawatt-hours on the Y axis. To save all these settings for future reference, click on the Favorites menu and choose "Save Chart as Favorite". Note that the order of processes is based on their order in the tree you set up in Analysis view.*

Electricity Generation Capacity (MW)

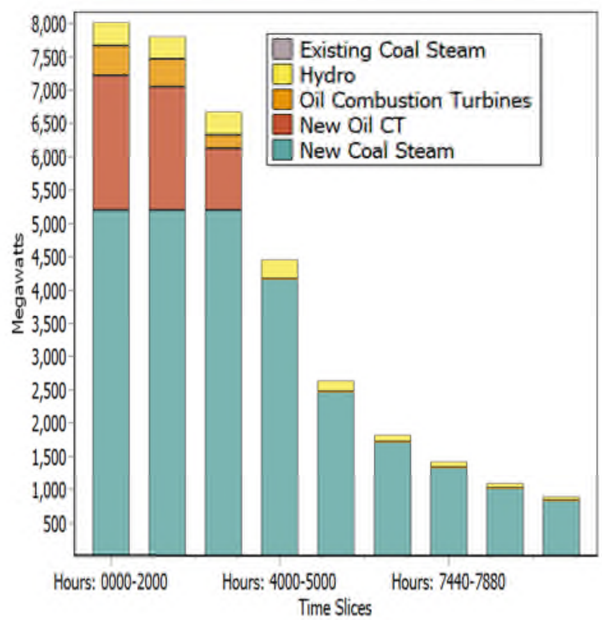


Notes: base year = 2300 MW, 2040 =11,400 MW

Actual Reserve Margin (%)

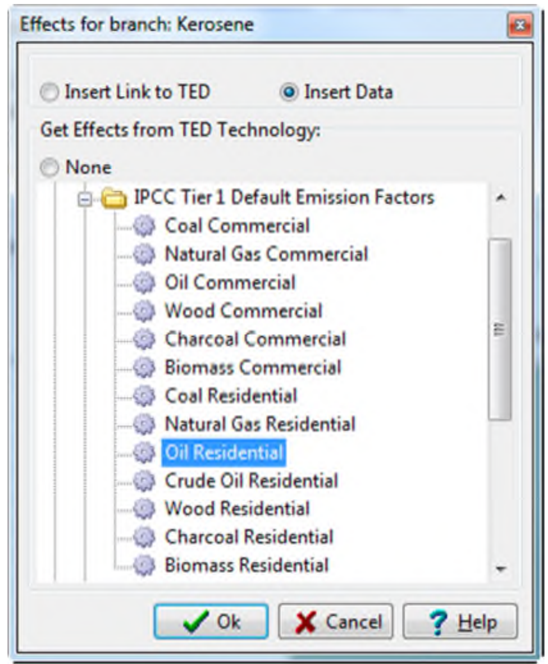


Power Dispatched in 2040 (MW)



1.5 Emissions

You will now use LEAP to estimate the emissions of major pollutants in the Reference scenario. To do this, first you must return to **Analysis View and go to General: Basic Parameters to switch on Energy Sector Environmental Loadings.** Now select Current Accounts and then create *links* between each relevant technology branch (those marked with the icon) and matching or similar technologies contained in the Technology and Environmental Database (**TED**). You create links to the data in TED by first selecting the **Environmental Loading** tab, and then clicking the TED button ( ). This will display the box shown on the right.



For this exercise you will make use of the default emission factors suggested by the Intergovernmental Panel on Climate Change (IPCC). To create the links, first click on a technology branch and then select the **Environment** tab in the data screen. Then for each relevant demand-side and electric generation technology select the appropriate IPCC Tier 1 default technology, using the TED technology selection form (shown above).

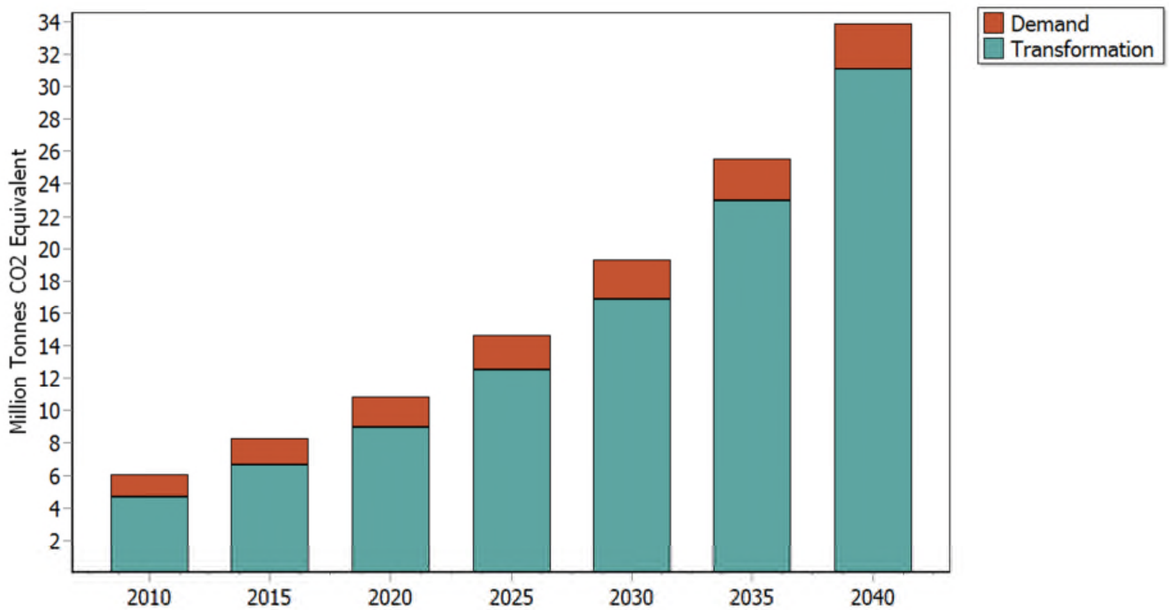
Make sure the input fuels to the TED technology are similar to fuels used by the LEAP technology. In some cases, the IPCC tier 1 technologies do not contain entries for all fuels. In this case you will need to pick the closest matching entry (e.g. the IPCC "Oil Residential" category can be linked to the LEAP "Kerosene Lighting" category).

You do NOT need to add environmental loading data for any demand-side devices that consume electricity, such as lights or refrigerators, since their environmental impacts occur upstream (e.g. in the power plants that produce the electricity).

1.5.1 Viewing Results

Click on the **Results View** to see environmental results for the Reference scenario. Click on the top-level branch “Freedonia” and select the category **Environment: Global Warming Potential**. Compare your results to those shown below. Also check the results for other non-greenhouse gases, such as sulfur and nitrogen oxides.

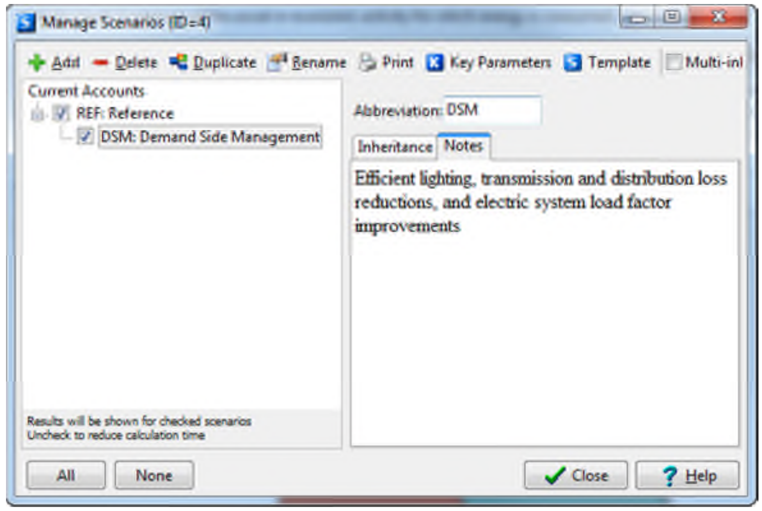
Global Warming Potential of Emissions from Freedonia
Reference Scenario (all greenhouse gases)



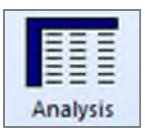
Note: Base Year = 6.1, 2030 = 33.9 Million Tonnes CO2 EQ.

1.6 A Second Scenario: Demand-Side-Management

You will now create a second scenario to explore the potential for electricity conservation in Freedonia. Use the **Manage Scenarios** ( ) option and use the Scenario Manager screen to add a new scenario. Add the scenario under the Reference scenario so that by default it inherits all of the Reference scenario assumptions and modeling expressions.



Give the new scenario the name "Demand Side Management", the abbreviation "DSM", and add the following notes: "Efficient lighting, transmission and distribution loss reductions, and electric system load factor improvements."



Exit the scenario manager and select the "Demand Side Management" scenario on the main screen, and then edit the data for the scenario to reflect the following notes:

> ***Hint:*** *Remember you must be in* ***Analysis View*** *to change scenarios. Use the view bar to select it if you are not.*

The DSM scenario consists of four policy measures:

1. **Refrigeration:** Proposed new efficiency standards for refrigerators are expected to cut the average energy intensities of refrigeration in urban households by 5% in 2020 compared to Current Accounts values, and by 20% in 2040. In rural households intensities are expected to remain unchanged.
   Hint: *You can enter this information in several ways.*

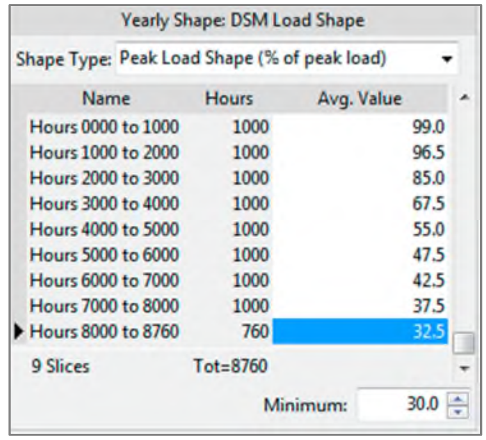
   - *Use the time series wizard, select interpolation, and enter the values for refrigerator energy intensity in future years (calculate the values on your own), or*

   - *enter an expression which calculates the value for you, such as Interp(2020, BaseYearValue * 0.95, 2040, BaseYearValue * 0.8)*

2. **Lighting:** A range of measures including new lighting standards and utility demand-side-management programs are expected to reduce the energy intensity of electric lighting in urban households by 1% per year (-1%/year), and to reduce the expected growth in electric lighting intensity in rural areas from 1% (reference scenario) to 0.3% per year (+0.3%/year).

3. **Transmission and Distribution:** Under the planned DSM program, electric transmission and distribution losses are expected to be reduced to 12% by 2025 and to 9% by 2040%.

4. **Electric System Load Factor Improvements:** Various load-leveling measures in the DSM plan are expected to lead to gradual improvements in the system load factor, which increases to about 64% in 2040. Do not enter this load factor explicitly in LEAP; instead, to represent this new load factor create a new yearly shape with the data shown on the right.


Yearly Shape: DSM Load Shape

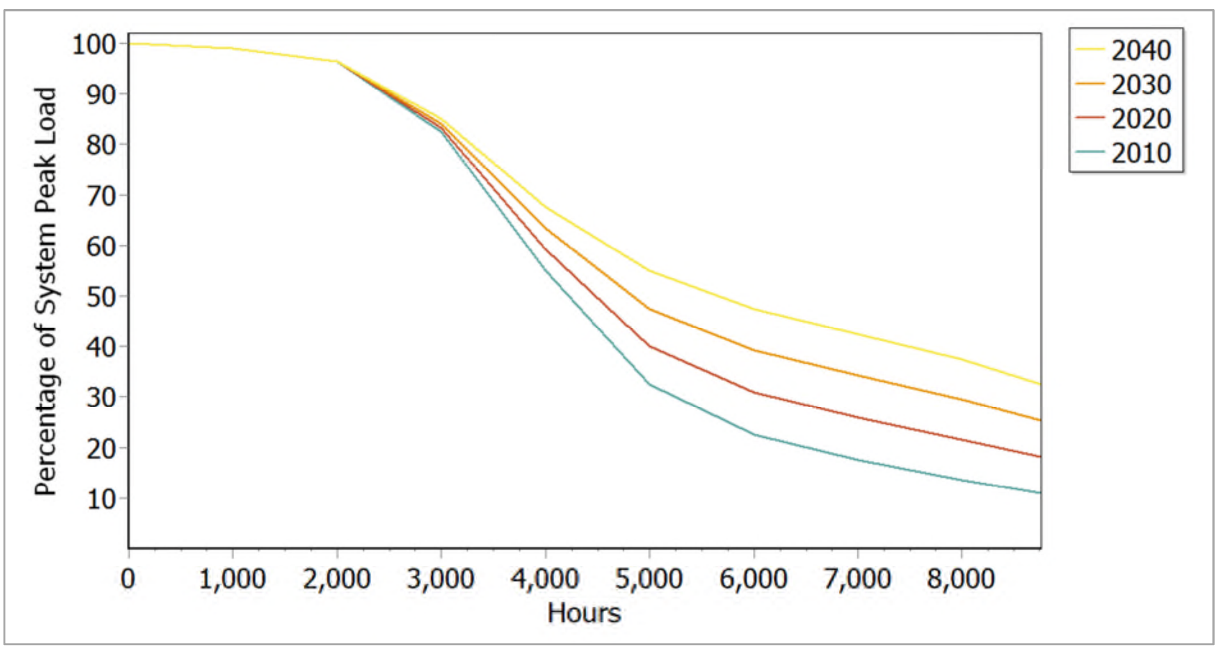
Shape Type: Peak Load Shape (% of peak load)

Name	Hours	Avg. Value
Hours 0000 to 1000	1000	99.0
Hours 1000 to 2000	1000	96.5
Hours 2000 to 3000	1000	85.0
Hours 3000 to 4000	1000	67.5
Hours 4000 to 5000	1000	55.0
Hours 5000 to 6000	1000	47.5
Hours 6000 to 7000	1000	42.5
Hours 7000 to 8000	1000	37.5
Hours 8000 to 8760	760	32.5

9 Slices Tot=8760

Minimum: 30.0

Hint: *Create a new yearly shape called "DSM Load Shape" (see section 1.4.2 to remember how. In the DSM scenario go to the* ***System Peak*** *variable for electricity generation, click on the ▪ button to the right of the expression field and choose Yearly Shape for the curve you just created. The chart below will show how LEAP interpolates between the load curve in 2010 (System Load Curve) and the load curve in 2040 (DSM Load Curve).*

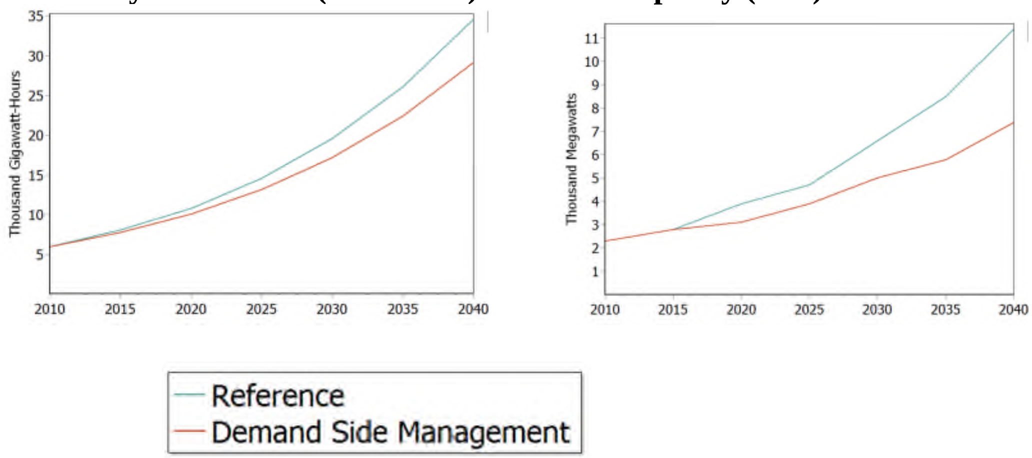


1.6.1 DSM Scenario Results

Click on the **Results View** to see the results of the DSM scenario. Compare your results with those shown below:

Electricity Generation: Reference Scenario Compared to DSM Scenario

Electricity Generation ('000 GWh) **Capacity (GW)**



Generation in DSM scenario in 2040 = 29,159 GWh. Capacity = 7400 MW.

Hint: *To recreate the electricity generation graph in the results view, go to Show: Transformation: Outputs, and set units and scenarios to match the above graph. Make sure that the highlighted branch on the tree matches the results that you want to see (in this case you should have "Transformation: Electricity Generation: Processes" highlighted). Show results every 5 years by choosing "Selected" on the x-axis menu. Check the table view to see exact values in a given year.*

Exercise 2: Demand

Exercise 2 further develops the demand analysis begun in Exercise 1 covering three other sectors: industry, transport, and commercial buildings. Use the information in section 2 to complete the tree structure, Current Accounts data and Reference scenario analysis for these sectors.

2.1 Industry

2.1.1 Current Accounts

There are two principal energy-intensive industries in Freedonia: Iron & Steel and Pulp & Paper. All other industries can be grouped into a single category. The adjoining table shows the output of each subsector. Industrial energy analysis is typically done in either economic (e.g., value added) or physical (e.g. tonnes) terms. The choice generally depends on data availability and the diversity of products within a sub-sector. In this exercise, both methods are used.

Industrial Output (2010)

Iron and Steel	600,000 Tonnes
Pulp and Paper	400,000 Tonnes
Other Industry	1.8 Billion US$

> ***Hint:*** *When adding the branch for "Industry", set the activity level unit to "No data" (since for this sector you are specifying different activity level units for each subsector).*

Energy use in the Iron & Steel and Pulp & Paper industries can be are divided into two end-uses: process heat and motive power.

Iron and Steel

- Currently, process heat requirements average 24.0 GJ per tonne, and boilers using bituminous coal produce all of this.
- Each tonne of steel requires an average of 2.5 GJ of electricity use.

Pulp and Paper

- Wood-fired boilers meet all process heat requirements of 40.0 GJ per tonne of pulp and paper products.
- Each tonne of pulp & paper requires 3 Megawatt-hours of electricity use.

Other Industry

- Freedonia's other industries consumed a total of 36 Million GJ of energy in 2010.
- 40% of this energy was electricity and the remainder was residual fuel oil.

> ***Hint:*** *When adding the branch for "Other Industry", set the branch type to the green category icon. This indicates that you want to enter an aggregate energy intensity at this branch. You can then add two more branches for electricity and fuel oil below this branch. These*

lower branches will only contain fuel shares, not energy intensities. Note also that you will also need to calculate the energy intensity in GJ/US Dollars using the total value added for the "Other" subsectors (see above).

2.1.2 Reference Scenario

Iron and Steel

- Total output is not expected to change: all plants are operating at maximum capacity and no new plants are planned within the analysis period.
- Natural gas is expected to provide for 10% of process heat requirements by 2040.
- Natural gas boilers are 10% more efficient than coal boilers.

Hint: *You will need to switch back to Current Accounts to add a new branch for Natural gas. You can use the following simple expression to calculate natural gas energy intensity as a function of coal energy intensity:*

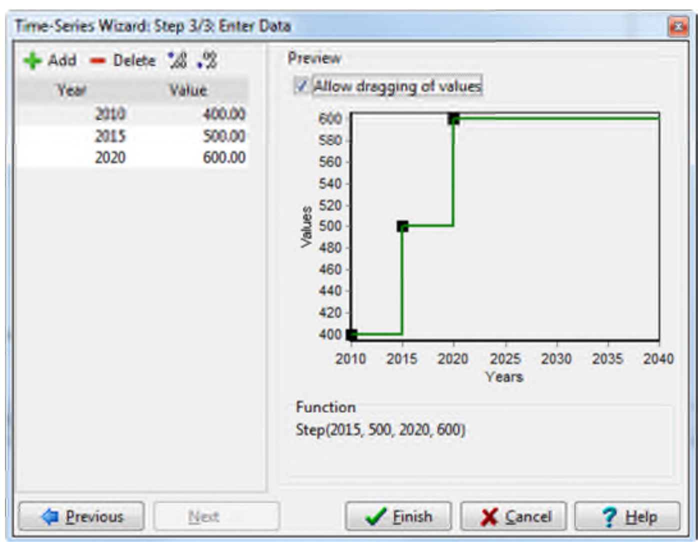
*Coal * 90%*

Hint: *Remember to use the "Interp" and "Remainder" functions to help you calculate boiler shares.*

Pulp and Paper

- Two new paper plants are expected: one in 2015 and one in 2020. Each will add 100 thousand tonnes per year to the total output of this industry.

Hint: *Use the Step Function in the* ***Time Series Wizard*** *to specify discrete changes in activity levels or other variables (see right).*



Other Industry

- Output of other industries is expected to grow at a rate of 3.5% per year.
- The fuel share of electricity is expected to rise to 55% by the year 2040.

2.1.3 Viewing Results

Now review your results and compare to the answer sheet shown below.

Industrial Energy Demand in Freedonia: Reference (Million Gigajoules)

Fuels	2010	2040	Subsectors	2010	2040
Coal (bituminous)	14.4	13.0	Iron and Steel	15.9	15.8
Electricity	20.2	63.6	Other	36.0	101.0
Natural Gas	-	1.3	Pulp and Paper	20.3	30.5
Residual Fuel Oil	21.6	45.5			
Wood	16.0	24.0			
Industry	**72.2**	**147.3**	**Industry**	**72.2**	**147.3**

2.2 Transport

2.2.1 Current Accounts

Passenger Transport

- All passenger transportation in Freedonia is either by road (cars and buses) or rail. (You may ignore air and water transport for this exercise.)
- In the year 2010, cars were estimated to have traveled about 8 billion km; buses traveled about 1 billion km.
- Surveys also estimate that cars have a (distance-weighted) average number of occupants (load factor) of 2.5 people, while the similar average for buses is 40 passengers.
- Surveys have found that the current stock of cars has a fuel economy of about 12 km/liter (roughly 28 m.p.g.). Buses, in contrast, travel about 3 km/liter.
- The national railroad reports 15 billion passenger-km traveled in 2010.

	Calculating Passenger-Km	
A	Car Use (billion veh-km)	
B	Load Factor (pass-km/veh-km)	2.5
*C=A*B*	**= Total Car Pass-km**	
D	Bus Use (billion veh-km)	
E	Load Factor (pass-km/veh-km)	40.0
*F=D*E*	**Total Bus Pass-km**	
G=F+C	Road Passenger-km	
H	Rail Passenger-km	
I=G+H	**Total Passenger-km**	
	Calculating Energy Intensities	
J	Car Fuel Economy (veh-km/l)	12.0
K	Load Factor (pass-km/veh-km)	2.5
*L=1/(J*K)*	**Energy Intensity (liters/pass-km)**	
M	Bus Fuel Economy (veh-km/l)	3.0
N	Bus Load Factor (pass-km/veh-km)	40.0
*O=1/(M*N)*	**Energy Intensity (liters/pass-km)**	

Hints:

- *You may wish to enter total population as the activity level at the sector level (see section 1.3 for population data).*
- *Use the information above to calculate the total number of passenger-kms, the percentage for each mode, and the average energy intensity (per passenger-km). Fill out the form above to help you.*
- *For emissions purposes, assume all current cars use gasoline fuel and all current buses use diesel fuel.*

- 20% of rail transit is by electric trains, the remainder by diesel trains. The energy intensity of electric trains is 0.1 kilowatt-hours per passenger-km. The energy intensity of diesel trains is 25% higher than that of electric trains.

Freight Transport

- An average of 250 tonne-km of freight is transported per capita.
- 85% of freight transport is by road, the rest by rail.
- Road transport uses an average of 4 MJ of diesel fuel per tonne-km.
- Diesel freight trains have an energy intensity of 3 MJ/tonne-km.

> **Units Cancellation in LEAP**
>
> When specifying freight transport activities, notice how LEAP automatically cancels out the numerator and denominator units of your data as you step down through the branches of the tree.
>
> In this example, start by specifying population at the sector level, at the next level you then specify tonne-km/person. In other words, LEAP cancels the units
>
> ~~[People]~~ x [tonne-km] / ~~[person]~~

2.2.2 Reference Scenario

Passenger Transport

- The unit demand for passenger travel (pass-km/person) is expected to rise slightly faster than average income levels (the elasticity of demand for travel with respect to income is 1.1).
- At the same time the total population is growing at 2.5% per year.
- Average income per capita is expected to grow from its current level, $3000, at a rate of 3.5% per year through 2040.
- Cars are expected to account for 75% of passenger road traffic by 2040.

Hint: *create variables called "Income" and "Population" under* ***Key Assumptions*** *on the Tree, then calculate future transport demands as a function of these variables. Use the following expression for per capita transport demand:*

GrowthAs(Key\Income, 1.1)

Freight Transport

- The per capita demand for freight transport is expected to grow at a rate of 2% per year over the analysis period.
- The energy efficiency of all transport modes (both passenger and freight) is expected improve by 0.5% per year through 2040, except for cars, which are expected to improve by 1% per year.

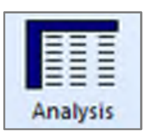
2.2.3 Viewing Results

Now switch to **Results View** and compare your results with the tables shown below.

Transport Energy Demand in Freedonia: Reference (Million Gigajoules)

Branches	2010	2040	Fuels	2010	2040
Freight	38.5	125.9	Diesel	56.5	182.6
Rail	4.5	14.7	Electricity	1.1	6.1
Road	34.0	111.1	Gasoline	22.1	240.1
Passenger	41.1	303.0			
Rail	6.5	36.4			
Diesel	5.4	30.3			
Electric	1.1	6.1			
Road	34.7	266.6			
Diesel Buses	12.6	26.5			
Gasoline Cars	22.1	240.1			
All Transport	**79.6**	**428.8**	**All Transport**	**79.6**	**428.8**

2.3 Commerce: Useful Energy Analysis

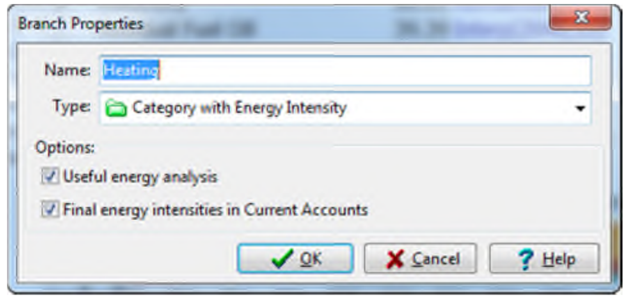


This exercise considers space-heating uses in commercial buildings, and serves to introduce the application of useful energy analysis techniques. Useful energy analysis is particularly helpful where multiple combinations of fuels and technologies can provide a common service at (such as heating), and in situations where you want to independently model device efficiencies, and overall energy service requirements.

