SEI Stockholm Environment Institute

SEI Asia Centre

Training on Low Emissions Analysis Platform

Day 1: 19 October 2021

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Sida
SWEDISH INTERNATIONAL DEVELOPMENT COOPERATION AGENCY

Stockholm Environment Institute

- **Bridging science and policy** – an independent, non-profit research institute focused on sustainable development
- Over 200 staff worldwide: headquarters in Sweden, centers in the **U.S.**, Kenya, Colombia, Great Britain, **Thailand**, Estonia
- Principal research areas: **climate mitigation** and adaptation, **energy**, **air pollution**, water resources, climate finance, environmental economics
- Commitment to **stakeholder inclusion**, **capacity development**, and **transparency**

A sustainable future for all

Workshop registration

Please register your attendance daily

Participants need to register for at least 3 days

to be eligible for an attendance certificate

Registration link day 1

https://tinyurl.com/LEAP-SEIAsia-Day1

Workshop connection information

Web meetings

https://tinyurl.com/SEIAsiaLEAPtraining

Zoom meeting ID: 872 2041 5222
Zoom passcode: 353649

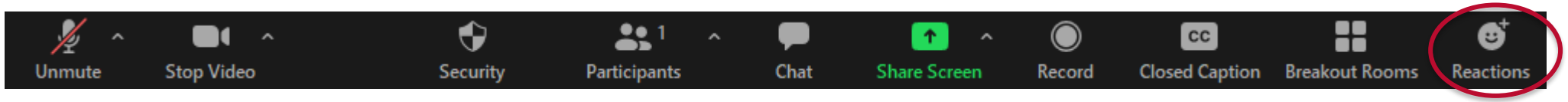
Shared files

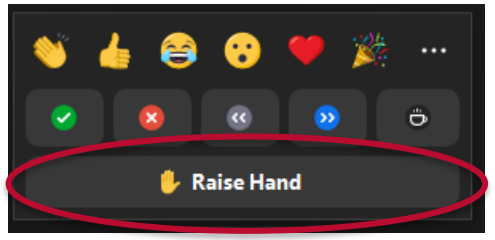
https://tinyurl.com/SEIAsiaLEAPMaterials

Password: seiasia1021

Zoom etiquette

- Please:
  - **Enter your name in Zoom** so meeting hosts can identify you in participant lists
  - **Mute yourself when not speaking**
  - Use your camera if possible
  - If you have a question, **raise your hand in Zoom**

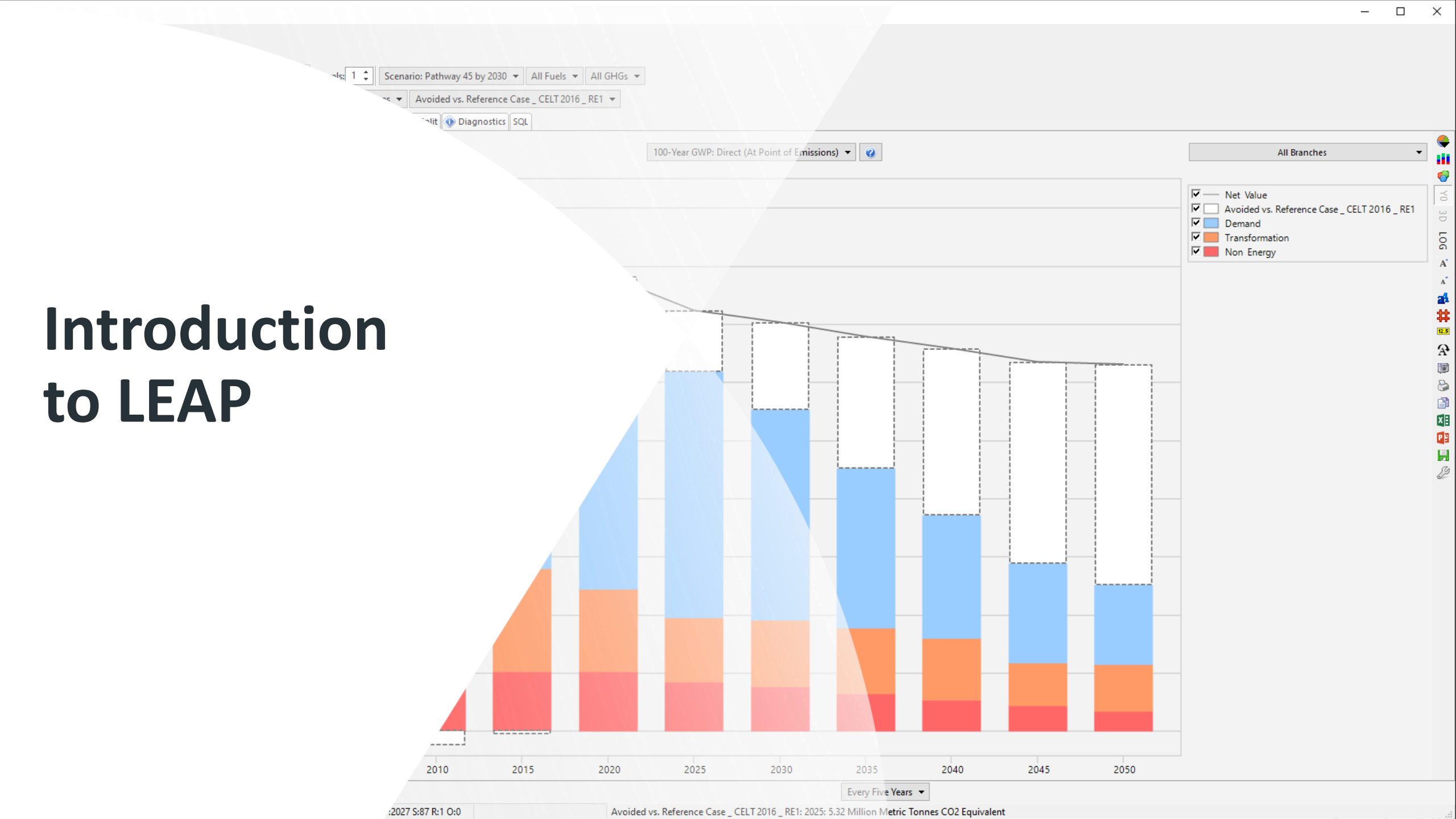




Workshop overview

- **Day 1:** Introduction to LEAP and energy demand modeling
- **Day 2:** Energy supply and emissions modeling
- **Day 3:** Cost-benefit analysis and optimization modeling
- **Day 4:** Linking LEAP and WEAP and other advanced topics

Introduction to LEAP



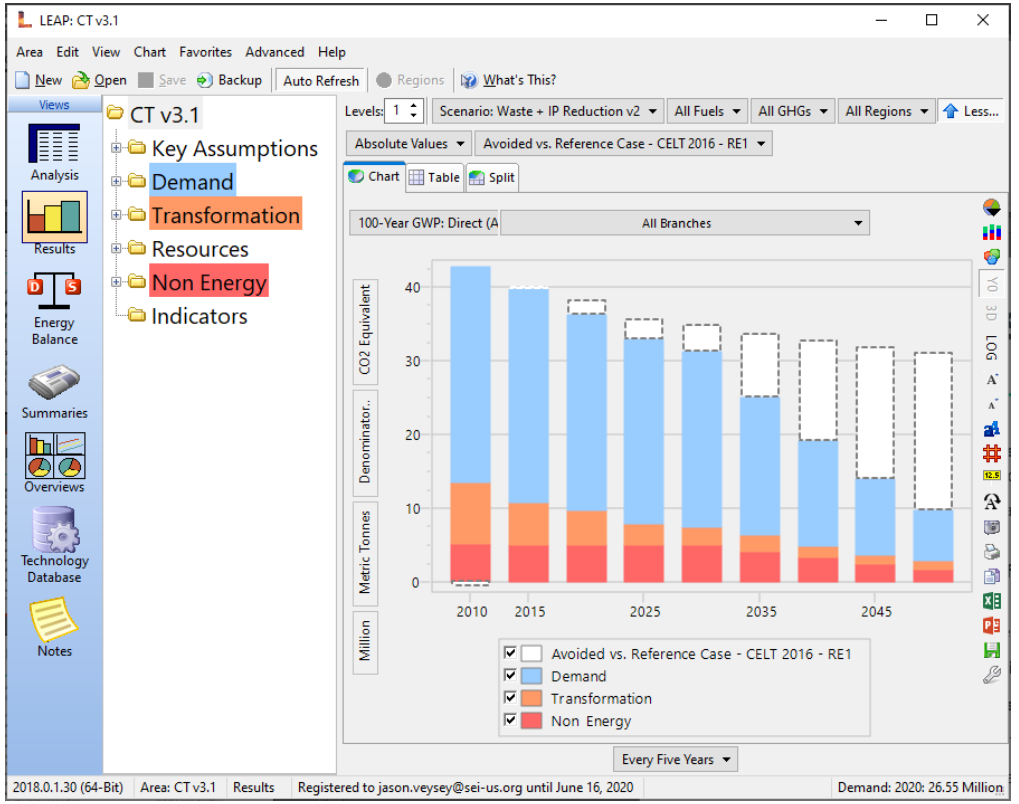
What is LEAP?

- A software tool for **quantitative modeling of:**
  - Energy systems
  - Pollutant emissions from energy and non-energy sources
  - Costs and benefits
  - Health impacts
  - Sustainable development indicators
  - Related externalities
- Created by SEI to **support sustainable development**
  - Inform decision making
  - Empower stakeholders to perform their own analyses
- Well-suited to **medium and long-term planning**
- Facilitates data management and documentation, **communication** with stakeholders

LEAP is not a model: it's a **tool for creating models**

Key characteristics

- **Broad scope, flexible data structures**
  - Capable of providing results in data-scarce environments
- **Multiple modeling methodologies** supported
- User-selected modeling methods embedded in an **accounting framework** (energy, emissions, costs, natural resources)
- **Scenario-based**: scenarios for different policies, assumptions, analytical questions
- **Graphical user interface, powerful visualizations**
- Suitable for **modeling at various scales**: national, subnational, regional, global
- **Libraries of default data**: units, pollutants, fuels, emission factors
- Annual time step with seasonal/time-of-day details
- Integration with **Microsoft Office**
- Widely used for **energy planning**, national communications, low emission development strategies, air pollution action plans



LEAP Timeline

1980: Mainframe model for Kenya Fuelwood project

1985: PC version. Studies in Africa, Asia, and Latin America

1992: GHG emissions modeling

1994: Chinese version

1997: GHG mitigation assessments

2000: Windows version

2006: API allowing links to other models

2011: Least-cost optimization modeling

2012: "Energy for a Shared Development Agenda": global energy model

2013: Energy-water nexus analysis: link to WEAP water planning tool

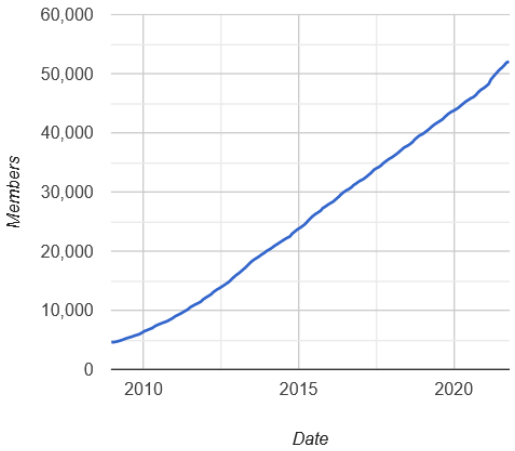
2015: LEAP-IBC for analysis of impacts from air pollution

2016: New results visualization capabilities

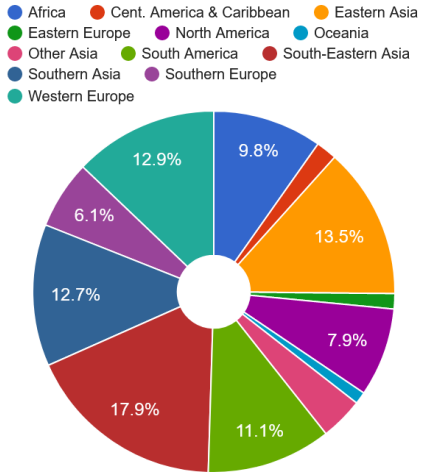
2020: Advanced optimization modeling, results mapping, indoor air pollution assessment

2021: Net-zero GHG emissions studies

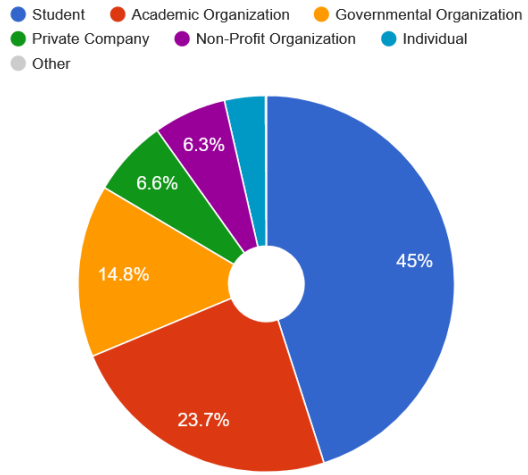
1980 1985 1990 1995 2000 2005 2010 2015 2020



