GIZ's Clean Affordable and Secure Energy for Southeast Asia

Phase 2 LEAP Training

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Today's Agenda

- Introduction to LEAP 2024 – what's new
- *Short break*
- Energy demand (review)
- Energy requirements, transformation, and energy balances
- Introduction to afternoon assignment

Coming Up…

- Other LEAP branch types
- Environmental loadings
- Cost-benefit analyses using scenarios
- Introduction to LEAP-IBC
- Walkthrough of Asiana sample dataset

Workshop Learning Goals

1. Open, run, and examine existing LEAP models to get a “feel” for them,
2. Create new scenarios in existing LEAP models by revising energy, emissions or cost assumptions, or by adding new technologies,
3. Navigate scenario results,
4. Feel equipped to add new components or sectors to a LEAP model, or to rework the modeling of existing sectors,
5. Diagnose simple problems with existing LEAP models, and know how to ask for help.

Logistics

Questions: Raise your hand, and if we don't notice, please flag down one of the in-person facilitators

Chat screen: *Not monitored*

File sharing: https://tinyurl.com/Phase2GIZTraining

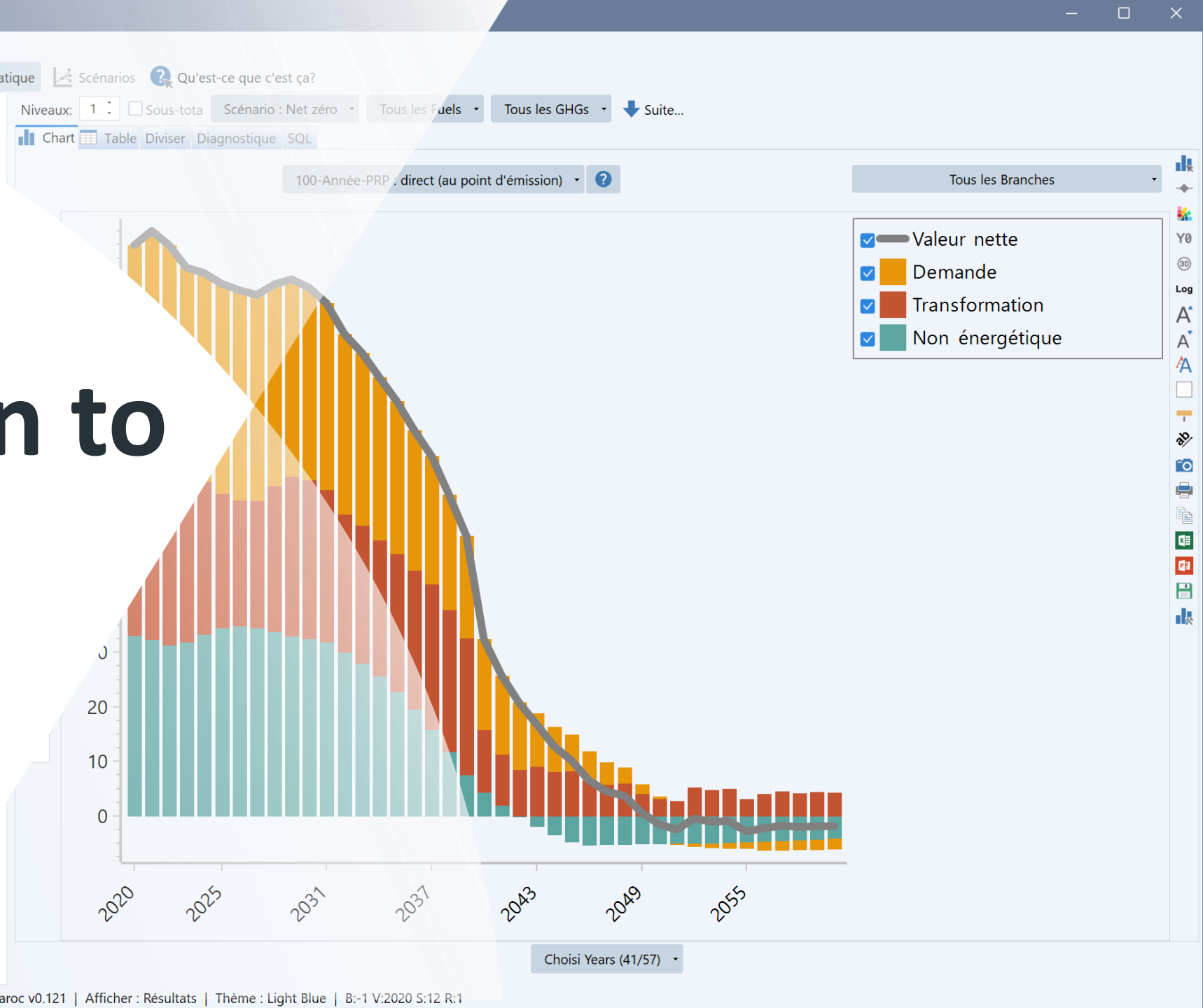
Software Registration

Username: CASE Phase 2 Training

Password: 897-734-988-095-426

Enter the above in LEAP by selecting **Help:Register** (not Help:Register Online). You may "skip" any request to enter your email address or username.

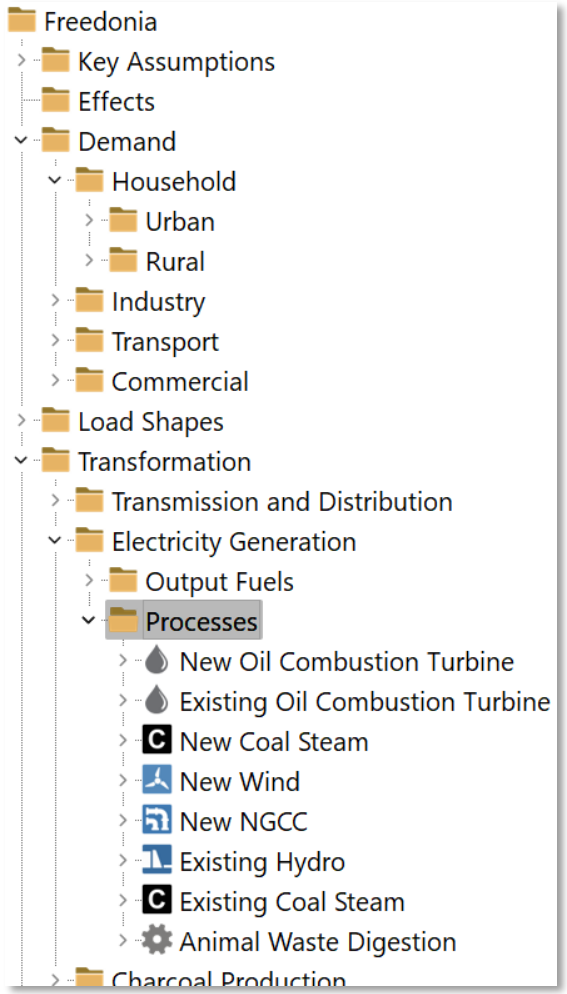
Introduction to LEAP 2024



What Is LEAP? (A quick reminder)

- A Windows-based software tool for energy, climate change mitigation, and air pollution planning, with a focus on scenario analysis.
- Widely applied by thousands of users in almost every country at multiple scales: global, continental, national, subnational, city-scale.
- Covers all fuels, all sectors, and all pollutants: including both energy and non-energy sectors.
- Not just for modeling – also supports data management, results visualization and stakeholder engagement.
- Promotes a needs-based and end-use oriented approach to modeling with flexible data structures and a wide choice of modeling methods.

The LEAP Tree



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

Tree Branch Typology

- **Categories:** often for organizing other branches or specifying energy consumption of a group of fuels together
- **Technology** branches represent devices or processes which produce/consume fuel. Three basic types:

- **Activity Level Analysis (on demand side) or Transformation Process (on supply side)**

- **Transport Analysis (demand side only)**

- **…other branch types**

- **Key Assumptions:** independent variables (demographic, macroeconomic, etc.)

- **Fuels**

- **Effects**: environmental loadings (emissions) or other environmental externalities

- **Indicators:** custom output variables – used to store complex expressions or perform calculations which are not part of LEAP's default results

Expressions

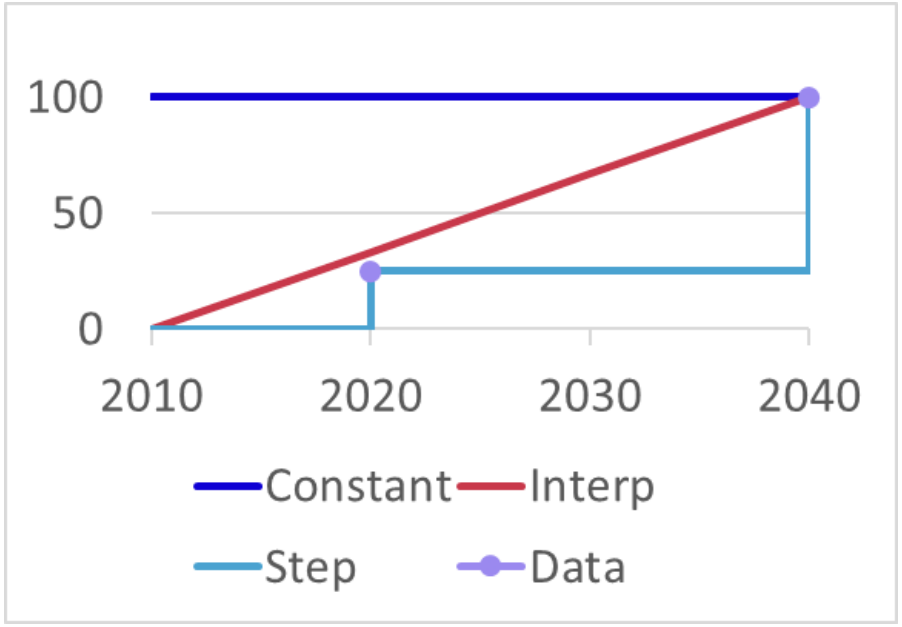
A good analogy: Excel formulas

- Expressions resolve to a numerical value for all years, or a special instruction to LEAP
- Expressions can include:
  - Numbers
  - Built-in functions
  - References to other variables elsewhere in the model
  - References to values outside the model