2.3.1 Current Accounts

- Commercial buildings in Freedonia utilized a total of 100 million square meters of floor space in 2010.
- Total final energy consumption for heating purposes was 20 million GJ in 2010.
- Residual fuel oil and electricity each currently supply half of the total heating energy. Natural gas is expected to be introduced in the near future
- Electric heaters have an efficiency of nearly 100%, while fuel oil boiler efficiencies average 65%, and natural gas boilers have 80% efficiencies.

Hint: For this exercise, you need to setup a **Category with Energy Intensity** branch for heating. Check the boxes to indicate that you wish to conduct a **useful energy analysis** and that you wish to enter **final energy intensities in Current Accounts**. Use the branch properties screen to set this up as shown right.



2.3.2 Reference Scenario

- Floor space in the commercial sector is expected to grow at a rate of 3% per year.
- Due to expected improvements in commercial building insulation standards, the *useful* energy intensity (i.e. the amount of heat delivered per square meter[1]) is expected to decline by 1% per year. Until 2040.
- By 2040, natural gas boilers are expected to have reached a market penetration (i.e. share of floor space) of 25%, while fuel oil boilers are expected to decline to only a 10% market share. Electricity heating fills the remaining requirements. (Notice that these *activity* shares are different from the *fuel* shares you entered for Current Accounts).
- Finally, gradually improving energy efficiency standards for commercial boilers are expected to lead to improvements in the average efficiency of fuel oil and natural gas boilers. Fuel oil systems are expected to reach and efficiency of 75% by 2040, and natural gas systems are expected to reach an efficiency of 85% by 2040.

2.3.3 Viewing Results

After entering the above data, switch to **Results View** and compare your results with the table shown below.

Commercial Space Heating Energy Demand: Reference (Million Gigajoules)

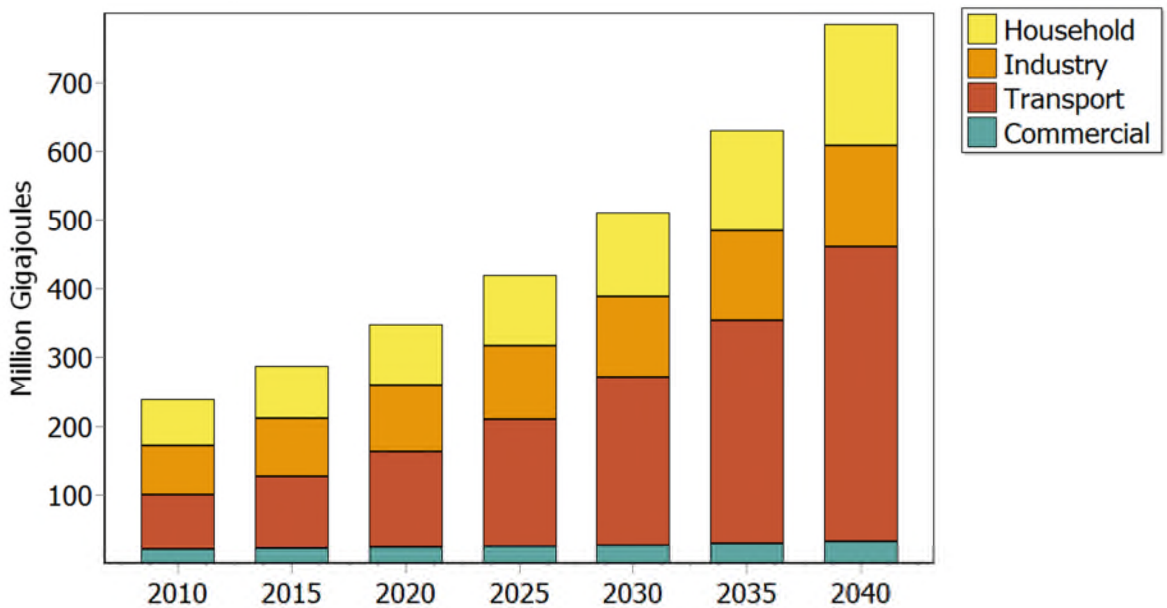
Fuels	2010	2040
Electricity	10.0	19.3
Natural Gas	-	8.7
Residual Fuel Oil	10.0	3.9
Total Commercial	20.0	31.9

[1] As opposed to the *final* energy intensity: the amount of fuel used per square meter.

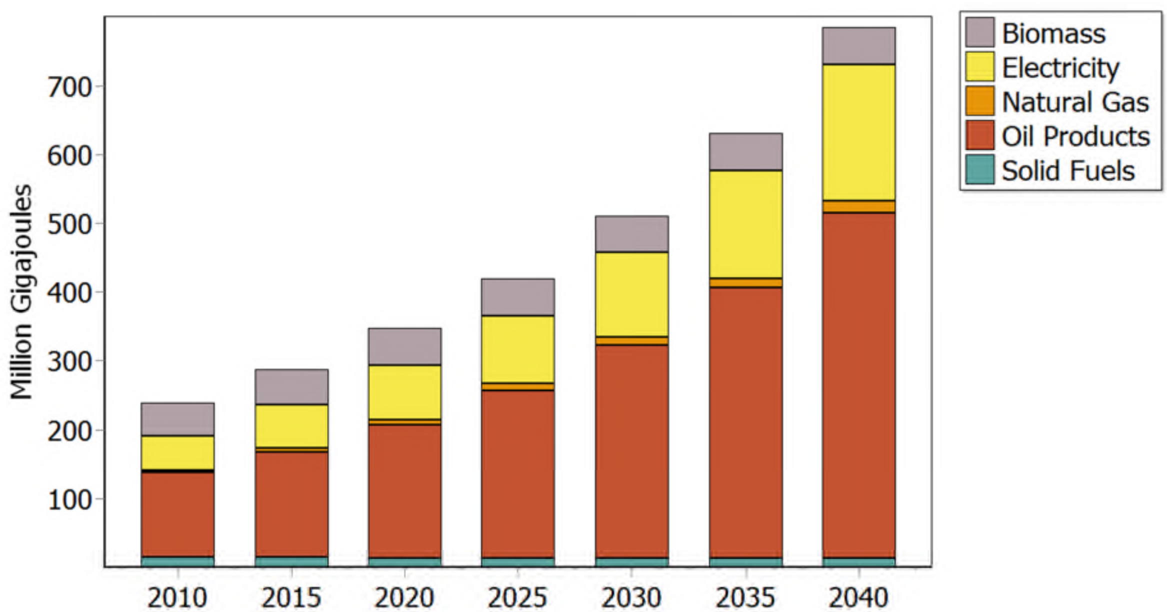
2.4 Total Final Demands

Before proceeding to the Transformation exercises, check your overall energy demand results by comparing with these charts.

Energy Demand by Sector: Reference Scenario



Energy Demand by Fuel Group: Reference Scenario



Hint: *To see the energy demand by fuel group graph above, choose Show:* ***Demand: Energy Demand Final Units*** *and choose fuels on the right legend drop down menu and then select the* ***Group Fuels*** *check box.*

Exercise 3: Transformation

In this fourth exercise you will further develop the simplified Transformation data set you constructed in Exercise 1. In this exercise you will add new modules to examine charcoal production, oil refining and coal mining.

3.1 Charcoal Production

No charcoal is imported or exported. It is all produced by conversion from firewood. All charcoal in Freedonia is currently made using traditional earth mounds. These have a conversion efficiency (on an energy basis) of around 20%. In the future, more efficient "brick beehive" kilns are expected to be available. These have a conversion efficiency of 47%. They are expected to be used to meet 5% of total charcoal demand by 2020, 20% of charcoal demand by 2040.

> ***Hint:*** *Create a standard (i.e. not a simple) module and select the option to enter efficiency data as efficiencies (to match the data above).*

3.2 Electricity Generation

With the addition of the extra demand sectors in Exercise 2, the demand for electricity generation triples to around 16,200 GWh. Thus, you now need to specify a larger and more realistic electric generation system to match the additional demand for electricity. Change the data you entered in Exercise 1 in Current Accounts for the Electricity Generation module to match those below:

Plant Type	Year 2010 Capacity (MW)	Base Year Output (% of GWh)
Hydro	1,000	34%
Coal Steam	2,500	44%
Oil Combustion Turbine	2,000	22%
Total	**5,500**	**100% (16,200 GWh)**

In the future, mitigation options may include wind. Add a new technology for wind in current accounts but don't fill in any data yet.

3.3 Oil Refining

Oil refineries in Fredonia processed approximately 4.16 million tonnes of crude oil in the year 2010, which was well under their feedstock capacity of about 6 million tonnes of crude[2]. The efficiency of the refineries (on an energy basis) was about 95.0%. There are currently no plans to increase refining capacity.

The refineries used only one feedstock fuel: crude oil, and produced seven types of products: gasoline, avgas, kerosene, diesel, residual/fuel oil, LPG, and lubricants. The refineries can be operated with sufficient flexibility that the mix of refinery products matches the mix of requirements for those products.

[2] Note: you are limited to entering capacity data in basic energy units (tonnes of oil equivalent or tonnes of coal equivalent per year). For the purposes of this exercise, assume 1 tonne of coal = 1 TCE and 1 tonne of crude oil = 1 TOE.

Any oil product requirements that cannot be produced from the refinery are imported into Freedonia.

> ***Hint:*** *Set the properties of the oil refining transformation module to a standard module with capacity data.*

> ***Hint:*** *Set up the dispatch rules to dispatch by process shares. Remember to set the process share of crude oil to be 100.*

3.4 Coal Mining

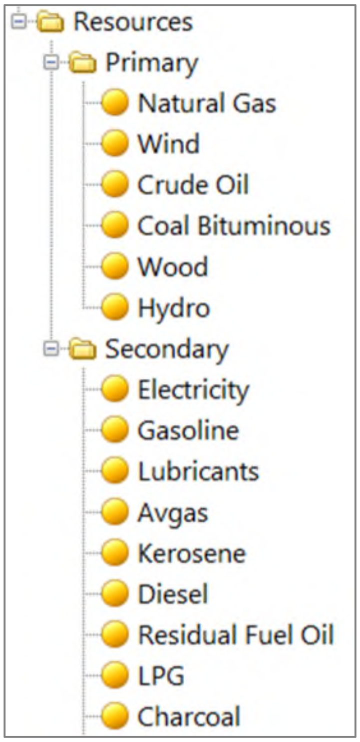
All coal mined in Freedonia is bituminous. In the base year, the country's coal mines produced 3.4 million of coal, mining capacity stood at 6 million tonnes, and the efficiency of coal mining (including coal washing plants) was 80%.

The Reference scenario assumes that coal mining capacity will increase as follows: 14 million tonnes by 2020, and to 23 million tonnes by 2040. It is assumed that mine capacity will expand linearly in years between these data years. In spite of this expansion program, it is expected that sometime after 2030 imports of coal will be needed to meet domestic requirements, not because of resource limits, but because the capacity of the mines is unable to expand as fast as demand for coal grows.

> ***Hint:*** *Known capacity should be entered in the* ***Exogenous Capacity*** *variable. Imports of coal should not be entered as capacity, but instead are governed by the* ***Output Properties*** *variable at the Coal Mining\Output Fuels branch. Make sure that the Shortfall Rule is set to "Import fuel to meet shortfall" to meet the modeling demands described above.*

3.5 Resources

The final step in entering data is to specify which primary resources are produced domestically and which need to be imported. In LEAP you can specify the base year reserves of fossil fuels and the maximum annual available yield of renewable energy forms such as hydro and wind. Unless you indicate otherwise, LEAP will assume that any resources not available domestically are imported.

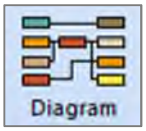


Data on resources are stored under the Resource branches. Notice that one branch is listed for each fuel used in the Fredonia data set. These branches are updated automatically as you edit the rest of the tree structure in LEAP. You cannot add or delete branches in the resources part of the tree.

In Freedonia, the only domestic energy resources are coal, hydropower, biomass (wood) and wind. All natural gas and oil resources have to be imported. No detailed data are available yet on the coal, hydropower, biomass and wind resource base, so for this analysis assume that these resources are essentially unlimited.

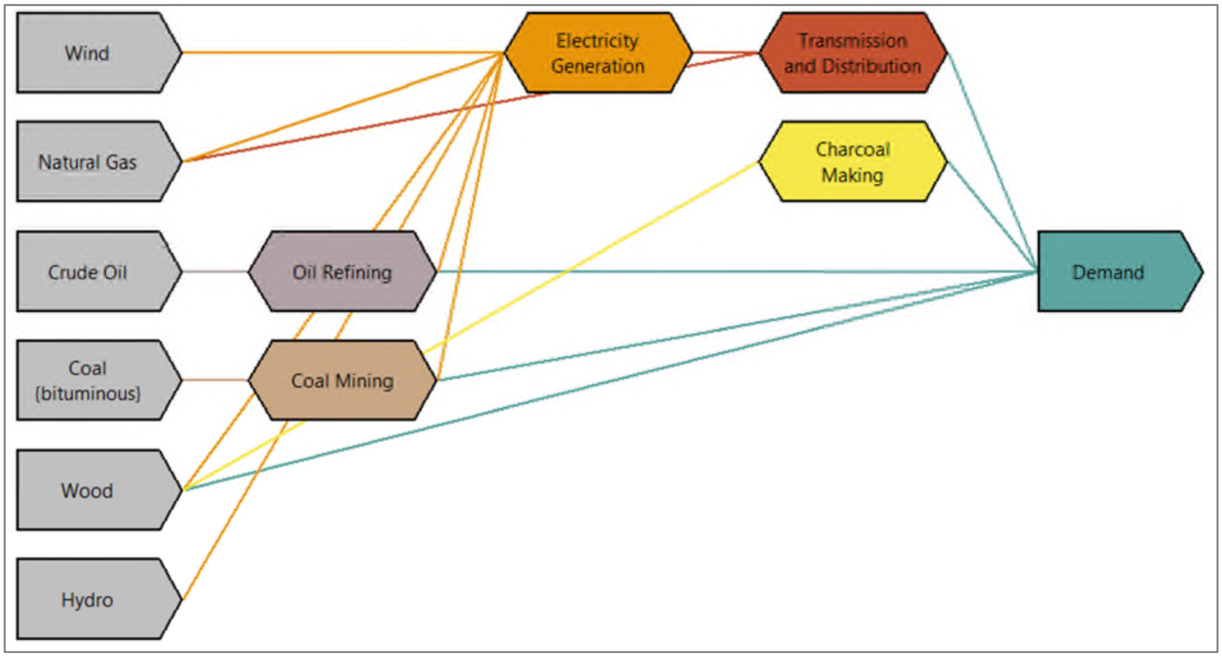
To reflect this in LEAP, go to the Resource branches and enter base year reserves (for coal) and yields (for wood, hydropower and wind) of 1 Trillion GJ each. Enter zeros for the reserves of crude oil and natural gas. Notice that, by definition, you do not need to enter resource availability data for any of the secondary fuels.

3.6 Viewing Results



Before viewing results, review your energy system diagram and check that it looks similar to the one shown below:

Energy System Diagram



Now switch to the **Energy Balance View** and check your base and end year energy balances against the following tables:

Energy Balance of Freedonia in 2010 (Million GJ)

	Solid Fuels	Natural Gas	Crude Oil	Hydropower	Biomass	Electricity	Oil Products	Total
Production	125	0	0	20	81	0	0	226
Imports	0	4	184	0	0	0	0	187
Exports	0	0	0	0	0	0	0	0
Total Primary Supply	125	4	184	20	81	0	0	413
Coal Mining	-25	0	0	0	0	0	0	-25
Oil Refining	0	0	-184	0	0	0	174	-9
Charcoal Production	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	-111	0	-184	-20	-32	50	123	-174
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	79	80
Commercial	0	0	0	0	0	10	10	20
Total Demand	14	3	0	0	49	50	123	240
Unmet Requirements	0	0	0	0	0	0	0	0

Energy Balance of Freedonia in 2040 (Million GJ)

	Solid Fuels	Natural Gas	Crude Oil	Hydropower	Biomass	Electricity	Oil Products	Total
Production	638	0	0	13	98	0	0	750
Imports	0	17	251	0	0	0	409	677
Exports	0	0	0	0	0	0	0	0
Total Primary Supply	638	17	251	13	98	0	409	1,427
Coal Mining	-128	0	0	0	0	0	0	-128
Oil Refining	0	0	-251	0	0	0	239	-13
Charcoal Production	0	0	0	0	-44	0	0	-44
Electricity Generation	-498	0	0	-13	0	225	-145	-431
Transmission and Distribution	0	0	0	0	0	-27	0	-27
Total Transformation	-625	0	-251	-13	-44	198	94	-642
Household	0	7	0	0	30	110	30	177
Industry	13	1	0	0	24	64	45	147
Transport	0	0	0	0	0	6	423	429
Commercial	0	9	0	0	0	19	4	32
Total Demand	13	17	0	0	54	198	502	785
Unmet Requirements	0	0	0	0	0	0	0	0

Hints: *If your energy balance does not seem correct, troubleshoot demand and current accounts (in this case 2010) before addressing any errors your scenarios. Some other tips for troubleshooting energy balances:*

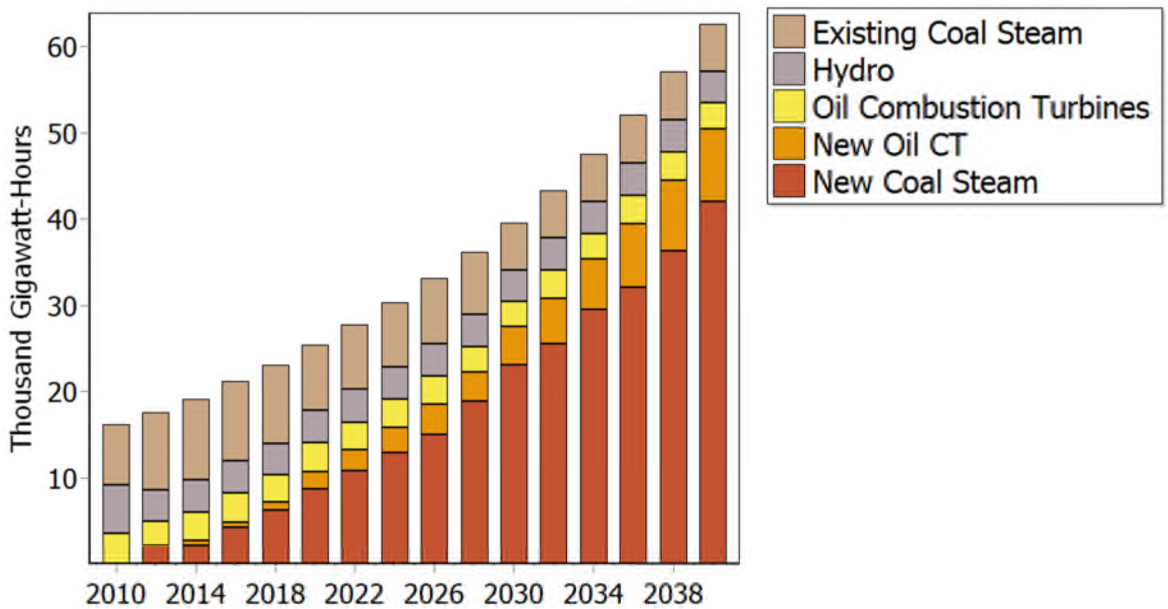
1. *If the value of energy requirements (independently of whether they are imported/exported/domestically produced) does not match the results, it is good to trace your results to see if you can localize which demand, transformation and resources branches are not functioning as you expect.*

2. *If the energy requirements seem correct, but imports, exports and/or domestic production seems incorrect, then it is possible that numbers have been input correctly, but branch properties are not set correctly. Here are some things to check:*

   - *Check the output properties of each transformation module. This can be found in analysis view, in the "Output Fuels" folder in each transformation module (i.e. Transformation\Oil Refining\Output Fuels). Check the "Output Properties," "Import Target" and "Export Target" variables to make sure those make sense.*
   - *Check the "Base Year Reserves" and "Yield" variables in the Resources branch to ensure that you have sufficient primary and secondary resources to produce resources and energy domestically.*
   - *Check the import and export target variables at the Primary and Secondary Resources branch. These variables add additional imports and exports for resources that have not been already specified as outputs of one or more Transformation modules.*

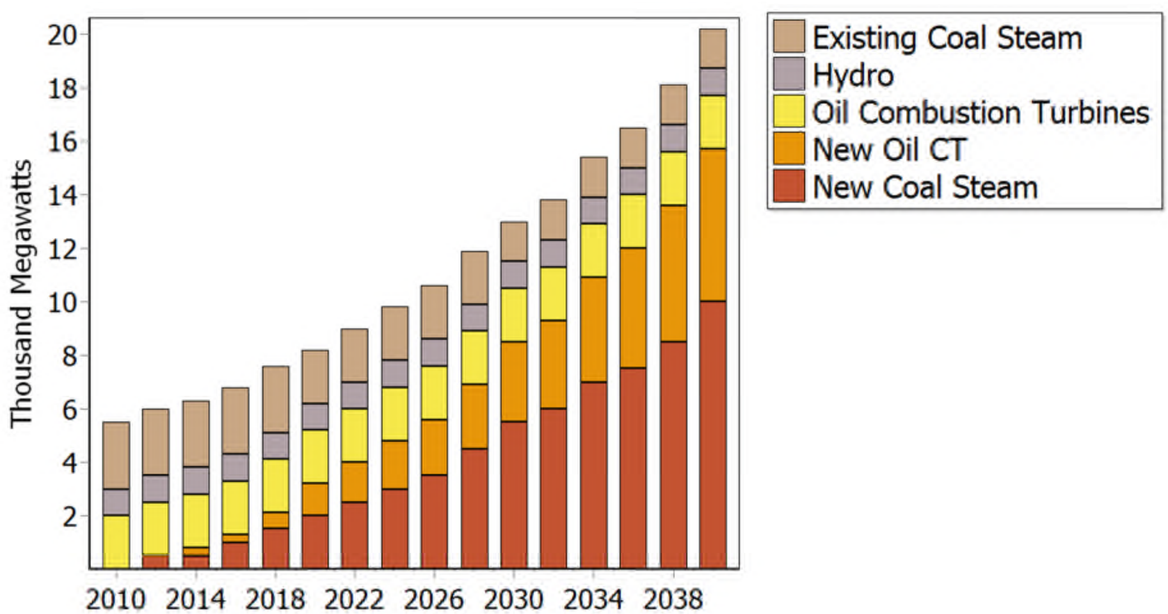
Now switch to **Results View** and compare your results with the charts shown below.

Electricity Generation: Reference Scenario



Notes: base year = 16, 200 GWh, 2040 = 62,640 GWh

Electricity Generation Capacity: Reference Scenario



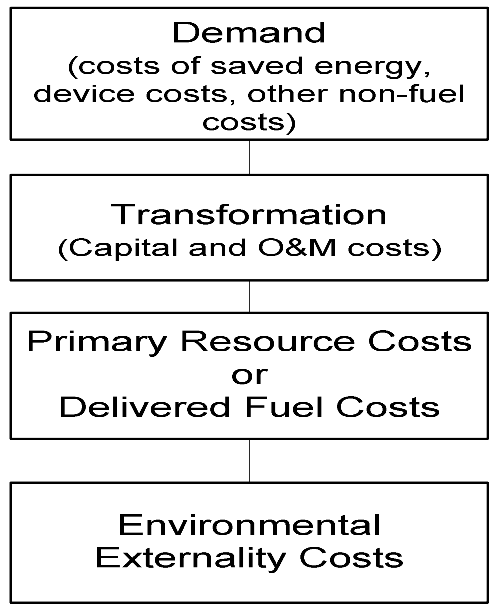
Exercise 4: Cost-Benefit Analysis

In this exercise you are going to enter data to describe the costs of various demand and supply-side technologies. You are then going to use LEAP to do an integrated cost-benefit analysis of various policy scenarios.

Make sure you start with a data set that has all of the data entry completed through Exercise 3.

4.1 Cost-benefit Analysis in LEAP: A Brief Introduction

LEAP performs cost-benefit calculations from a societal perspective by comparing the costs of any two policy scenarios. LEAP can include all of the following cost elements:



- Demand costs capital and operating and maintenance costs expressed as total costs, costs per activity, or costs of saving energy relative to some scenario.
- Transformation capital costs
- Transformation fixed and variable operating and maintenance costs.
- Costs of indigenous resources
- Costs of imported fuels
- Benefits of exported fuels
- Externality costs from emissions of pollutants
- Other miscellaneous user-defined costs such as the costs of administering an efficiency program.

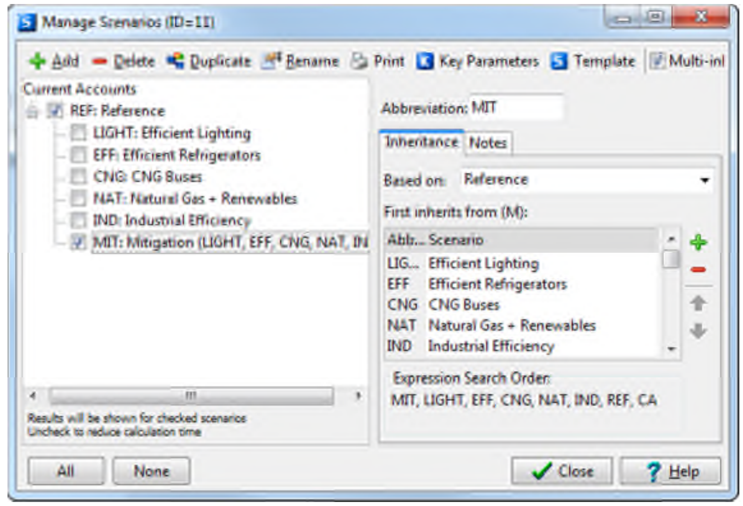
To set-up a costing analysis in LEAP it is first necessary to draw a consistent boundary around your system, so that LEAP will not double-count costs and benefits. For example, if you count the costs of fuels used to generate electricity you should not also count the cost of the electricity in an overall cost-benefit calculation.