Number of LEAP users over time



Users by region



Types of users

Four decades of development and implementation

Distribution

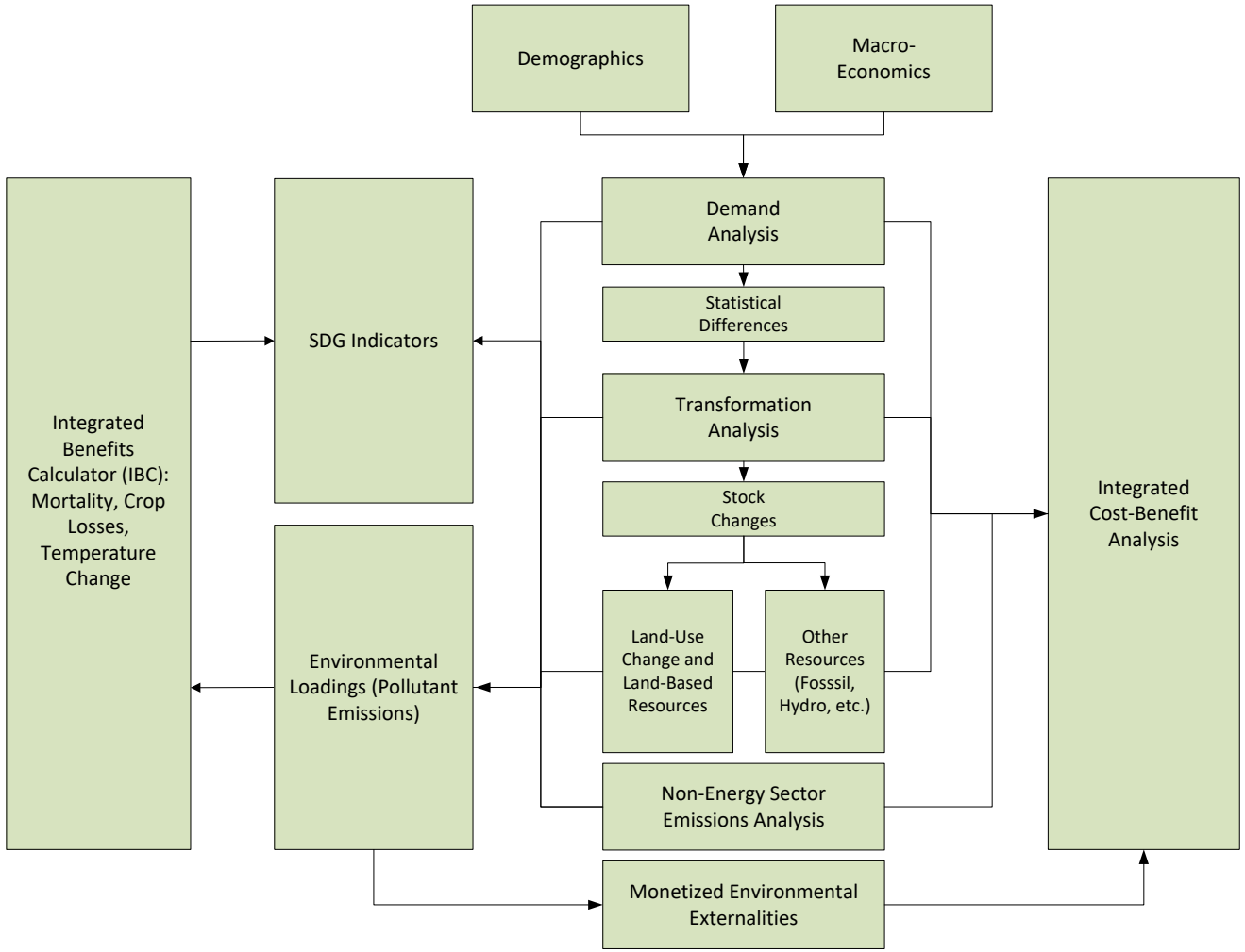
Access via the LEAP website: https://leap.sei.org/

- **User name and password** required to fully enable software. Available on completion of a **license** agreement
- License cost
  - Free for all students
  - **Free for non-profit, academic, and governmental institutions in low-income and lower-middle-income countries**
  - Nominal cost for non-profit, academic, and government users in upper-middle income countries
  - Full-cost license for all other users
- Simple and quick to apply for a license online
- **Technical support** available though LEAP website or leap@sei-us.org

Prerequisites

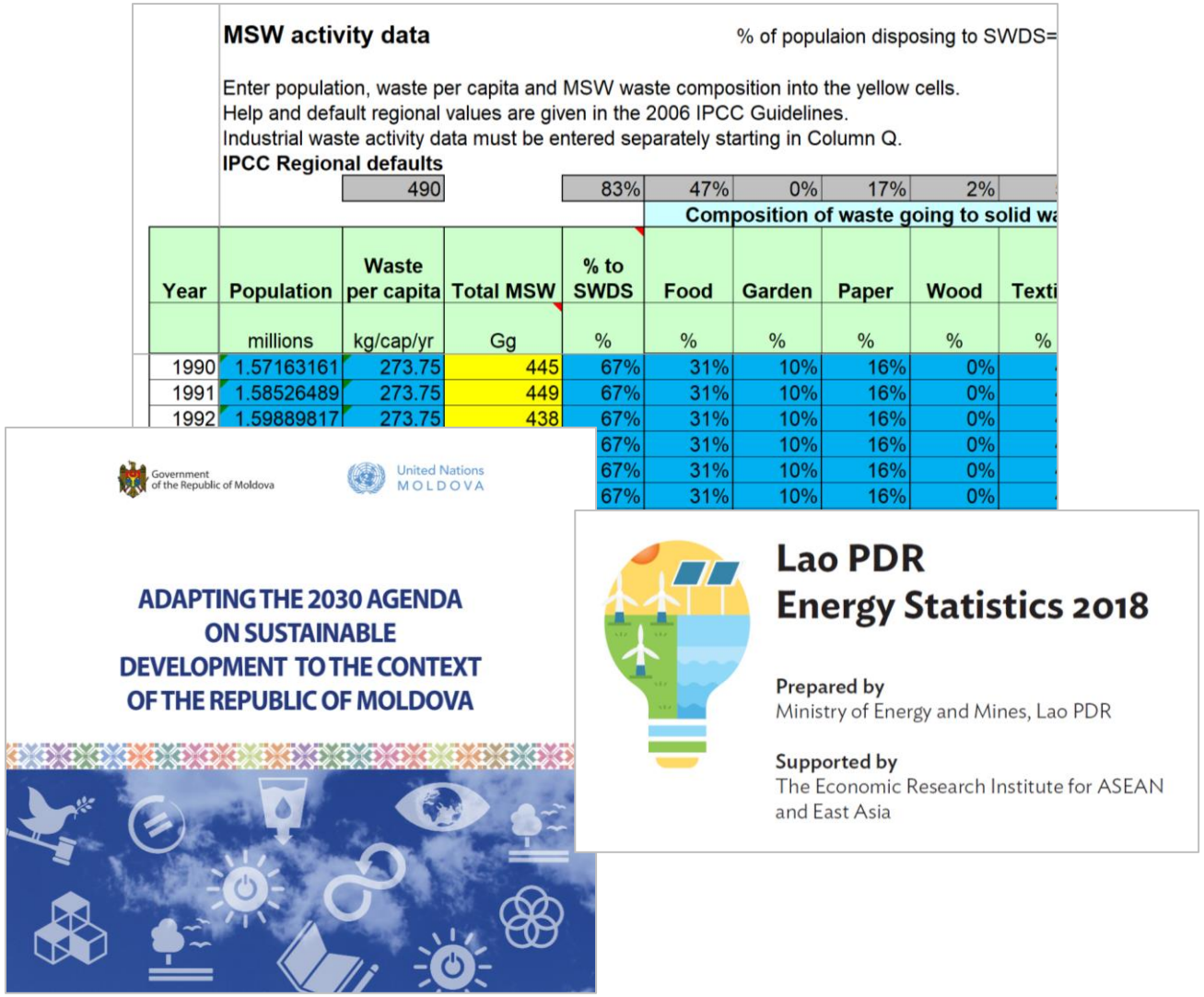
- **Windows application**
  - Windows 7 or later
  - Not supported on Mac, Linux, or Unix
- At least **4 GB RAM**
- At least **1 GB free disk space**
- **Administrator rights for installation**

Structure of a representative LEAP analysis



Typical inputs…

- Demographic and macroeconomic data and projections
- Energy balances, surveys, and audits
- GHG inventories
  - Activity data
  - Emission factors
  - Emission totals
- Grid operator reports
- Equipment stock, sales, and performance data
- Natural resource reserves and potentials
- Plans and policies
  - Climate
  - Energy
  - Air pollution
- Costs
  - Equipment capital, operation and maintenance
  - Fuel and other consumables
  - Policy implementation



MSW activity data % of populaion disposing to SWDS=

Enter population, waste per capita and MSW waste composition into the yellow cells.
Help and default regional values are given in the 2006 IPCC Guidelines.
Industrial waste activity data must be entered separately starting in Column Q.
IPCC Regional defaults 490 83% 47% 0% 17% 2%

Composition of waste going to solid wa

Year	Population	Waste per capita	Total MSW	% to SWDS	Food	Garden	Paper	Wood	Texti
	millions	kg/cap/yr	Gg	%	%	%	%	%	%
1990	1.57163161	273.75	445	67%	31%	10%	16%	0%	
1991	1.58526489	273.75	449	67%	31%	10%	16%	0%	
1992	1.59889817	273.75	438	67%	31%	10%	16%	0%	
				67%	31%	10%	16%	0%	
				67%	31%	10%	16%	0%	
				67%	31%	10%	16%	0%	

Government of the Republic of Moldova
United Nations MOLDOVA

ADAPTING THE 2030 AGENDA ON SUSTAINABLE DEVELOPMENT TO THE CONTEXT OF THE REPUBLIC OF MOLDOVA

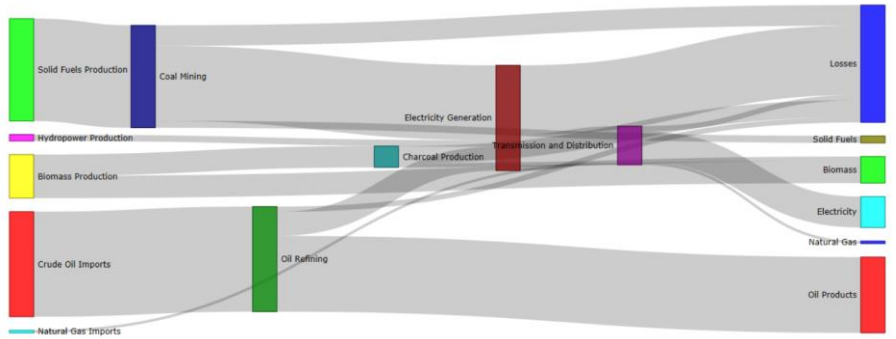
Lao PDR
Energy Statistics 2018

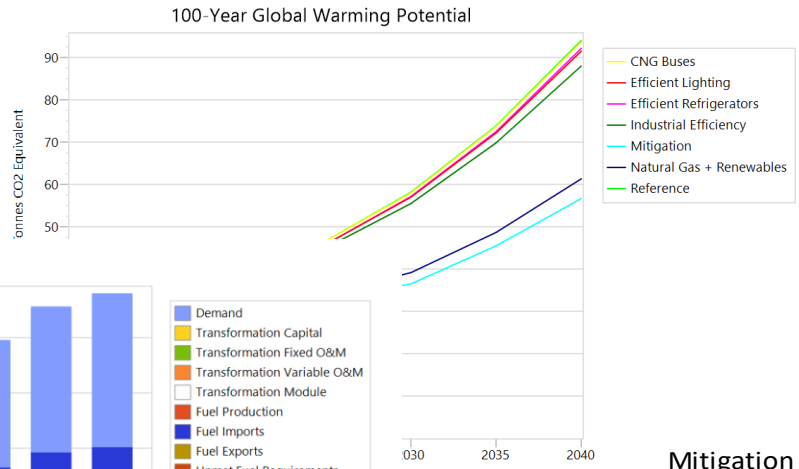
Prepared by
Ministry of Energy and Mines, Lao PDR

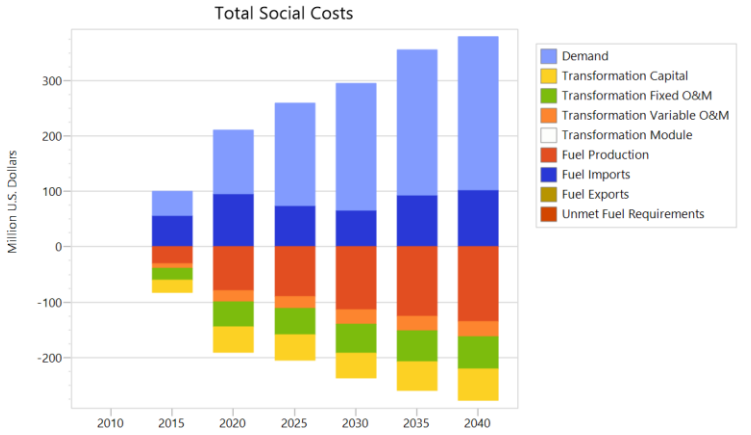
Supported by
The Economic Research Institute for ASEAN and East Asia

… and outputs

- Energy demand and supply
  - Domestic/local production
  - Imports and exports
- Pollutant emissions – direct and indirect
- Social costs
  - Real and discounted
  - Baseline and policy scenarios
- Energy balances and Sankey diagrams
- Equipment capacities, stocks, and utilization
- Natural resource exploitation
- Impacts of air pollution
- Decomposition analyses
- Marginal abatement cost curves (MACCs)
- Other user-defined indicators



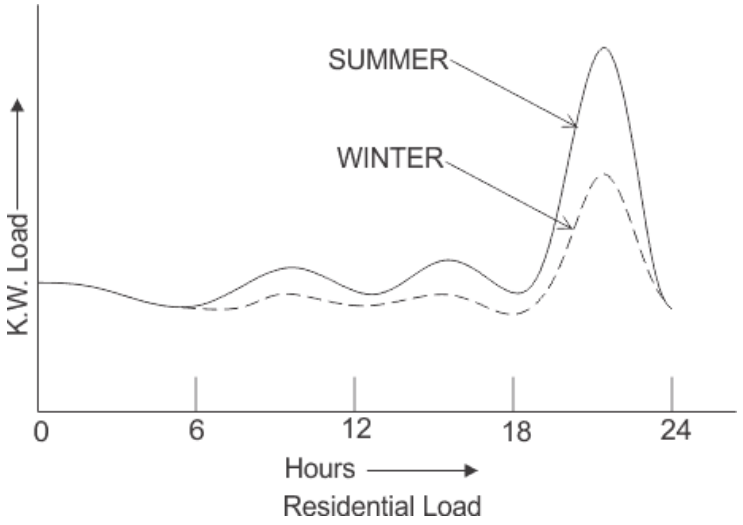




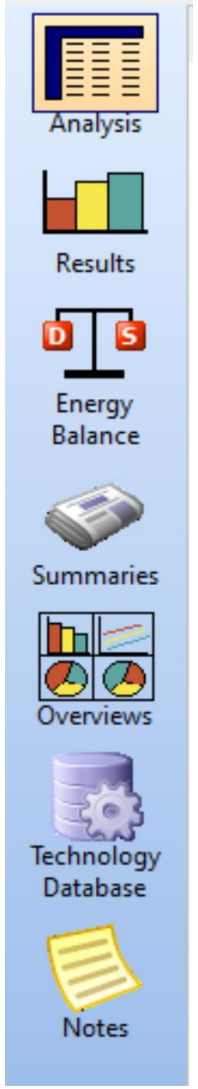
Mitigation	
Demand	5.00
Household	0.73
Industry	1.70
Transport	2.56
Commercial	-
Transformation	-3.00