Expressions and Time Series Data

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

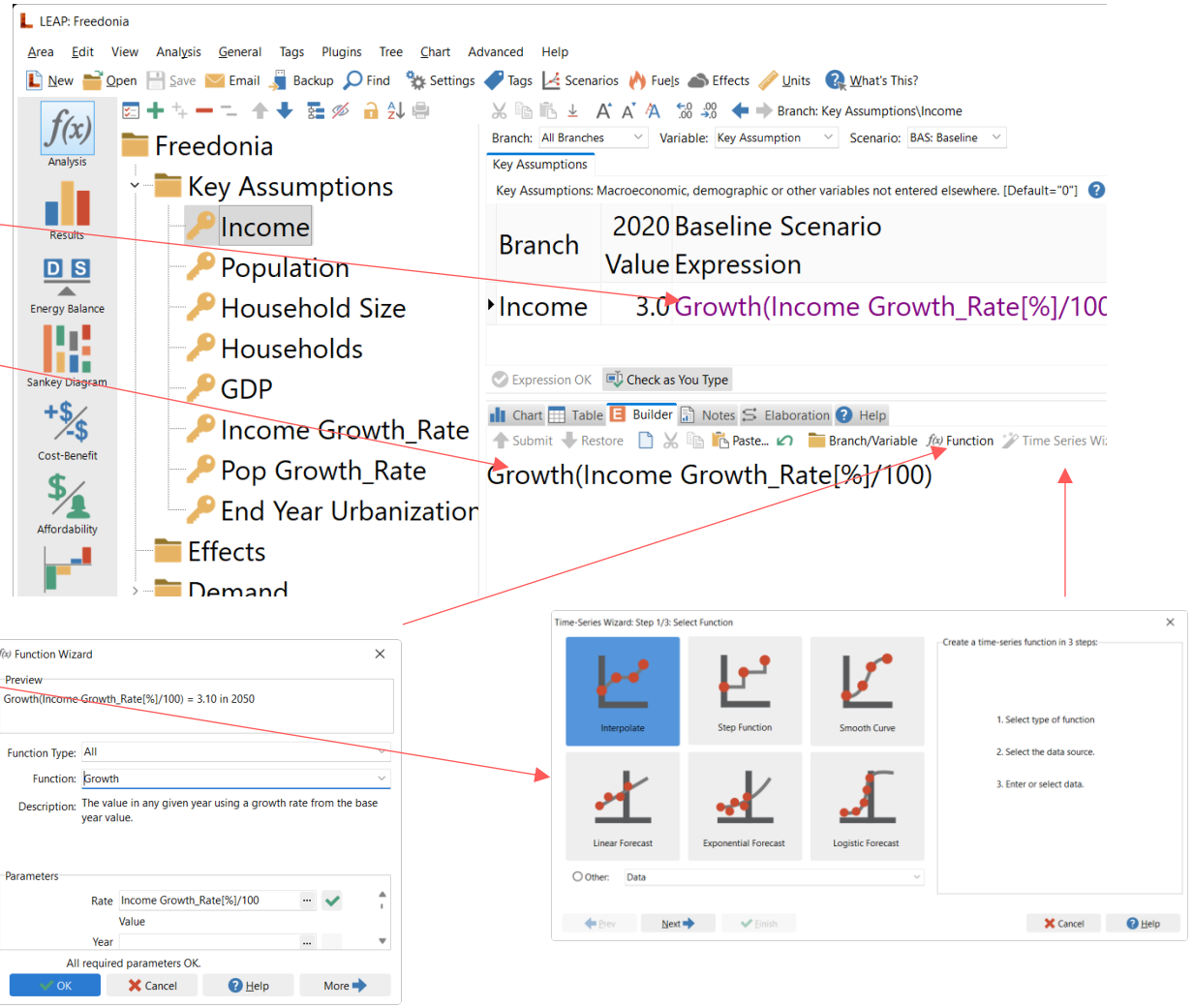
- **100** => constant value in all years
- **Interp(2010, 0, 2040, 100)** => linear interpolation between specified points
- **Step(2010, 0, 2020, 25, 2040, 100)** => step-wise interpolation between specified points
- **Data(2020, 25, 2040, 100)** => specified points only (0 in all other years)



Expressions: 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**



LEAP Glossary

Area

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

View

- A screen in the LEAP interface used to perform a set of related functions (e.g. Analysis, Results).

Current Accounts

- A special “scenario” containing historical data beginning in the **Base Year**. Every model includes Current Accounts.

Scenario

- A set of model inputs and results corresponding to a possible state of the world. Scenarios begin in the **First Scenario Year**, and end in the **End Year**.

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.

Why a New Version?

- At SEI, we aim to boost energy, climate & air pollution policy-making by making policy-relevant analyses
  - easier to undertake,
  - more accessible
  - more rigorous
  - more credible
  - more inclusive
  - better able to address important emerging concerns
- New version of LEAP pushes forward over all these dimensions.

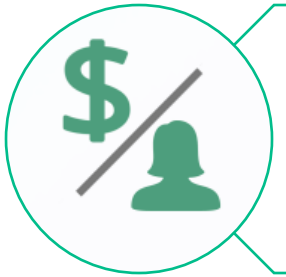
New version FAQ

- **Compatibility:** New version is fully backwards compatible with earlier versions.
- **Hardware/software requirements**: any standard Windows-based PC with 2 GB RAM. 32-bit or 64-bit.
- Can also be used on an Apple Mac via a Windows virtual machine (e.g., VMWare Fusion or Parallels).
- **Use with existing LEAP License?** Yes! No charge to upgrade.
- **Licensing:** All users require a license. Licenses are available at no cost to Governments, NGOs and academics in low-income and lower-middle-income countries and substantially discounted for these users in upper-middle-income countries. Free for students worldwide.

Introducing the New Features

Full Energy System Optimization Modeling

- Powerful and easy-to-use methods for modeling holistic decarbonization pathways.

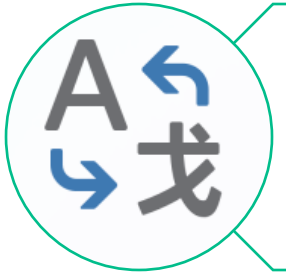


Energy Affordability Analysis

- A new approach for studying the affordability of pathways for marginalized communities: helping to highlight social and environmental justice concerns.

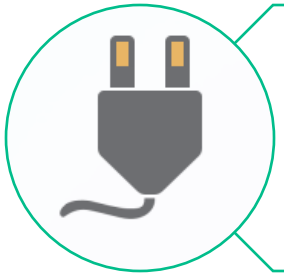
The LEAP Cloud Data Server (LCDS)

- Simplifying data collection and model maintenance.



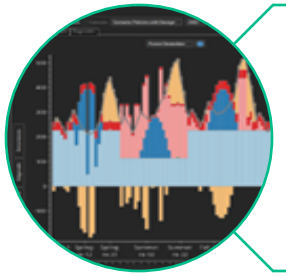
Accessibility

- New translations of the LEAP user interface in 14 languages: making it more accessible and helping to improve engagement between modelers and stakeholders.



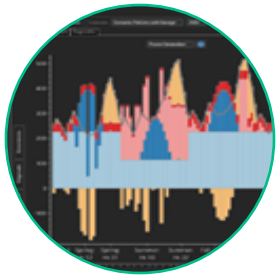
Plugins

- Simpler, more modular, and more community-based model development.



User Interface (UI)

- Major revamp of the user interface making it easier and more enjoyable to use, while still being immediately recognizable for existing users.



A Modern User Interface

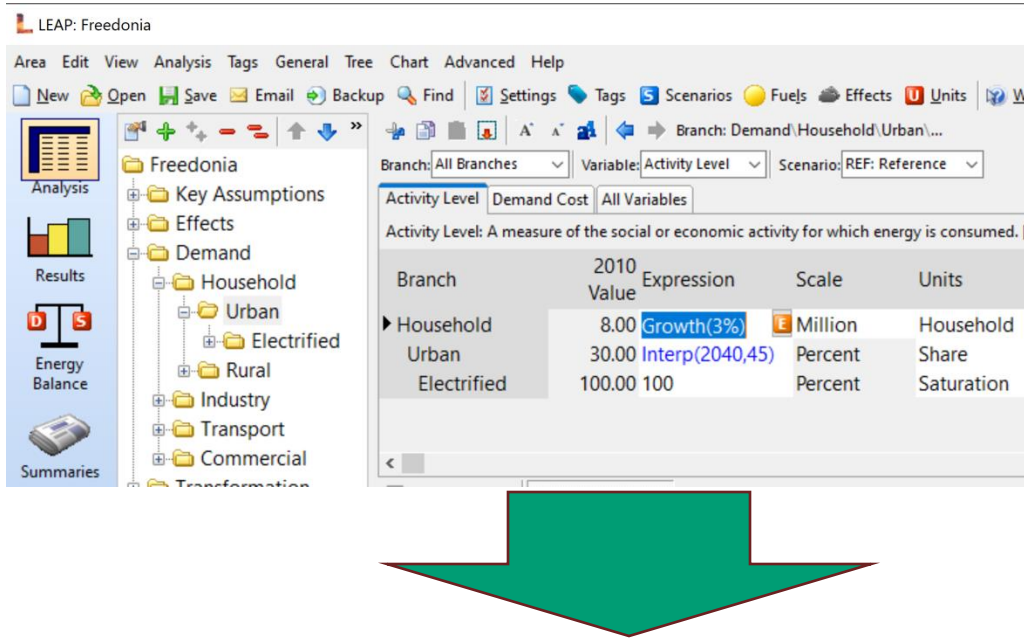
Major user interface (UI) revamp

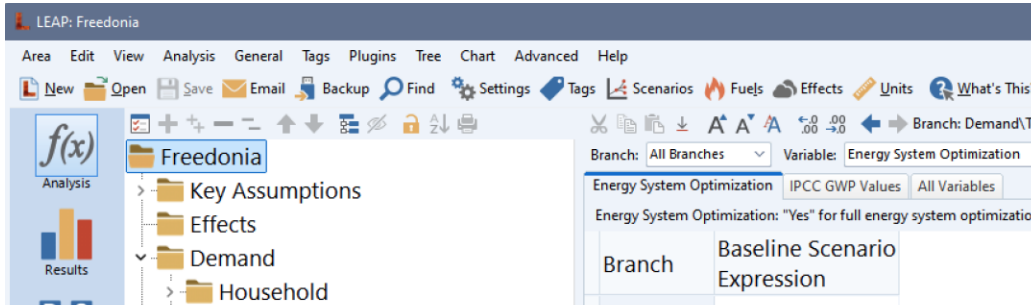
Making it more professional looking,

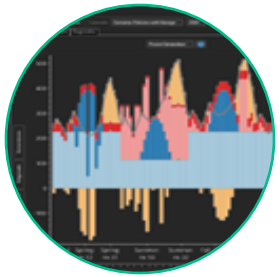
more configurable, and easier and

more enjoyable to use:

- updated icons
- support for the latest high-resolution monitors
- better use of color
- support for both light and dark themes







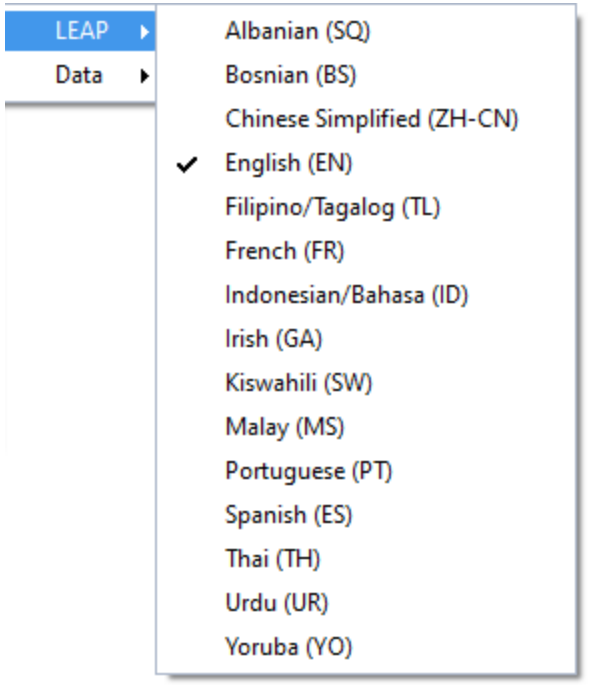
A Modern User Interface

- Bookmarks to make navigating within your models more convenient
- Improved editing and documentation features
- An expanded “view bar” highlighting LEAP’s analysis and results visualization abilities
- A brand-new online context-sensitive help system reflecting all the recent changes to LEAP
- Heat maps to help you quickly identify the most important numbers in your analysis.