If you have not already done so, switch on costing by going to the **Scope** tab of the **General: Basic Parameters** screen and enable costs. Now go to the **Costing** tab and select the boundary that will be drawn around the system for the purposes of costing. For this exercise you should select “Complete Energy System” as the boundary, meaning that fuel costs are accounted for only when they are imported or exported or when indigenously produced fuels are extracted as primary resources. Set the discount rate to 5%.

You will now start by constructing a series of policy scenarios that will be analyzed. Next you will enter the costs data relevant for these scenarios including demand, Transformation and resource costs. Finally you will examine some costing results including an overall cost-benefit comparison of the various scenarios.

4.2 Creating Policy Scenarios

Go to the **Manage Scenarios** screen ( ) and create the following five scenarios:



- Efficient Lighting
- Efficient Refrigerators
- CNG Buses
- Natural Gas & Renewables
- Industrial Efficiency

Hint: *You can delete the DSM scenario that you created in Exercise 1.6*

The **Manage Scenarios** screen should look like the one shown right. Make sure each of the new policy scenarios is created beneath the Reference scenario. In this way the scenarios will inherit the expressions already entered for the Reference scenario.

Finally, create a **Mitigation** scenario under the **Reference** scenario that is a combination of the five policy scenarios listed above. Use the Inheritance tab to set that this scenario also inherits its expressions from these five policy scenarios.

4.3 Entering Costing Data

Next you will enter the data that that will be used to evaluate how these scenarios differ from the Reference scenario.

In general, the unit costs of different technologies are the same for different scenarios, but the scenarios will differ in terms of how much of each technology is implemented or how much of each fuel is consumed. Thus, you first need to enter cost data in the **Current Accounts** scenario. After that you will enter data describing the penetration of the technology in the different policy scenarios.

You will start by specifying cost data for demand-side options. In general you need to enter three types of data describing:

- **Technology Penetration:** how many of the new (efficient) types of devices will be installed in the Policy scenario?
- **Technology Performance:** how efficient are the new devices?
- **Technology cost:** how much do the new devices cost? You may either specify the total costs of competing devices used in the Reference and Policy scenarios or you can

simply enter the incremental cost of the new devices introduced in the Policy scenarios relative to the costs of the device used in the Reference scenario.

4.3.1 Efficient Lighting Scenario

Hint: *Before entering in data, create a new technology branch under the urban lighting category folder for your new efficient technology.*

- **Technology Penetration:** A program to install efficient lighting systems could reduce electricity consumed in urban households, using compact fluorescent (CFL) and other technologies. Assume that the program starts in 2012 and is capable of reaching 40% of all households by 2017 and 75% by 2030. Enter this data in the **Efficient Lighting** Scenario for the **Activity Level** variable.

- **Technology Performance:** Efficient lighting can be assumed to consume only 30% of the electricity used by conventional lighting in urban households. Enter this data in the **Current Accounts** Scenario for the **Final Energy Intensity** variable.

- **Technology Cost:** Standard light bulbs cost 1$ each but have a lifetime of only one year. Efficient light bulbs cost $6 each but are assumed to last for 3 years. Each household is assumed to have 5 working lights. Enter this data in the **Current Accounts** Scenario for the **Demand Cost** variable. You will be entering data per household so make sure you first select the **Activity Cost** Method. You will also need to use the Annualized Cost function to specify the annualized cost of both the existing and the efficient technology per household per year. So for example the annualized cost per household for efficient light bulbs would be written as:

    AnnualizedCost(6*5, 3)

    This uses a standard mortgage formula to annualize the cost per household (5 bulbs x $6/ bulb) over the 3 year life of the bulb. Write a similar formula for standard/existing light bulbs.

    Hint: *The Function Wizard (Ctrl+F) is helpful when using Functions such as AnnualizedCost.*

4.3.2 Efficient Refrigerators Scenario

- **Technology Penetration:** Government is considering introducing a new efficiency standard for refrigerators. This would start in 2014. By 2025 all urban refrigerators in the country (not rural) can be assumed to meet the new standard.

- **Technology Performance:** The standard would require that manufacturers produce refrigerators with an average energy intensity of 380 kWh/year.

- **Technology Cost:** The cost of improving refrigerator efficiency to 380kWh is approximately $100 US per fridge. Both current and efficient fridges have a lifetime of about 10 years. In this example you only have data describing the *incremental cost* of the new efficient device. Thus, when entering data for the **Demand Cost** variable in the **Current Accounts** scenario, you will need to specify a cost of zero for the existing refrigerator and then annualize the $100 incremental cost over the 10 year lifetime of the efficient refrigerator. It is perhaps worth noting that to do a cost-benefit analysis you do NOT need to specify all of the costs of a scenario. You need only specify how one scenario's costs differ from another's.

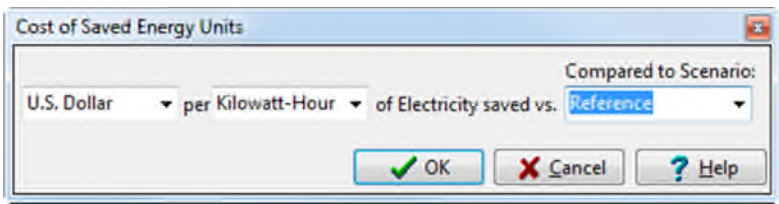
4.3.3 Industrial Energy Efficiency Scenario

In the "Other Industrial" sector of Freedonia energy is used in a wide variety of different processes. An energy audit of selected industries has estimated that energy consumption can be reduced through variety of measures at an average cost of about 5 cents per KWh saved (for both electricity and oil). These measures have the potential to save up to 30% of the energy consumed in the "Other Industry" sector by 2040.

Unlike in the previous two examples, for this type of analysis the cost information is not available in a form that allows you to count up the number of new devices that will be installed. Instead you will have to specify the costs by entering the **Cost of Saved Energy.**

In **Current Accounts**, select the **Demand Cost** Variable for the Electricity and Fuel Oil branches under the "Other Industry" branch. Now select the Cost of Saved Energy Method. When you select this method a dialog box will appear. In it choose units of *Dollars/KWh saved versus the Reference Scenario*. The dialog should look like the one shown here.

Once you have set the units, click **OK** and then enter the data of $0.05/Kwh saved. Repeat this for each fuel.



Now select the Industrial Efficiency scenario, and specify the energy savings that can be expected. One easy way to do this is to select the **Final Energy Intensity** variable (specified at the **Other Industry** branch) and then enter the following formula which tells LEAP that the energy intensity will be 30% less than in the baseline Reference scenario by 2040:

BaselineValue * Interp(2010, 1, 2040, 0.7)

4.3.4 CNG Buses Scenario

Switching buses from diesel to CNG is seen as a good option both for improving air quality in densely populated and polluted cities as well as being a good way of mitigating CO_2 emissions.

- **Technology Penetration:** CNG buses could start to be introduced in 2012. By 2017 they could meet 7% of total bus passenger-kms, and by 2040 this could reach 70%.

- **Technology Performance:** Natural gas powered CNG buses use 0.29 MJ/Passenger-km: slightly less than existing diesel buses.

- **Technology Cost:** CNG buses cost US$0.1 per passenger-km more than existing buses but these costs are annualized over the 15 year lifetime of the buses.

4.3.5 Transformation Costs

Wind and natural gas combined cycle (NGCC) plants will all be included in the last mitigation scenario. Before entering in costing data, you must create new branches for both technologies and specify their performance characteristics. Use the table below to set this up in current accounts.

Performance Characteristics for Future Electric Facilities

	Wind	**NGCC**
Dispatch Rule	Merit Order	Merit Order
Merit Order	1	1
First Simulation Year	2011	2011
Process Efficiency [%]	100	55
Maximum Availability [%]	35	80
Capacity Credit [%][1]	30	100
Historical Production [GWh]	0	0
Exogenous Capacity [MW]	0	0
Lifetime [years]	30	30

[1] The capacity credit variable takes into account the portion of capacity that is fixed due to the intermittency of renewable technologies. This means that the all technologies other than wind will have a capacity credit of 100%.

Each of your demand side policy options will have a variety of impacts on the size and operation of the Transformation sectors. Therefore, unlike for the demand-side options where you only needed to enter cost data to describe the new options you were studying, for Transformation you need to specify costs for all of the various power plants and fuels that may be affected.

Start by specifying the capital costs and the fixed and variable operating and maintenance costs of the various Electric Generation power plants in your system. Use the following table for the data you need in LEAP.

Costs for Existing and Future Electric Facilities

Existing Plants	Capital ($/kW)	Fixed O&M ($/kW)	Variable O&M ($/MWh)	Interest Rate [%]
Coal	1000	40	3	5
Hydro	2000	0	1	5
Combustion Turbine	400	10	0.7	5
New Plants				
Coal	1000	40	3	5
Combustion Turbine	400	10	0.7	5
Natural Gas Combined Cycle	500	10	0.5	5
Wind	800	25	0	5

NB: these costs do NOT include fuel costs. You will deal with fuel costs below when you specify resource cost data.

4.3.6 Natural Gas and Renewables Scenario

In the **Reference Scenario**, Coal and Oil Combustion turbines are assume to be the main types of power plants to be built in the future. Recall that this data was specified for the Endogenous Capacity variables (located under the Electric Generation module's list of processes).

In this policy scenario you will instead examine the impact of building a different mix of power plants in the future. This scenario will analyze the impact of building a mix of Natural Gas Combined cycle and Wind power for our base load plus some oil combustion turbines to meet our peak load requirements.

Select the **Natural Gas and Renewables** Scenario, and in the **Endogenous Capacity** screen, replace the Reference scenario data with the following:

Capacity Addition Sizes in the Natural Gas and Renewables Scenario

Process	Addition Order	Addition Size (MW)
Natural Gas CC	1	400
New Oil CT	2	200
Wind	3	200

***Hint*:** Make sure you enter in these technologies directly into the Mitigation Scenario as well. You do not have to add the addition size (this value will be inherited), but you do need to create the structure with the correct addition order as above.

4.3.7 Resource Costs

Finally, under the Resources section of the tree, you will specify the unit costs for indigenously produced and imported primary resources and secondary fuels. Use the following information to enter these costs.

Primary Resources (Indigenous production and imports):

- Coal - $20/tonne in 2010, rising to $30/tonne in 2040
- Natural gas - \$0.1/m^3 in 2010, rising to \$0.2/m^3 in 2040
- Crude Oil - $30/tonne in 2010, rising to $50/tonne in 2040

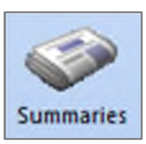
Secondary Resources (Indigenous production and imports):

- Diesel, Gasoline, LPG, Kerosene, Fuel Oil, Avgas and Lubricants - $300/tonne in 2010, rising to $400/tonne in 2040
- Electricity is not priced here since you are modeling electricity costs instead on the basis of input fuel and power plant costs.

Enter this base year cost data in the **Current Accounts** scenario since all of the scenarios assume the same unit costs. Cost projections can be entered once for the **Reference** scenario.

4.4 Cost-Benefit Results

In the Manage scenarios screen you can click the check boxes on the tree to indicate which scenarios should be calculated. To keep the results reasonably simple at first you may want to check only the Reference and Mitigation Scenarios.



In the Summaries view you can display the **Net Present Value** (NPV) of the mitigation scenario relative to another selected scenario (in this case the reference scenario). The NPV is the sum of all discounted costs and benefits in one scenario minus another (summing across all years of the study).

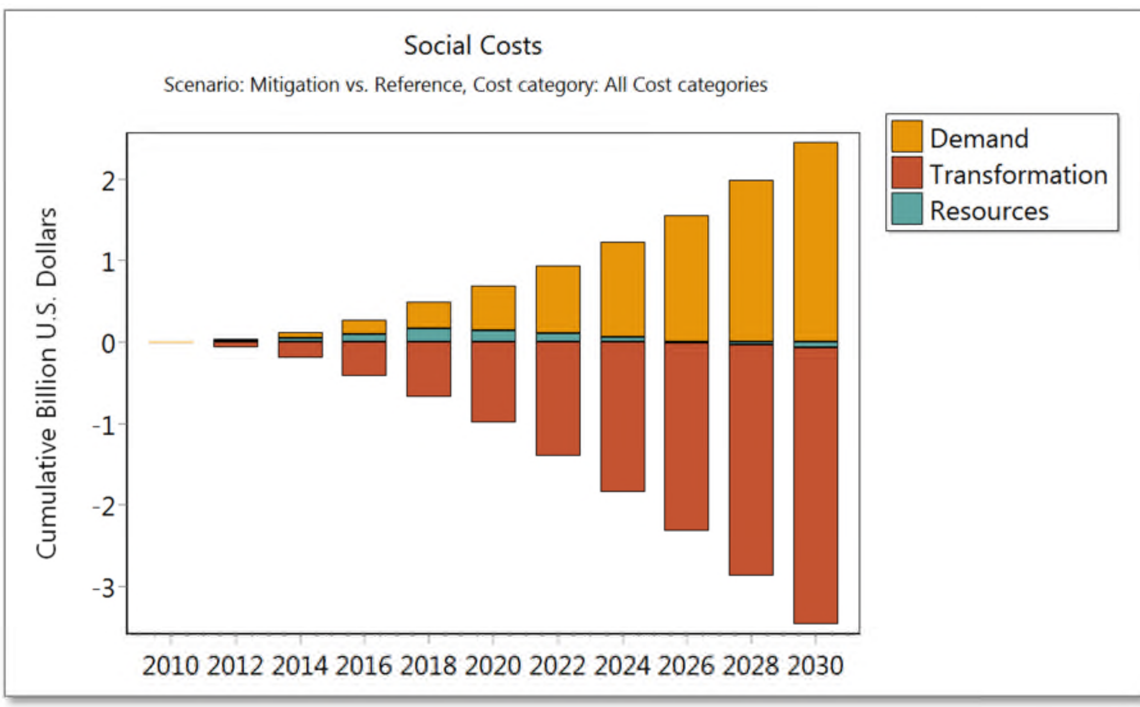
You should see results similar to those shown below. Notice that these indicate that on the demand- side the Mitigation scenario costs more than the Reference scenario (since here you are investing capital and O&M into energy efficiency measures) but that this is more than made up for in savings in the Transformation modules and in avoided resource requirements, so that the overall NPV of the mitigation scenario is negative indicating that it costs less than the Reference scenario.

Cumulative Costs and Benefits 2010-2040

Billion 2010 US Dollar. Discounted at 5.0% to year 2010, Compared with the Reference Scenario

Costs	Efficient Lighting	Efficient Refrigerators	CNG Buses	Natural Gas + Renewables	Industrial Efficiency	Mitigation
Demand						
Household	0.2	0.6	0.0	0.0	0.0	0.8
Industry	0.0	0.0	0.0	0.0	1.7	1.7
Transport	0.0	0.0	2.6	0.0	0.0	2.6
Commercial	0.0	0.0	0.0	0.0	0.0	0.0
Transformation						
Transmission and Distribution	0.0	0.0	0.0	0.0	0.0	0.0
Electricity Generation	-0.3	-0.3	0.0	-2.1	-0.5	-2.9
Charcoal Production	0.0	0.0	0.0	0.0	0.0	0.0
Oil Refining	0.0	0.0	0.0	0.0	0.0	0.0
Coal Mining	0.0	0.0	0.0	0.0	0.0	0.0
Resources						
Production	-0.1	-0.1	0.0	-2.2	-0.2	-2.2
Imports	-0.2	-0.2	-0.2	3.9	-0.9	1.9
Exports	0.0	0.0	0.0	0.0	0.0	0.0
Unmet Requirements	0.0	0.0	0.0	0.0	0.0	0.0
Environmental Externalities	0.0	0.0	0.0	0.0	0.0	0.0
Net Present Value	-0.4	0.0	2.4	-0.5	0.2	1.8
GHG Savings (Mill. Tonnes CO2 Eq.)	60.0	48.3	-9.3	987.1	120.0	1,033.1
Cost of Avoided CO2 (U.S. Dollar/Tonne CO2 Eq.)	-7.0	0.9	n/a	-0.5	1.3	1.8

You may also want to look at cost results graphically. You can do this in the Results View. Select the top branch in the tree and show results category Costs. Often it is most useful to view costs in terms of differences versus the Reference scenario. For example, try to display the following chart that shows the incremental cumulative discounted costs in the Mitigation scenario versus the Reference scenario.



Exercise 5: A Transportation Study

In exercise five you will use LEAP's transportation analysis features to construct a range of scenarios that examine different policies for cars and sport utility vehicles (SUVs). SUVs are the kind of large energy-intensive vehicles, the popularity of which is causing rapidly growing fuel consumption and greenhouse gas emissions, especially in the USA.

You will first use LEAP to construct a Current Accounts inventory of fuel use and selected emissions from these vehicles. Next, you will create a "Business as Usual" scenario that projects fuel use and emissions into the future under the assumption of no new policies to reduce fuel use and emissions. Finally you will create and compare a range of scenarios that examine measures designed to reduce fuel use and emissions.

As with other exercises, you will start by creating an Area and then setting up the basic parameters of the study.

Select menu option **Area: New Area**, or click on the **New Area** ( ) button on the main toolbar. Call the new area "**Transportia**" (or any other name you like). Check the radio button to create the area from default data then click OK.

5.1 Basic Parameters and Structure

Go to **General: Basic Parameters.**

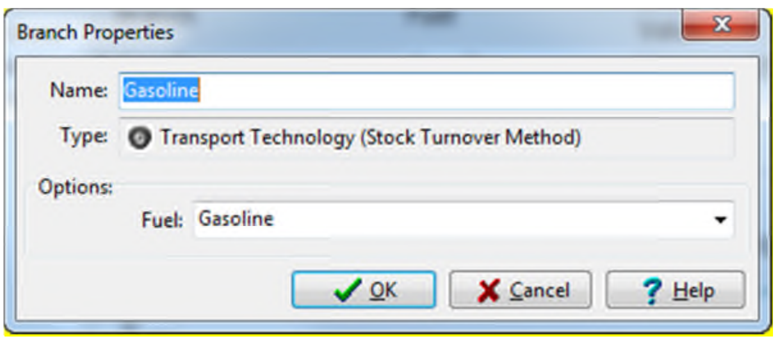
- On the Scope tab, make sure only the Energy Sector and Non-GHG environmental loadings boxes are checked. This study will not make use of Transformation, Costs or Resource data.
- On the Years tab, enter 2010 as the base year, 2011 as the First Scenario Year and 2030 as the end year.
- Transportia uses U.S. measurement units rather than the International S.I. units, so you will need to set different default units for your study. On the Default Units tab select **Gallons of Gasoline Equivalent** as the default energy unit, **Miles** as the default Distance unit, **Pounds/Million BTU** as the default energy-based emissions unit and **grammes/Vehicle-Mile** as the default transport-based emissions unit.
- On the Stocks tab, make sure the Top-down sales and stock data =box is checked and that the number of vintage years is 22.

You are now ready to enter your tree structure. First, Make You will create two major categories, one for **Cars** and one for **Sport Utility Vehicles** (SUVs). To add each of these click on the Add button ( ) above the tree and create each as a category branch ( ).

Under each category create subcategories for conventional **Internal Combustion Engine (ICE)** vehicles and one for the new type of **Hybrid-Electric Vehicles** (see box).

Under each of the conventional **Internal Combustion Engines** categories you will consider two alternative technologies, **Gasoline** and **Diesel**, so create two technologies.

When adding these make, sure you create them as Transport Technology (Stock Turnover) branches ( ), and select the correct fuel for each as shown below. Under the **Hybrid** categories you will only consider gasoline vehicles.



Hybrid-Electric Vehicles

Hybrid vehicles combine a small internal combustion engine with an electric motor and battery to reduce fuel consumption and tailpipe emissions. Energy lost during braking is captured and returned to the battery in a process called "regenerative braking."

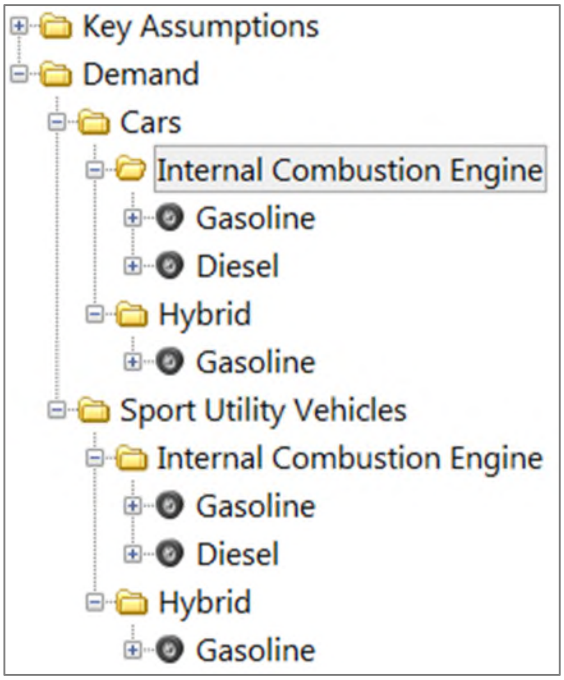
Unlike electric vehicles, hybrids have the advantage that they do not need to be “plugged-in” to the electric supply. Hybrid engines operate more efficiently and produce less pollution than conventional internal combustion engines.

Hybrids should be competitively priced when all the costs over the life of the vehicle are included. This is because any cost premium is likely to be offset by fuel savings.

By combining gasoline with electric power, hybrids will have the same or greater range than traditional combustion engines. Hybrids offer similar performance compared to conventional internal combustion engine vehicles.

The Toyota Prius: one of the available hybrid-electric cars.

Your completed tree structure should look something like this:



5.2 Current Accounts Data

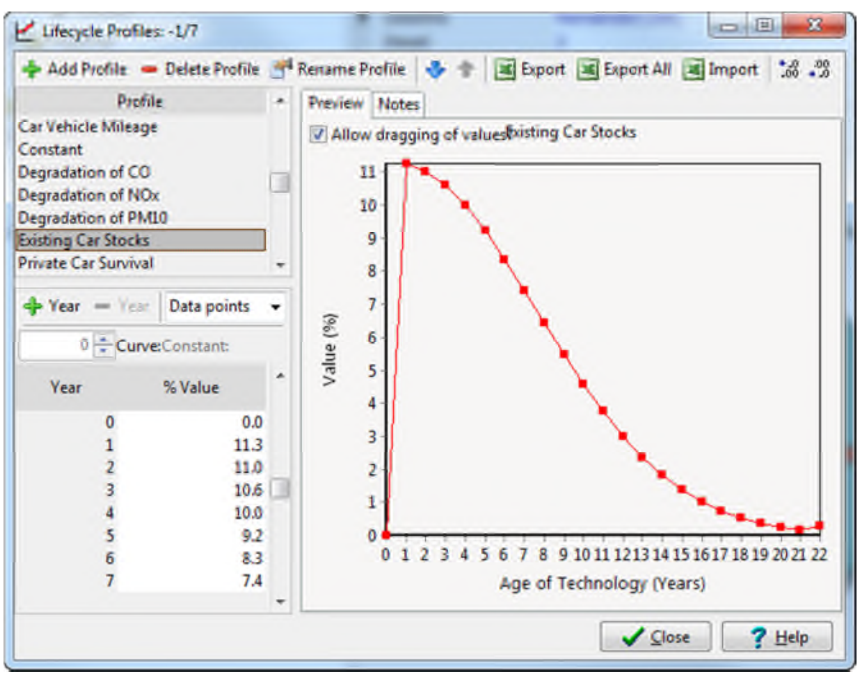
You are now ready to enter the following base year (Current Accounts) data for your analysis.

- There were 6 million cars and 4 million SUVs on the road in the base year (2010), not including new cars sold in that year.
- The existing stock of cars and SUVs is made up of vehicles of different ages (vintages). The percent share of each of these vintages is given in the table on the right.

*Hint: Create a new **lifecycle profile** named "**Existing Car Stocks**" to represent the distribution of vintages within the base year stock. The Lifecycle Profiles screen is accessed under the **General** menu. First add a profile then enter the data shown on the right. The figure below shows how this information will look when entered into the lifecycle profile screen. Back in Analysis View, go to the **Stock share** tab for each technology branch and in the **Stock Vintage Profile** column, select the **Existing Car Stocks** profile.*

Age (Years)	% of Stock
0	0.00
1	11.26
2	11.04
3	10.60
4	9.99
5	9.22
6	8.34
7	7.40
8	6.43
9	5.48
10	4.58
11	3.75
12	3.01
13	2.37
14	1.82
15	1.38
16	1.02
17	0.74
18	0.53
19	0.37
20	0.25
21	0.17
22	0.27

Important: Note that LEAP requires that all **stock vintage profiles** have zero vehicles of age zero years. This is because the data you enter for base year stocks should not include those new vehicles sold in the base year. These vehicles are specified using the sales variable.



- In the base year, 0.8 million cars were sold, and 0.5 million SUVs. As these and other vehicles age they will gradually be retired from the vehicle stock (taken off-road). A survival profile describing this retirement of vehicles can be represented by an exponential function of the following type:

$$S_t = S_{t-1} \cdot e^{t \cdot 0.02}$$

  Where S is the fraction of surviving vehicles, t is the age in years of the vehicle.

  > ***Tip:*** *Create another* ***lifecycle profile*** *named "****Private Car Survival****" to represent the percent survival of vehicles as they get older. First add a profile then create an exponential curve with the constant parameter –0.02. Back in Analysis View, go to the* ***Sales Share*** *tab for each technology branch and in the* ***Survival Profile*** *column, select the* ***Private Car Survival*** *profile.*

- Among internal combustion engine cars and SUVs, 2% of sales and 2% of the base year stock is diesel vehicles. The remainder was gasoline vehicles.
- 0.05% of the base year stock of cars is Hybrid vehicles. 0.5% of the cars sold in the base year were Hybrids.
- All new cars and new SUVs are assumed to be driven 15,000 miles in their first year on the road. As the age of vehicles increases they are driven less. This decrease in driving can be represented by an exponential function, similar to the one above, and also with the constant parameter –0.002.
- The base year fuel economy of the different types of vehicles is shown in the following table. Fuel economy is assumed to stay constant as a vehicle's age increases.
- No hybrid SUVs are currently available.