Time frame

- LEAP is intended as a **medium- to long-term** modeling tool
- Most of its calculations occur on an **annual time-step**
- The modeling horizon can extend for an **unlimited number of years**, but most studies use a forecast period of 20-50 years
- Energy demand and supply for selected fuels/sectors (e.g., electricity) can be calculated with a **finer level of temporal detail**
  - Years are split into user-defined “time slices” representing seasons, types of days, and times of day
  - Demand is determined by time slice, and supply is dispatched by time slice to meet demand
  - **Time slices can easily be reconfigured to explore impacts of temporal resolution on results**



LEAP user interface: Views



Analysis is where you enter or view input data and construct your model and scenarios

Results is where you examine the outcomes of your scenarios as graphs and tables

Energy Balance lets you see calculated energy results as specially formatted energy balance tables and Sankey diagrams

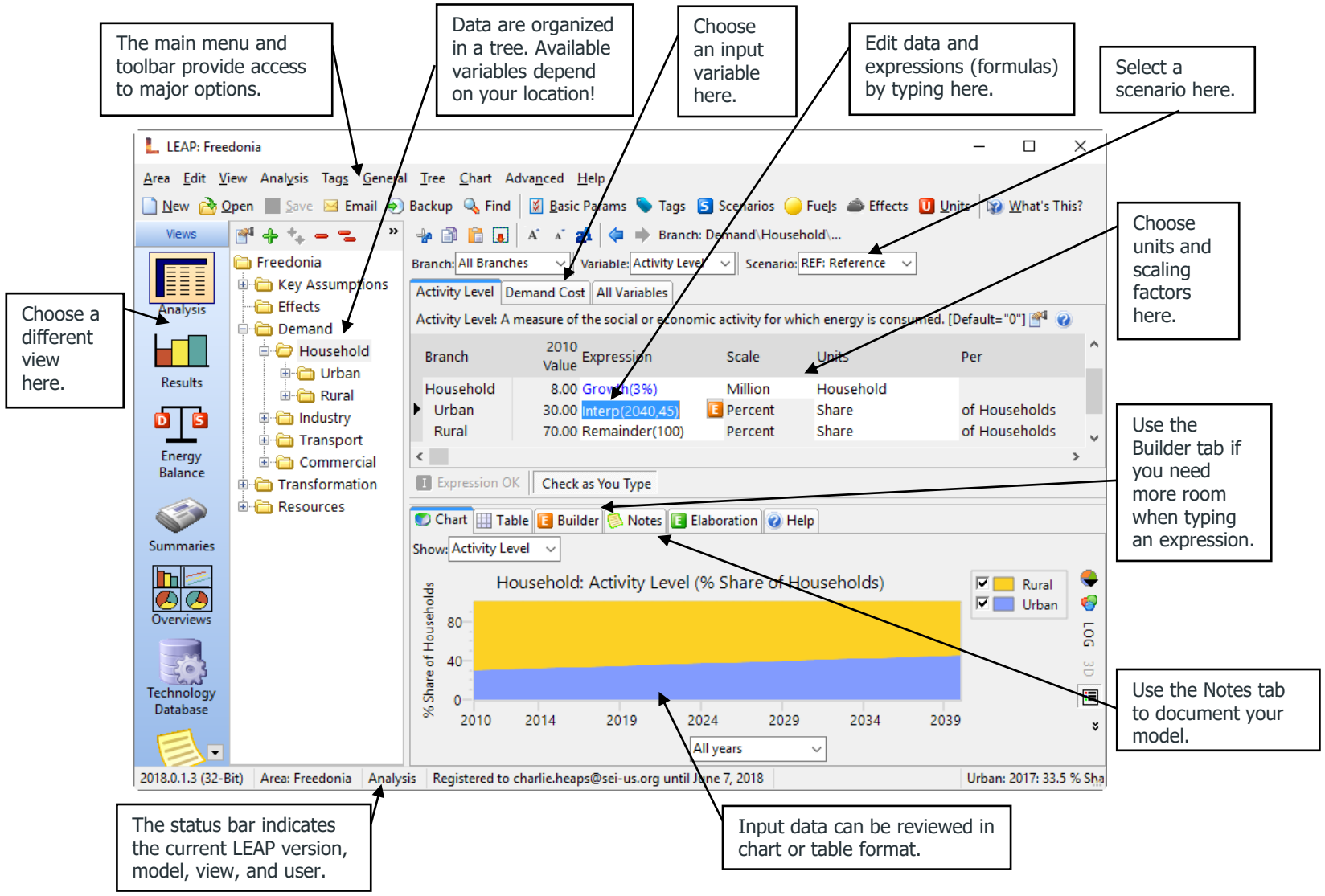
Summaries allows you to create your own customized tabular reports, including cost-benefit summary reports, MACCs, and decomposition analyses

Overviews is used to group together “Favorite” charts created earlier in the Results view

Technology Database provides default data on the technical characteristics, costs, and environmental impacts of various energy technologies available internationally and in particular regions

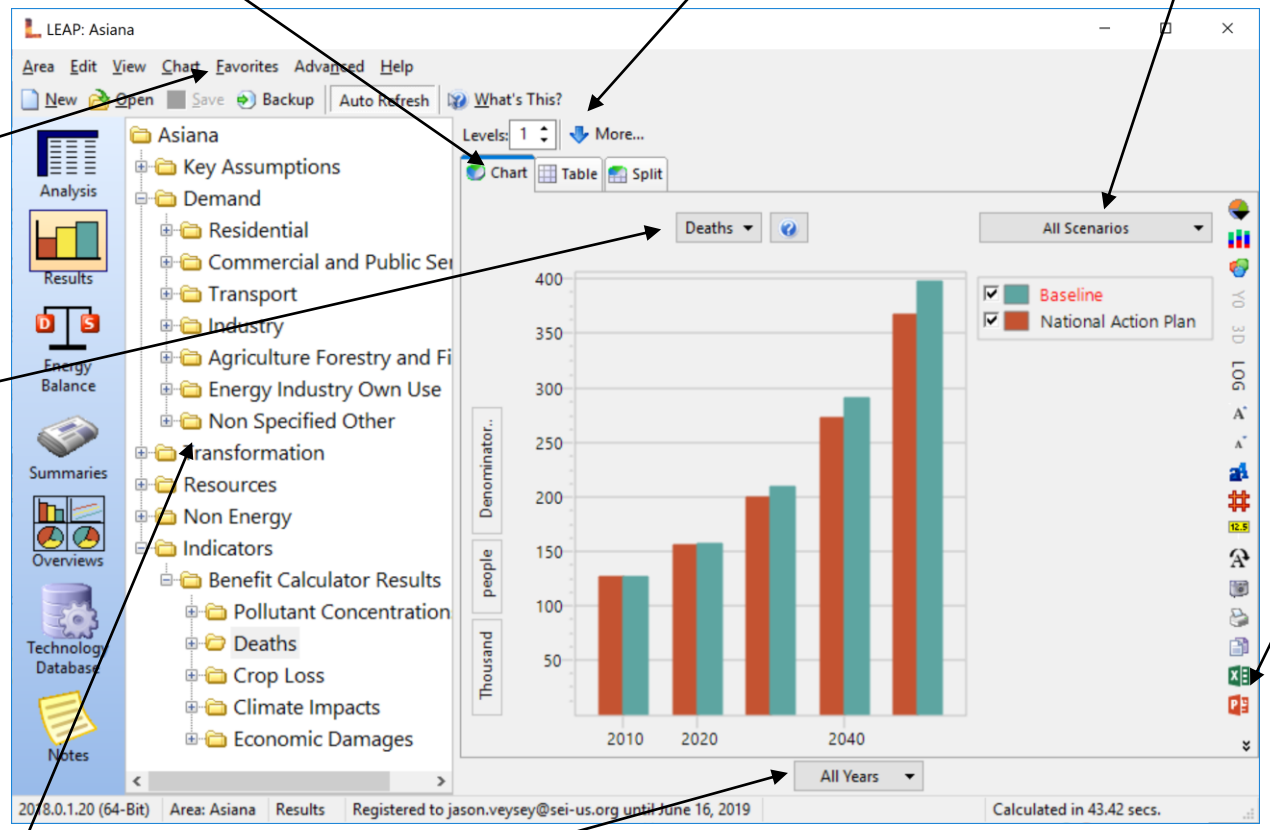
Notes is a simple word processing tool with which you can enter documentation and references for different parts of your model

User interface



Analysis View:
model design and construction

User interface



Results can be shown in chart, table, or map format.

Set other context-specific options here.

Define chart series here: branches, pollutants, fuels, scenarios, years, and more.

Charts can be saved as Favorites, which can then be grouped and plotted together in the Overviews view.

Change chart types, colors, and other formatting here.

Choose an output variable here.

Export outputs directly to Excel and PowerPoint.

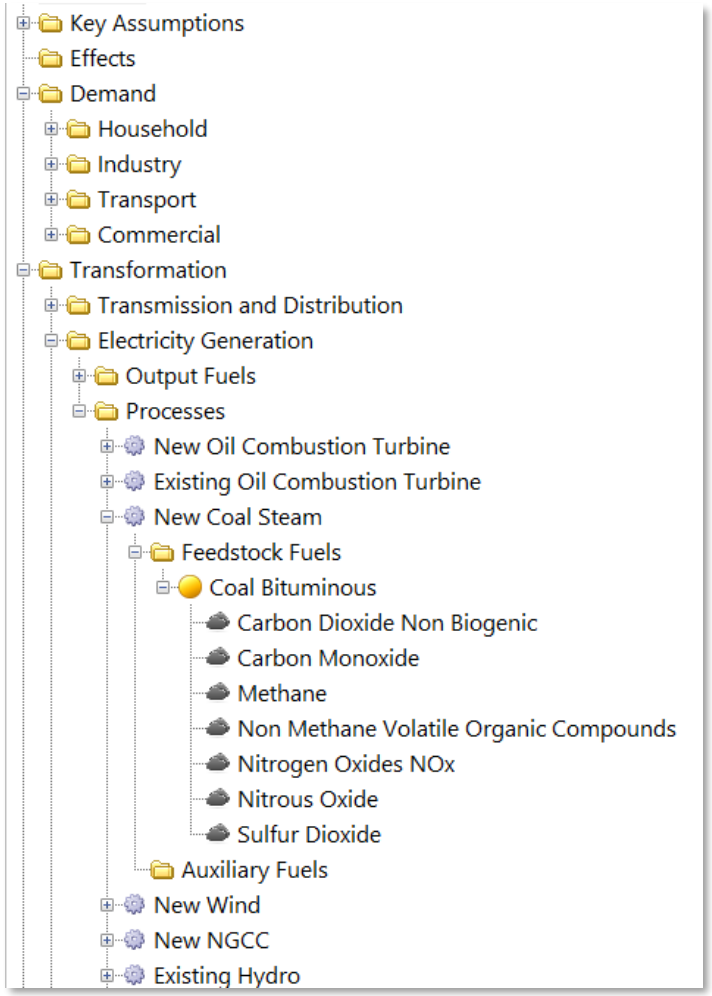
The data shown and available output options depend on your location in the tree.

Define a chart's x-axis here: branches, pollutants, fuels, scenarios, years, and more.

Results View:

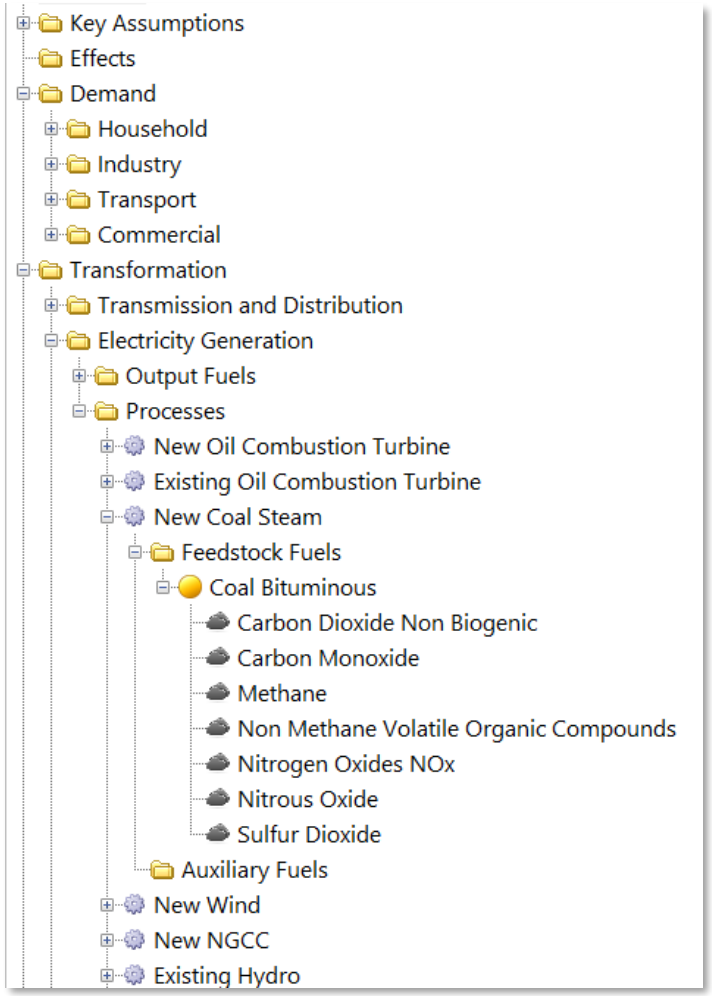
results visualization and analysis

The tree



- **Defines a model's structure** – organizes input data and results
- Made up of **branches**; each branch contains context-dependent **variables**
- Supports standard graphical user interface interactions – copy & paste, click & drag
- LEAP sets top-level branches depending on model's scope; other branches generally **determined by user**