Accessibility

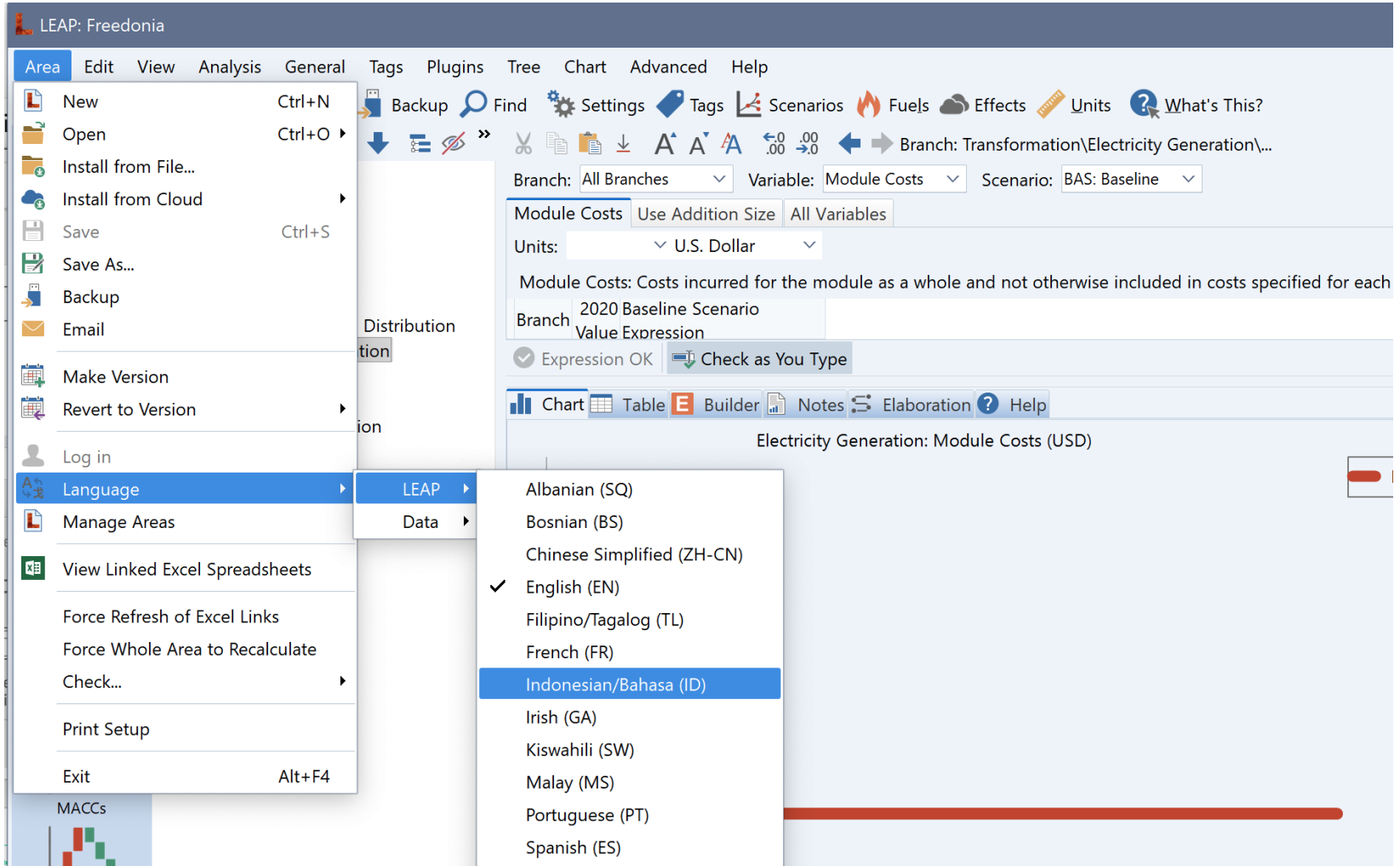
Translations of the UI and data structures make it more accessible and help improve engagement.

- Software translations in 14 languages (more to come!)
- Uses Google Translate and volunteer review.
- Your own model (branch names, fuels, scenarios…) can also be Google Translated to any language and you can easily switch among languages.



Accessibility

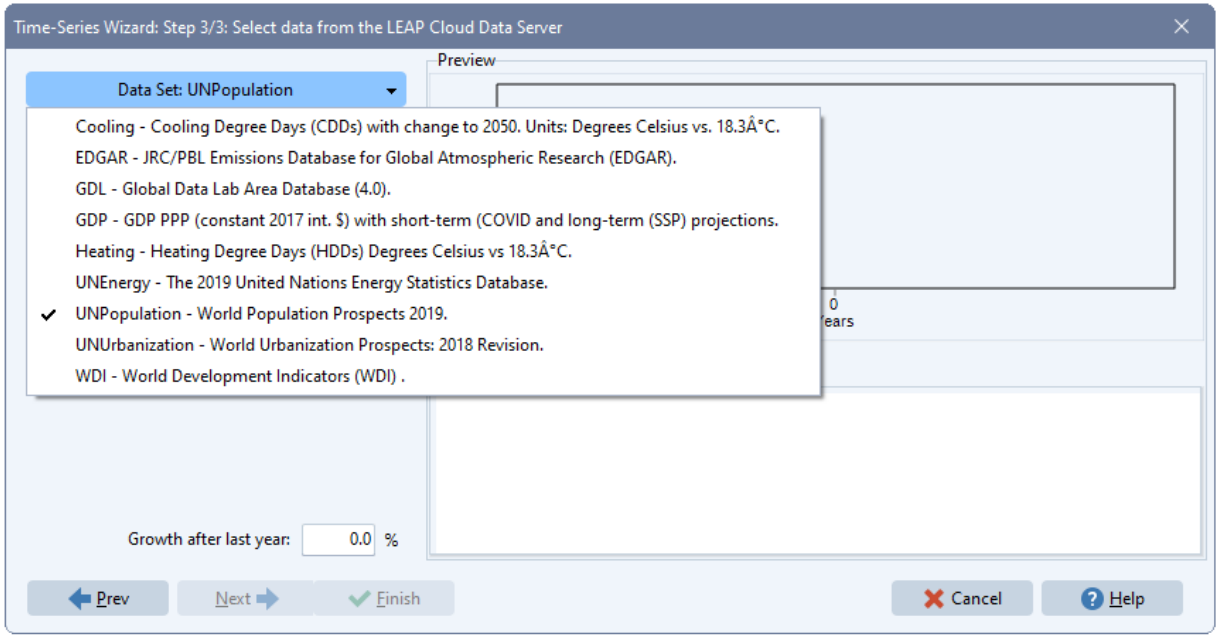
How to use?



The LEAP Cloud Data Server (LCDS)

A new easy-to-use system for connecting LEAP models to an internet-hosted database containing international open-source data covering energy, emissions, and development topics.

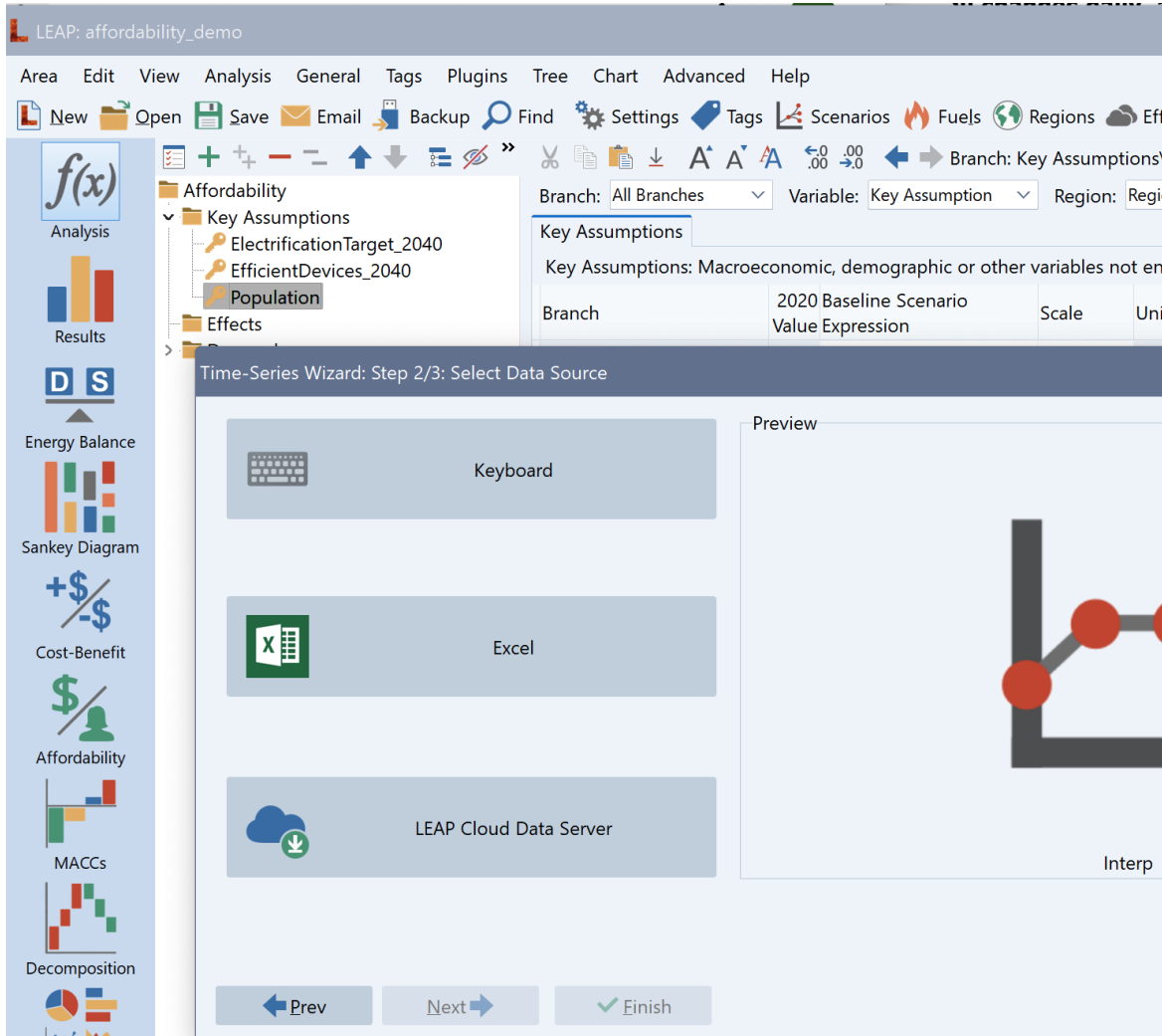
- Simplifies model development, data collection and model maintenance
- **Phase 1 (available):** nationally-oriented statistics useful to energy modelers
- **Phase 2 (coming next):** technology-oriented data

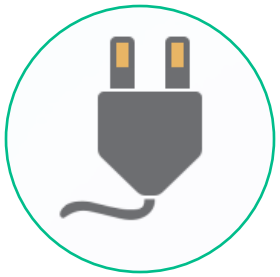


The LEAP Cloud Data Server (LCDS)

How to use?