Fuel Economy in 2010 (Miles per Gallon)

	Gasoline ICE	Diesel ICE	Gasoline Hybrid
Cars	25	28	40
SUVs	15	17	23

5.3 Business as Usual Scenario

You are now ready to create a "Business and Usual" scenario (BAU) that projects fuel use into the future under the assumption of no new policies to reduce fuel use and emissions.

Go to the **Manage Scenarios** screen ( ) and click the Add button ( ) to add a new a new scenario named "Business as Usual" (BAU). Then enter the following data:

- Sales of vehicles are expected to double, reaching 2 million vehicles/year in 2030. However all this growth is expected within the SUV market segment. Annual car sales remain at 0.8 million/year in 2030, while annual SUV sales more than double, reaching 1.2 million in 2030.
- Hybrid market penetration remains constant in the BAU scenario. No hybrid SUVs are introduced.
- In the absence of new standards, fuel economy of all vehicles remains unchanged in the future.

5.4 Results

You are now ready to view BAU results for sales, stocks, mileage and fuel use. Check your results against each of the following categories for the years 2010, 2020, and 2030.

BAU Scenario Results

Annual Sales of Vehicles (Thousands)					
Cars	Internal Combustion Engine\Gasoline		780	780	780
	Internal Combustion Engine\Diesel		16	16	16
	Hybrid\Gasoline		4	4	4
SUVs	Internal Combustion Engine\Gasoline		490	833	1,176
	Internal Combustion Engine\Diesel		10	17	24
		Total	1,300	1,650	2,000
Stock of Vehicles (Millions)			**2010**	**2020**	**2030**
Cars	Internal Combustion Engine\Gasoline		6.7	6.9	6.9
	Internal Combustion Engine\Diesel		0.1	0.1	0.1
	Hybrid\Gasoline		0.01	0.03	0.04
SUVs	Internal Combustion Engine\Gasoline		4.4	5.9	8.9
	Internal Combustion Engine\Diesel		0.1	0.1	0.2
		Total	11.3	13.1	16.2
Annual Vehicle-Mileage (Billion Vehicle-Miles)					
Cars	Internal Combustion Engine\Gasoline		94.8	98.2	99.1
	Internal Combustion Engine\Diesel		1.9	2.0	2.0
	Hybrid\Gasoline		0.1	0.5	0.5
SUVs	Internal Combustion Engine\Gasoline		62.8	85.9	128.2
	Internal Combustion Engine\Diesel		1.3	1.8	2.6
		Total	160.9	188.3	232.5
Fuel Consumption (Million Gallons Gasoline Eq.)					
Cars	Internal Combustion Engine\Gasoline		3,793	3,929	3,965
	Internal Combustion Engine\Diesel		69	72	72
	Hybrid\Gasoline		3	12	13
SUVs	Internal Combustion Engine\Gasoline		4,186	5,723	8,546
	Internal Combustion Engine\Diesel		75	103	154
		Total	8,125	9,838	12,750

Hint: *if your results differ by more than a few percent from those shown above, first check, and if necessary debug, your Current Accounts data. First eliminate the possibility of errors in your Current accounts data before trying to debug future values.*

5.5 Current Accounts Emissions Factors

Next, you will enter environmental loadings data describing some of the pollution loadings associated with the vehicles you are studying. To keep data entry to a minimum, for this short exercise you will examine only four pollutants: the greenhouse gas, Carbon Dioxide (CO_2) and three pollutants contributing to local air pollution: Nitrogen Oxides (NO_x), Carbon Monoxide (CO), and Particulate matter of size less than 10 microns (PM_{10}).

CO_2 emissions from vehicles are dependent only on the type of fuel used and the efficiency (fuel economy) of the vehicle. Therefore they can be specified in terms of emissions per unit of energy consumed. The measurement units used are Pounds of CO_2 per MMBTU of fuel consumed.

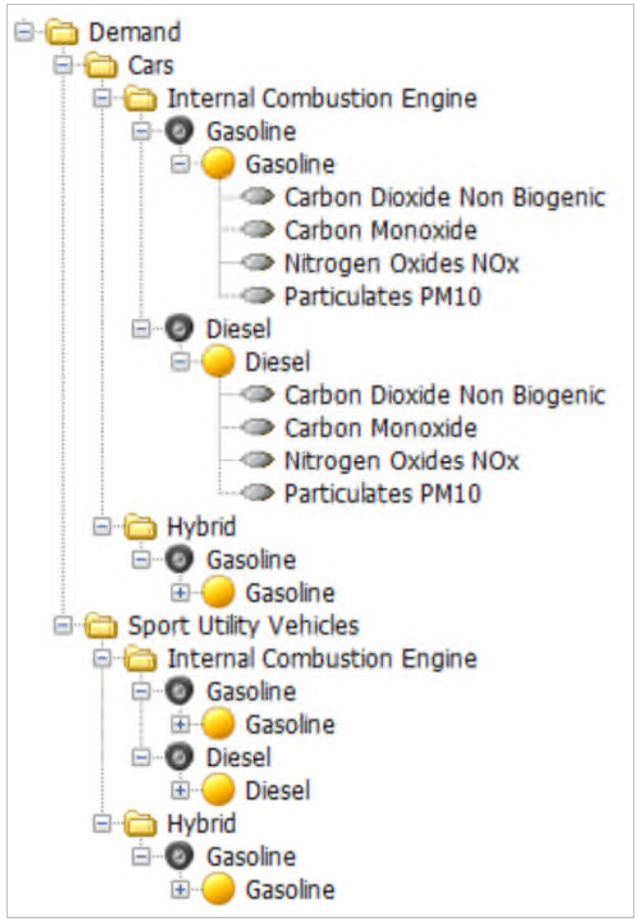
Local air pollutants are much more dependent on the type of control technology used in the vehicle, and also tend to be regulated by the Government at certain levels. For this reason these emission factors tend to be specified per vehicle-mile traveled. The units used are grammes of pollutant per Vehicle-Mile traveled. Because emissions of these pollutants depend critically on the performance of the catalytic converter or other control technology used in the vehicle, they can also be expected increase per vehicle-mile quite substantially as vehicles get older. For this reason, in addition to specifying the emission factors for new vehicles, you will also need to specify degradation factors for each pollutant that specify how emissions increase as vehicles get older.

The Government of Transportia is continually reviewing and improving its regulations for vehicle emissions, based on recommendations from its Environmental Protection Agency. Since 2000, the emissions standards for new vehicles have been tightened a number of times. The following table specifies how average emission factors for each type of new vehicle have evolved since 2000.

Car	Pollutant	Units	2000	2005	2014	New Standard?
Gasoline	CO2	lbs/MMBTU	159.50			
	CO	g/veh-mile	6.20	5.30	3.50	1.70
	NOx	g/veh-mile	0.44	0.35	0.04	0.03
	PM10	g/veh-mile	0.40	0.30	0.20	0.05
Diesel	CO2	lbs/MMBTU	161.00			
	CO	g/veh-mile	1.05	0.54	0.20	
	NOx	g/veh-mile	0.60	0.27	0.08	
	PM10	g/veh-mile	1.50	1.50	0.50	0.20

Data on emissions from hybrid vehicles are not yet available. However, because they are regulated in the same way as conventional internal combustion engine gasoline vehicles they are assumed to have the same emission factors as that type of vehicle.

One set of standards is due to come into force for vehicles manufactured in 2014, the Government is also considering introducing a new set of emissions regulations, with the proposed new emission factors, listed in the final column. This proposed set of regulations has not yet been approved and thus, the date when this will come into law and affect new vehicles being manufactured has not yet been decided.



To enter the above data into LEAP you will first need to create a series of environmental loading branches ( ) under each of your technologies ( ). Go to the environmental loading tab, and use the Add button ( ) to add CO_2, CO, NO_x and PM_{10} effects. Once complete, your tree structure should appear as shown on the right.

It is important to set the correct units for each pollutant. For CO_2, set the Type to "**Per unit energy consumed**" and then select units Pound/MMBTU. For the other pollutants select type "**Per unit travel**" and then select units: grammes/vehicle-mile.

Since the above data represent emissions standards that came into force governing the manufacture of new vehicles in a specific year, you will need to enter the data for 2000, 2005, and 2014 using a step function. Since the year for the new standard has not yet been decided you can specify that year using a **Key Assumption** named "New Reg Year". Set the value of this variable to 2050 so that the new standards will, in effect, not be used in any initial scenario calculations.

So for example, you might create an expression to represent CO emissions from gasoline vehicles as follows:

Step(2000, 6.2, 2005, 5.3, 2014, 3.5, Key\New Reg Year, 1.7)

Finally for the three local air pollutants you will also need to specify how the emission factors increase over time, as each vintage of vehicles on the road gets older. To do this you will again need to go to the lifecycle profile screen (**Alt-L**) and create three named profiles to represent degradation of CO, NO_x and PM_{10}. The degradation of these can each be represented by exponential curve with the following constant parameters: CO=0.006, NO_x=0.008, PM_{10}=0.005. Back in Analysis View, go to the **Environmental Loading** tab for each technology branch and in the final **Degradation Profile** column, select the appropriate profiles.

Emissions of carbon dioxide (CO_2) depend only on the amount of fuel burnt in the vehicle. Therefore a single constant emission factor can be used, and no degradation curve is required. Hence, for CO_2 emission factors leave the **Degradation Profile** set to constant.

> ***Hint:*** *To avoid entering the above step function under every technology branch, you may choose to create key assumptions for each set of emission factors and link to them under each technology.*

5.6 Business as Usual Emissions

Projecting emissions into the future is simple for BAU, since this scenario assumes no new policies to reduce emissions. Check your emissions results for the years 2010, 2020, and 2030 against the following table.

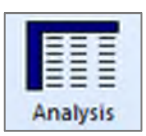
BAU Scenario Results

Pollution Emissions	2010	2020	2030
CO2 (Millions of Tonnes)	70	85	110
CO (Thousand Tonnes)	1,079	882	930
PM10 (Thousand Tonnes)	69	52	54
NOx (Thousand Tonnes)	82	36	14

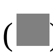
5.7 Policy Scenarios

You are now ready to examine a series of policy scenarios. You will start by examining a range of different measures individually, and then later combine them into different combinations of integrated scenarios.

5.7.1 Improved Fuel Economy (IFE)



The first policy being considered by the Government is to introduce stricter fuel economy standards for conventional (i.e. non-hybrid) internal combustion engine gasoline and diesel vehicles. The proposed new standard will require new cars and SUVs to increase their fuel economy by 5% in 2015, by 10% in 2020 and by 20% in 2025 (all values relative to the base year fuel economy).

To model this policy, first go to the **Manage Scenarios** screen (), and then create a new scenario below the BAU scenario called "Improved Fuel Economy". To reduce data entry, you may want to create a new **Key Assumption** to represent the above improvements. For example, you could create a variable called "Target Economy", set its Current Accounts value to 1 and then in the **Improved Fuel Economy** scenario, specify its future values using the following expression:

Step(2015, 1.05, 2020, 1.1, 2025, 1.2)

Next, go to the **Fuel Economy** tab for each appropriate vehicle type and enter the following expression for the **Improved Fuel Economy** scenario:

BaselineValue*Key\Target Economy

This will cause future fuel economy to be calculated as the product of the BAU fuel economy and the target fuel economy.

5.7.2 Increased Market Penetration of Hybrid-Electric Vehicles (HYB)

A second policy being considered is to increase the market penetration of hybrid-electric vehicles. This is likely to be done through a range of consumer and producer tax incentives and subsidies. It is expected that with these incentives hybrids can increase their market penetration so that by 2030, 50% of the market for cars and SUVs is for hybrids.

Hybrid fuel economy is expected to improve as the technology matures. Hybrid Gasoline cars reach a fuel economy of 60 MPG by 2030, while Hybrid SUVs reach 35 MPG.

Create a new scenario called "Hybrids" and enter an **Interp** function to specify how the future sales of cars and SUVs will be split between conventional ICEs and Hybrids.

5.7.3 Increased Market Penetration of Diesel Cars and SUVs (DSL)

Because of their higher efficiency and GHG benefits, the Government is also considering a policy to increase the market penetration of diesel cars and SUVs. However, it is not clear that whether these benefits are justified given that diesel vehicles have higher emissions of local air pollutants, especially particulates. It is expected that with various incentives diesels could increase their market penetration to 30% of the market for conventional ICEs by 2030.

Create a new scenario called "Diesel" and enter an **Interp** function to specify how the future sales of ICE cars and SUVs will be split between diesel and gasoline vehicles.

5.7.4 New Tailpipe Emissions Standards (TAIL)

As noted above in section 5.3, the Government is also considering introducing a new and more stringent tailpipe emissions standard. The Government wants to see what the emissions reductions benefits will be of introducing this new standard in 2020, both as a standalone policy and also as part of a wider package of measures to reduce pollution and combat climate change.

> ***Tip:*** *Create a new scenario called "Tailpipe Standard" then simply edit the value of the* ***Key Assumption*** *named "New Reg Year" that you created earlier for this new scenario. This variable represents the date when the new tailpipe emissions standard will be introduced. Change it to 2020.*

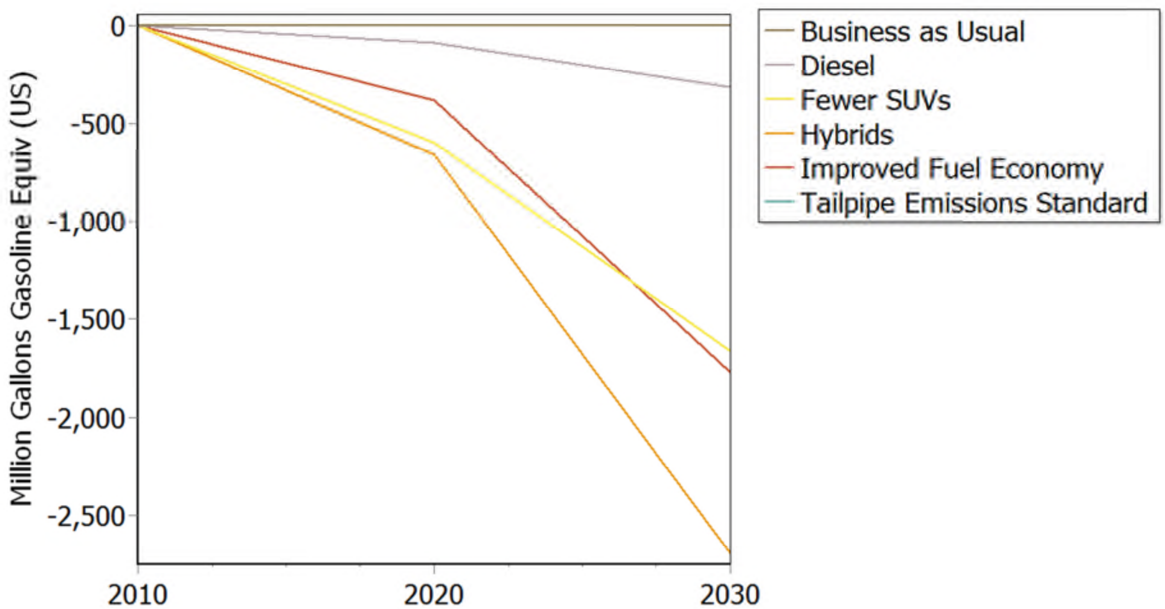
5.7.5 Promotion of Cars over SUVs (CAR)

The Government is also considering a series of measures to discourage consumers from purchasing large and fuel-inefficient SUVs. With a series of policies such as fuel or carbon taxes, and motor vehicle insurance based on vehicle weight or fuel economy, it is expected that SUV sales in 2030 can be reduced by 500,000 while car sales will increase by a similar amount relative to the business as usual scenario.

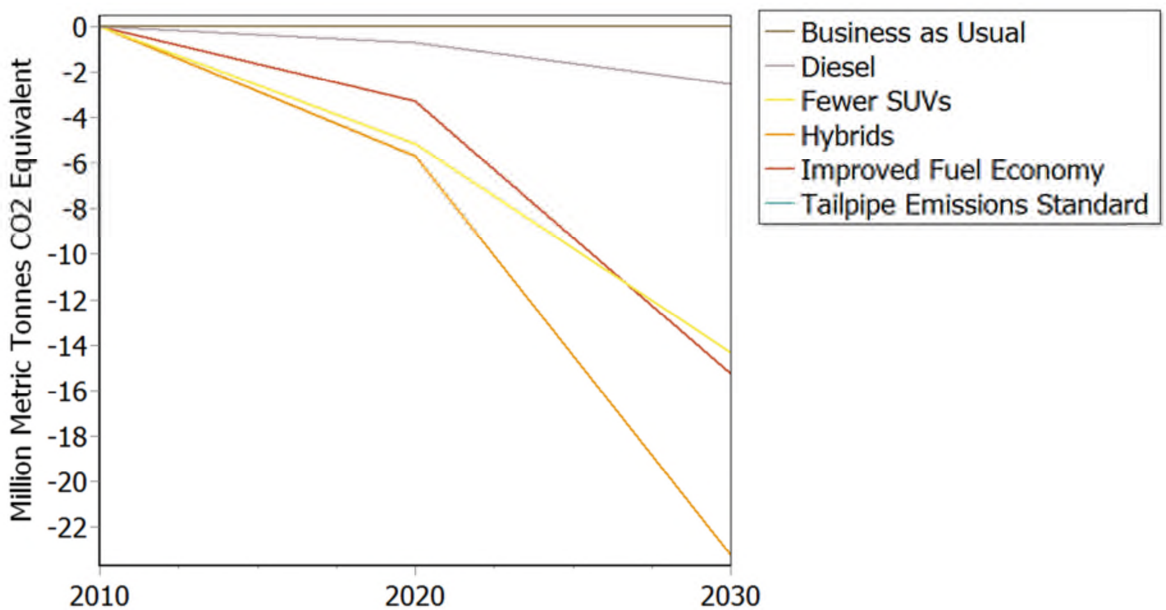
5.8 Results

You are now ready to view the results of your scenarios. Compare the results you get to the charts on the following pages.

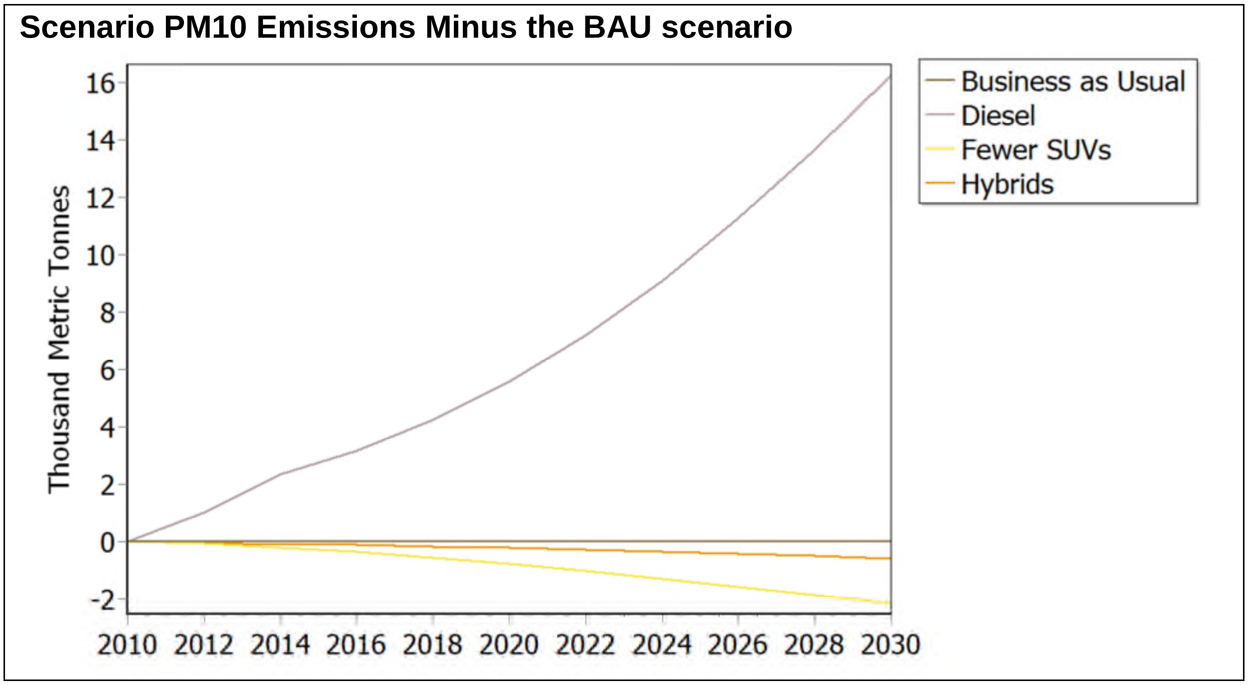
Scenario Energy Demand Minus the BAU scenario



Scenario CO_2 Emissions Minus the BAU scenario



For these two charts, results for scenario “tailpipe emissions standard” are same as for BAU scenario.



Notice that some scenarios result in environmental trade-offs. In particular, notice that increased use of diesel vehicles leads to reductions in CO2 emissions but to significant increase in PM_{10} and NO_x.

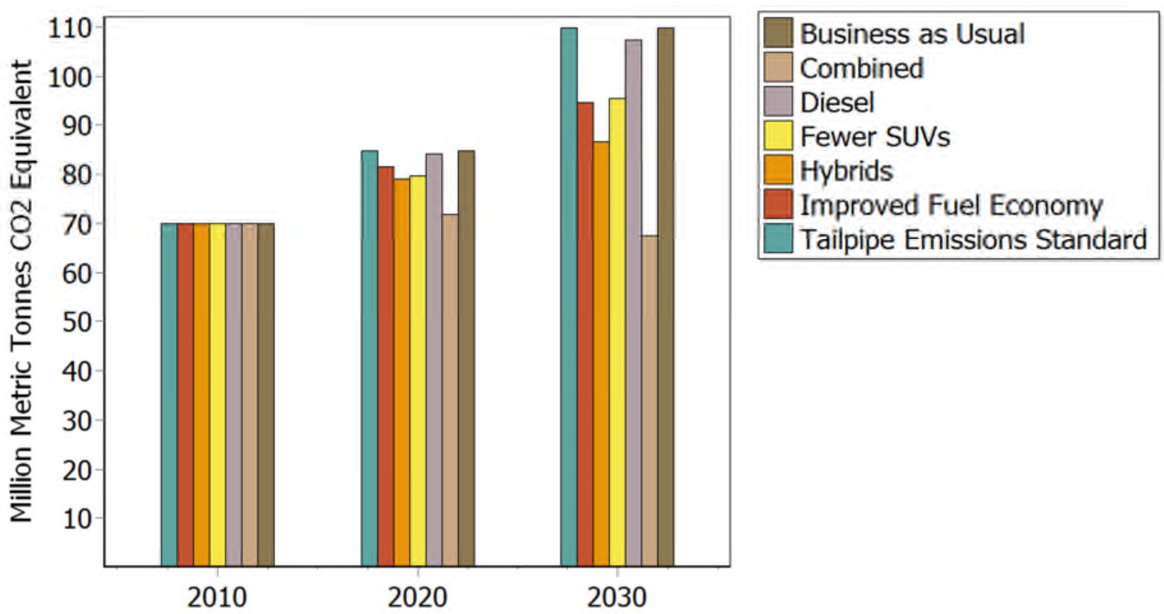
You can try creating your own combinations of scenarios. Start by combing the following scenarios:

- Improved Fuel Efficiency Standards for Conventional Gasoline Vehicles.
- Introduction of a new Tailpipe Emissions Standard.
- Increased Market Penetration of Hybrid-Electric Vehicles.
- Promotion of Cars over SUVs.

Go to the **Manage Scenarios** screen ( ) and create a new scenario named "Combined" that inherits from the BAU scenario. On the inheritance tab, click on the add button ( ) to add each of the above named scenarios to the area marked "Also Inherits From". You do not need to enter new data for this scenario, as it will automatically inherit the data entry expressions used in each of the scenarios from which it inherits.

Now compare the results for this new combined scenario to the individual policy scenarios and to the BAU scenario.

Scenario Global Warming Potential (all GHGs) Compared



Exercise 6: Least-Cost Electric Generation

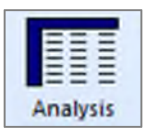
In this simple exercise you will use LEAP's optimization features to investigate a range of different technologies for generating electricity. You will compare the costs of generating electricity including the capital, operating and maintenance and fuel costs of those technologies and you will perform sensitivity analyses to examine which options are the cheapest when the externality costs of local air pollution are either included or excluded. You will then go on to explore the implications of a cap on CO2 emissions – how it alters the set of technologies chosen and how it affects the overall cost of the scenario.

This exercise will also show you how to import a year's worth of hourly electrical load data into LEAP, as a way of describing how demands vary among seasons and times of the day.

Please note that this exercise is a highly simplified representation of an electric generating system and the data values provided are not intended to be realistic. ***Please do not cite or use the data shown in this exercise in any real study.***

NB: this exercise requires Microsoft Excel as well as LEAP.

6.1 Entering Electric Generation Data

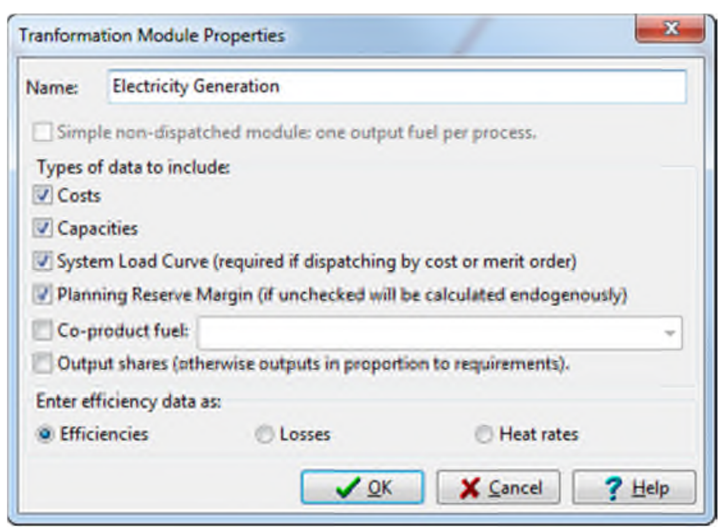


Start by opening the LEAP area "Optimization Example Partial.leap", which will be provided to you. This data set is partially completed already.