Types of tree branches

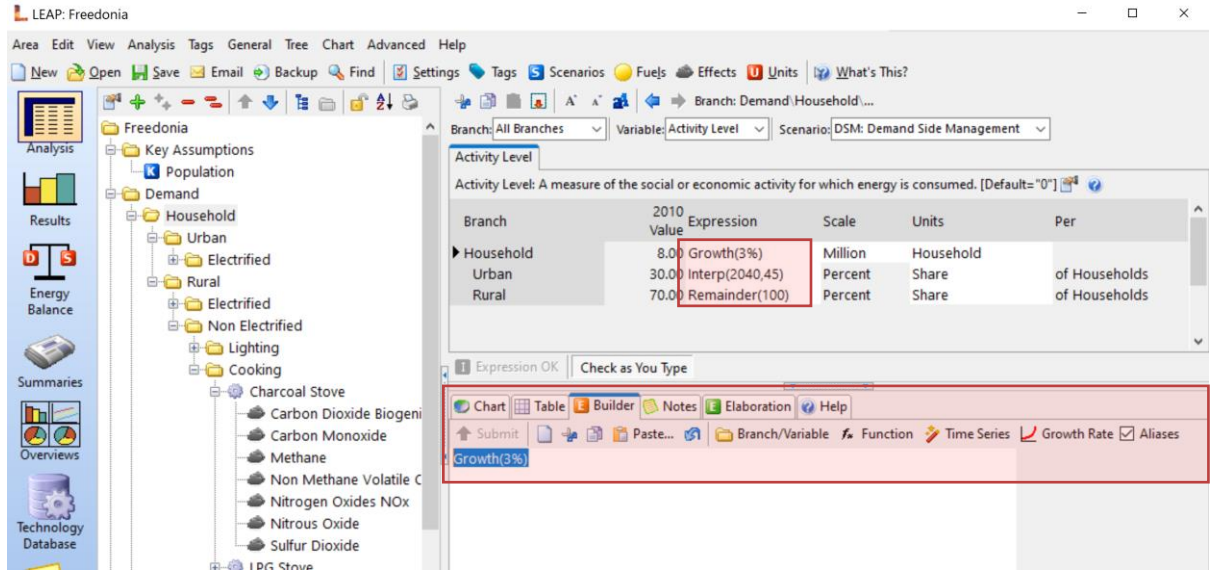


- **Categories:** used mainly for organizing other branches
- **Technologies**: final-energy consuming devices and energy transformation processes
- **Key Assumptions:** user-defined independent variables (demographic, macroeconomic, etc.)
- **Fuels** (energy carriers)
- **Effects**: environmental loadings (e.g., emissions)

Modeling methods: two levels

- Basic, non-controversial **physical accounting calculations are handled internally within LEAP** (e.g., energy, equipment stocks, natural resources, costs, pollutants)
- Users can specify **additional modeling through LEAP expressions and other options**

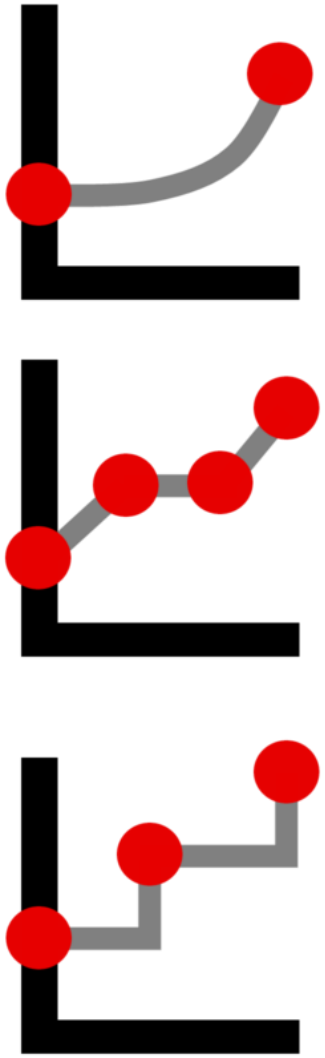
Expressions



- Similar to formulas in **spreadsheets**
- Used to specify **values of variables**
- **All expressions define a time series of values**: can be a constant in all years (a simple numerical expression) or a formula that yields different results in each year
- Can use many **built-in functions** and **refer to values of other variables**
- Can be **linked to Excel** spreadsheets
- Can be **inherited across scenarios and regions**

Expressions: some examples

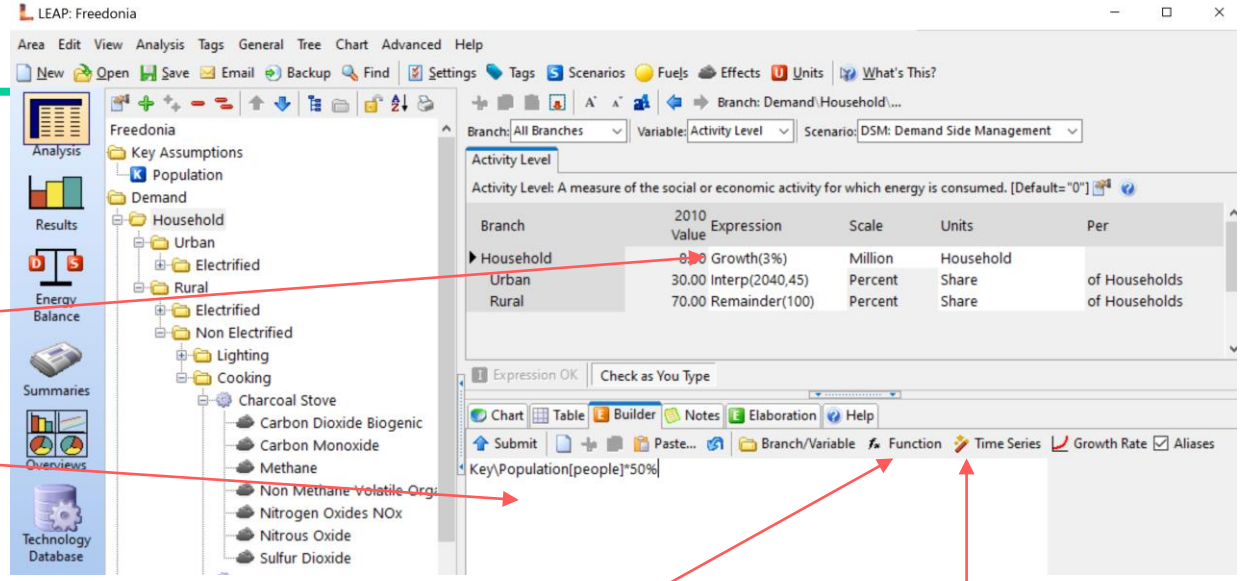
- **Simple number**
  - A constant value in all scenario years
- **Simple formula**
  - Example: “0.1 * 5970”
  - Calculates a constant value in all scenario years
- **Growth rate**
  - Example: “Growth(3.2%)”
  - Calculates exponential growth over time
- **Interpolation**
  - Example: “Interp(2000, 40, 2010, 65, 2020, 80)”
  - Performs linear interpolation between values
- **Step function**
  - Example: “Step(2000, 300, 2005, 500, 2020, 700)”
  - Calculates discrete changes in particular years
- **GrowthAs**
  - Example: “GrowthAs(Income,elasticity)”
  - Causes variable to grow at same rate as another variable, subject to an elasticity

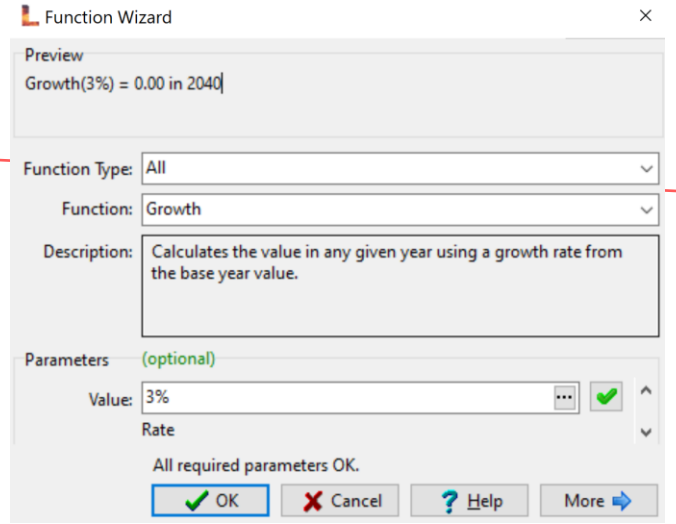


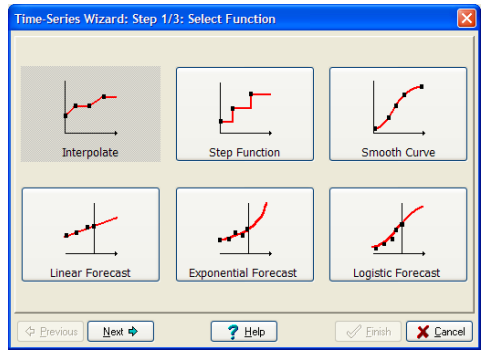
Expressions: ways to edit

In Analysis view…

- **Type** to directly edit an expression
- Use **Expression builder** to make an expression by dragging and dropping functions and variables
- Choose **Function Wizard** for help selecting a built-in function
- Use **Time-Series Wizard** to enter time-series functions and data (Interp, Step, etc.)
- There are also multiple ways to import and export data from/to **Excel**







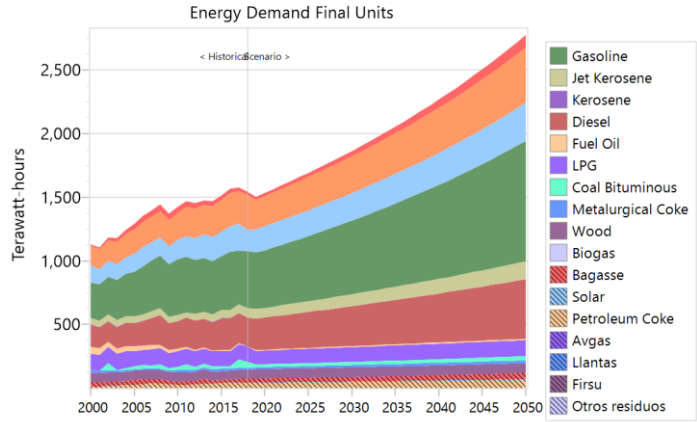
Scenario analysis

The future is unknown…

…but we can explore it using scenarios

Scenario: An internally coherent, physically plausible storyline that describes a possible state of the world. Scenarios are represented in LEAP by exogenous inputs (data and assumptions), calculation methods, and results produced from the inputs and methods.

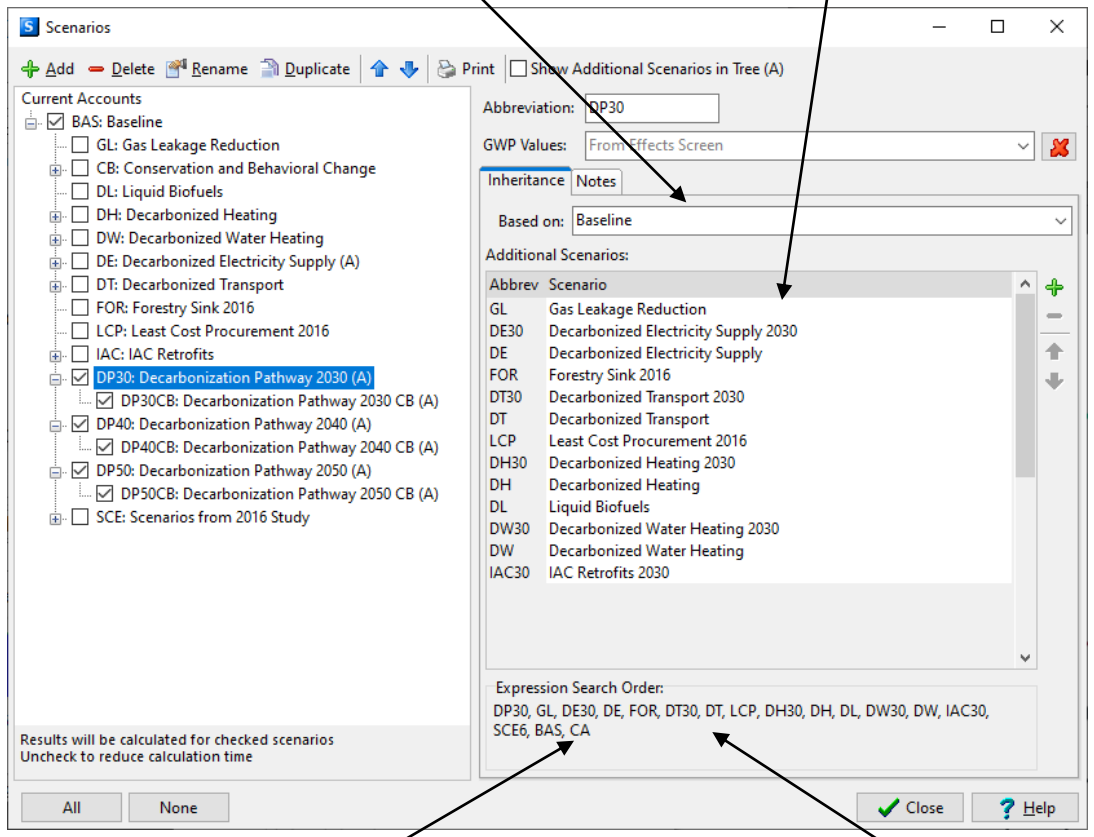
- LEAP recognizes **two types of scenarios**
  - Current Accounts – historical data
  - Future projections – baseline, policies, mitigation measures, etc.



Scenario inheritance

Parent scenario: the default source of expressions and data for projection years

Other scenarios from which to inherit. The order matters!



For a projection scenario, the last scenario in the inheritance chain is always Current Accounts.

LEAP follows this order when searching for expressions and data to inherit.

A scenario can **inherit** expressions and data **from multiple other scenarios**

Expressions are color-coded in the Analysis view. Blue = defined in the scenario, black = inherited from another scenario, green = inherited from another region.