- Set country in settings
- Create variables that shall link to database
- Open Time Series Wizard
  - In Window 2/3 select LEAP Cloud Data Server
  - Choose dataset from list
- Available databases : UNPopulation, UNEnergy, UNUrbanisation, Edgar, Cooling and Heating Degree Days
- Download requires internet connection, but afterwards data is cached on local machine
- LEAP will notify you of updates





Plugins

A new modular and community-based architecture for LEAP models, streamlining model development with easy-to-integrate “mini models”.

- Plugins contain suggested data structures and default data.
- Helps promote standardized methodologies for modeling particular sectors or industries.
- Developed and maintained by subject-matter experts and shared with the wider LEAP community via an online repository (coming soon!).
- When used with LCDS can include default data that varies by country.

Demo: **https://tinyurl.com/LEAPclouddata**

Energy System Optimization Modeling

- For many years LEAP has supported a wide choice of methods including both simulation and optimization
- Until now, LEAP was limited to doing partial optimization of only a single sector in an energy system (e.g., electric generation). **Now, LEAP supports full least-cost energy system optimization**
  - takes full advantage of the capabilities of NEMO (LEAP's companion optimization modeling tool)
  - allows optimizing selected demand end uses, and can model pipeline & transmission networks, in addition to optimizing all of Transformation
  - makes full use of the data already entered in a LEAP model – allowing you use LEAP's scenario management and data definition language
  - all results can be viewed directly within LEAP in standard formats familiar to planners.
  - can be conducted for specific scenarios and results compared to those calculated in simulation- or partial optimization-based scenarios.
  - Enables specification for overall constraints on GHGs and other pollutant emissions and calculation of least-cost energy system configuration that meets those constraints

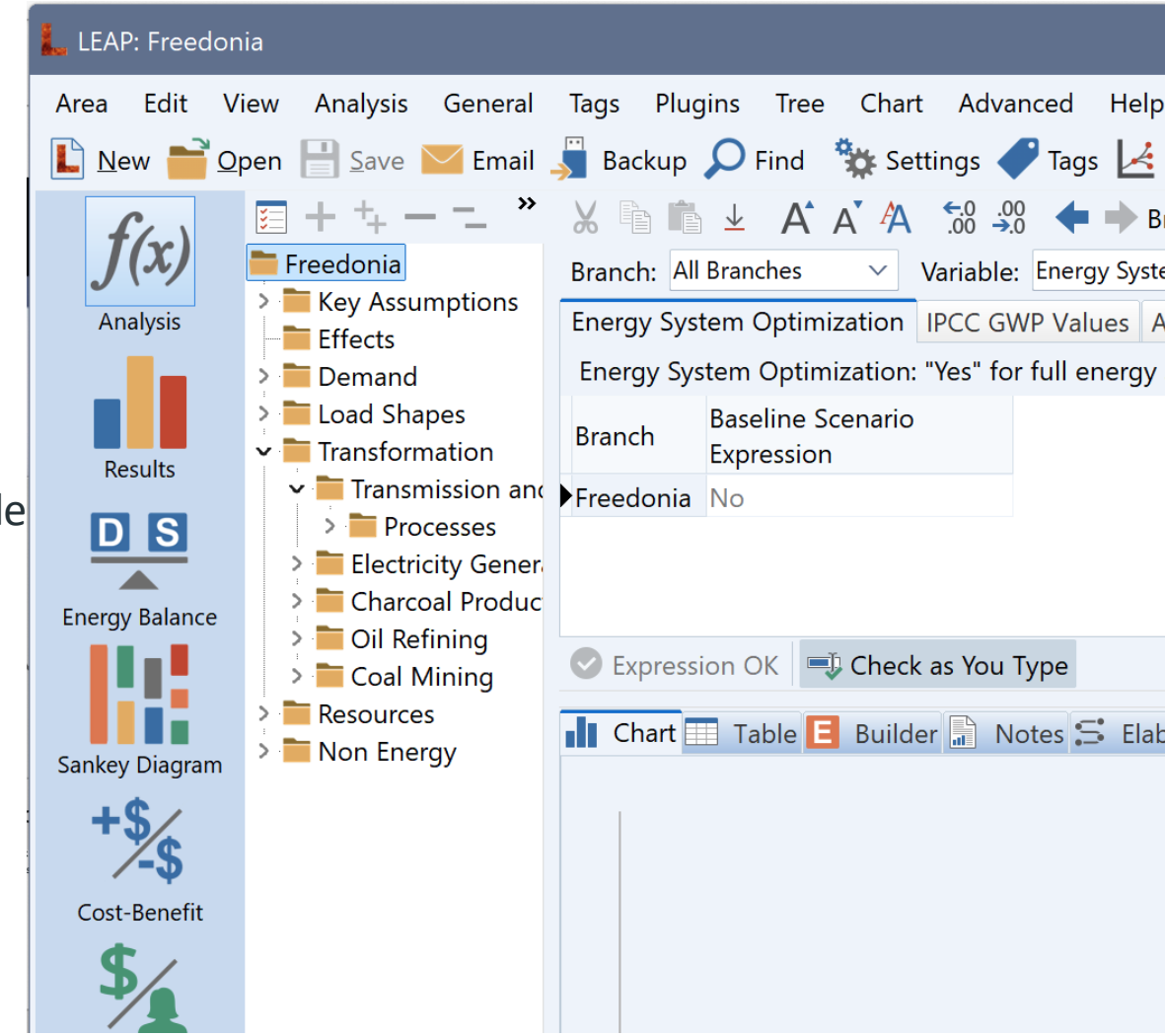
Key for modeling deep decarbonization & net zero pathways

Energy System Optimization Modeling

How to use?

- Install LEAP and NEMO (NEMO is a requirement)
- Set up your LEAP model
- Turn on full energy optimization for your model (partial energy system optimization is still possible)
- Choose optimization algorithm (*Highs* is recommended)
- Where necessary, add additional data into additional variable relvant for optimization
  - Costs
  - Lifetime
  - Capacity addition size
  - ….
- Possibility to set system wide prices for carbon or other pollutants (externality cost)

Demo: **https://tinyurl.com/LEAPoptim**



Energy Affordability Analysis

Considering environmental justice implications of different energy and climate policy options is key to achieving a just clean energy transition

New Affordability Feature:

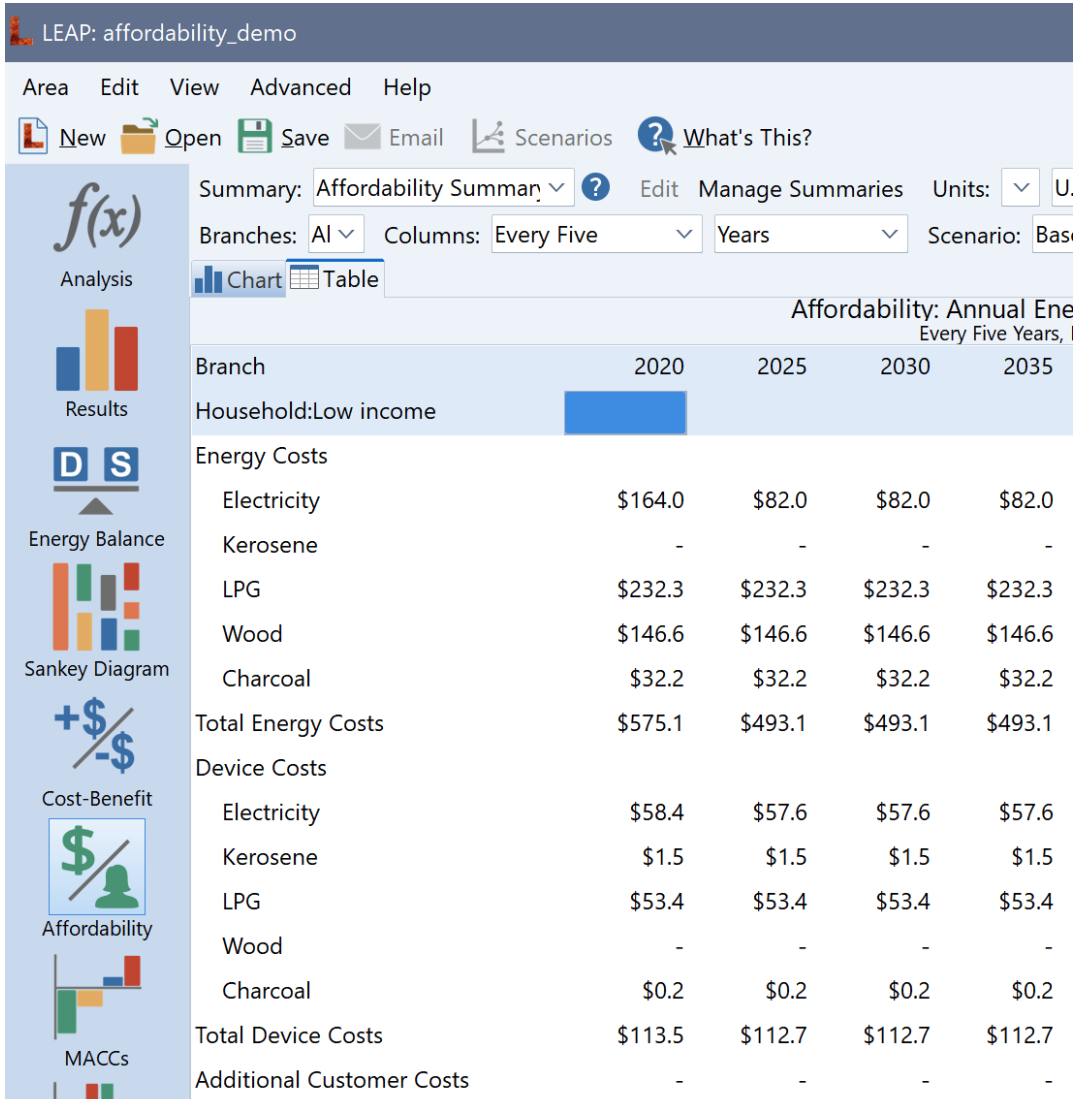
- Study the affordability of policy pathways for different groups
- Examine impacts on:
  - Total energy costs
  - Total device costs
  - Energy affordability (typical threshold is 4% of annual income)
  - Energy uses and prices by group
- Enables specification of targeted subsidies or tariffs for specific groups, fuels, and technologies

Energy Affordability Analysis

How to use

- Turn on Affordability analysis in *Settings* and *Fuels* database
- Set up demand structure to represent different user groups and turn on Affordability branch in Properties
- New variables annual income, fuel prices and customer costs and demand costs allow specification of differential investment costs and energy prices
- New *Tariff()*-function enables specification of differential energy tariffs for different users under Energy Costs
- Key results are presented in Affordability View and can be used to analyse affordability

Demo: **https://tinyurl.com/LEAPaffordability**



Recap: New Features

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- Powerful and easy-to-use methods for modeling holistic decarbonization pathways.