Under the Demand branches, a single branch specifies that the demand from electricity grows from nothing in the base year (2010) to 200 Thousand GW-Hrs in the end year (2020). This information is entered for the Final Energy Intensity variable under a single branch in the Current Accounts scenario. In this simple exercise the same energy demand assumptions will be used in all scenarios.

Now look at the Transformation tree branches. You will see a single module describing Transmission and Distribution losses. Here we have created a simple Transformation module containing the simple assumption of 10% electrical losses. This value is assumed to stay the same in all years and across all scenarios.

Your first data entry task is to create a new module that will be used to describe the various possible Electric Generation technologies.



Start by adding a new Transformation module called **Electric Generation** and set its properties are set to include costs, capacities, a system load curve and a planning reserve margin. Efficiency data should be set to be entered directly (as percentage efficiency values). Make sure the new module appears below the Transmission and Distribution module in the Tree branch structure.

Once you have created the module you can start to enter the basic data describing its various technologies. Enter all of the following data for the **Current Accounts** scenario. Set the planning reserve margin to 10% and make sure the module has a single output fuel Electricity.

You can leave the default properties for the output fuel unchanged. No data should be entered for import and export targets for this output fuel.

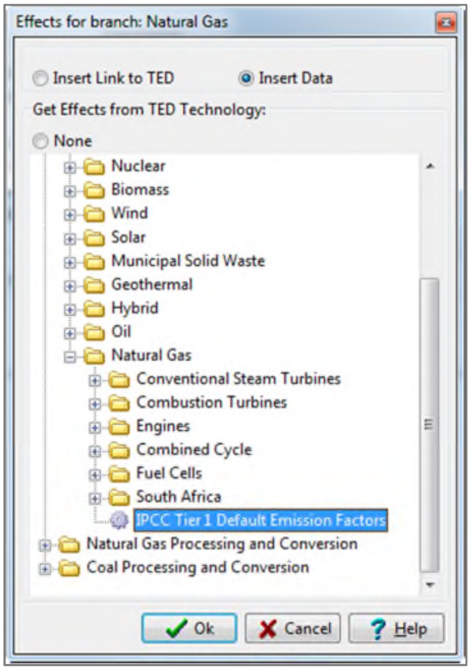
Next you can specify the set of electric generation technologies to be evaluated. Create each one as a separate process within the **Electric Generation** module, and do this while editing the **Current Accounts** scenario. The following table provides the data you will need to define these processes.

Technology	Feedstock	Efficiency (%)	Max Availability (%)	Capacity Credit (%)	Capital Cost (Thou $/MW)	Fixed O&M Cost ($/MW)	Variable O&M Cost ($/MWh)	Fuel Costs	Lifetime (yrs)
NGCC	Natual Gas	48	90	100	1900	9	3	$8/MMBTU	30
Wind	Wind	100	35	25	2600	17	4	n/a	25
Coal	Coal Bit	35	90	100	2200	40	3	$100/Tonne	30
Hydro	Hydro	100	60	50	9000	30	5	n/a	40

Entering Cost Data

Most of the above data in this table needs to be entered for the various variables defined for each process. Feedstock fuel costs need to be specified within the **Resource** branches of the tree. Enter the natural gas and coal fuel costs at the Indigenous Cost variable (under the Resources\Primary branches).

Finally, to ensure the energy balances are correctly calculated, make sure that you specify very large reserves of natural gas and coal bituminous and very large availability of wind and hydro power. In Current Accounts, enter one trillion GJ as the **Base Year Reserves** for these fuels under the Resources\Primary branches. Enter the same value for wind and hydro availability in the **Yield** variable.



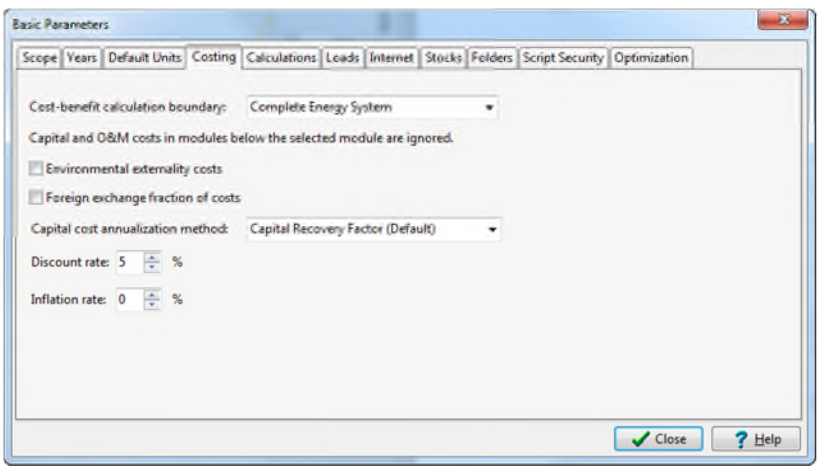
In addition to the data in the above table, enter a 5% **Interest Rate** and set the **First Simulation Year** to the year 2000 for all processes. Make sure the Exogenous Capacity variables are all set to zero. Finally, set the Dispatch Rule to **RunningCost.**

In this simple exercise we are not trying to represent actual historical patterns of dispatch, and thus we will not be using the **Historical Production** variable to tell LEAP how much of each process to dispatch. Instead we will be using LEAP's optimization calculations to calculate process capacity values consistent with minimizing costs while meeting demands. Setting the First Simulation Year to a date before the base year of the study tells LEAP to ignore the **Historical Production** variable.

Before leaving the processes branches make sure you have specified a set of emission factors for each process. Using the techniques you first followed in Exercise 1.5 add IPCC Tier 1 emission factors for the coal and NGCC (natural gas) power plants. Connect each relevant feedstock fuel branch (those marked with the icon) and the IPCC Tier 1 technologies the **Environmental Loading** tab, and then clicking the TED button ( ). This will display the box shown on the right.

Finally, visit the General: Basic Parameters: Costing screen (shown below). Here you will need to set a few options that will be used to calculate cost results. Make sure this screen has the following settings:

- The cost-benefit accounting boundary should be set to **Complete Energy System.**
- Environmental Externality costs can initially be switched off. Also, foreign exchange costs are not used in this exercise so that can also be left off.
- Set the discount rate to 5%
- The capital cost annualization method should be set to **Capital Recovery Factor** (the default). This method is required when using optimization.



6.2 Creating Load Shapes by Importing Hourly Load Data

Next you will create a set of data that describe how the electric generation load varies among different seasons and times of day. The variations in the electric load are important in determining what mix of base load or peak load plants make should be built and operated.

Creating and using this load shape in LEAP is a four-step process.

1. **Time Slices:** First you will specify a set of time slices into which each year will be divided. In this example we will divide each year into 4 seasons and each season will

be further divided into days and nights.

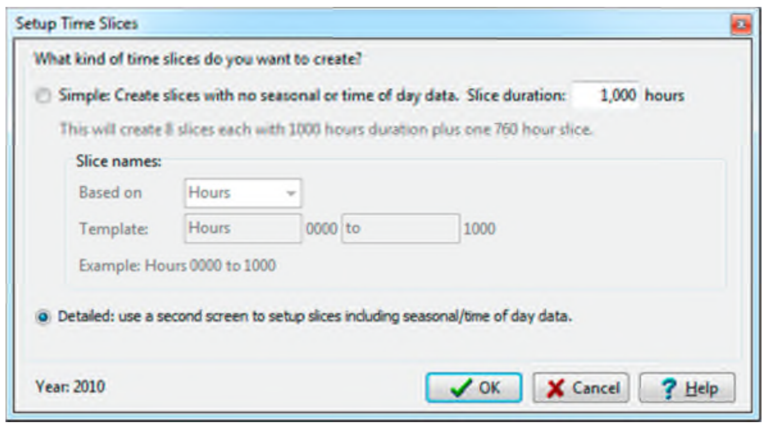
2. **Hourly Data Spreadsheet:** Second, you will select a set of predefined hourly data that describes how the electric load varied across all 8760 hours of a single year. This hourly data is predefined and stored in a separate Microsoft Excel spreadsheet provided to you.

3. **Yearly Shape:** Third, you will use LEAP's YearlyShape screen to import the hourly data contained in the spreadsheet and automatically map it to the time slices you have created.

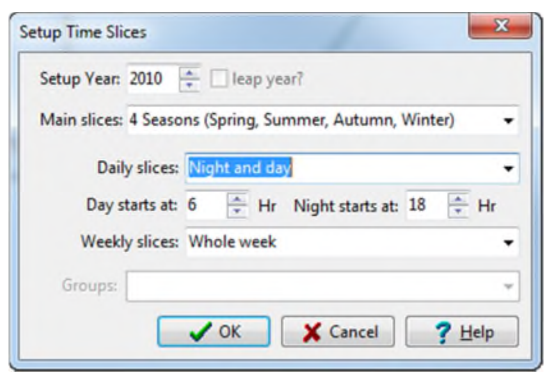
4. **System Energy Load Shape:** Finally, you will use this newly created load shape in your LEAP data set by assigning it to the System Energy Load Shape variable in your analysis.

Let's follow each of those steps in detail.

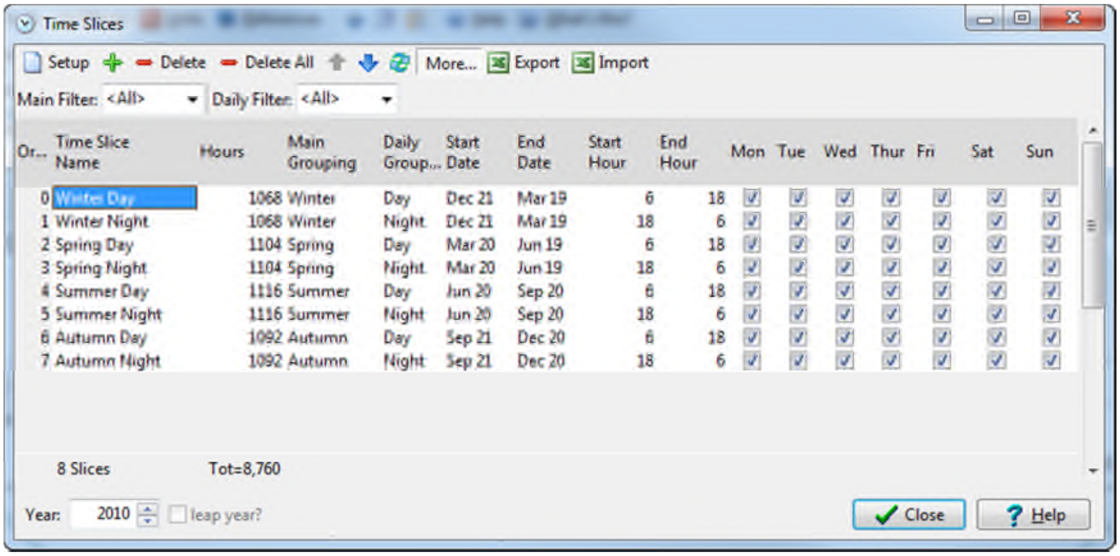
1. **Time Slices:** First let's create a detailed set of time slices. Go to the General: Time Slices screen and click the Setup toolbar button ( ). Choose "Detailed: use a second screen to setup slices including seasonal/time of day data."



Set up the time slices as shown here so that the main slices are 4 seasons (spring, summer, autumn, winter) and the daily slices are day and night. In this exercise we will not use any weekly slicing.

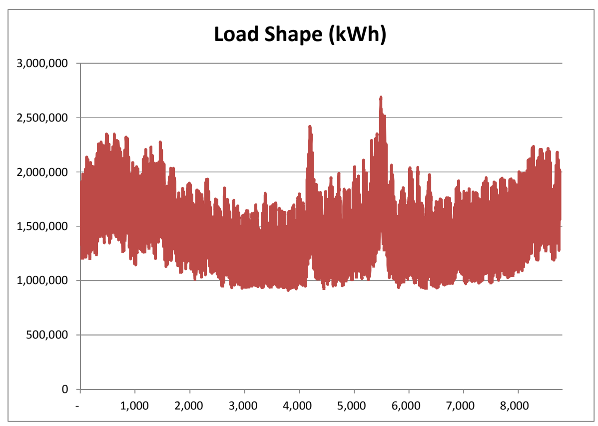


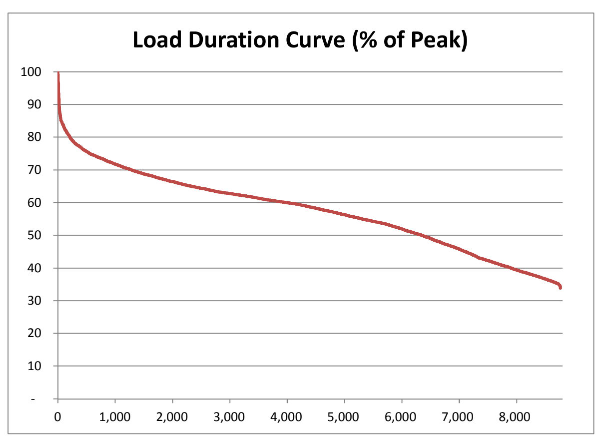
Once you click OK, LEAP will generate the detailed set of time slices shown below. Each slice will include data describing its number of hours, its start and end dates and the days of the week covered by each slice. You can click the **More…** button on the toolbar to see this detailed information. Notice that for non-leap years the total number of hours in all time slices will be 8760 hours. This automatically generated time slice data can be edited manually on this screen but typically that is not necessary, which is the case in this example. You can now return to the main screen.



2. **Hourly Spreadsheet Data:** Next, open up a copy of Microsoft Excel and load the spreadsheet.

\My Documents\LEAP2011 Areas\Optimization Example\Sample Load Shape.xls (or .xlsx)

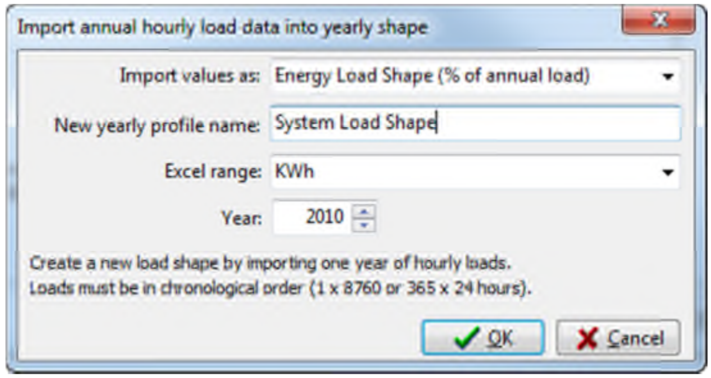




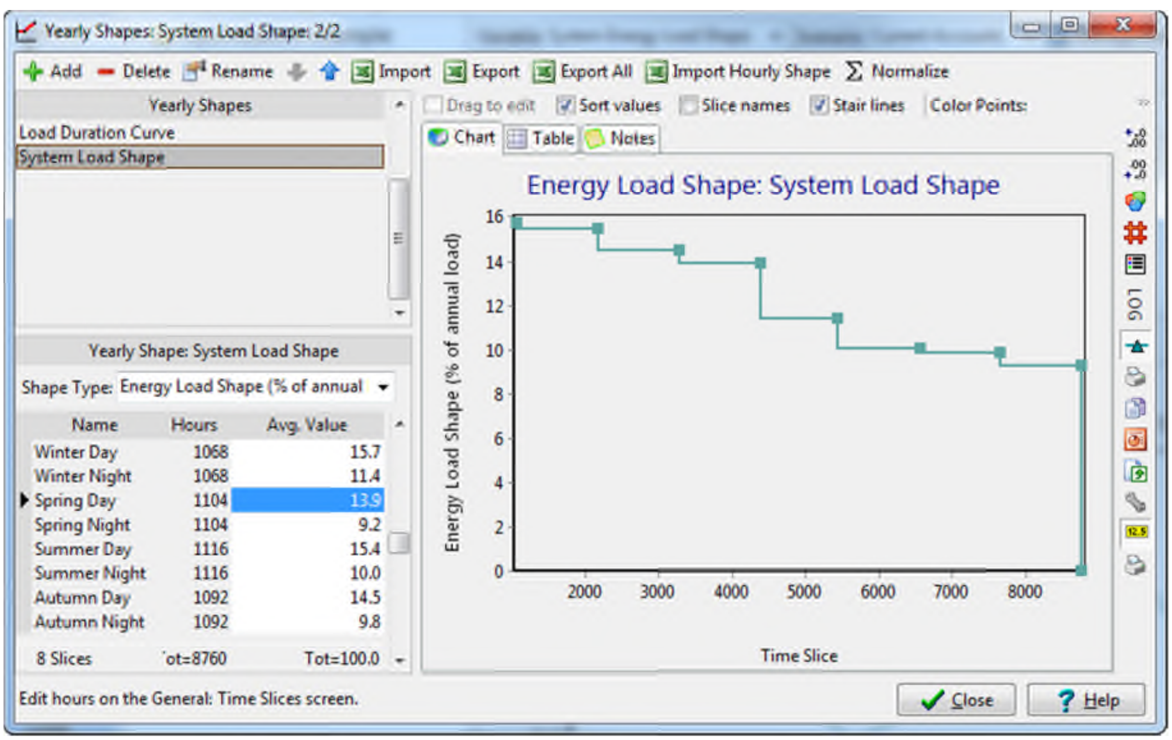
Notice that this spreadsheet contains hourly data for all 8760 hours of a single year, from the first hour of January 1st to the last hour of December 31st. The numbered hours are listed in the "Hour" column (column A) from 1 to 8760 while the corresponding electric demands are listed in the KWh column (column B). These values are plotted in the "Load Shape" chart in the spreadsheet (shown here). Notice the large variations both among seasons and between different times of the day and days of the week.

In columns C, D and E this same data has been reorganized by sorting the values from high to low and normalizing them in percentage terms against the annual peak value in order to produce a standard Load Duration Curve that shows how demand varies from the hour with the highest demand to the hour with the lowest. This Load Duration Curve is also shown here. Notice that as a result of the sorting operation, the load duration curve loses any information about seasons, days of the week or times of the day.

3. **Yearly Shape:** You will now import this hourly data into LEAP. Keeping Excel open, go to the General: Yearly Shapes screen and select the toolbar option **Import Hourly Shape.** A dialog box will appear as shown here. Set this up to import values as an energy load shape (this type of load shape is required when using optimization in LEAP). Choose the Excel range named "KWh" as the import range: this range contains the KWh values in column B of the spreadsheet. Finally, remember to enter a name for the new yearly shape. We suggest you name it "**System Load Shape**".



When you click OK, LEAP will import all of the hourly values in the spreadsheet and automatically map these values to the time slices you specified in step 1 above. The result will be a yearly shape that should look like the one shown below. Notice that in this screen shot we have used the chart options to organize the chart so that it shows values sorted from high to low.

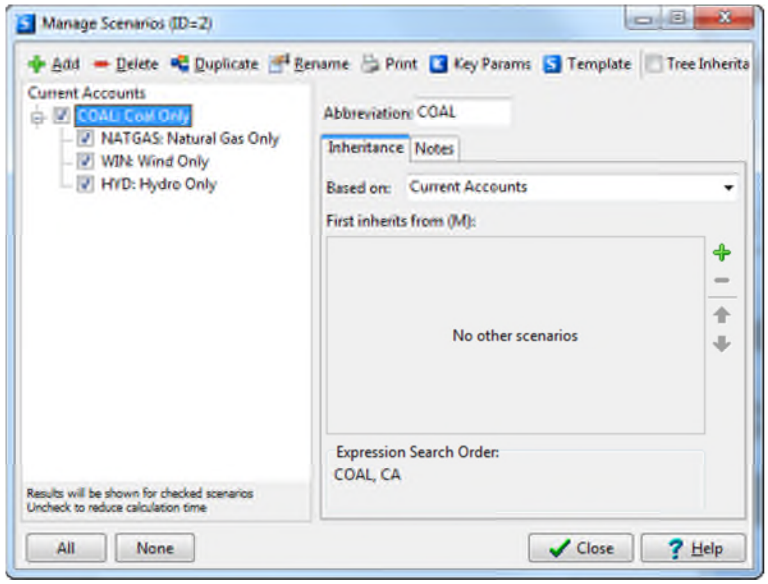


4. **System Energy Load Shape:** The final step in using this is data requires that you assign this newly created load shape to the System Energy Load Shape variable. Exit the YearlyShape screen and then in Analysis view locate the Transformation\Electric

Generation branch. In Current Accounts, enter the following expression for the System Energy Load variable:

YearlyShape(system load shape)

6.3 Simulation Scenarios to Explore Technology Characteristics



You are now ready to explore the costs and emissions associated with different technologies. Before exploring a least-cost scenario using LEAP's optimization features, let's first set up some very simple scenarios each of which looks at just a single generation technology. Go to the Manage Scenarios screen ( ) and create a first scenario named **Coal Only** that inherits from your Current Accounts data. Next create three more scenarios each of which directly inherits from the Coal scenario. Name these: **Natural Gas Only**, **Wind Only**, and **Hydro Only**. Once these have been created, the Manage scenarios screen will look like the screen shown here. NB: to minimize data entry it is important that the four additional scenarios inherit directly from the Coal scenario.

Once you have created these five scenarios return to the main screen and then select the **Endogenous Capacity** variable for the first scenario **Coal Only**. Use the plus button ( ) on the right of this screen to add the Coal process to this list and enter the value of 100 MW for the Addition size for this variable.

Doing this tells LEAP that in this scenario LEAP should automatically add coal capacity whenever it is needed. In LEAP's standard **simulation** calculations it is up to you to tell LEAP *what* types of power plants to add, although LEAP will decide *when* to add them. Later on, when we come to use LEAP's optimization calculations, you will see that LEAP will decide both of these questions: *what* processes to add and *when* to add them.

Repeat this same process for the three other scenarios: **Natural Gas Only**, **Wind Only**, and **Hydro Only**. In each case, add only the one process relevant for that scenario, and using 100 MW for the Addition size.

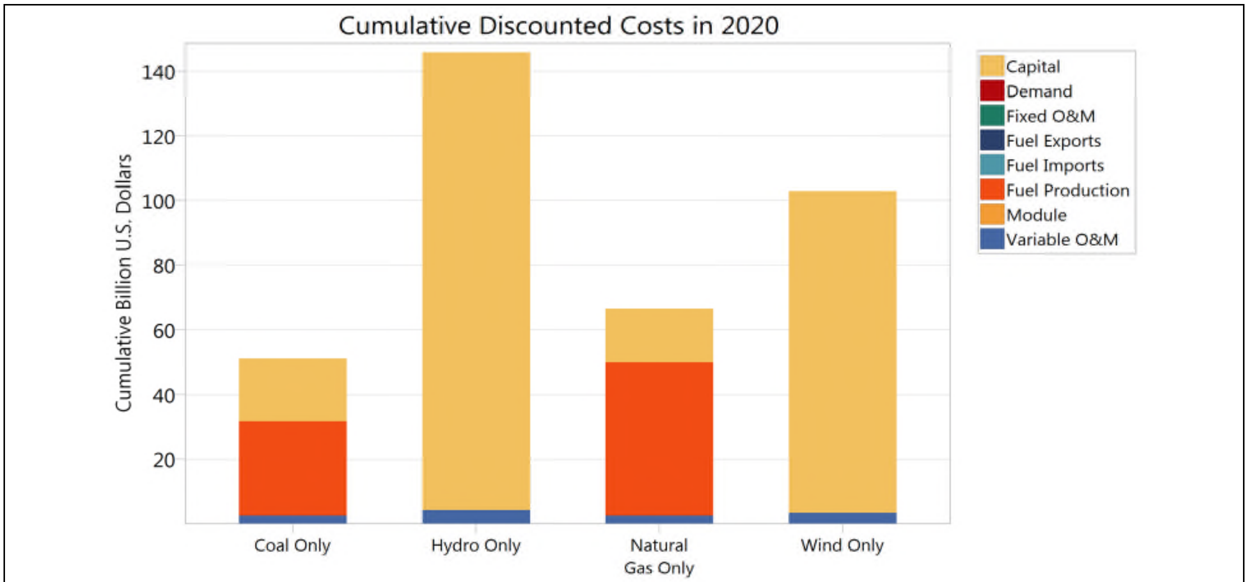
6.3.1 Results

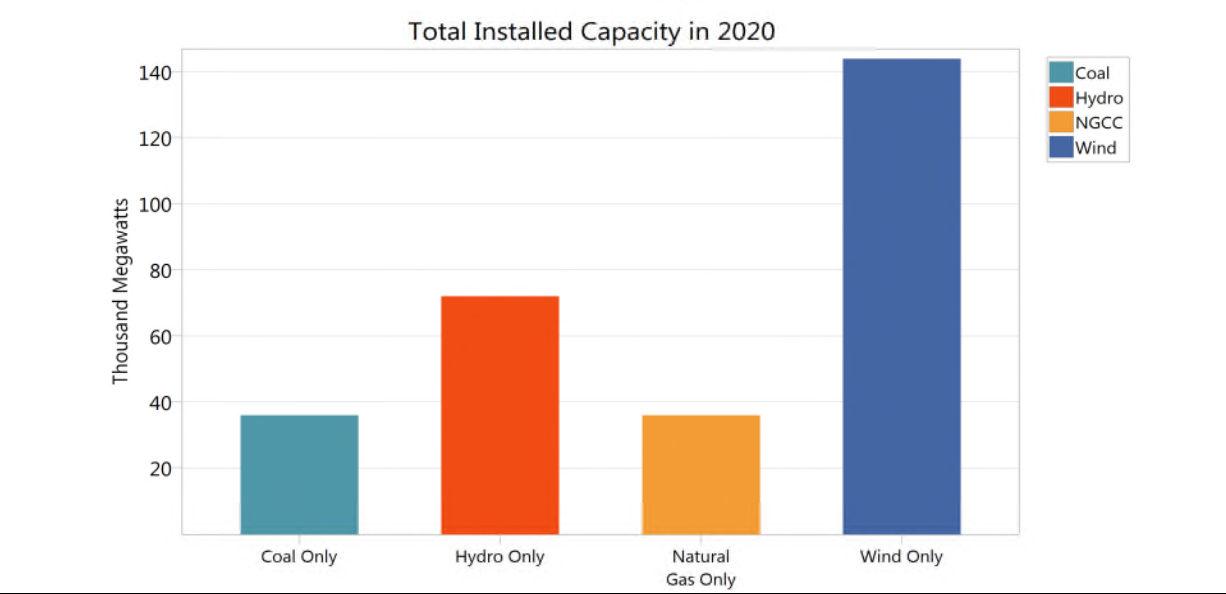
You are now ready to see some results for these 5 scenarios. Go to the Results View and create two different charts as follows:

1. **Social Costs:** First create a chart comparing the total cumulative, discounted social costs in 2020 (at the top area branch) for each scenario. Make sure you configure the chart to show scenarios on the X axis and Cost Categories in the legend. Save this chart as a favorite chart called "**Costs by Scenario**"

2. **Capacity:** Next create a chart showing total installed capacity in 2020 in each scenario. Save this chart as a favorite chart called "**Capacity by Scenario**"

These two charts should look like those shown below:





Try to answer these questions:

- Why is coal the cheapest option *in this analysis?*

- Why does LEAP install more capacity for wind and hydro even though all scenarios are designed to meet the same level of demand for electricity?