Branch: All Branches | Variable: Activity Level | Region: Connecticut | Scenario: RES1: Res RE Thermal

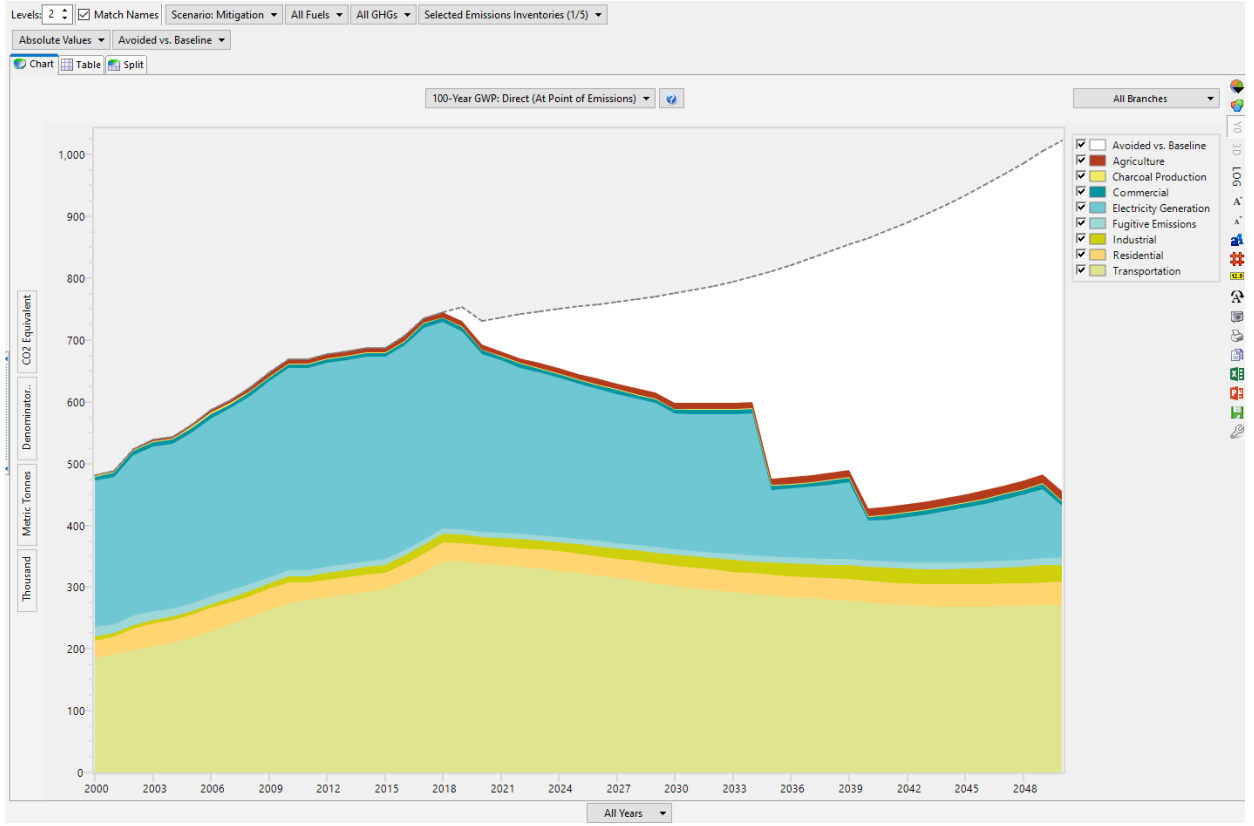
Activity Level | Final Energy Intensity | Demand Cost | Avg Environmental Loading | All Variables

Activity Level: A measure of the social or economic activity for which energy is consumed. [Default="0"]

Branch	2013 Value	Expression	Scale
Residential			
Heating	61.23	Interp(2014,960.4,2050,973.9)	Thousan
Tech Container			
Diesel Furnace_0	24.93	Interp(2014,25.1,2020,22.3,2030,14,2050,0.3)	Percent
Distillate Radiator_0	46.92	Interp(2014,46.8,2020,41.6,2030,26.2,2050,0.6)	Percent
Elec HP_0	0.19	Interp(2014,0.2,2020,8,2030,31.2,2050,69.6)	Percent
Elec Rad_0	1.93	Interp(2014,1.9,2050,3.03)	Percent
Geo HP_0	0.01	Interp(2014,0,2020,2,2030,7.8,2050,17.4)	Percent

Scenario reporting

- LEAP provides **powerful features for analyzing and comparing scenario results**
  - Differences between scenarios
  - Amounts avoided in a scenario
  - Scenarios as series in charts and tables



LEAP glossary

Area

- A LEAP model or the system being modeled. Areas may be divided into multiple geographic regions.

Base year

- The first year in a model.

End year

- The last year in a model.

Scenario

- A consistent set of model inputs and results corresponding to a possible state of the world. Models can contain multiple scenarios.

Current Accounts

- A special scenario containing historical data. Every model includes Current Accounts.

First scenario year

- The year following the last year in Current Accounts. The first year in projection scenarios.

Tree

- A hierarchical data structure that organizes a model's inputs and results.

Branch

- An item in the tree: categories, technologies, modules, processes, key assumptions, etc.

Variable

- An input variable for a model, contained in a branch. Branches may have multiple variables, which are shown in tabs on screen.

Expression

- A formula that specifies time-series values of a variable for a given branch, scenario, and region.

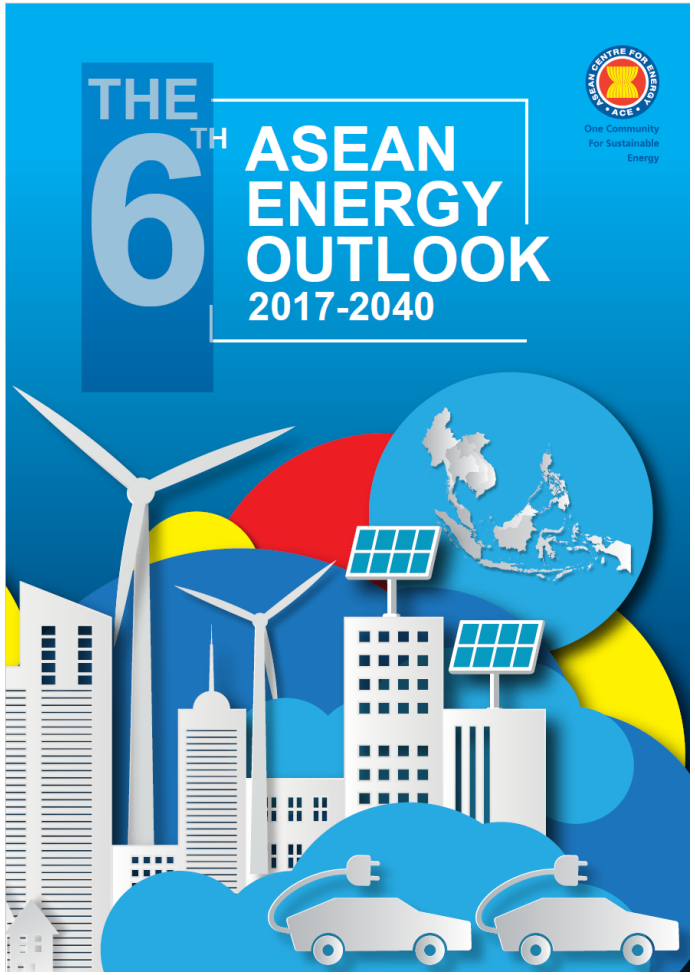
LEAP is *not…*

- A system dynamics model
- A general equilibrium model
- A macroeconomic model
- An agent-based model
- An electricity system production cost model
- An electricity system network reliability (AC power flow) model

Example LEAP applications

Sixth ASEAN Energy Outlook

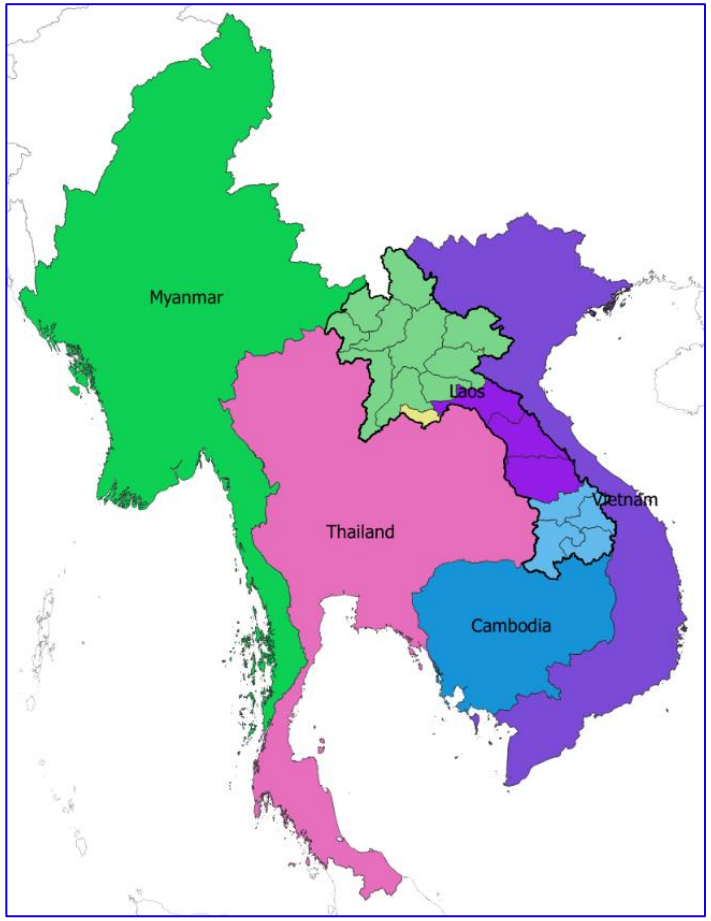
- Regional LEAP model with national detail
- Energy demand, energy supply, and emissions
  - Bottom-up modeling of key demand and supply sectors
- Simulation of national plans and policies, regional targets including SDG 7 attainment



Example LEAP applications

Integrated resource and resilience planning in Lao PDR

- Highly resolved LEAP/NEMO model of national electricity system
- Nodal simulation of electricity grid and power flow
- Applied in large scenario ensemble analysis for robust decision making

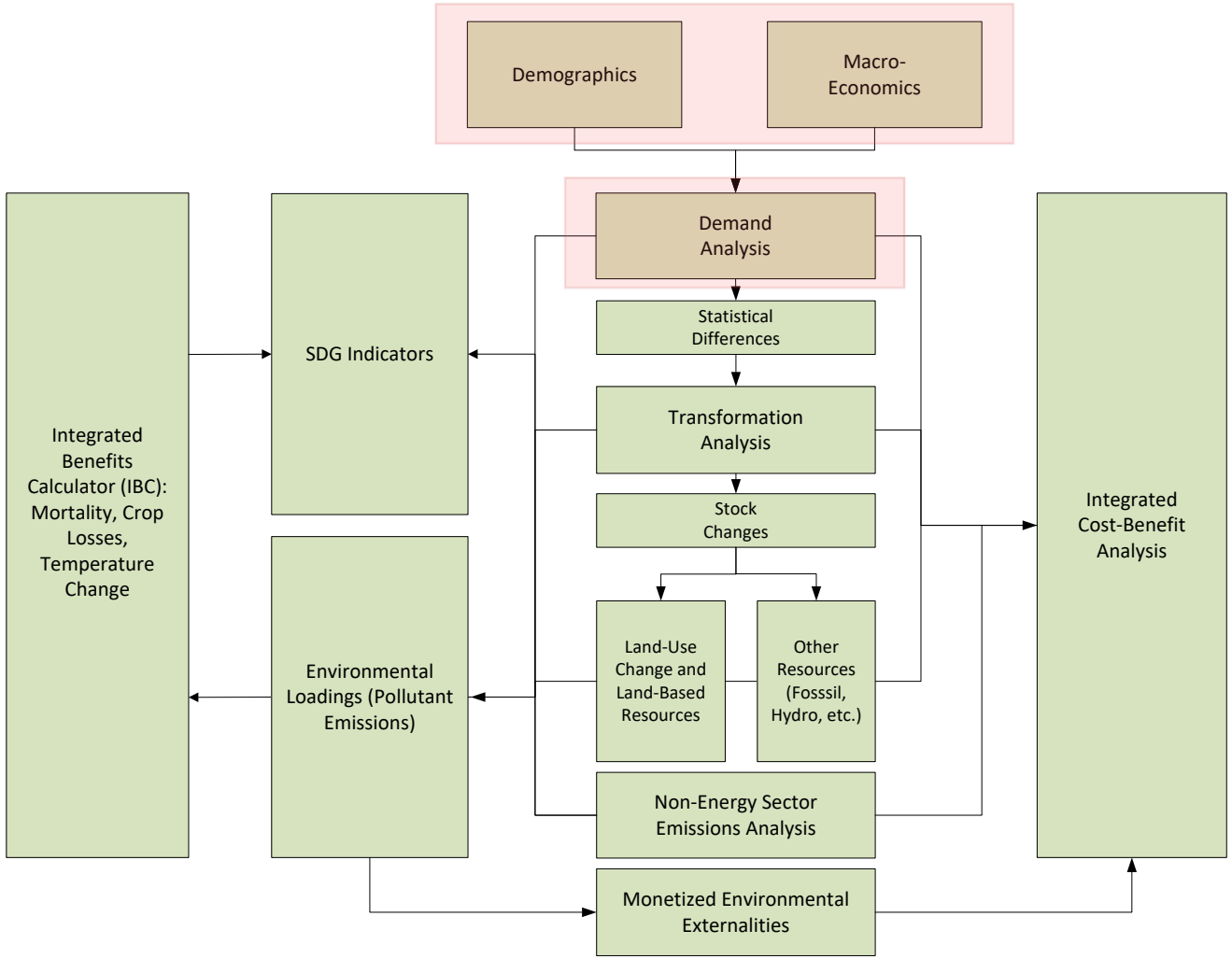


LEAP license for this workshop

- **User name:** SEI Asia LEAP Training
- **Password:** 897-735-038-898-864
- **Software expires:** 1 November 2021 (after this date, saving changes to data will be disabled)