Energy Affordability Analysis

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- Simplifying data collection and model maintenance.

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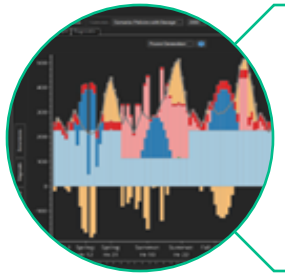

User Interface

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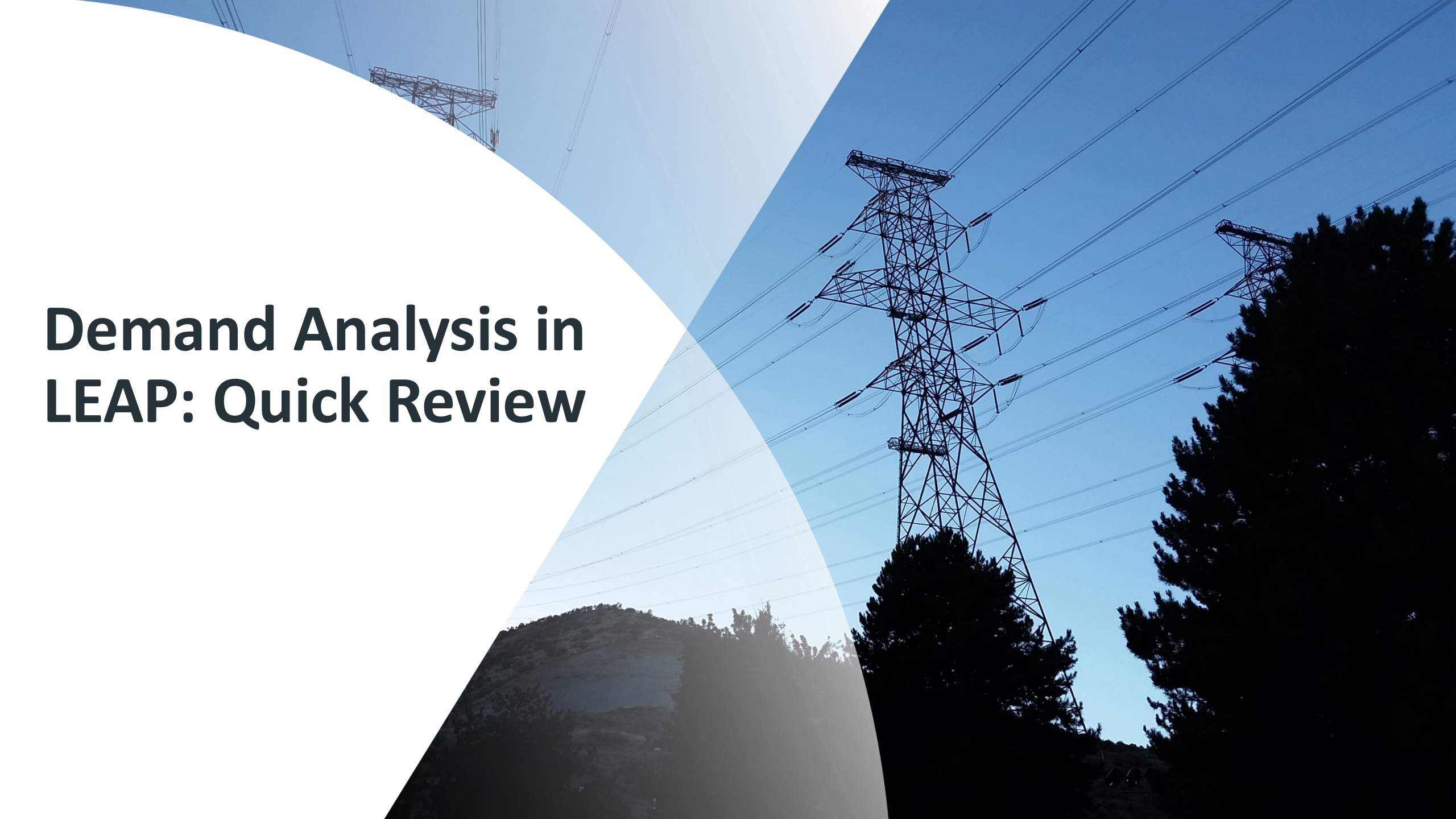
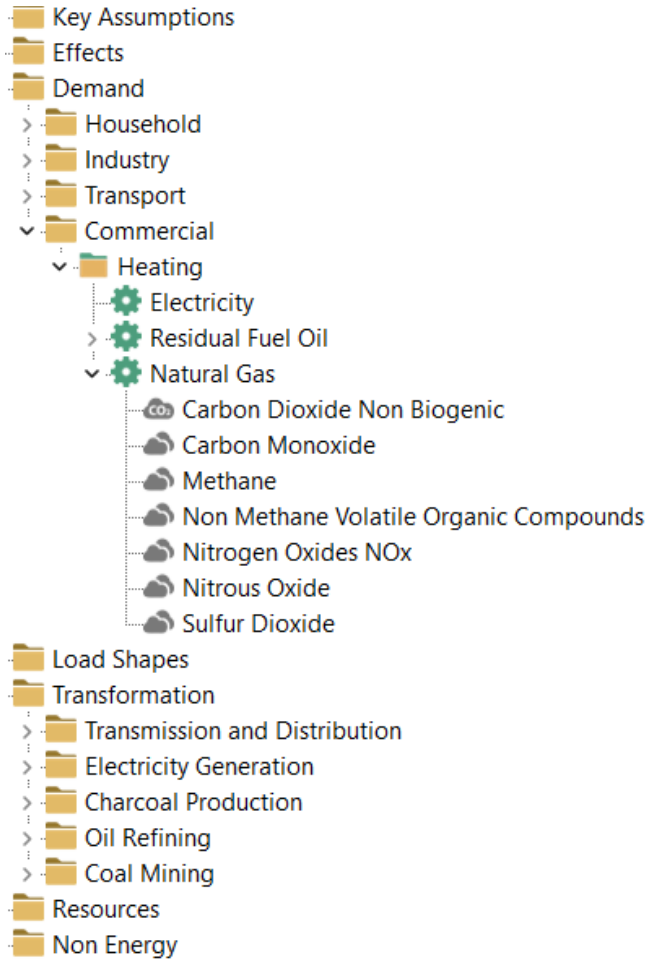
Demand Analysis in LEAP: Quick Review



Demand Modeling Overview

- Final energy consumption of each fuel represented within LEAP's Demand branches
- Significant flexibility in representing final energy demands in model. Demand branches may be used to:
  - Include additional levels of disaggregation
  - Represent individual technologies or whole categories of fuel consumption
  - Organize different projection methods

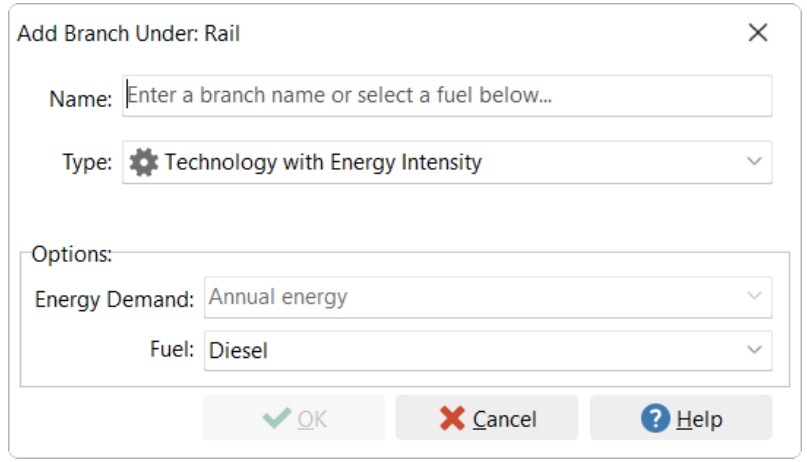


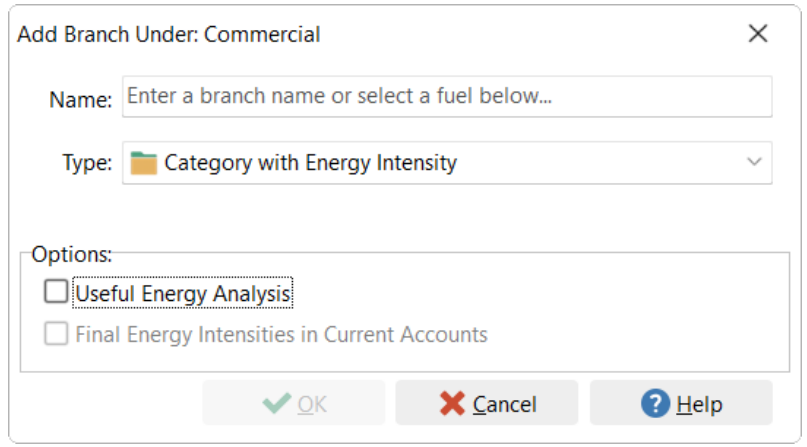
Activity Analysis

Energy demand calculated as follows:

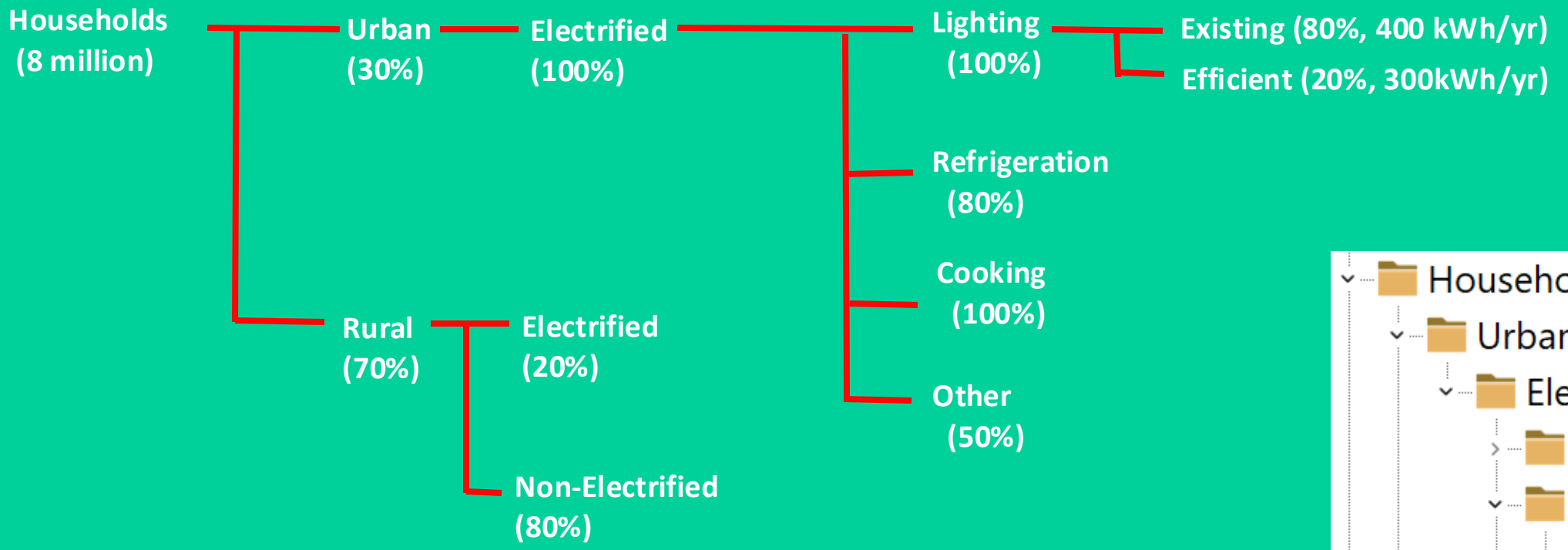
$$E = AI$$

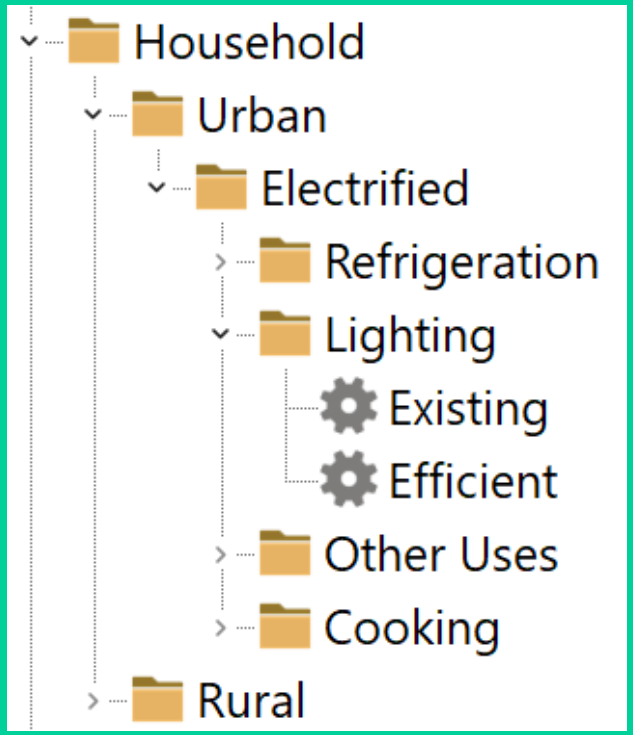
- Where: E is energy demand, A is activity level, and I is energy intensity (energy per unit of activity)
- For example – energy demand in the cement industry can depend on changes in both the quantity of cement produced, and the energy required to produce each tonne of cement.





A Simple Demand Data Structure





A Transport Example

Gasoline demand M from motorbikes may depend on…

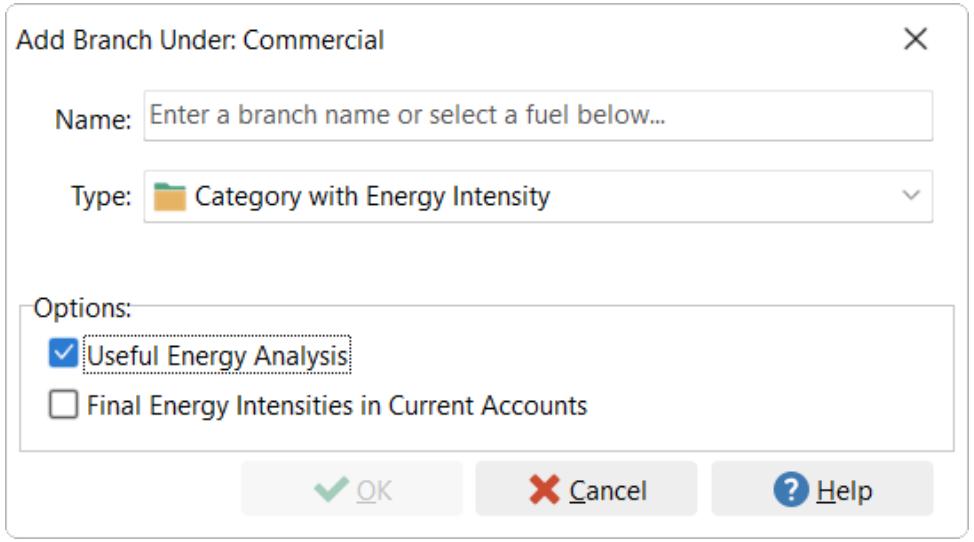
- A, the total annual number of passenger-kilometres traveled
- B, the fraction of all passenger transport delivered by motorbikes
- C, the load factor for motorbikes [people/motorcycle]
- D, the fuel economy of motorcycles [gasoline use per vehicle-km]

…so that $M = A * B / C * D$

Useful Energy Analysis

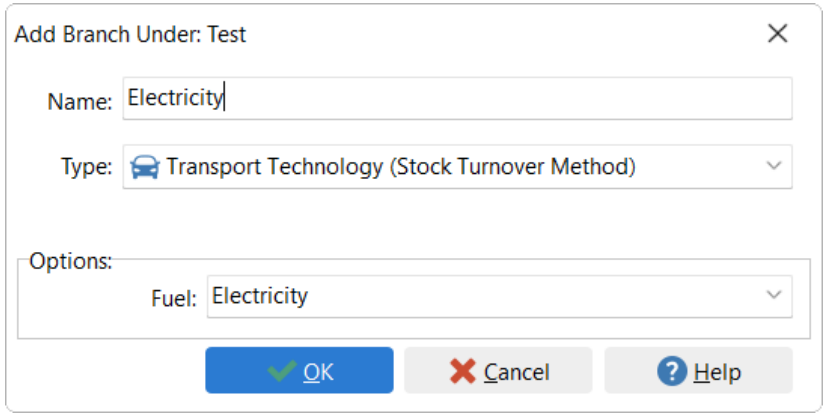
$$E = AD/\eta$$

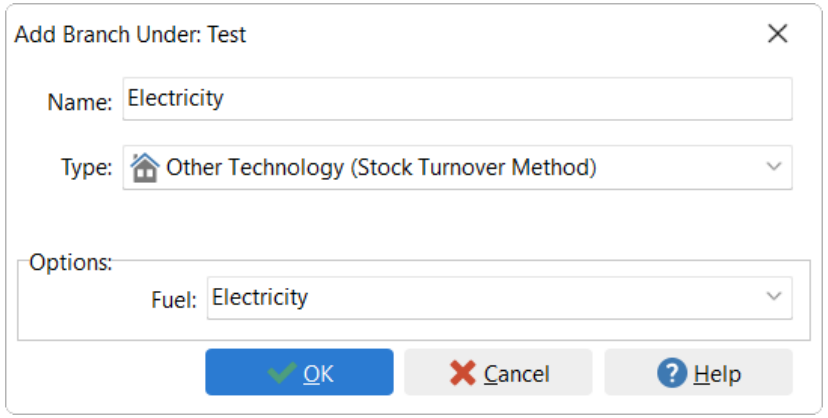
- Where: E is energy demand, A is activity level, and D is useful energy intensity of a device, η is the efficiency of that device
- For example – energy demand for heating can depend on the size of the heated area, the amount of heat needed per m^2 of heated area, and the efficiency of heating equipment.



Stock Turnover Modeling

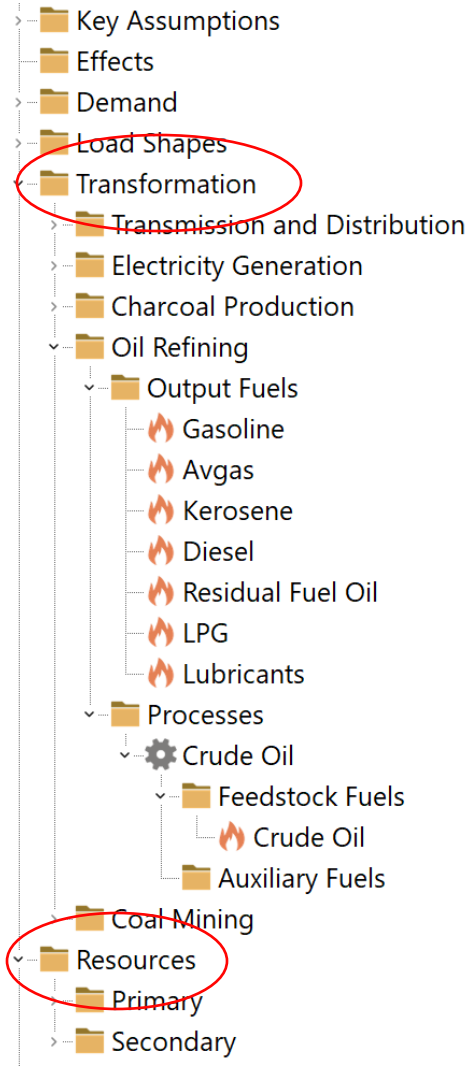
- Simulates the evolution of a fleet of vehicles or devices based on sales and retirements
- Separately tracks each vintage of vehicles/devices – i.e., vehicles/devices sold in a given year
- Allows the characteristics of a vintage to change with age (emission factors, specific energy consumption, usage)
- Supports probabilistic retirement functions and user-defined expressions for sales, scrappage, and more