6.4 Incorporating Externality Values

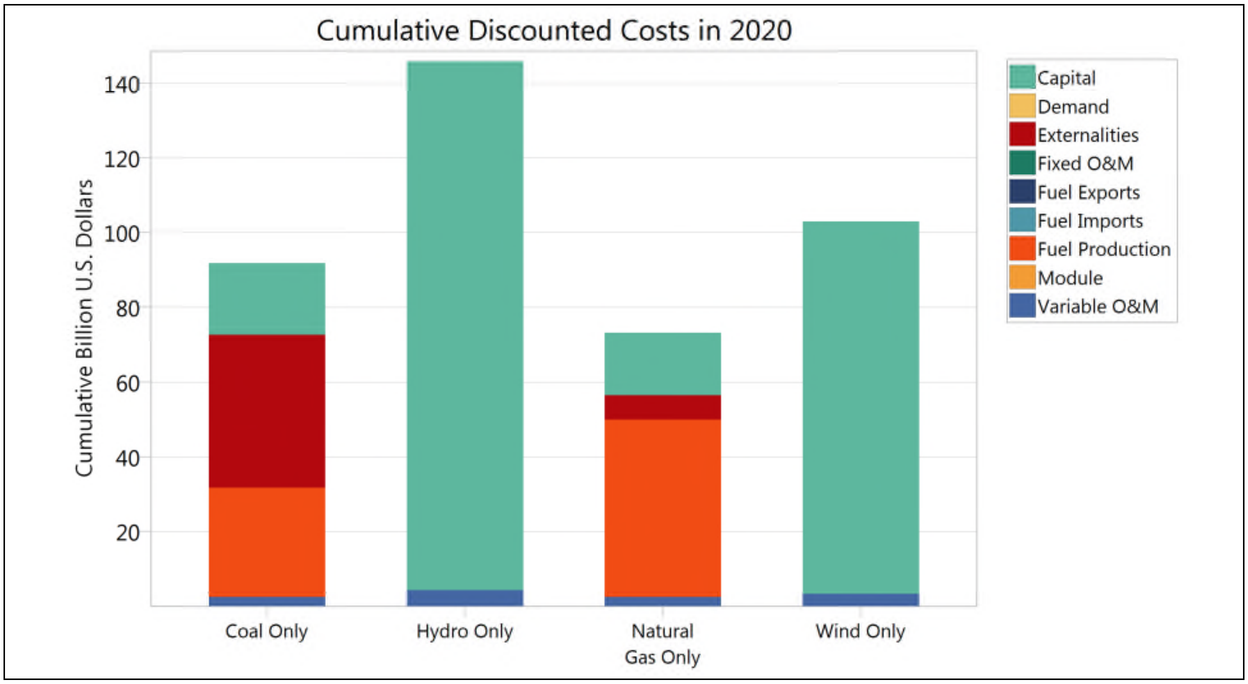
The results you obtained above are influenced by the fact that we have so far ignored a crucial factor: the damage costs associated with pollution associated with burning fossil fuels. These costs are often ignored because they are not directly monetized in most energy systems. However they are a real cost and cause real economic impacts such as damage to human health and crops.

Next you will enter data that describes these externality values. Go back to the General: Basic Parameters: Costing screen and make sure that **Environmental Externality Costs** is checked on. Now return to the Analysis view and under the top level **Effects** branch, add two new branches for the effects nitrous oxides (NO_x) and sulfur dioxide (SO_2).

Pollutant	Externality Value ($/kg)
NOx	7
SO2	2

Now in the **Externality Cost** variable, enter the externality values given in the table above in $/kg. Enter this data for the **Current Accounts** scenario so that these externality values are used by all of the scenarios.

Now select the Results View again. Once LEAP has recalculated its results, show the favorite result **Costs by Scenario.** You should see a chart like the one below. Notice that LEAP has now calculated a new set of costs corresponding to externality costs.

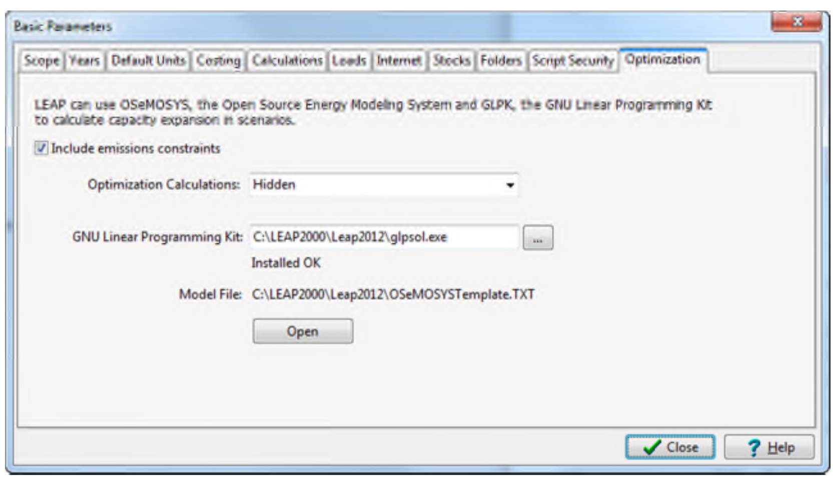


Now try to answer these questions:

- How do your results change and why?
- What option is cheapest now?
- Why do externalities vary so much among different types of power plants?
- What other important types of externalities have we so far ignored in these calculations?

6.5 Using Optimization to Identify a Least-Cost Scenario

You are now ready to try out LEAP's optimization capabilities. These will allow LEAP to automatically decide what combination of power plants will meet demands at the lowest cost.



First, visit the General: Basic Parameters: Optimization screen and check that optimization is properly installed within LEAP. You should see a screen like the one shown on the right.

Now set up a new scenario in which you can use these optimization features. Go to the **Manage Scenarios** screen and create a new scenario called **Optimization** (Opt) that inherits directly from **Current Accounts**.

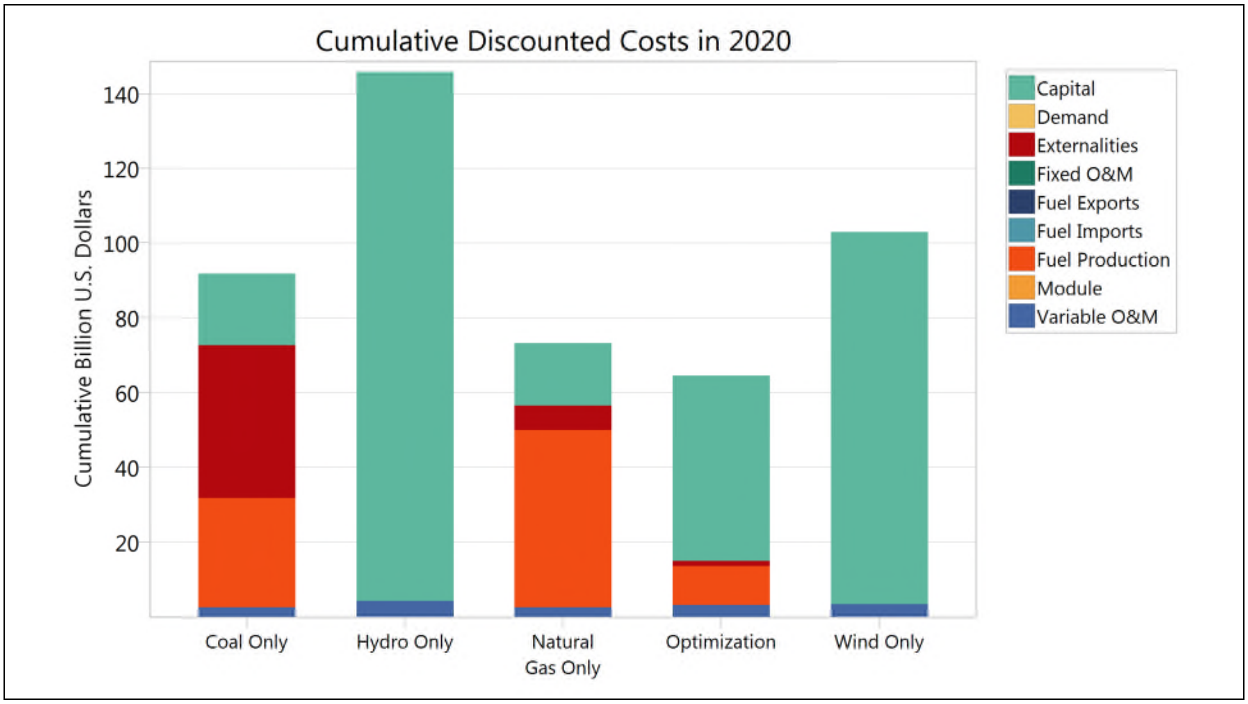
Return to the main screen in analysis view and select the **Optimization** scenario. You only need to set a simple setting to use optimization since you have already entered all of the basic data needed by the optimization calculations. LEAP will automatically make use of the same data you already entered in your simulation calculations.

Select the Transformation\Electric Generation branch and then select the Optimize variable. Change its value from **No** to **Yes**. If you don't see this variable, check that you are currently editing the optimization scenario (This variable does not appear in Current Accounts).

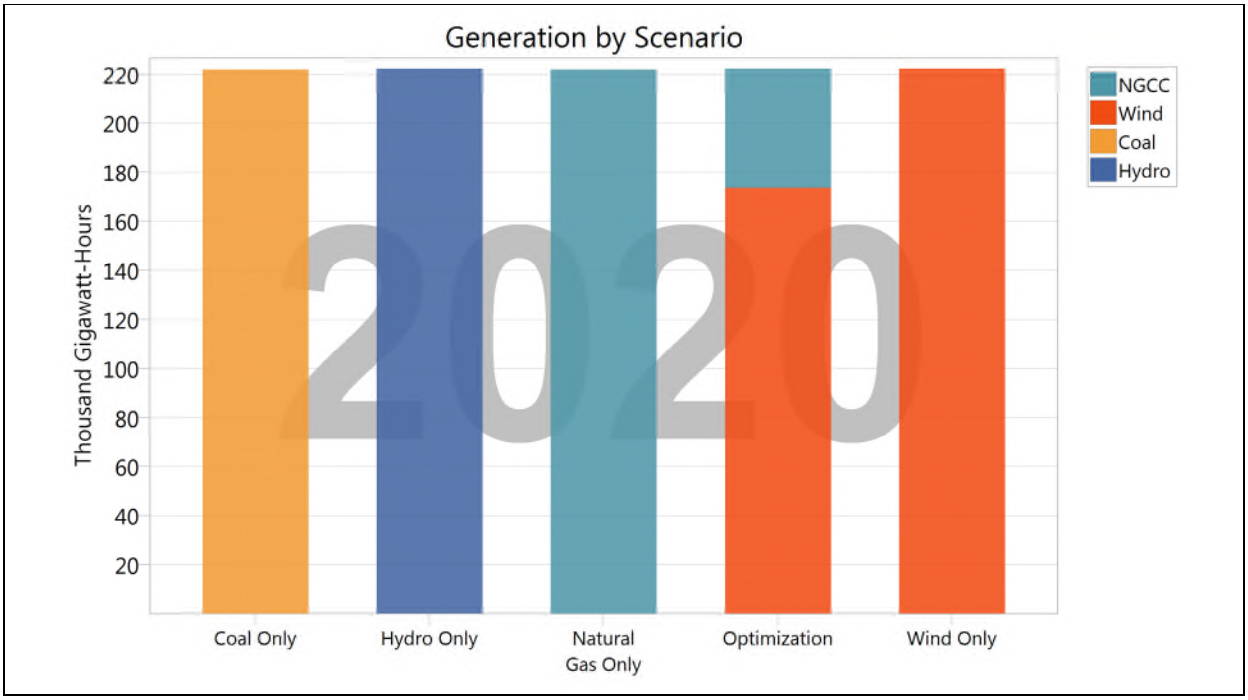
Note also that you don't need to set the Dispatch Rule for this scenario, since LEAP will use the optimization calculations to decide how much to dispatch each process. Thus, the Dispatch Rule is hidden for any scenarios using optimization. That's all you have to do!

Now select the Results view again. LEAP will again recalculate its results. You will notice that during its calculations LEAP's calculations will appear to pause during which time it will run the OSeMOSYS optimization model, which is used to calculate the optimization scenario.

Once calculations are complete you can again show the favorite result **Costs by Scenario.** You should see a chart like the one show below. Notice that LEAP has now created results for this new optimization scenario. You should see that total social costs are slightly cheaper than even the cheapest of the other scenarios you created previously.



To see how this is possible, let's look at another chart showing Electric Generation by process for each scenario in 2020.



Notice that unlike in the other simple one technology simulation scenarios, in the Optimization scenario LEAP has chosen a mix of power plants. Since the load shape we entered earlier varies by season and time of day there will be some periods where a very high peak demand exists. These periods favor power plants that are relatively cheap to build but expensive to operate (NGCC). Base load periods favor power plants that are more capital intensive but which have low running costs (e.g. wind).

6.6 Using Constraints to Specify a CO_2 Cap

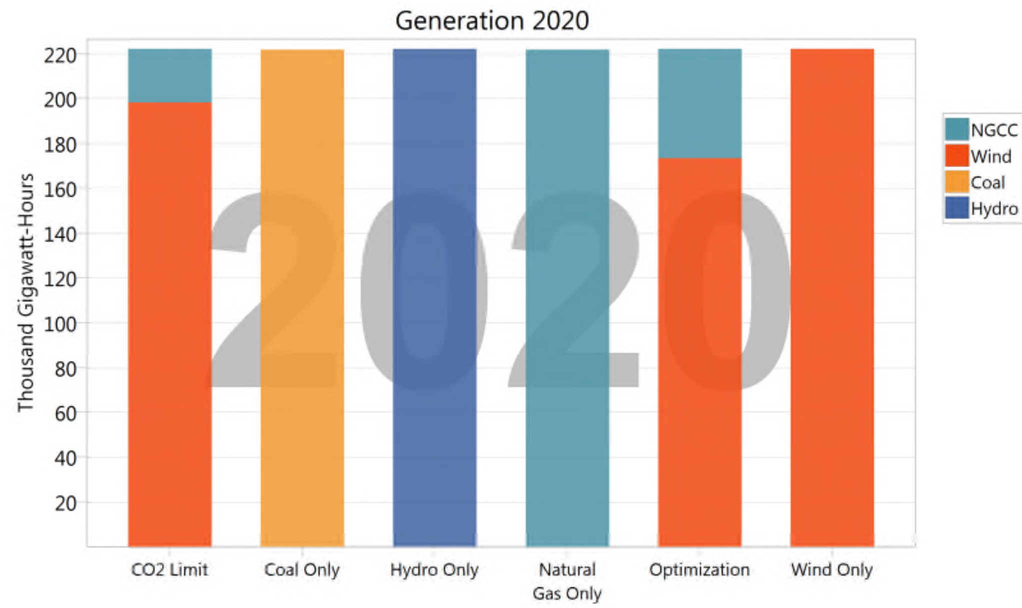
In this next exercise you will create an additional scenario that looks at how the least cost choice of technologies will change if a maximum level of CO_2 emissions is imposed on the system.

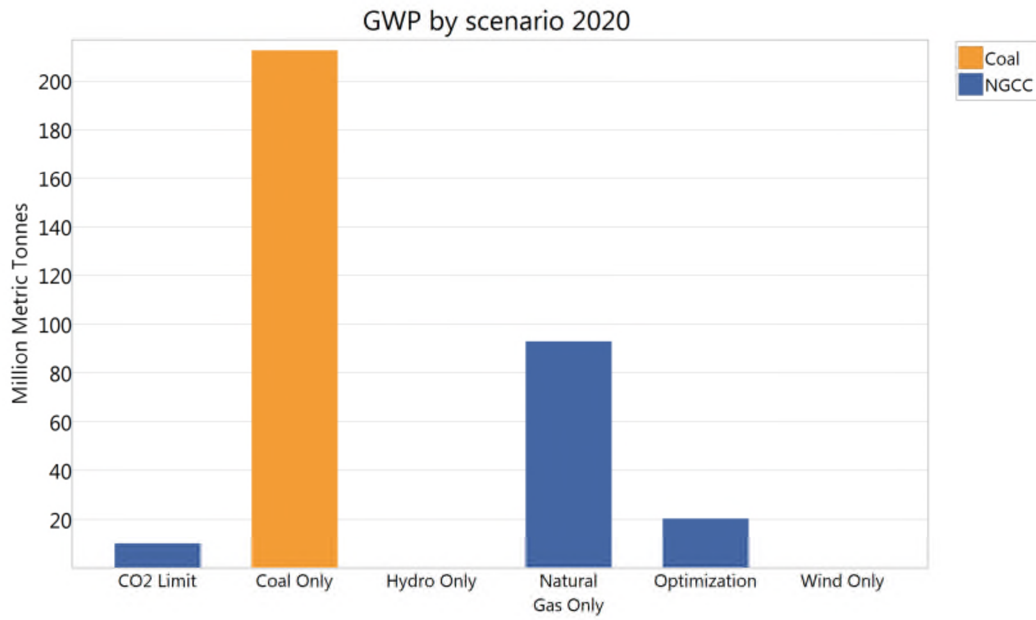
To create an emissions constraint, first return to the General: Basic Parameters: Optimization screen and make sure the **Include Emissions Constraints** box is checked on.

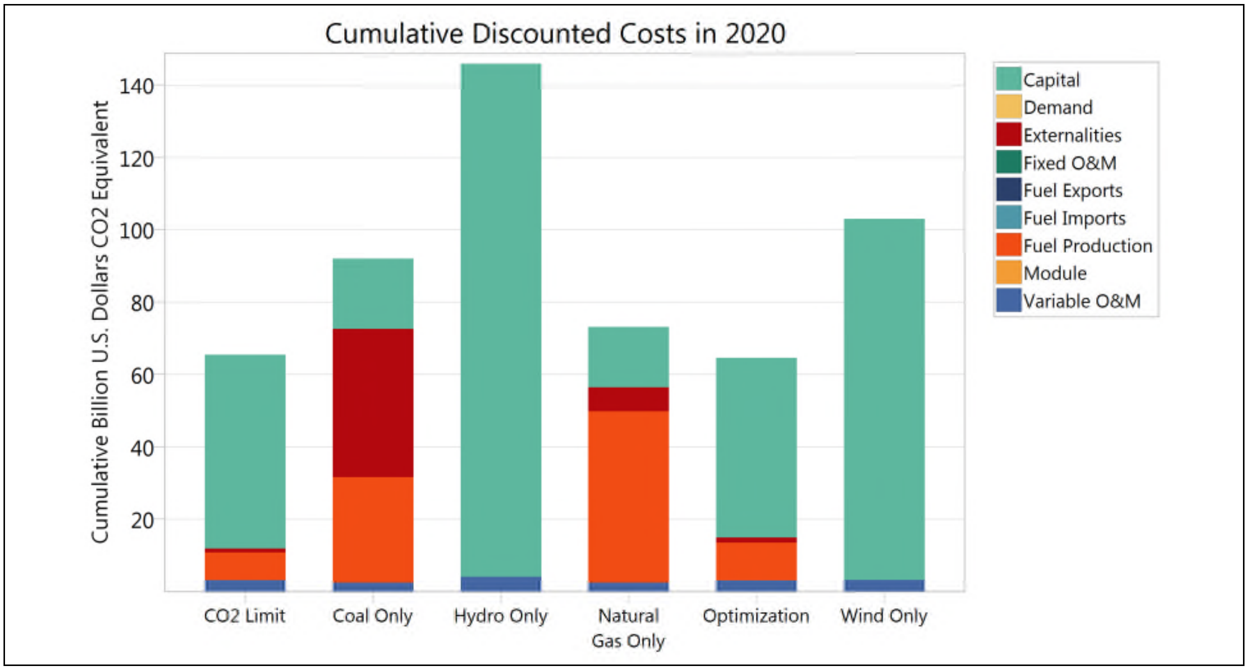
Now return to the main screen and locate the Emission Constraints branches under the high level **Effects** branch. Add a new effect under this branch for **Carbon Dioxide Non Biogenic.** For **Currents Accounts** and all existing scenarios no constraint is needed so simply leave the default **Unlimited** expression in the **Annual Emission Constraint** variable.

Next, go to the **Manage Scenarios** screen and create a new scenario called **CO2 Limit** (COL) that inherits from the Optimization scenario. Return to main screen and for this scenario enter a value of 10 million tonnes in the **Annual Emission Constraint** variable.

Finally, select results view again and look at results for generation, total GHG emissions and social costs. You should see charts like those below.







Now try to answer these questions:

- By what percentage did the CO_2 cap reduce GHG emissions in 2020 compared to non-capped optimal scenario?
- By what percentage do costs increase?

6.7 Using Your Own Data

Now go back and review the capital, O&M and fuel costs used in this exercise, as well as the technical parameters including lifetime, efficiency, maximum availability and capacity credit.

Bear in mind that the values used in this exercise are only sample values: they are not necessarily intended to be realistic (and of course you should not use them in any real study!)

- How do these values compare to the costs of electric generation in your country?
- Try replacing the capital and fuel costs used in this exercise with your own data (if available). How does the optimal mix of power plants change?
- Finally, think about which of these variables are likely to change in the future. For example, you may want to consider how many renewable technologies such as solar and wind energy have been getting significantly cheaper in recent decades, while fossil fuel prices (especially oil) generally have been rising. Try entering some **Growth** expressions to describe these trends. What impact do these changes have on the optimal mix of power plants?

LEAP

Greenhouse Gas Mitigation Screening Exercise

For LEAP and Excel

June 2012

SEI STOCKHOLM ENVIRONMENT INSTITUTE

Contents

1 Introduction

These computer exercises are designed to introduce you to some of the basic techniques used in a GHG Mitigation Assessment.

You will undertake two very simple exercises that will help you to learn some of the skills needed to conduct a GHG Mitigation assessment.

1. **In Exercise One,** you will conduct a simplified static screening of mitigation options. This will consist of two basic parts.

    - In part one, you will complete a simple spreadsheet that calculates some of the main quantitative indicators used in a mitigation screening, including the GHG emissions reductions potential from each mitigation option (in Tons of CO2 equivalent) and the costs (in annualized $ per ton of CO2 equivalent).

    - In part two you will combine these numbers with a qualitative assessment of various different screening criteria in order to develop an overall screening matrix.

2. **In Exercise Two,** you will use LEAP to create a simple GHG mitigation scenario. The scenario will be created by taking some of the data developed in the first simple static screening exercise and using it as input to LEAP's dynamic integrated energy and GHG mitigation analysis. You will use LEAP to create some of the charts and tables that would typically be included in a national communication on mitigation.

3. In **Exercise Three** you will enter additional data to quantify the costs and benefits of the scenario within LEAP.

2 Logistics

Organize yourselves to work in groups of 2 or 3 for the quantitative aspects of these exercises. For the qualitative exercises, form teams of about 5-10 people each, appoint a chair, who will moderate the discussion, and a reporter, who will take notes and prepare a brief (5 minute) presentation to plenary.

The workshop presenters will provide further information about how you will be divided into groups and which rooms will be used by each group.

3 Country Context

While the information presented in these exercises is fictional, it may be useful to imagine a hypothetical country so that you can better assess some of the qualitative criteria.

The country is a rapidly growing developing country. Its urban population is fully electrified and has average income levels close to those in the OECD, while its poorer rural population has very limited access to modern energy services, and is heavily reliant on biomass fuels to meet basic needs.

The country has a warm climate and is only sparsely populated. It has a large potential for forestation, and solar energy and also has good wind resources. It also has good but limited potential for expanding its hydropower system. However, all potential areas for hydropower development are already densely populated and hence any hydropower development will require large numbers of people to be resettled.

4 Exercise One: Mitigation Screening Exercise

4.1 Part One: Constructing a Cost Curve

The goal of this exercise is to conduct a simplified quantitative screening of GHG mitigation options. To complete this exercise you will need to work with Microsoft Excel. We assume basic familiarity with Excel.

Start by opening the Excel spreadsheet “**Screening_partial.xls**”.

This spreadsheet is a partly completed GHG mitigation screening calculation developed for a fictitious set of data[1]. The spreadsheet is made up of various worksheets: with one worksheet devoted to each potential mitigation option. You can access the different worksheets by clicking the tabs at the foot of the screen in Excel.

The options included in the spreadsheet are only meant to illustrate the use of the screening techniques: they are NOT intended as recommendations of mitigation options for any particular country and they are specified using entirely fictitious data. Moreover, the options are not intended as a comprehensive list of mitigation options that might be available in a country.