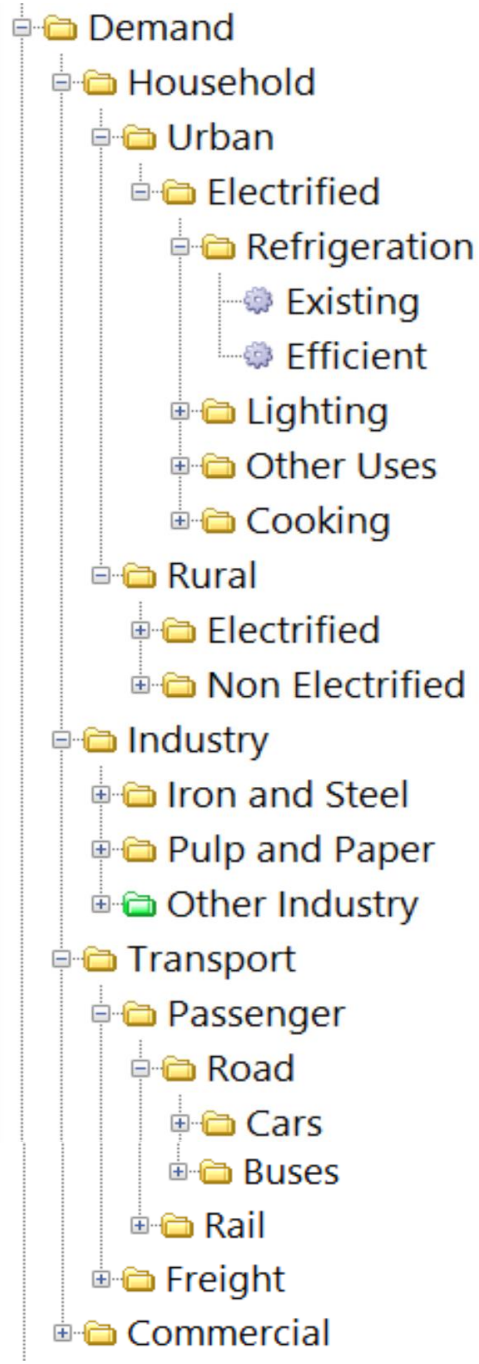
Modeling energy demand with LEAP

Structure of a representative LEAP analysis

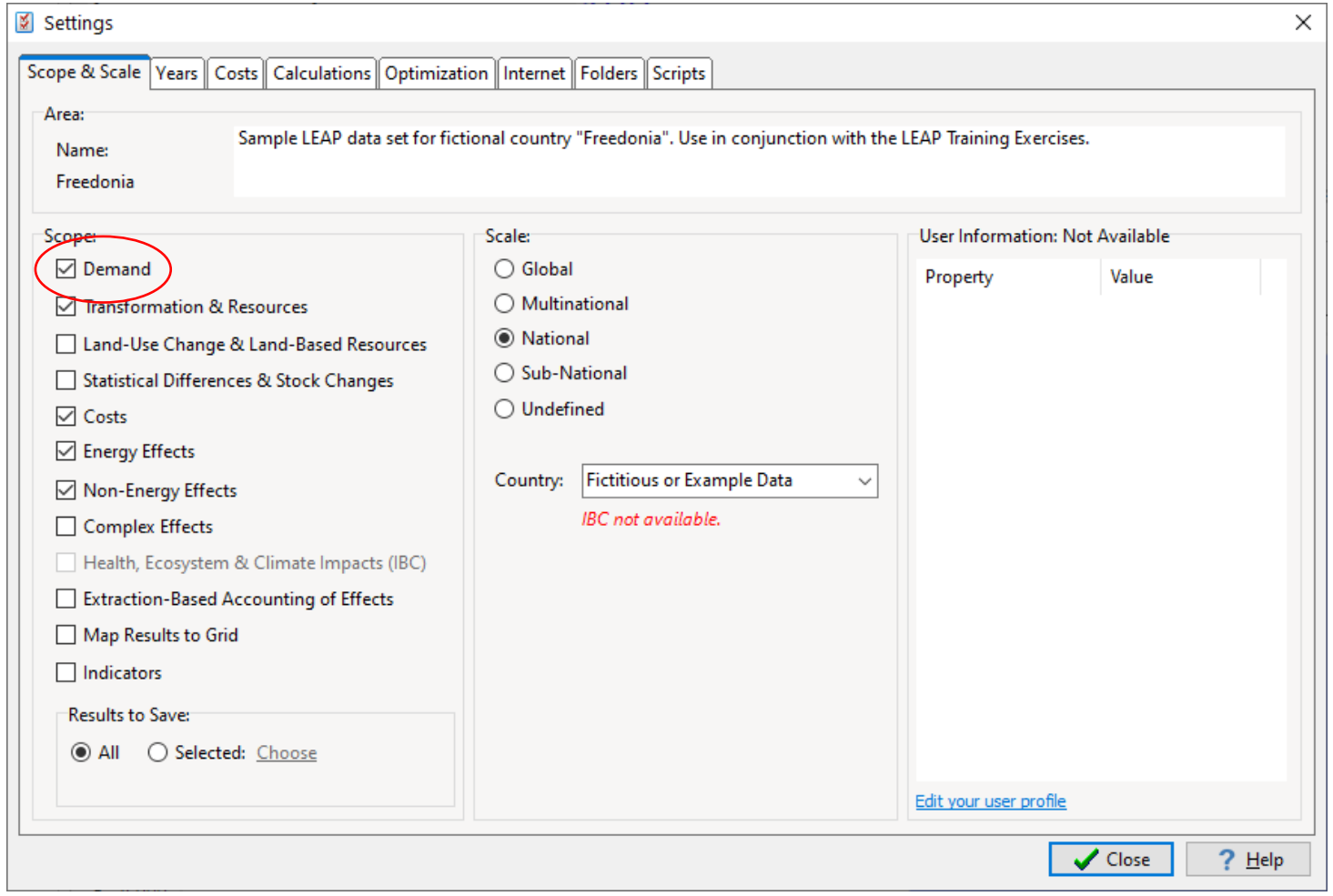


Demand modeling overview

- LEAP supports modeling all energy consumption and associated costs and emissions in an area
  - **Final energy demands in Demand branch** (focus of this lecture and first exercise)
  - Intermediate energy demands in Transformation branch (supply side of model)
- Significant **flexibility** in representing final energy demands in model
  - **Level of disaggregation**
  - **Technology specification** (equipment or devices that consume energy)
  - **Projection methods**



Enabling demand modeling

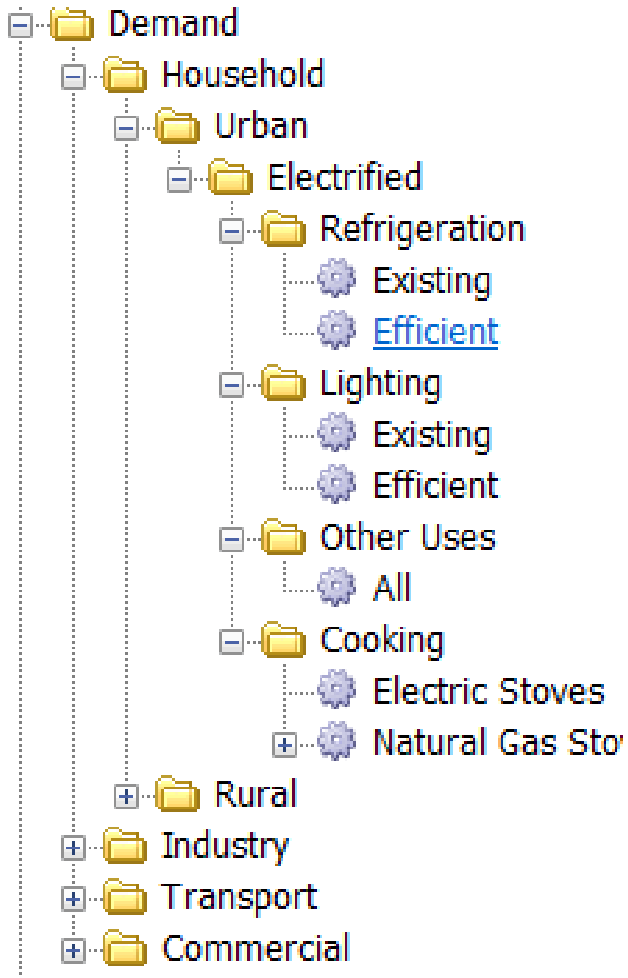


Disaggregation: bottom-up / end-use

- Detailed accounting of sectors, subsectors, end-uses, and devices that consume energy

- Provides a more fundamental understanding of why energy is used in an economy: probably best approach for thinking about long-term transitions
- Captures impacts of structural shifts and from technology-based policies such as energy efficiency

- Data-intensive
- Reliant on expertise of analyst for many trends and assumptions
- Hard to capture impacts of fiscal policies (e.g., carbon tax)

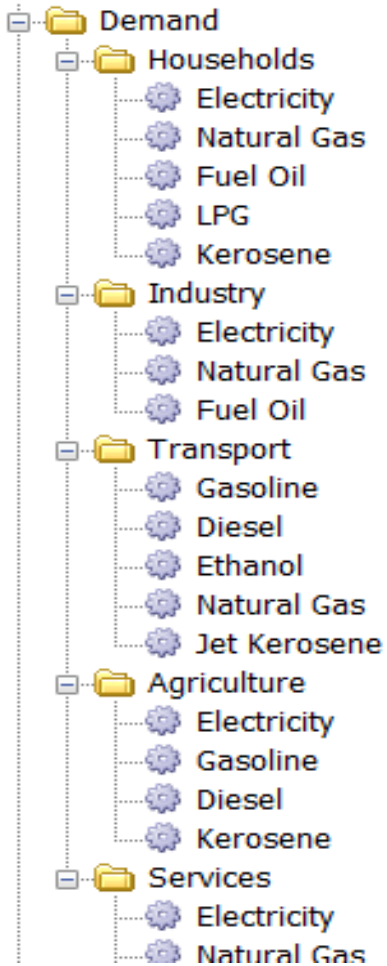


Disaggregation: top-down

- A more aggregate approach often with energy consumption broken down only by sector and fuel
- Consumption often forecast into future using simple historical trends or aggregate econometric relationships (GDP, fuel prices, etc.)
- Generally relies on good historical time-series data

- Lends itself to capturing impacts of fiscal policies (e.g., carbon tax)
- Less data-intensive

- Hard to account for inertia due to technology / equipment investments
- Provides little insight into physical bases of demand
- Not well-suited for examining technology-based policies

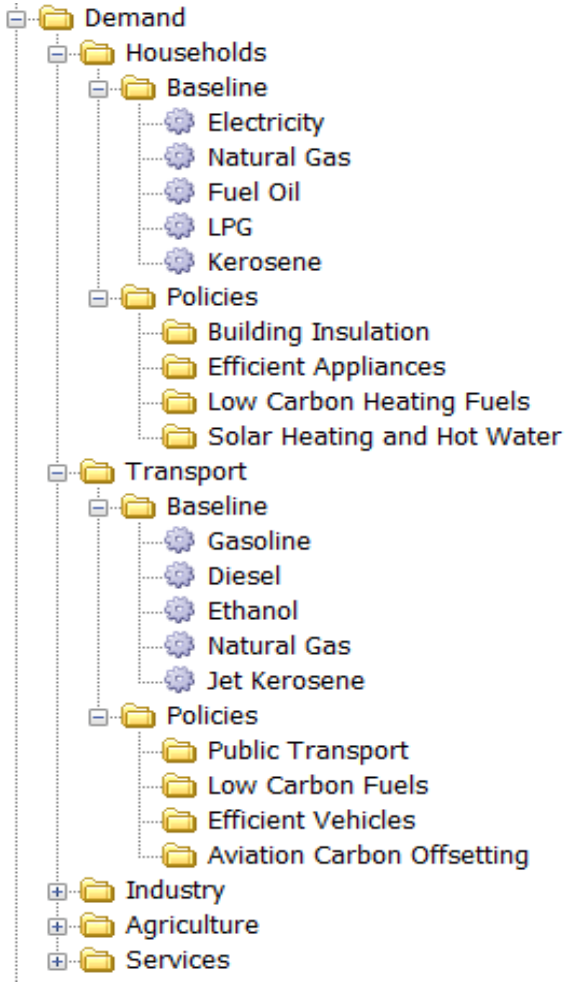


Disaggregation: hybrid / decoupled

- Baseline scenario forecast using top-down approach
- Bottom-up policy measures modeled in alternative scenarios
- In LEAP, policy measures are entered as negative “wedges” of consumption: subtracted from baseline energy use in each sector

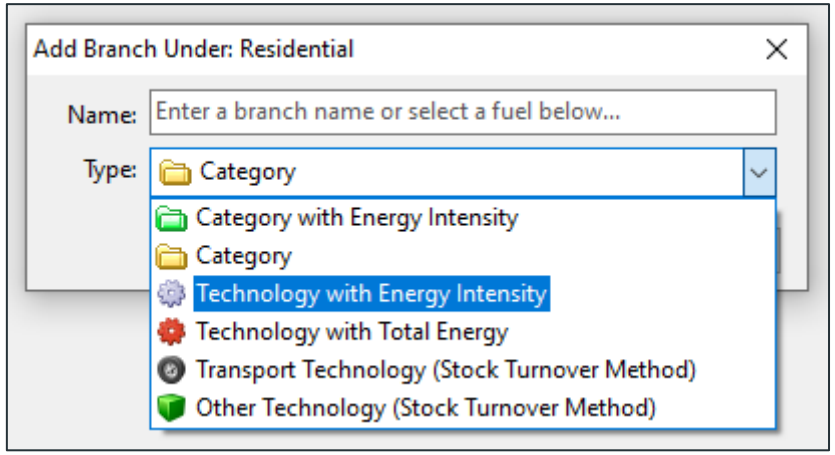
- Less data-intensive than end-use approach, but able to capture technology-based policies

- 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 relative to baseline



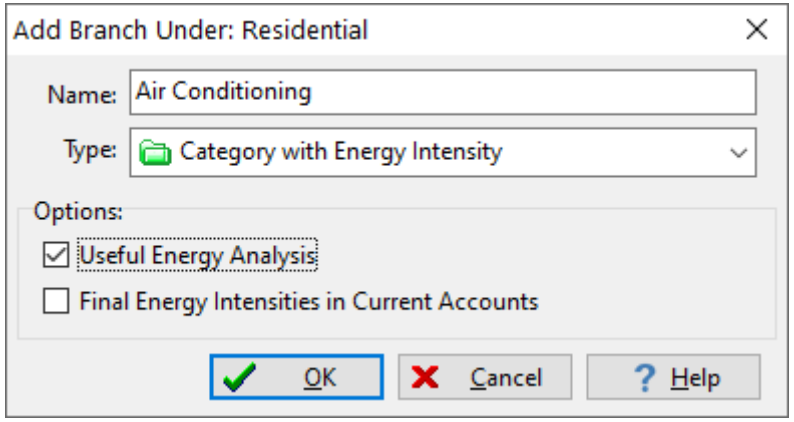
Technology specification

- Final energy consumption in LEAP occurs in special branches called “technologies”
- Four types of technologies are available
  - **Technology with Energy Intensity**
    - LEAP provides **Activity Level** and **Energy Intensity** variables for technology
    - Product of activity and energy intensity is energy consumption
  - **Technology with Total Energy**
    - LEAP provides **Total Energy** variable for technology – its value is energy consumption
  - **Transport Technology**
    - LEAP provides several **variables for vehicle stock turnover modeling** – starting stock, sales, average distance traveled, fuel economy, and more
    - Energy consumption is based on number and age of vehicles, distance traveled, and fuel economy
  - **Other Technology**
    - LEAP provides several **variables for stock turnover modeling of other (non-vehicle) devices** – starting stock, sales, energy use per device, and more
    - Energy consumption is based on number of devices and energy use per device



Technology specification

- A variant of Technology with Energy Intensity modeling allows **energy intensity and activity to be specified for a category containing technologies** rather than the technologies themselves => **Category with Energy Intensity**
- Energy demand is then calculated at category level as activity x energy intensity
- **Technologies in category meet shares of category-level demand** – using Fuel Share variable
- Category with Energy Intensity approach also supports modeling **useful energy demand**



Final energy vs. useful energy

- **Final energy** is energy used by final consumers' devices
- **Useful energy** is energy available after energetic conversions by those devices – i.e., energy delivered to end-use