Energy Supply Analysis in LEAP

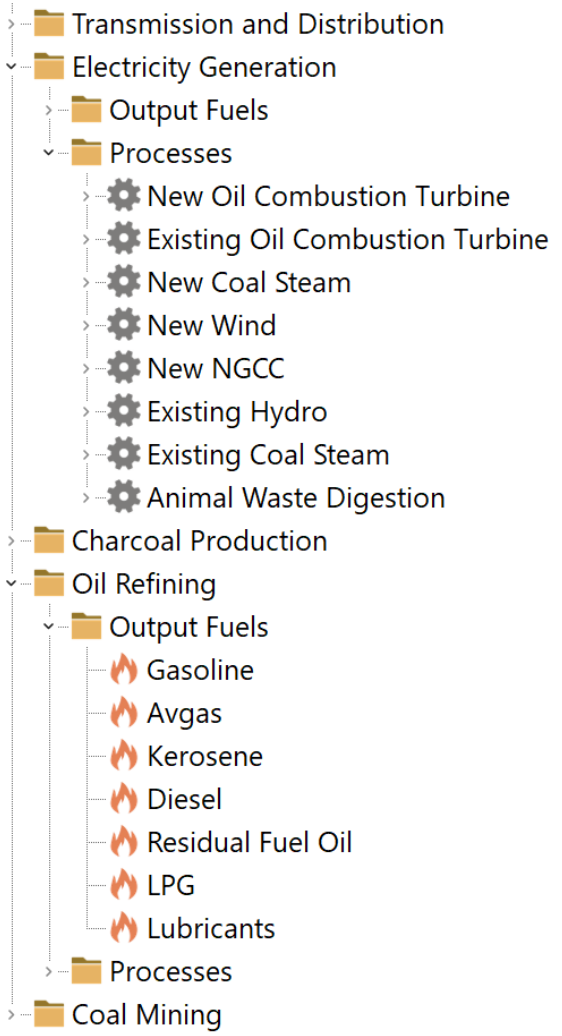
Supply Modeling Overview



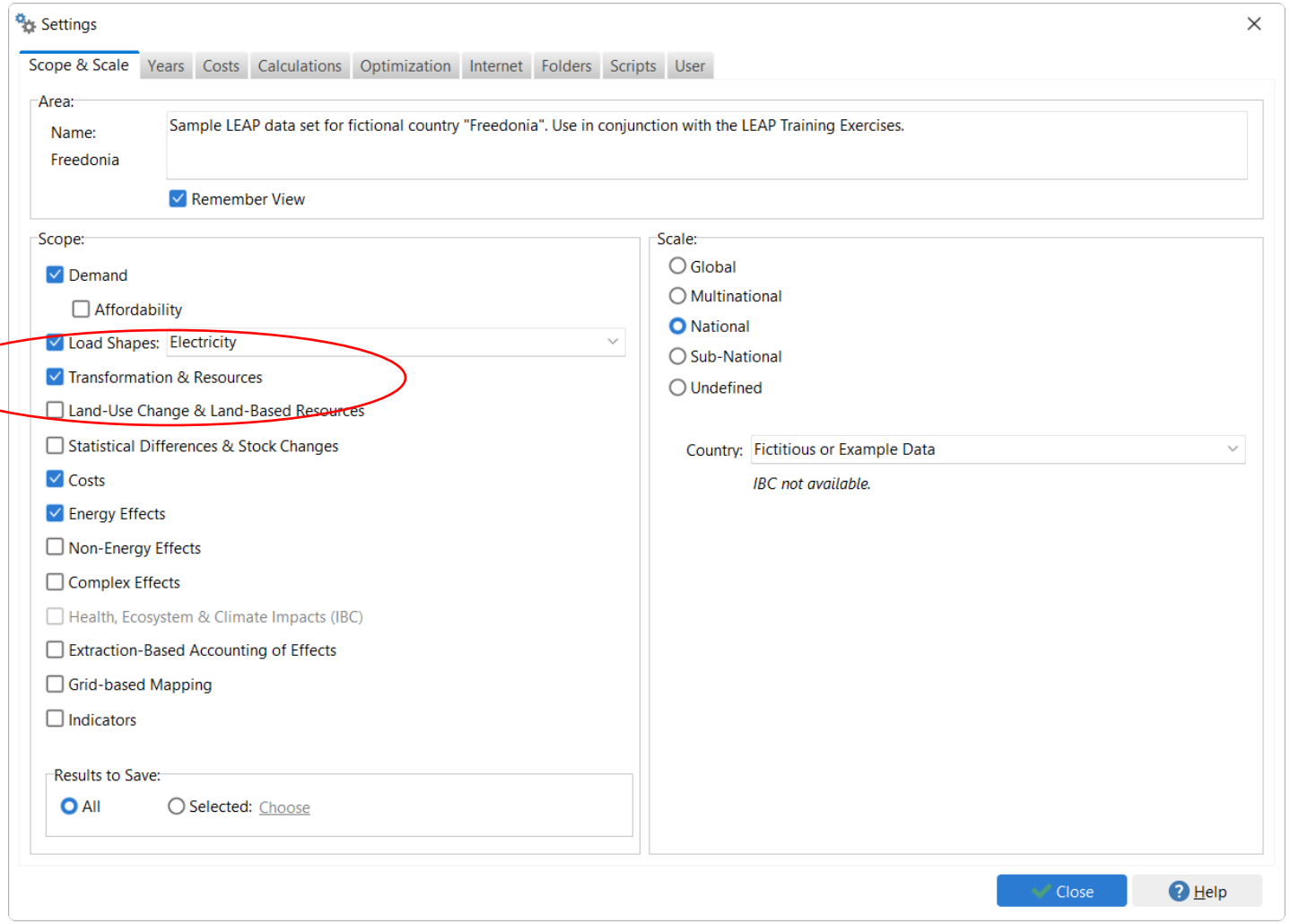
- LEAP supports modeling all links in the energy supply chain, from resource extraction to energy trade, energy conversion, and delivery to end-users
- Two main branches in LEAP tree: **Resources** and **Transformation**
  - Resources – Extraction of primary energy resources, imports and exports
  - Transformation – Conversion of one fuel (energy carrier) to another; transport, transmission, and distribution of fuels
- **Total primary energy supply**, primary resource **reserves** (non-renewable) and **annual yields** (renewable), imports and exports are all tracked in the Resources branch
- Transformation structure: **modules** (energy-producing sectors), each containing one or more **processes**
  - Processes use feedstock (input) fuels to produce output fuels

Transformation Modules

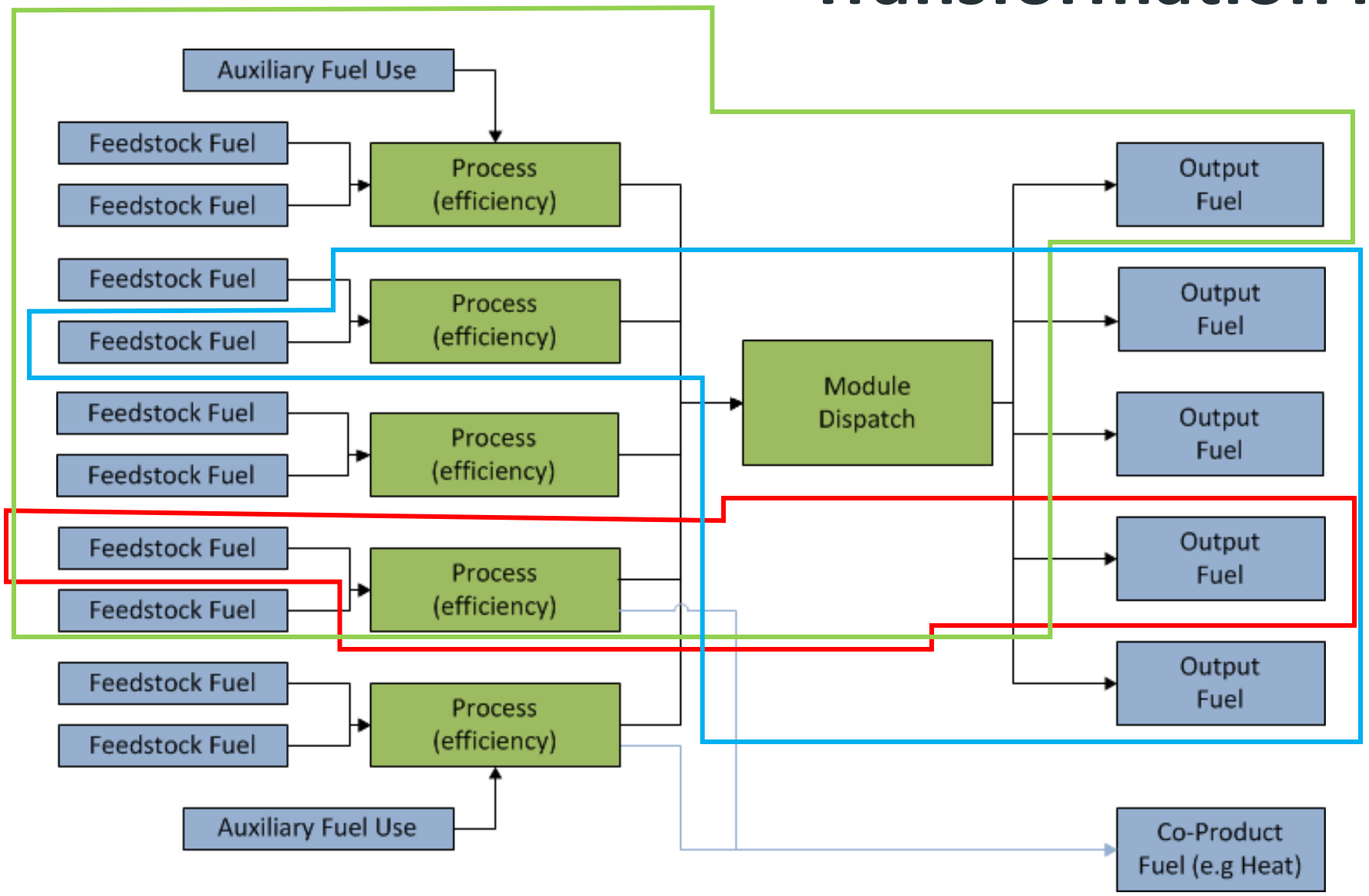
- Supply “modules” respond to fuel requirements in every “time slice”, by transforming feedstock fuels into outputs
- In scenarios, LEAP uses supply modules to respond to two key questions:
  - **Capacity Expansion:** Is capacity limited? How much capacity to build and when?
  - **Energy Production/Dispatch:** How should the capacity be operated in each time slice?