The potential mitigation options included in the spreadsheet are:

- LPG cooking stoves used to substitute for kerosene stoves in urban households.
- Efficient motor drives in the industrial sector.
- Efficient refrigerators in the domestic sector.
- Hybrid cars in the transport sector.

[1] The spreadsheet is based on a screening tool named “GACMO” developed by UNEP and SEI.

- Electric cars in the transport sector.
- Combined heat and power (CHP) in the industrial sector.
- Hydro power for electric generation.
- New coal power plants with carbon capture and storage (CCS) technologies
- Solar photovoltaics for electric generation.
- Reforestation as a way of enhancing GHG sinks.

The workbook includes three additional tabs (worksheets) labeled "Assumptions," "Screening Matrix" and "Cost Curve".

- **The Assumptions sheet** includes the basic characteristics of the fuels used in the spreadsheets including their emissions factors and prices. It also includes other defaults such as the discount rate used to annualize costs and the Global Warming Potential (GWP) of the three GHGs included in this simplified analysis: CO2, N2O and CH4.

- **The Cost Curve sheet** is used to plot a cost curve for all of the options analyzed in the worksheet. The cost curve plots cumulative GHG reduction from successive mitigation options (Tons of CO2 avoided) against cost per unit of GHG reduction (e.g. $/Ton). A property of the curve is that the area under the curve yields the total cost of avoided emissions. As you complete the data for the options in each tabbed worksheet the Cost Curve will be plotted.

- **The Screening Matrix** will be used for the qualitative component of the exercise.

This exercise illustrates a simple approach to developing a cost curve, the so-called **"partial approach"**. In this approach:

- Each technology is evaluated separately and compared to a reference technology.
- Overall emission reductions and costs are created by combining options while assuming no interaction between options.

This approach is simple to conduct but does not consider the possible interactions between options. For example, the costs and mitigation potential of demand-side efficiency options will depend on what kind of supply technologies are used to generate electricity. In these simple exercises we ignore these problems and simply assume that electricity is provided by the average baseline electricity mix. In reality, supply-side mitigation options (e.g. more hydro) might affect the carbon intensity of the supply mix, and hence the actual level of emissions that can be avoided by a demand-side efficiency measure.

A second issue is that our spreadsheet analysis will be static: we will only consider the savings that might be achieved in a single year: 2030. Later on, in the second exercise we will use a dynamic modeling tool, LEAP, to create integrated scenarios that examine how both the baseline and the mitigation options might evolve over time from the base year in 2010 to 2030. In this latter approach we will be able to consider interactions between measures.

In spite of its limitations, the **partial approach** can still be a useful approach for getting a rough first estimate of GHG mitigation costs and potentials and therefore it is the approach we will use here in this first exercise.

Spreadsheet Exercise

Use the following descriptive information for each option to complete the worksheet and prepare a cost curve and accompanying data table that describes the GHG emissions reductions potential from each mitigation option (in Tons of CO2 equivalent) and their costs (in annualized $ per ton of CO2 equivalent). Bear in mind that the descriptions and data provided here are simplified for the purpose of this analysis and use fictitious data.

NB: Some cells may be locked or protected to indicate that the calculations have already been completed. You may be interested in viewing the formulas, but we do not recommend editing them.

The options are as follows…

- **LPG Stoves:** By 2030, efficient LPG stoves could replace kerosene stoves in 3 million households. Kerosene stoves annually consume 8 GJ of energy per household and work at an efficiency of 30% while the LPG stoves work at an efficiency of 60%. LPG stoves cost $40 and have an expected lifetime of 8 years. Kerosene stoves cost $15 and last 5 years.

- **Efficient Motor Drives in Industry:** By 2030, the introduction of efficient electric motors throughout the industrial sector is expected to be able to save 10,000 GWhr of electricity at a cost of 10 cents ($0.10) per kWh.

  NB: For this example, try entering an incremental cost and electricity saving.

- **Efficient Refrigerators in the Residential Sector:** By 2030, efficient refrigerators could replace standard refrigerators in 1 million households. Efficient refrigerators will use 400 kwh/year, while standard refrigerators consume 700/kwh/year. Efficient refrigerators cost $500 and have a lifetime of 10 years. Standard refrigerators cost $300 and last 8 years. Assume one refrigerator per household.

- **Hybrid Cars in the Transport Sector:** New affordable hybrid vehicles are quickly becoming available in the country, expecting to replace one million conventional ICE vehicles by 2030. This will decrease the fuel consumption in these vehicles from 10 liters/100 km (for conventional vehicles) to 6 liters/100 km by 2030. Each vehicle drives 18,000 km/year. Hybrid vehicles will cost approximately $5,000 more than a conventional car. Assume that vehicles have a lifetime if 15 years. Note that 1 liter of gasoline is equivalent to 0.033152 GJ.

- **Electric Cars in the Transport Sector:** Under a new transportation policy, electric cars are expected to replace 500,000 conventional internal combustion engine (ICE) cars) by 2030. These cars will require an average of 30 kWh/100 km. Each electric vehicle will cost about $10,000 more than a conventional car. Assume the lifetime and mileage from the hybrid example above. Note that for this simplified example we have not included infrastructure costs of the policy, which could include necessary investments in plug-in stations.

- **Combined Heat and Power (CHP) in Industry:** By 2030, 20 million GJ of industrial process heat produced from oil-fired boilers could instead be produced from more efficient natural gas fired CHP plants. The oil-fired boilers operate at 55% efficiency, while the CHP plants would produce heat at 50% efficiency together with electricity at 25% efficiency (for a combined efficiency of 75%). The electricity can be sold back to the grid and is assumed to displace the average baseline mix. To produce this amount of heat, 800 MW of CHP plant will be required at an incremental cost of $1400/kW. CHP plants have a lifetime of 35 years.

- **Coal Power Plants with Carbon Capture and Storage (CCS) Technology:** Carbon capture and storage (CCS) is emerging as an alternative technology that may allow up to 85% of CO2 to be collected and transported for long-term storage when combined with coal power plants. CCS technologies are not yet commercially available, but in this policy scenario it is assumed that by 2030 2000 MW of this new technology could replace existing coal power plants. The existing coal power plants have a 30% thermal efficiency, a capital cost of $1000/kW and have a lifetime of 35 years. CCS capital costs are estimated to be $3000/kW and the technology has a lifetime of 35 years. The new coal power plants are more efficient, but also suffer an energy penalty because of the CCS requirements, which gives them an overall efficiency of 35%. Both power plants have an availability of 80%.

  Note: *to make sure emission factors are calculated correctly in the spreadsheet it is important to select "Coal w/CCS" as the fuel used by the CCS plant.*

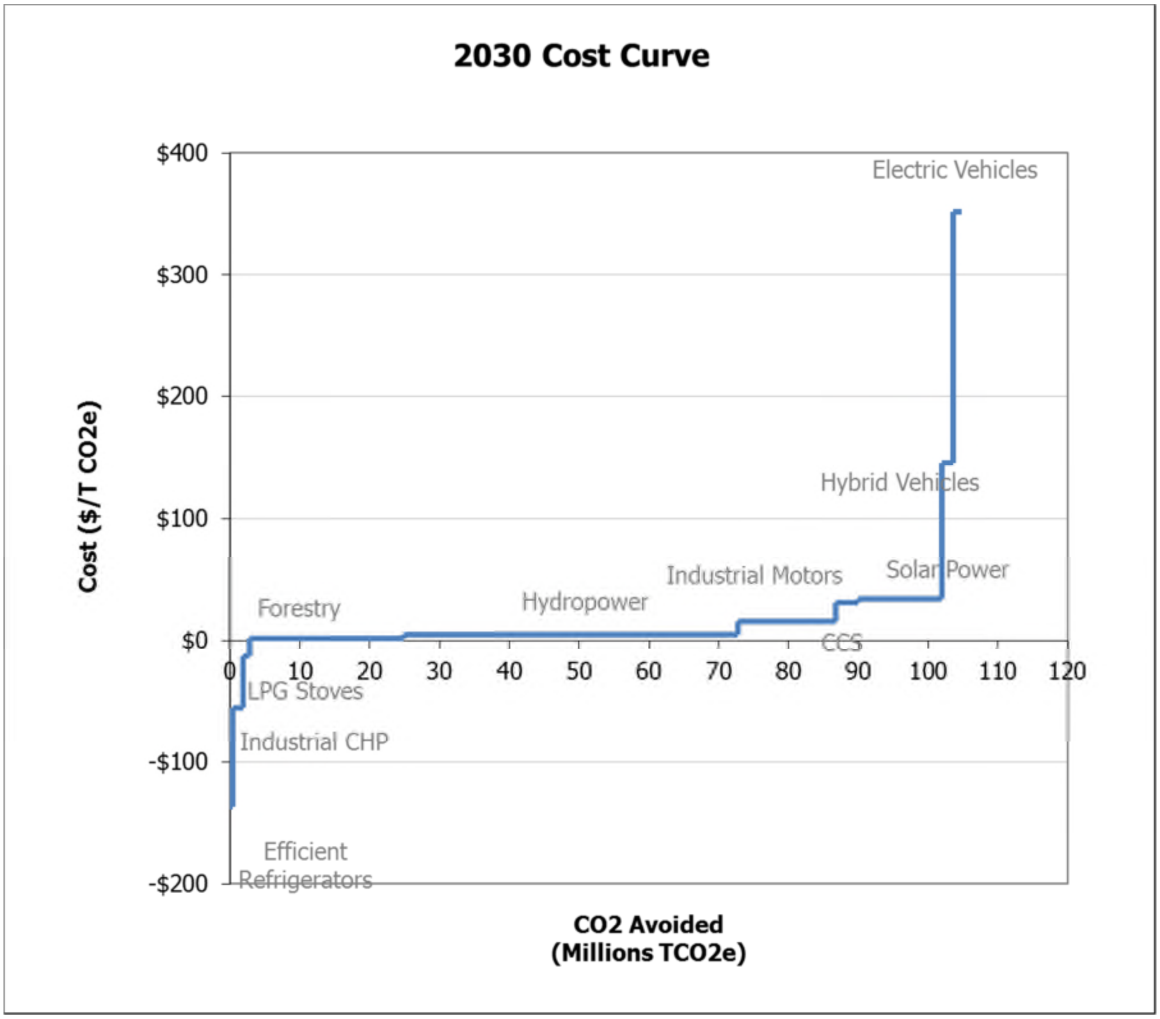
- **Hydro power for electric generation:** Approximately 6000 MW of hydropower could be built by 2030 displacing coal which is expected to be built in the future as the main base load power plant in a baseline scenario. The hydro plants will have an efficiency of 100%, an expected availability of 70% and a plant lifetime of 35 years. Hydropower capital costs are expected to be $4000 per KW. Variable O&M costs are expected to be $1 per MWhr. The hydropower plant would be built and run to replace coal fired plant that would have an expected availability of 80%, a thermal efficiency of 30%, a lifetime of 35 years, a capital cost of $1000 per KW, and variable O&M costs of $3 per MWhr.

- **Solar Photovoltaics for Electric Generation:** 4000 MW of solar power could be built by 2030, again displacing coal-fired base load plant. The solar plants would have an efficiency of 100%, an expected availability of 30% and a lifetime of 30 years. As solar technologies become more competitive, total capital costs are expected to decrease to $2000 per KW in 2030. Variable O&M costs are expected to be $20 per MWhr. Because of solar's low availability; the 4000 MW of solar would only displace about 1500 MW of coal plant. The coal fired plant would have a thermal efficiency of 30%, an expected availability of 80%, a lifetime of 35 years, a capital cost of $1000 per KW, and variable O&M costs of $3 per MWhr.

- **Reforestation (Enhancing GHG sinks):** Reforestation projects are expected to cover 4 million ha by 2030. Each hectare is expected to sequester about 1.5 tons of carbon per year at a cost of $5 per ton of carbon.

Use the above information to complete the spreadsheet. You should end up with a cost curve looking like the one shown on the next page.

Option Name	Million Tons CO2 Opton Mitigation	Million Tons CO2 Cumulative Mitigation	$/Ton CO2 Cost of Saved CO2
Baseline	-	-	
Efficient Refrigerator:	0.4	0.4	-$136
Industrial CHP	1.4	1.8	-$55
LPG Stoves	1.0	2.8	-$13
Forestry	22.0	24.8	$1
Hydropower	48.0	72.8	$4
CCS	13.9	86.7	$16
Industrial Motors	3.2	89.9	$31
Solar Power	12.0	101.9	$34
Hybrid Vehicles	1.7	103.6	$146
Electric Vehicles	1.2	104.8	$352



Notice that the curve shows costs increasing from left to right. The options on the far left actually have negative costs, indicating that for these options GHG mitigation can be achieved with net benefits to the economy. The area under the curve yields the total cost of avoided emissions.

NB: This cost curve will reorder automatically based on the numbers you enter in each worksheet. If your options appear in a different order than above, this likely indicates a problem in your analysis. Use the chart to help troubleshoot your analysis.

4.2 Part Two: Developing a Screening Matrix

In part two of this exercise you will work together as groups to decide on an overall ranking for the mitigation options you began to examine in part one.

To do this, complete the empty screening matrix sheets provided in the screening Excel spreadsheet.

You can develop your screening using either the simple screening sheet (in which you can decide yourself how to score and rank options) or using the detailed screening sheet which has built-in options for conducting a multi criteria attribute (MCA) approach.

Simple Approach

In the simple screening matrix, the first few rows of the matrix show the numbers you developed for the cost curve in exercise one.

The remaining rows can be used to rate the options based on more qualitative criteria, for which numbers are either not available or are uncertain.

As a group, decide on how you want to rate each of the options. Various approaches are possible and equally valid. For example, you may wish to use:

- A score (e.g. 0-5 or 0-10),
- A ranking (1^{st}, 2^{nd}, 3^{rd}, etc.)
- A rating (low/medium/high),
- A comment for each criterion.

You may wish to let each person in the group "vote" on a score or ranking or you may decide to agree a rating more informally.

Detailed (MCA) Approach

The detailed matrix uses a multi criteria attribute (MCA) approach to automatically calculate overall scores and rankings based on the scores you give for each criteria for each individual option. Fill in the cells of the sheet so as to score each option against each criterion from zero (worst) to ten (best). Scores are already provided for the overall mitigation potential and overall cost of each option, again scaled from zero (worst) to ten (best) based on the data you entered earlier.

You should also enter the weightings for each criterion in column C. Each criterion can have a weighting from 0 to 100, but make sure that the total weighting across all criteria is 100.

At the bottom of the matrix, the spreadsheet automatically calculates an overall score for each option, again scaled from zero (worst) to ten (best), and also shows the options ranked from best to worst.

If you have time you may want to make multiple copies of this spreadsheet. Try completing different versions of the matrix to reflect the views of different stakeholders. For example, you may want to try playing the roles of:

- a national government's energy or environmental ministry,
- a local non-governmental environmental or development organization, or
- a national or international donor agency.

Each stakeholder may have different opinions about the scores assigned to each option. They may also have different opinions about the importance of each criterion. How do changes in criteria and scores affect your overall ranking of options?

Presenting Your Results

With either approach, once you have completed at least one screening matrix as a group, you will be asked to present your findings in plenary in a short (3-5 minute max) presentation.

Start by appointing one member of your group as your reporter. That person will be asked to present the cost curve you developed, along with the screening matrix. Try to answer these questions:

- As a group: what process did you use to develop the screening matrix?
- Which options seem the best and worst based on your process?
- In what ways is this analysis too simplified to reflect real-world conditions?
- How might you improve upon it in a real mitigation assessment?
- What finance and support mechanisms could support any of these measures?
- Do you believe that developing a screening matrix will be useful as a step in your own national mitigation assessments?

5 Exercise Two: Creating a Mitigation Scenario in LEAP

In this second exercise you will work with LEAP, the Long range Energy Alternatives Planning System to create a very simple example of a mitigation scenario.

The exercise is not intended to fully train you in the use of LEAP. It is intended only to give you a brief introduction to some parts of the system, to give you a chance to create a simple mitigation scenario and to produce various reports of the type that might be included when reporting on a mitigation assessment in a National Communication.

Exercise 2 builds upon the data and results developed for static screening you undertook in Exercise one. In this second exercise you will take the basic information for selected mitigation options, and enter this into LEAP to create a dynamic mitigation scenario that examines how energy and emissions savings might occur over the period 2010-2030.

You will then use LEAP to create a few charts and tables that report the overall emissions savings in the mitigation scenario compared to the baseline scenario.

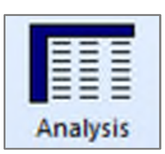
To keep things simple, you will work with a partially completed LEAP data set that already has a fully defined Baseline scenario.

5.1 A Very Brief Introduction to LEAP

Start **LEAP** from the **Start/Programs/LEAP** menu or by double-clicking the LEAP Icon (shown left) on the desktop. Once started, LEAP will display a title screen and then the main screen will appear (shown below).

As much as possible LEAP works like other standard Windows software, so if you are familiar with other Windows tools like Microsoft Excel or Windows Explorer, then you should be able to start using it straight away.

LEAP is structured as a set of different *views* of an energy system. The **View Bar** located on the left of the screen, displays an icon for each view. For this exercise we will only use three views:

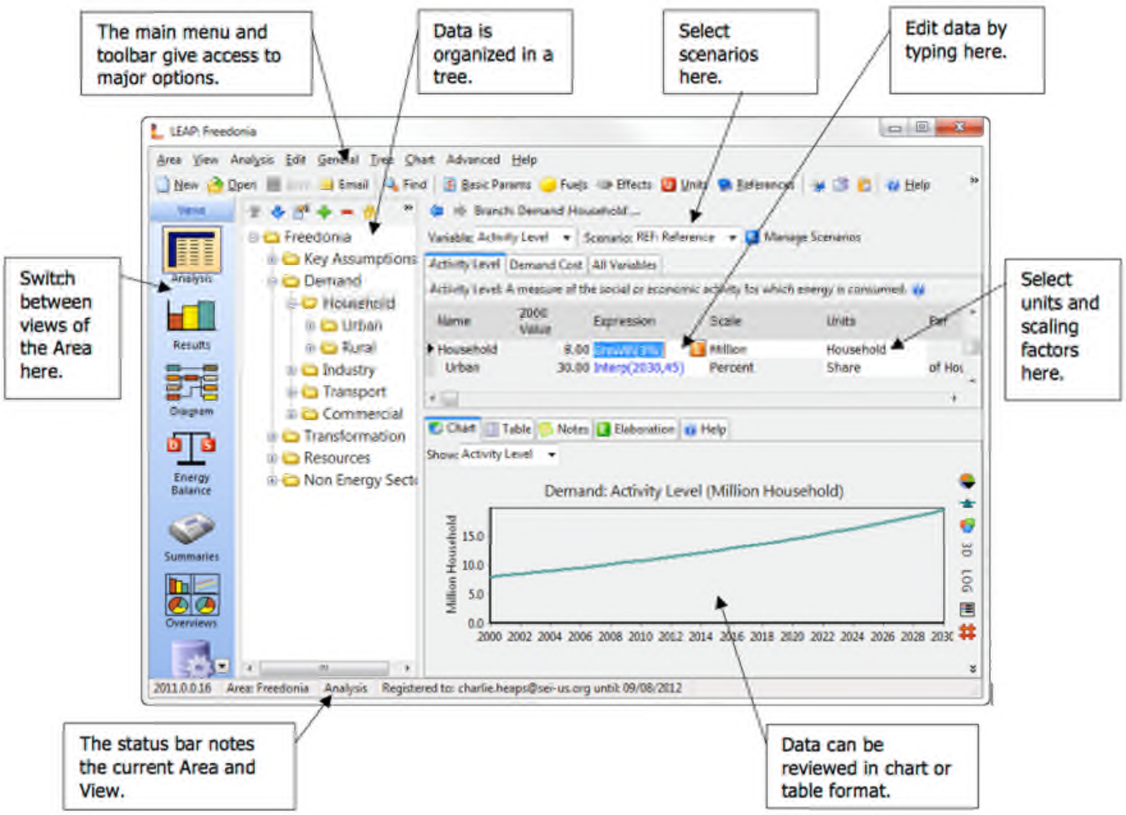


The **Analysis View** in which you will enter data and construct your mitigation scenario.

The **Results View** where you will examine the calculated scenarios as graphs and tables.

The **Overviews View** where you view a specific set of pre-defined “favorites” results charts.

The **Analysis View** (shown below) contains a number of controls apart from the view bar. On the left is a tree that is the main organizational tool for the data in LEAP. On the right are two linked panes. At the top is a table in which you view or edit the data describing your scenarios. Below it is an area containing charts and tables that summarize the data you entered above. Above the data table are toolbars that give access to commonly used commands and a standard menu.



The main parts of the **Analysis View** are described in more detail below:

- **The tree** is the place where you organize your data for both demand and supply (Transformation) analyses. The tree contains different types of branches:
  - **Category branches** are used mainly for the hierarchical organization of data in the tree.
  - **Technology branches** contain data on the actual technologies that consume, produce and convert energy.
  - **Fuel branches** are used to indicate resources as well as the feedstock fuels and outputs of Transformation processes.
  - **Environmental loading branches** represent the various pollutants emitted by energy demand and transformation technologies.

- **Data Table:** The top-right part of the screen shows a data table where you can view or edit the data associated with the variables at each branch in the tree. As you click on different branches in the tree, the data table shows a series of "tabs". Each tab corresponds to one variable. The variables you see depend on which part of the tree you click on. For each tab, a table presents the data associated with that variable. Each row in the table represents data for a branch in the tree.

- **Chart/Table/Notes:** The lower-right part of the screen summarizes the data entered above as a chart or a table.

- **Scenario Selection Box**: Above the data table is the scenario selection box, which you can use to select between **Current Accounts** and any of the scenarios in an area. Current Accounts are the data for the base year of your study. Different scenarios in LEAP all begin from the base year. In this exercise you will be given a completed **baseline** scenario, and you will then enter the data for a **Mitigation** scenario. Use the scenario selection box to select among the Current Accounts and the scenarios.

5.2 Reviewing Historical Data

In this exercise we will work on a partially completed data set or **Area** named "GHG Screening Exercise". An Area in LEAP is a complete description of a particular energy system, typically a country. Start by opening the area named **GHG Exercise Partial**. To do this select menu option **Area: Open** and then select the area named "GHG Screening Exercise partial". If the exercise cannot be found there, you may have to download it from the COMMEND website. To do this, go to **Area: Install: Install from Internet**.

Let's begin by reviewing the Current Accounts and Baseline scenario that has already been completed for you (to keep this exercise short!)

First, in the **Scenario Selection Box**, choose **Current Accounts.** The Current Accounts scenario includes multiple years of historical data. In this simple exercise we have entered future baseline data into current accounts as well.

Baseline scenarios are not a prediction of the future; instead they are plausible stories of how an area could involve in the absence of mitigation policies. There is also no "right" way to build a baseline scenario. Some baseline scenarios are based on historical trends while others may focus on expected trends for the future. The key thing to understand is that your baseline scenario is what you will be comparing back to; you will not be only looking at your baseline, but instead you will be looking at how your mitigation scenarios relate to the baseline.

Now use the tree to navigate the structure of this data set. First open up the tree branches under the main category "Key Assumptions." This folder contains macroeconomic and demographic variables that can be used to help model future energy demand. You will see entries for population and gross domestic product (GDP).

Now open up the folders under the Demand branch. You will see that this data set is very simple and aggregate. Demands are broken down by major sector (Residential, Industry, and Transport). Each sector has a simple set of branches listing the final fuels consumed in each sector. Each fuel is shown in the tree as a technology branch ( ). Finally under each fuel, are a set of branches that specify the emissions for each fuel ( ). In this exercise there are emissions specified for CO2, CO, CH4, VOCs, NOx, N20 and SO2.

Now let's look at the data associated with these branches. Click on one of the sector branches in the tree and then look at the tabs and data pane on the right. You will see that energy consumption data is also specified in a very simple way. Normally in LEAP you would specify separate data describing **activity levels** (e.g. number of households, or pass-km of transport) and **energy intensities** (GJ/households per year or GJ/pass-km). LEAP then multiplies these together to calculate total final energy demand. That is, it uses this relationship:

Total Final Energy Consumption = Activity Level x Final Energy Intensity

But in this exercise the data are specified in an even more simple fashion. The Activity Level variable has simply been set to "No data" and total energy consumption data is specified on the tab marked **Final Energy Intensity**. In other words we have used this relationship:

Total Final Energy Consumption = Final Energy Intensity

Select the **Final Energy Intensity** tab now. You will see the values of the total final energy consumption for each branch specified as data in Millions of Gigajoules. In the lower part of the screen the data is echoed back as a chart.

All the time-series values in this data set are specified using LEAP's built-in ***Interp*** function. The Interp function works by letting you specify values for any years. It then assumes a straight line change between the years calculated by simple linear interpolation. For example, this function…

Interp(2010,28, 2020,60, 2030,80)

…specifies a value of 28 in the year 2010 and a value of 60 in 2020. Thus the interpolated value that LEAP calculates in 2015 is 44.

Now open up the branches below one of the fuels and look at the **Environmental Loading** Tab. You will see a series of expressions that specify the emissions factors for each pollutant per unit of fuel consumption for that fuel. Typically emissions factors are specified in Tonnes/Terajoule or kg/Terajoule. To calculate total emissions of each pollutant, LEAP simply multiples total energy consumption by each emission factor using this relationship:

Total Emission = Total Final Energy Consumption x Emission Factor

Now let's have a look at how the data is specified for the Energy Supply system. This data is entered under the **Transformation** branches in the LEAP tree. In LEAP, energy supply data is specified by first making a list of ***modules*** immediately below the Transformation branch. These modules correspond to major energy supply sectors like electricity generation, transmission and distribution, oil refining, charcoal making, ethanol production, coal and oil extraction, etc. Each module can be further divided into different ***processes***, each of which can have one or more ***feedstock fuels***. A process might be a particular type of power plant or a type of oil refining facility for example. Each module is dispatched to produce one or more ***output fuels***.