Example – a stove

- Final energy = gas consumed (J)
- Useful energy = heat transmitted to food (J)

$$final\ energy \times efficiency = useful\ energy$$

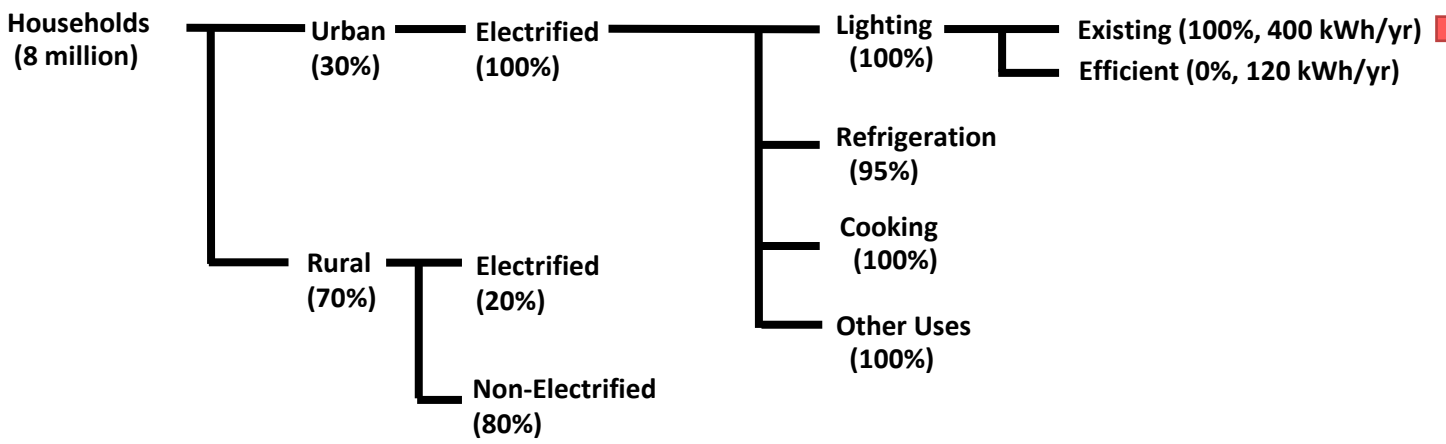
Projection methods

- Within a given branch structure – with a selected level of disaggregation and technology specification – various methods can be used to project changes in demand
- Common choices include:
  - **Activity analysis**
  - **Econometric modeling**
  - **Consumer choice modeling**
- **Expressions can link variables (and custom user variables can be added), allowing a wide variety of projection formulas**
- On the horizon: optimization of final energy demands given useful energy requirements (targeting release in 2022)

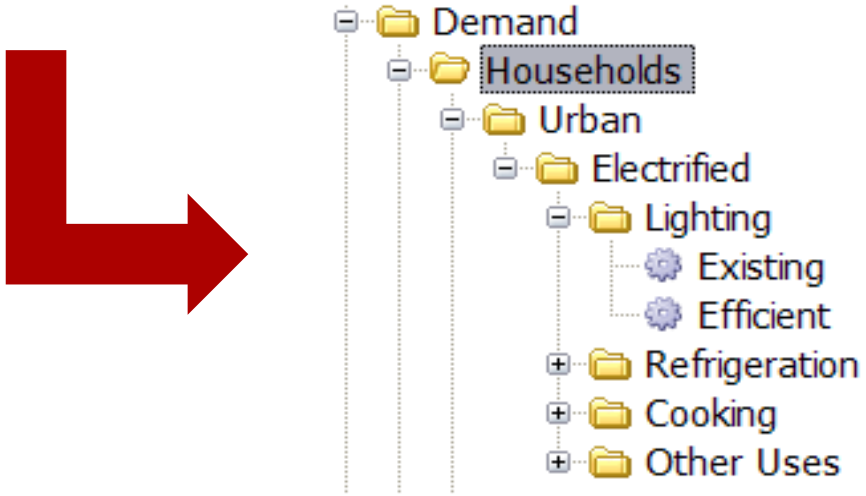
Activity analysis

- Most common projection method in LEAP models
- Defines energy demand as **product of activity and energy intensity** (energy consumption per unit of activity)
- Can be used to calculate final energy demand or useful energy demand
- Enabled by **Technologies and Categories with Energy Intensity**
- If Demand branch is disaggregated, LEAP provides Activity Level variables at each level of tree => **activity at bottom of tree is product of Activity Levels in hierarchy**

Activity analysis example



Energy consumption =
8M households
x 30% urban
x 100% electrified
x 100% with lighting
x 100% with existing technology
x 400 kWh/year
= **960 GWh/year**



Activity analysis and stock turnover

- Stock turnover modeling – with Transport and Other Technologies – can be thought of as **a form of activity analysis**
- Number of vehicles or devices is activity
- Fuel economy or energy use per device is energy intensity
- Key difference is **vehicle/device vintages are tracked**

Econometric modeling

- Energy demand or intermediate variables (e.g., activity level, energy intensity) are calculated using **expressions representing an econometric model**
- Parameters for model are typically estimated outside of LEAP
- Facilitated by **Technologies with Total Energy**

Example: $\ln e_t = \alpha + \beta \ln p_t + \gamma \ln i_t + \lambda \ln e_{t-1} + \delta t$

t is year, e is total final energy demand, p is fuel price, i is income, β is price elasticity of demand, γ is income elasticity of demand, α is a constant

Consumer choice modeling

- Equipment purchase decisions are simulated with a **multinomial logit model**

$$\text{Sales share} = \frac{e^{V_j}}{\sum_{i=1}^{J} e^{V_i}}$$

j is type of equipment, V is a linear function describing consumer utility for type of equipment

- Generally used with **stock turnover** technology specification (which has an explicit sales variable)

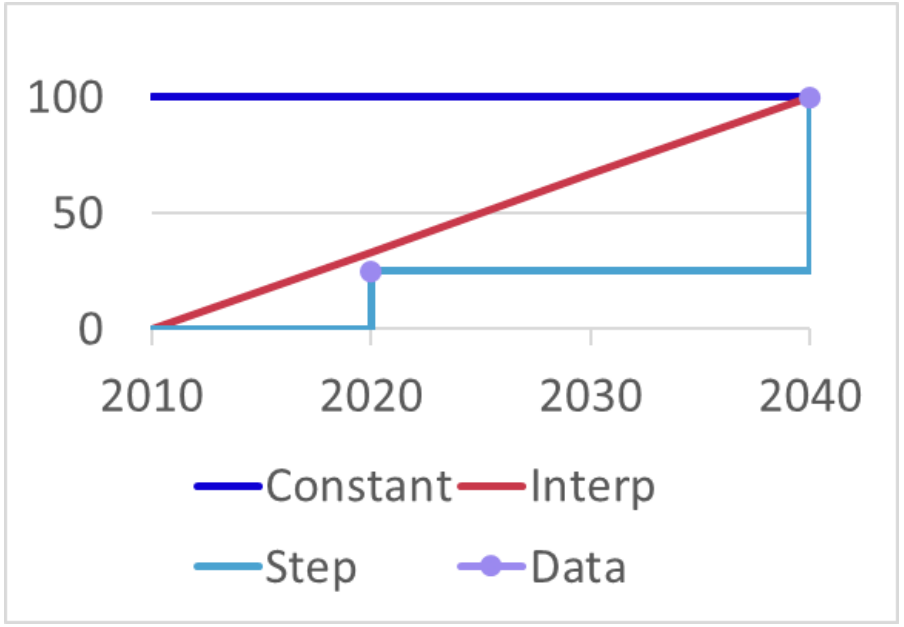
Projection methods: overall points

- **Methods can be mixed** in Demand branch
- **Some branch structures and technology specifications lend themselves to particular projection methods**
  - Example: bottom-up disaggregation with Technologies with Energy Intensity => activity analysis
- **However, this correspondence isn't rigid** – other methods can be introduced
  - Example: econometric methods used to project Activity Level and Energy Intensity for Technologies with Energy Intensity
- Scenario analysis involves describing how each variable in tree changes over time

Expressions and time series data

An expression in LEAP defines a value for a branch, variable, and region in each year of a scenario

- **100** => constant value in all years
- **Interp(2010, 0, 2040, 100)** => linear interpolation between specified points
- **Step(2010, 0, 2020, 25, 2040, 100)** => step-wise interpolation between specified points
- **Data(2020, 25, 2040, 100)** => specified points only (0 in all other years)



Expressions and time series data

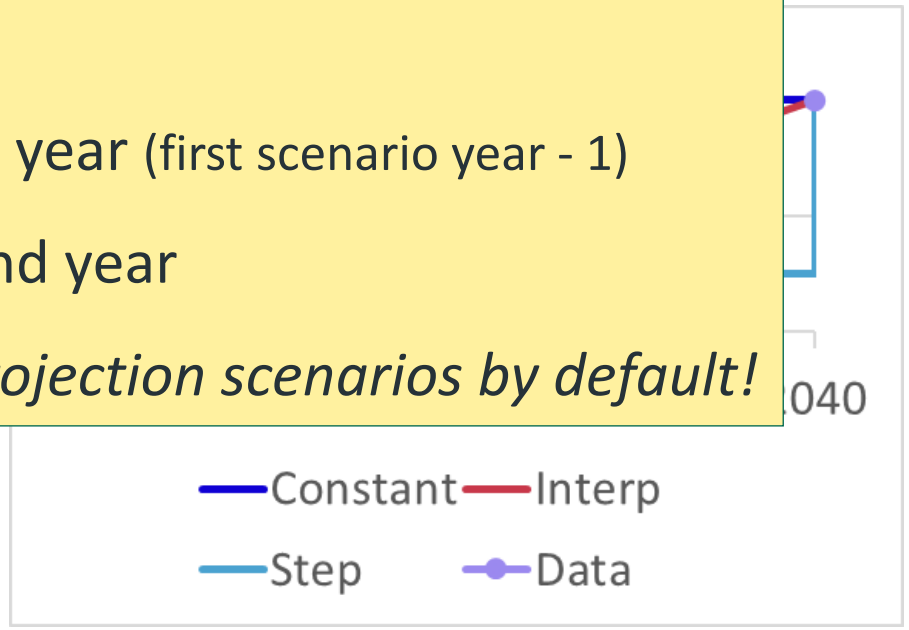
An expression in LEAP defines a value for a variable and region in each year of a scenario

- **10**
- **In**
  in
- **St**
  w
- **Data(2020, 25, 2040, 100)** => specified points only (0 in all other years)

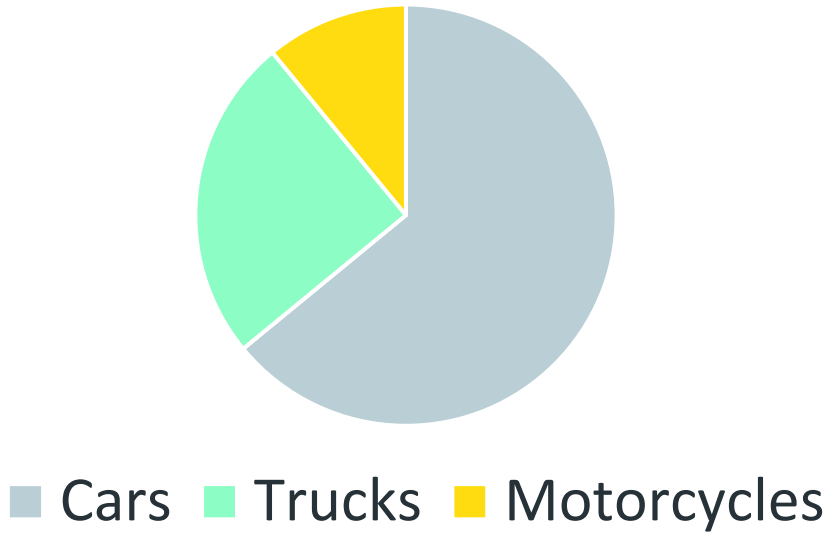
Scenario years

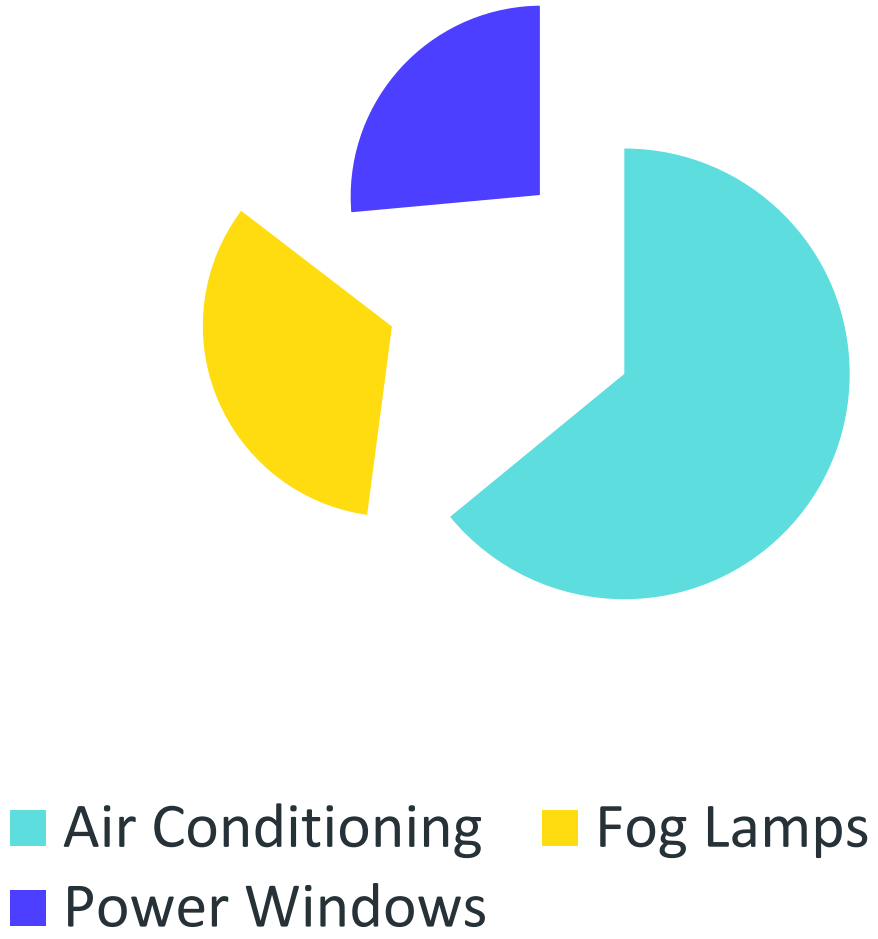
- **Current Accounts:** base year to last historical year (first scenario year - 1)
- **Projection scenarios:** first scenario year to end year

Current Accounts expressions are inherited in projection scenarios by default!



Percentages in LEAP





Percentages in LEAP

These are **exclusive** characteristics….