In our simple example, there are only two modules: one dealing with the **Transmission and Distribution** (T&D) of electricity and a second one below it dealing with **Electricity Generation**. The T&D module is very simple: it simply specifies expected losses during transmission and distribution. The Electricity Generation module has four processes describing the capacity, availability, efficiency and merit order dispatch characteristics of four types of power plants: hydro, coal, oil and solar. The first three exist in the base year, while solar is listed as a potential future type of power plant.

Now, let's switch to the **Results View** to see some results associated with the already complete Baseline scenario. Click on the results view, and if prompted allow LEAP to calculate results. This should only take a few seconds.

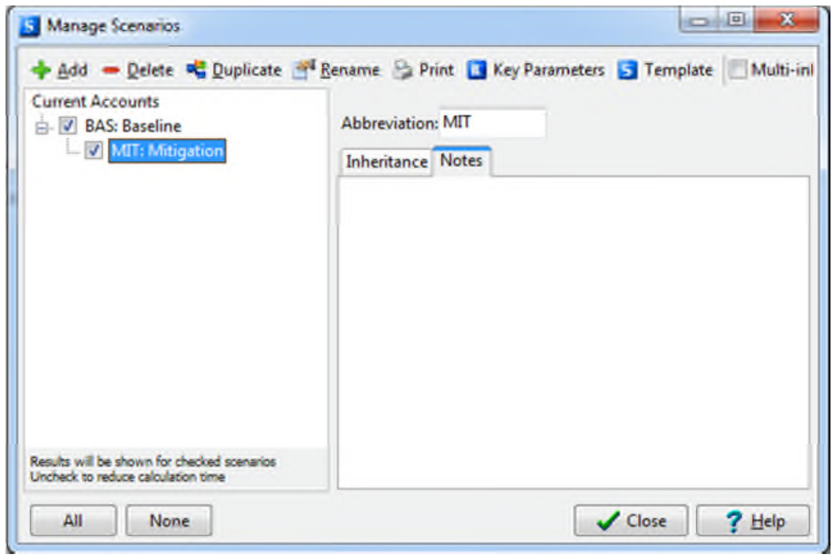
Now let's look at some results in Chart form. The Results view has numerous options for selecting results.

- First use the **tree** to pick the branches for which you wish to see results. For example, you might choose to see demands in the household sector, or GHG emissions for the whole area.
- The **Result** selection box at the top of the screen is used to pick the category of results you are interested in. Different types of results are available at different tree branches. For example, final energy demand results are only available at demand branches while emissions and GHG results are available at both demand and supply branches.
- Two tabs at the top of the view let you switch between **Charts** and **Tables**: both formats contain the same basic information.

Reports can be viewed for one or more scenarios and can be customized in a wide variety of ways. You can also use the "**Favorites**" option to bookmark the most useful charts for your analysis.

To make things easy, we have preconfigured a set of **Favorite** charts you can use to examine results. Take a look now at the Favorite results for **Total Final Energy Demand in 2030**, **Electric Generation** and **Global Warming Potential** (by sector and by greenhouse gas).

5.3 Entering Mitigation Data into LEAP



Now you are ready to create a mitigation scenario. Switch back to the **Analysis View** and click on the **Manage Scenarios** button ( ). In the resulting Manage Scenarios screen (shown right), use the Add button ( ) to add a new scenario named Mitigation.

Important: Make sure the mitigation scenario *inherits* from the Baseline scenario. That is, it must appear in the scenario tree indented and below the Baseline scenario as shown above. In this way, all of the data and expressions for the Mitigation scenario will initially be exactly the same as those in the Baseline scenario.

To specify the data for the new scenario you will only need to specify the places where the mitigation scenario is different from the Baseline. Much of the data specified for the Baseline (such as emissions factors) will remain unchanged.

Now close this screen and return to the Analysis View. If necessary, select Mitigation as the active scenario in the **Scenario Selection Box.**

We will now enter data to represent some of the options we studied in Exercise One in our mitigation scenario.

In a real mitigation study it might be desirable to do a thorough end-use oriented analysis in which both the baseline and the mitigation scenario are described in terms of the likely penetration of different technologies. That kind of exercise is data intensive and time consuming and goes beyond what can be done in this simple exercise. Instead, in this exercise we will specify most of our options by simply entering the amount of fuel consumption that is avoided (or increased) relative to the Baseline scenario as a result of implementing the mitigation option.

Let's enter the data for the Household LPG stoves option. If you look at the spreadsheet **screening.xls** you will see that this option is expected to reduce consumption of kerosene by 24 million GJ in 2030 while increasing consumption of LPG in 2030 by 12 million GJ. The changes can be assumed to start from nothing in the base year (2010) and increase linearly to reach these values by 2030.

We can specify this information in LEAP as follows. First, select the Residential branch in the tree then select the **Final Energy Intensity** tab and then enter the following two expressions for the Kerosene and LPG branches. The expressions should override the expressions that were inherited from the Baseline scenario.

For Kerosene:

BaselineValue - Interp(2010, 0, 2030, 24.0)

> This expression specifies that the energy consumption of kerosene in the mitigation scenario gradually decreases versus the baseline scenario, so that by 2030 it is 24 million GJ less.

For LPG:

BaselineValue + Interp(2010, 0, 2030, 12.0)

> This expression specifies that the energy consumption of LPG in the mitigation scenario gradually increases versus the baseline scenario, so that by 2030 it is 12 million GJ more.

Tips:

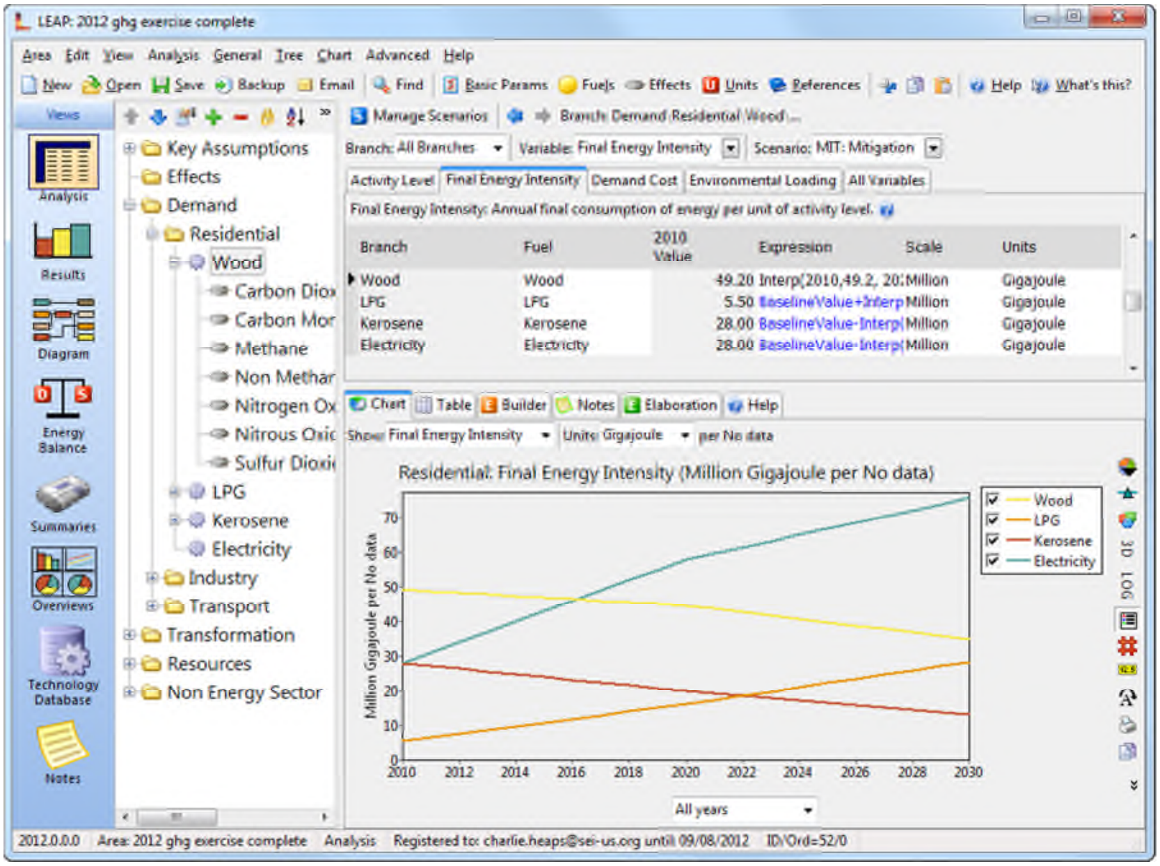
1. The screening spreadsheet automatically creates these formulae for each of the demand-side mitigation options, so you may find it easiest to simply copy and paste these formulae from Excel to LEAP.

2. Make sure the formulae you enter are adapted to the local number formatting conventions used on your PC. For example, in Spanish speaking countries the list separator will be the ";" character and the decimal separator will be the "." character. LEAP automatically uses the local number formatting of your PC. So for example, the first equation above would be entered as follows in Spanish speaking countries:

   BaselineValue - Interp(2010; 0; 2030; 24,0)

   Note also that to facilitate easy copying and pasting from Excel to LEAP, you can edit the list separator character used in equations via the Assumptions tab of the spreadsheet.

When entering the data in LEAP's Analysis View, the screen should look something like this:



Use this same approach to continue specifying the data for the other mitigation options that you wish to include in your mitigation scenario. For now only include the following measures (starred items have helpful tips listed below):

- LPG Stoves
- Efficient Refrigerators
- Hybrid and Electric Cars*
- Industrial CHP
- Hydro*
- CCS*
- Forestry*

Most of the other options can be entered into LEAP in a way similar to how you specified the LPG stoves option. However specifying either of the two supply-side options (CCS and hydro), the forestry option or the transport options requires a bit more explanation.

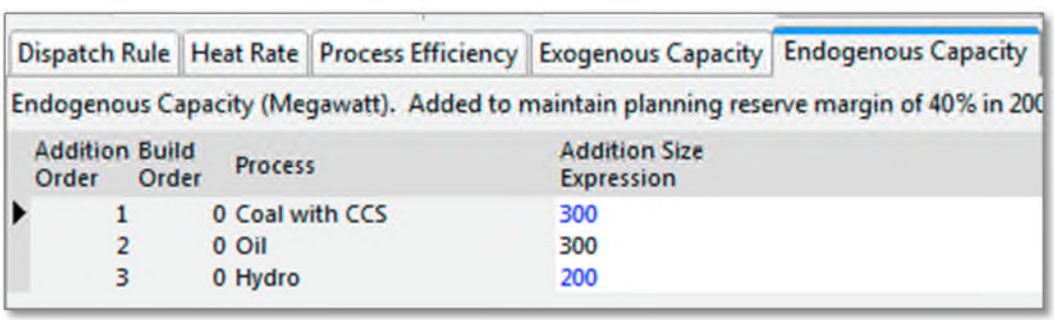
- **Entering data for the transportation measures:** Both of the hybrid and electric measures affect future gasoline usage. In LEAP, this would require entering two formulas in the same location and so for this simplified example we must combine the fuel usage estimates into one formula.

If you look at the screening spreadsheet you should see that the hybrid mitigation option is expected to decrease gasoline usage by 23.87 Million GJ in 2030 and the electric car mitigation option is expected to decrease gas consumption by 29.84 Million GJ. The two values can be added to give a total saving of 53.71 Million GJ so that the LEAP formula can thus be written as:

BaselineValue - Interp(2010, 0, 2030, 23.87+29.84)

Don't forget to add the additional requirements for electricity in a similar equation for the electric vehicle scenario.

- **Entering data for the Hydro and CCS Measures:** For these options you will need to enter data in the Transformation\Electricity Generation module. Click on the Processes branch and then select the **Endogenous Capacity** tab. This screen lets you specify a set of plants that will be added automatically and as needed as demands grow in order to meet a specified panning reserve margin. You can see that in the baseline LEAP will add Coal and Oil plants in amounts of 500 MW and 300 MW respectively as needed to keep the reserve margin on or above 40%. For the mitigation scenario, you will need to add the Hydro and Coal with CCS processes to the list. Click the Add button ( ) at the right of the table to add two new processes to the **Endogenous Capacity** screen for Coal with CCS and Hydro. You will need to delete ( ) the previous option for Coal and you will need to use the up ( ) and down ( ) arrows to make the Addition Order the same as the image below. Now change the **Addition size** values to read (Coal with CCS: 300, Oil: 300, Hydro: 200).



Addition Order	Build Order	Process	Addition Size Expression
1	0	Coal with CCS	300
2	0	Oil	300
3	0	Hydro	200

- **Entering data for the Forestry Option:** Unlike all the other options, the Forestry mitigation option is a non-energy sector option. Its implementation has no direct effect on the energy sector with which LEAP is primarily concerned. However, you can still characterize this option in LEAP in very simple terms. Select the **Non-Energy Sector Effects** branch to view the branch for forestry.

There is only one variable for non-energy sector branches, and that is environmental loading.

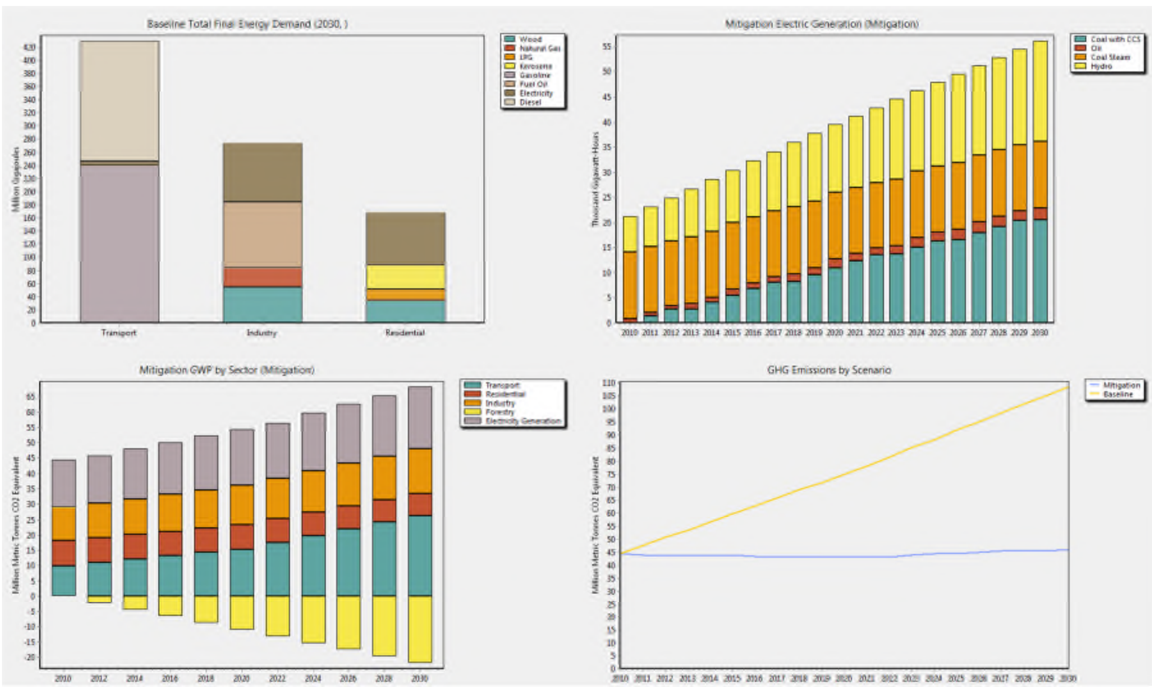
Now you can specify the emissions sequestered in the Mitigation scenario in 2030 (22 million tonnes of CO_2). Don't forget to set the scaling factor and units to Millions and Tonnes respectively. Enter the emissions sequestered as a negative value because they are a net sink compared to the Baseline scenario. One way to enter this would be to use the following expression:

BaselineValue - Interp(2010, 0, 2030, 22)

5.4 Viewing Results in LEAP

Once you have completed specifying the data for the mitigation scenario, switch to the Overviews view. This view allows you to take advantage of favorites charts that you have already created so that you can quickly see changes in results. For the purposes of this exercise we have created an overview with four useful charts.

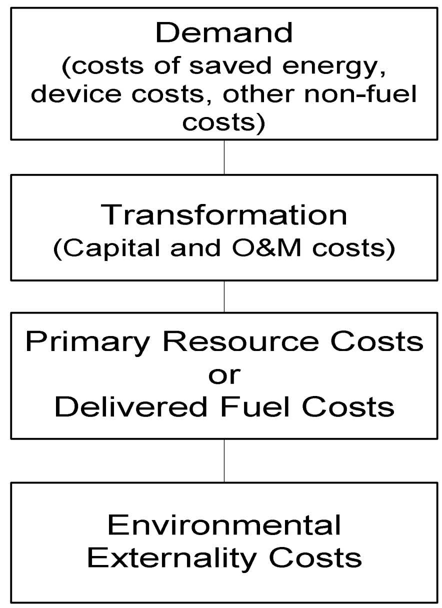
Compare your results to the ones produced here. These results are based on a scenario that includes all of the mitigation options except for Solar PV and Industrial Motors.



6 Exercise Three: The Costs and Benefits of the Mitigation Scenario.

In this third exercise we will enter data about the costs of the various policies and measures employed in the Mitigation scenario and then use LEAP to look at the overall costs of the scenario versus the "do nothing" baseline scenario.

LEAP performs cost-benefit calculations from a societal perspective by comparing the costs of any two policy scenarios. LEAP can include all of the following cost elements:



- Demand costs capital and operating and maintenance costs expressed as total costs, costs per activity, or costs of saving energy relative to some scenario.
- Transformation capital costs
- Transformation fixed and variable operating and maintenance costs.
- Costs of indigenous resources
- Costs of imported fuels
- Benefits of exported fuels
- Externality costs from emissions of pollutants
- Other miscellaneous user-defined costs such as the costs of administering an efficiency program.

To set-up a costing analysis in LEAP it is first necessary to draw a consistent boundary around your system, so that LEAP will not double-count costs and benefits. For example, if you count the costs of fuels used to generate electricity you should not also count the cost of the electricity in an overall cost-benefit calculation.

Contrast this integrated perspective with the rough project-by-project approach that we used in developing the original screening spreadsheets. Taking this integrated perspective has a number of distinct advantages:

1. It is able to capture interactivity: the effect that one measure has on another. For example: our efficient refrigerators measure was originally judged in terms of the CO_2 saved based on a simple assumption about the baseline electric fuel mix. But in an integrated scenario we may be combining demand-side efficiency measures with supply-side fuel switching measures. Using LEAP we can see the interactive effects.

2. LEAP's analysis is dynamic: thus we can see what happens over time as demand-side measures penetrate the market and the electric supply sector grows accordingly to meet demands.

If you have not already done so, switch-on costing in LEAP by returning to the Analysis View, and going to **General: Basic Parameters; Scope** screen. Now go to the **Costing** tab and select the boundary that will be drawn around the system for the purposes of costing. For this exercise we will select "Complete Energy System" as the boundary, meaning that fuel costs are accounted for only when they are imported or exported or when indigenously produced fuels are extracted as primary resources.

Now go back to the Analysis View and select the **Current Accounts** scenario. We will first enter data into LEAP that describes the costs (or benefits) of each.

You will need to refer to the spreadsheets you used for evaluating each mitigation measure. Enter the following information:

6.1 Demand-Side Measures

- **LPG Stoves:** From the spreadsheet, calculate the total annualized non-fuel costs per GJ of kerosene saved for this measure ($/GJ). Enter this data in LEAP for the Residential\Kerosene branch on the Demand Cost tab using the "Cost Saved Energy" cost method. Notice that costs of saved energy are always defined relative to some counterfactual. In this case the cost is defined relative to the baseline scenario. Notice also that in LEAP we will assess fuel costs separately from non-fuel costs, so you will need to calculate all of the costs except for the fuel costs.

- **Efficient Refrigerators in the Residential Sector:** Here you will need to use the spreadsheet to calculate the annual electricity savings and the total non-fuel costs of the measure. Again, use the "Cost Saved Energy" method.

- **Hybrid and Electric Cars in the Transport Sector:** Here you will need to use the spreadsheet to calculate the annual gasoline savings and the total non-fuel costs of both transport sector measures ($/GJ).

Tip: *Note that in our screening cost curve some of the measures (vehicles, refrigerators, LPG stoves, CHP) had negative overall costs (since fuel savings for these measures outweighed the investment costs). These are NOT the costs we enter into LEAP's demand analysis. Instead in LEAP we need to specify only the non-fuel costs of each measure. We will deal with the fuel savings later on using LEAP's integrated cost-benefit analysis perspective.*

- **Combined Heat and Power (CHP) in Industry:** Here you can specify cost data in terms of the cost per GJ of fuel oil replaced with CHP. Again, you will need to use the spreadsheet to calculate the annual fuel oil savings and the total non-fuel costs of the measure ($/GJ).

6.2 Transformation Measures

Entering data on the supply-side is more straightforward. We will take the data from the earlier exercises describing the capital, O&M, and lifetime of the four affected power plant types: coal, oil, hydro and coal with CCS and enter it on the various costing tabs under the Transformation: Electric Generation module. That data is repeated here for convenience:

Plant	Capital cost ($/kW)	Variable O&M Cost ($/MWh)	Lifetime (Years)
Coal	$1000	$3	35
Oil	$2000	$5	30
Hydro	$4000	$1	35
Coal with CCS	$3000	$3	35

Remember to use the default discount rate of 5% as the value for the Interest Rate for each plant. This is the value used to annualize the capital costs for each plant.

6.3 Non-energy Measures

LEAP is primarily an energy model. Currently it does not have the capability to include non-energy sector costs. Thus you cannot include the costs of the reforestation measure.

6.4 Resource Costs

Finally, we need to specify the costs of all of the various resources used in both scenarios. This data is entered under the Resource branches in LEAP for both indigenously produced primary fuels and for imported fuels.

Enter into LEAP the fuel prices specified on the **Assumptions** spreadsheet to complete the specification of the costs in your LEAP analysis. Enter costs into both the “Import Cost” variable and the “Indigenous Cost” variable for both primary and secondary fuels.

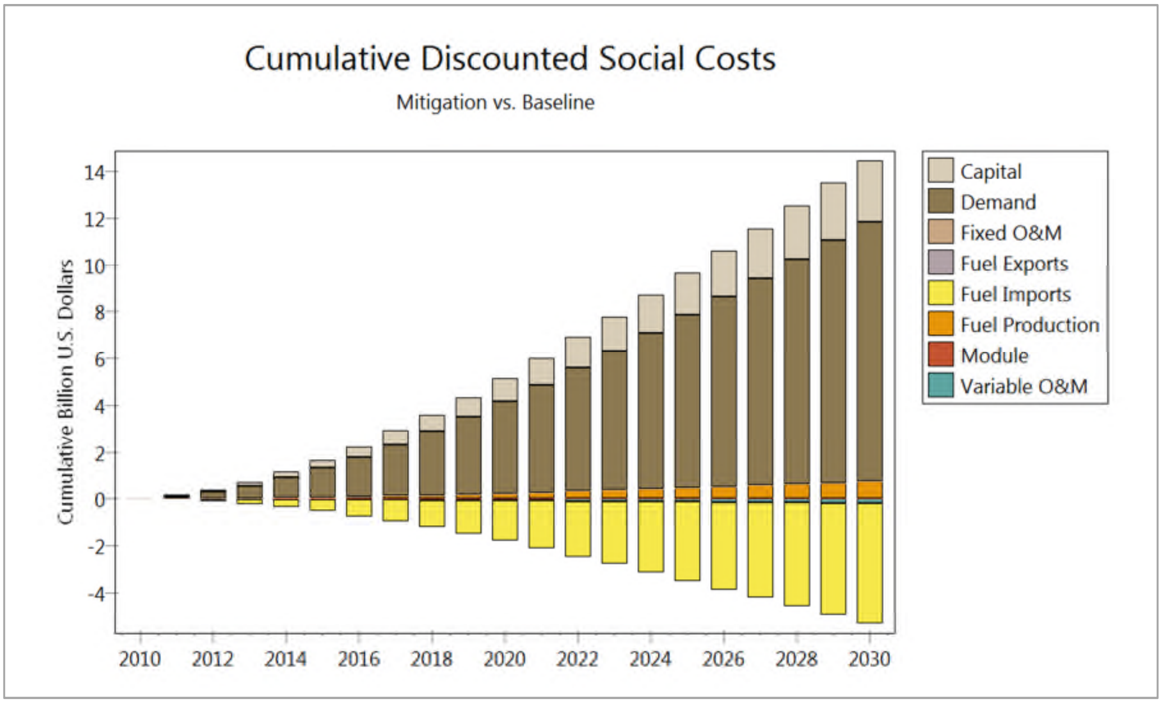
Finally, you should check that there are sufficient base year reserves of coal and natural gas available so that LEAP does not resort to importing these fuels. You can simply enter a very large number (e.g. 1 trillion GJ for each fuel) under the primary resources branch.

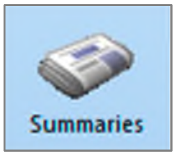
6.5 Viewing Results

You should now be ready to view some results. Click the results view and after LEAP has calculated review the overall cost results for the mitigation scenario minus the baseline scenario. Select a chart configured to show the following:

- Cost results for the whole area.
- Differences between the mitigation and baseline scenarios.
- Cumulative discounted costs
- X axis showing years, Legend showing cost categories.

You should see a chart like this:





You can also review a cost-benefit summary in the summaries view. It should look like the one shown on the right. Notice that the Net Present Value of the Mitigation scenario vs. the Baseline scenario is a cost of about 6.4 Billion US$.

Cumulative Costs and Benefits: 2010-2030. Compared to Scenario: Baseline.
Billion 2005 U.S. Dollar. Discounted at 5.0% to year 2010.

Costs	Mitigation
Demand	
Residential	0.4
Industry	0.4
Transport	10.3
Transformation	
Transmission and Distribution	0.0
Electricity Generation	7.1
Resources	
Production	0.7
Imports	-5.2
Exports	0.0
Unmet Requirements	0.0
Environmental Externalities	0.0
Net Present Value	13.8
GHG Savings (Mill. Tonnes CO2 Eq.)	664.6
Cost of Avoided CO2 (U.S. Dollar/Tonne CO2 Eq.)	20.8

Why are there positive costs for the demand and Transformation sectors but negative costs for Resources?

What are the main contributors to the high costs of the mitigation scenario?