…these are **non-exclusive** characteristics, which can overlap.

Percentages in LEAP

- LEAP unit for **exclusive** percentages:

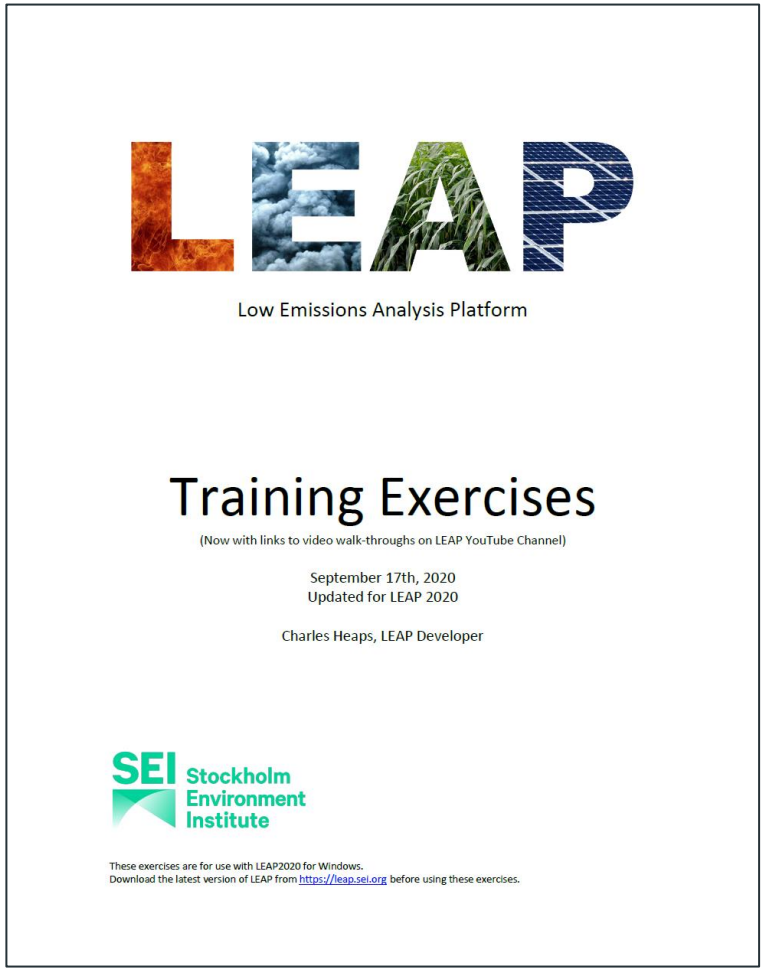
  Share

- LEAP unit for **non-exclusive** percentages:

  Saturation

Exercise 1: Energy demand modeling

Freedonia



LEAP

Low Emissions Analysis Platform

Training Exercises

(Now with links to video walk-throughs on LEAP YouTube Channel)

September 17th, 2020
Updated for LEAP 2020

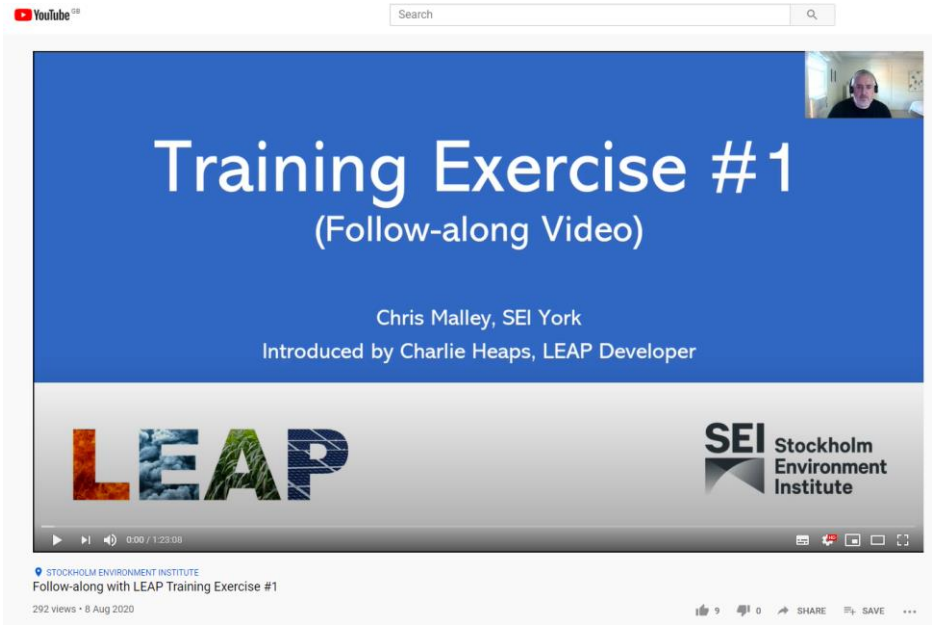
Charles Heaps, LEAP Developer

SEI Stockholm Environment Institute

These exercises are for use with LEAP2020 for Windows.
Download the latest version of LEAP from https://leap.sei.org before using these exercises.

exercise_1_2_3 - LEAPTrainingExerciseEnglish2020.pdf

Workshop Exercises 1 and 2:
Chapter 1 in Training Exercises document



https://www.youtube.com/watch?v=cW87lWDABgc

Freedonia

Exercise 1

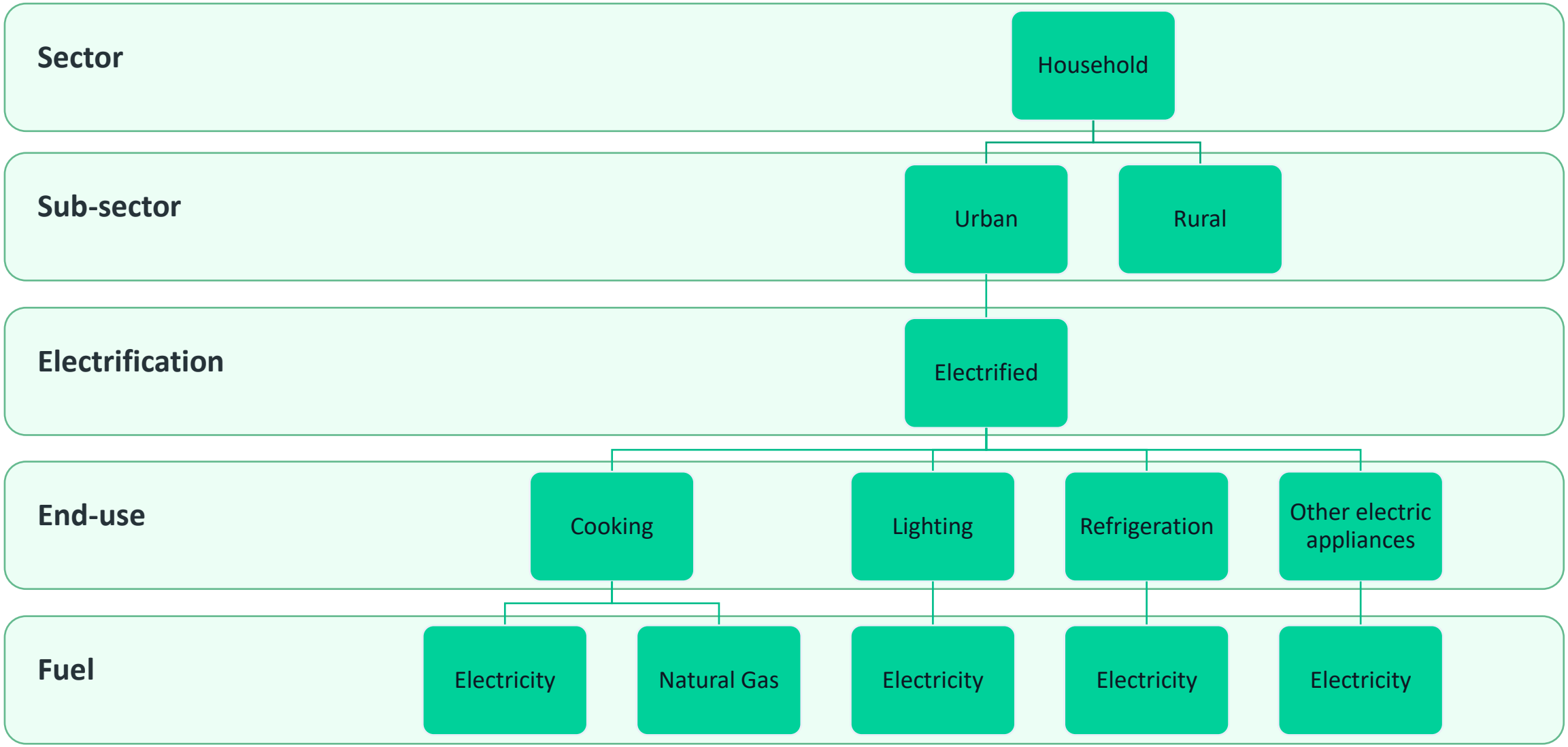
- **1.1. Overview of Freedonia**
- **1.2. Settings**
- **1.3. Demand**
  - 1.3.1. Data structures
  - 1.3.2. Current Accounts
  - 1.3.3. Viewing Results
  - 1.3.4. Reference Scenario
- **1.4. Transformation**
  - 1.4.1. Transmission and Distribution
  - 1.4.2. Electricity Generation
  - 1.4.3. Viewing Results
- **1.5 Emissions**
  - 1.5.1. Viewing Results
- **1.6. A Second Scenario: Demand-Side Management**
  - 1.6.1. DSM Scenario Results

Sketch the data structure

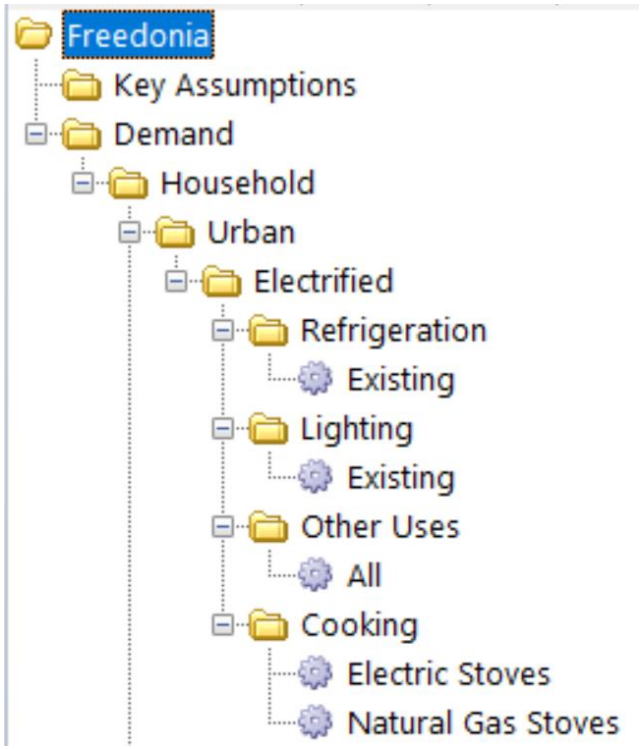
Keep in mind:

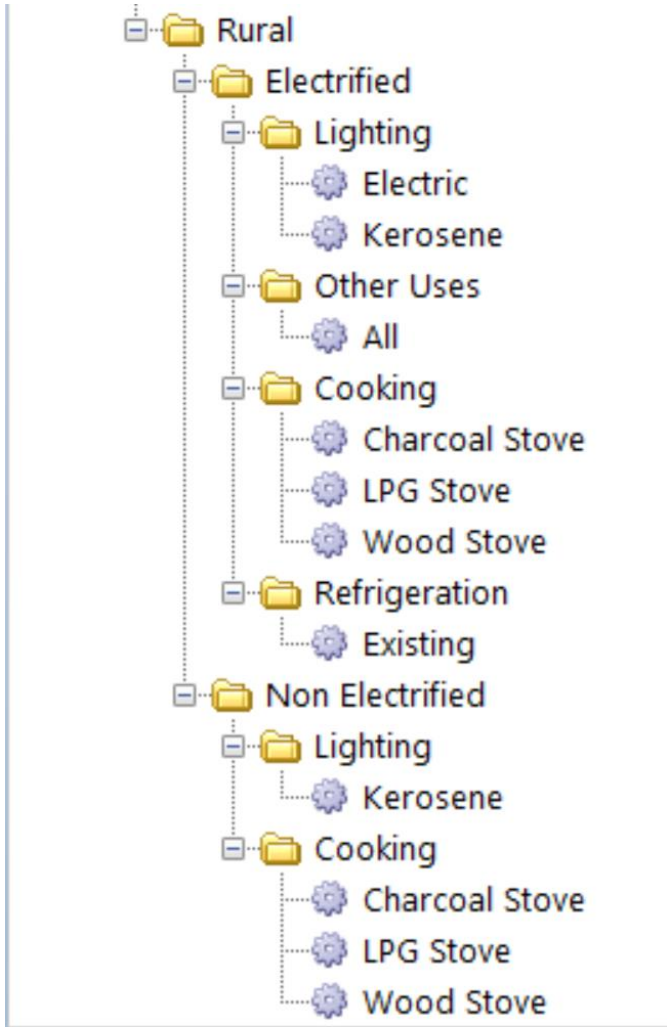
- There is not a single answer
- Be guided by data and assumptions
- Go from general to specific:
  - Sector > subsector > end use > technology/device > fuel

Sketch - Urban households

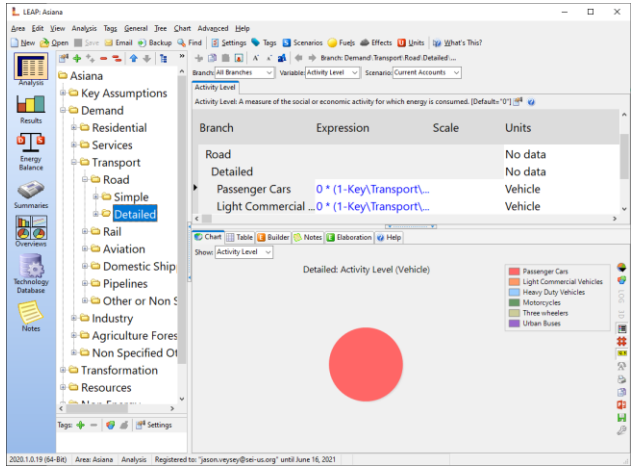


Freedonia – structure for Exercise 1





Saving and sharing models



Save

Open

LEAP Areas Repository

…\Documents\LEAP Areas

One folder with multiple files per area

Backup

Install

.LEAP file

One zipped file per area

Installing an area from a .LEAP file overwrites what's in local LEAP areas repository

Be careful, you can lose work!