Enabling Supply Modeling



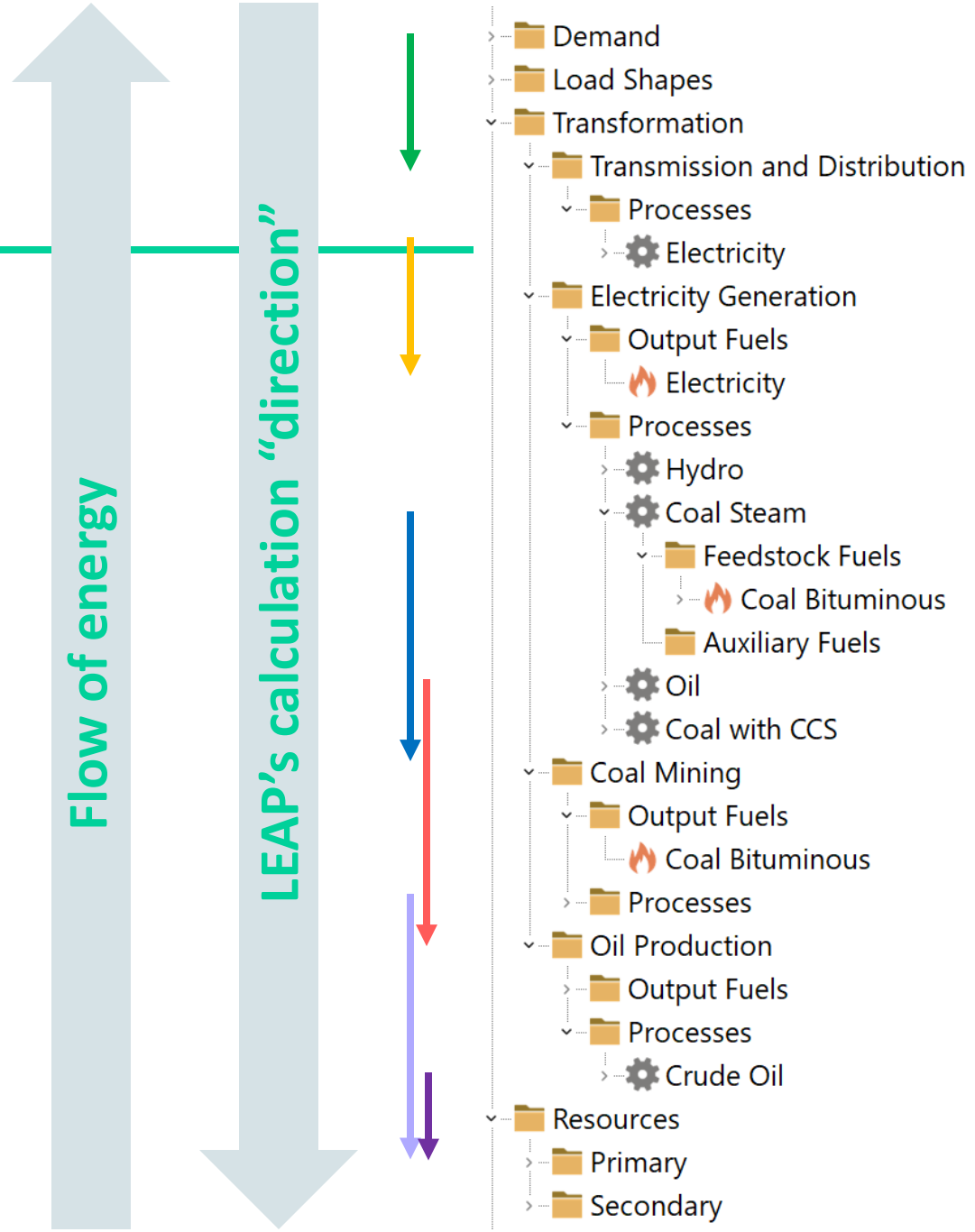
Transformation Module Layout



- Simple (e.g., transmission lines)
- Multi-output (e.g., petroleum refining)
- Multi-process (e.g., electricity generation)

Module Ordering

- Energy requirements are imposed on transformation modules from higher-level branches, starting with final energy demand
- Modules satisfy all requirements imposed on them, subject to capacity limits
- Multiple modules can produce the same fuel



Follow Along

1. Locate and open **follow_along_1.leap** in the Shared Materials directory.
2. Using the Results View, find the total final electricity demand in the year 2030.
3. In that year, how much electricity is produced (output) by the Transmission and Distribution module?
4. How much electricity is “transformed by” (input into) the Transmission and Distribution module?
5. What are the annual electricity requirements in 2030 for the Electricity Generation module?
6. How much bituminous coal is “transformed by” (input into) the Electricity Generation module?
7. What is the total primary energy supply of bituminous coal, in 2030?

Modeling Electricity Generation in LEAP

Two major issues to consider:

Capacity Expansion

- **Capacity needs must be met:** How much capacity to build and when? (MW)

Dispatch

- **Energy needs must be met:** Once built, how should capacity be operated? (MWh)

Capacity Expansion

"Simulation" or rules-based

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 (using NEMO)

Exogenous Capacity: User specifies current and future capacity of plants including retirements.

Optimized New Capacity: NEMO decides how to add capacity, obeying constraints such as planning reserve margin. Capacity expansion and dispatch are co-optimized to *minimize the net present value of all projected electricity production costs.*

Dispatch

“Simulation” or rules-based

Follows **Dispatch Rule:** Users can assign dispatch priorities (merits), dispatch for a fixed percentage of requirements, dispatch all available capacity, etc.

Optimization (using NEMO)

LEAP decides how to dispatch processes, obeying constraints. Capacity expansion and dispatch are co-optimized to *minimize the net present value of all projected electricity production costs.*

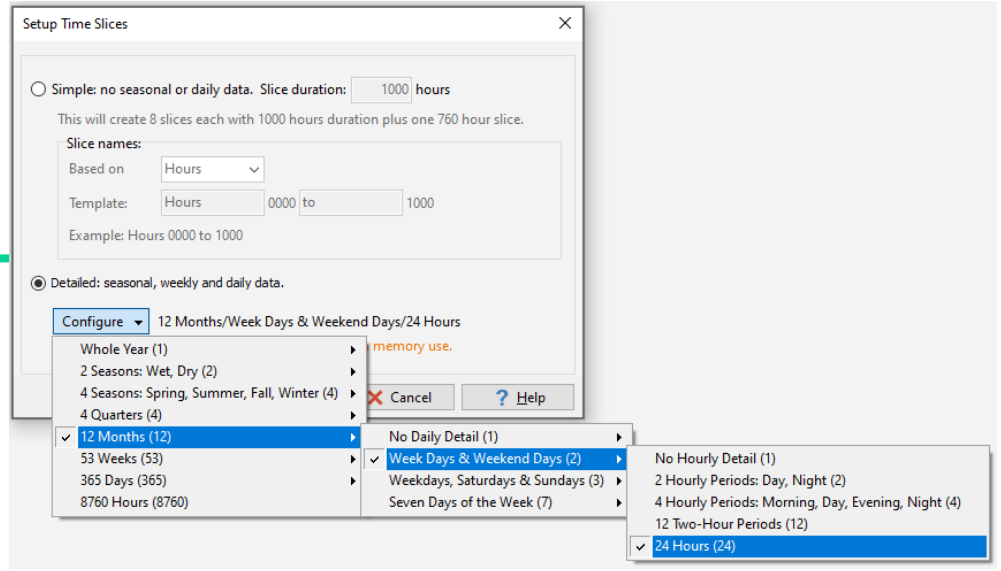
Dispatch

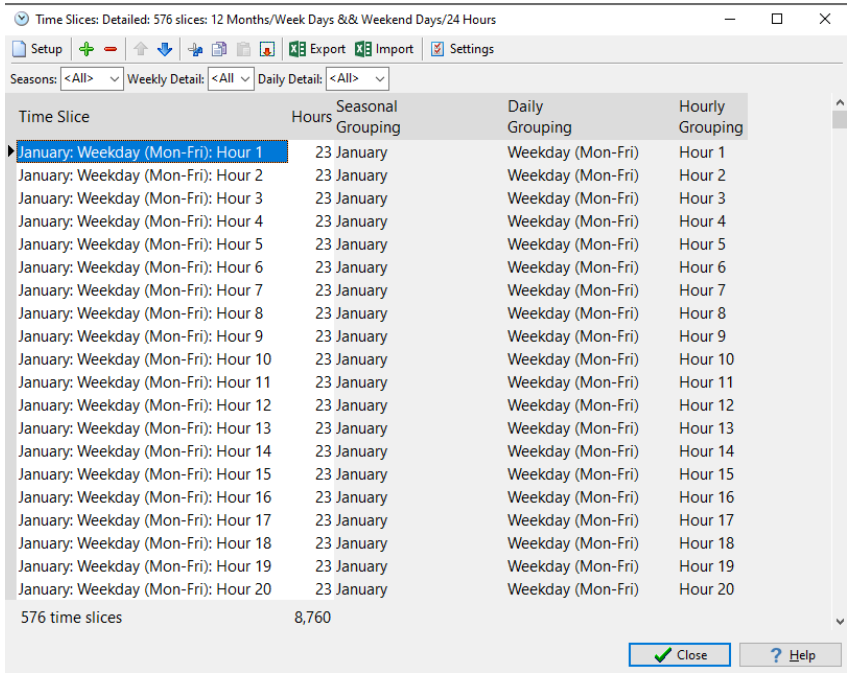
Transformation processes are called upon to meet energy and power requirements in each time slice. The time-sliced requirements are based on annual demand and the system's load curve.

The load curve can be specified exogenously or built up from load profiles associated with individual demands.

Time Slices

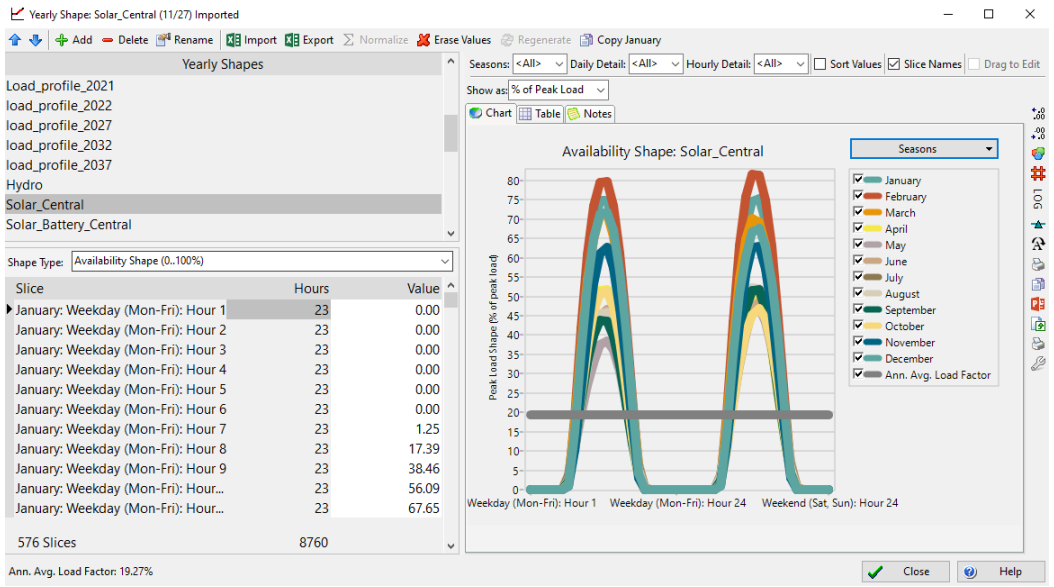
- Time slices **divide the year into sub-annual periods**
- **Only one set of time slices can be defined per model** – this same configuration is applied to every modeled year and region.
- **Various input variables** (e.g., maximum availability, merit order) and results (e.g. power generation, peak power requirements, curtailed energy production) **can be time sliced**
- **Module output requirements can also be time sliced**





Yearly Shapes

- The yearly shapes screen in LEAP is used to view and edit a **library** of any number of different shapes that can be used to specify **how values vary by time slice**.
- Yearly shapes can be created by **manually** entering data, or by **importing** time-sliced or hourly data (which LEAP aggregates based on the selected time-slice configuration).
- You can create four different types of yearly shapes:
  - **Peak Load Shapes** (% of peak load)
  - **Energy Load Shapes** (% of annual energy load)
  - **Availability shapes** (% availability 0..100%) used to describe the fraction of time a transformation process is available in each time slice
  - **Merit Order shapes** (integer values 0,1,2,...N) used to describe the merit order of dispatch of transformation processes



Determining Capacity Needs

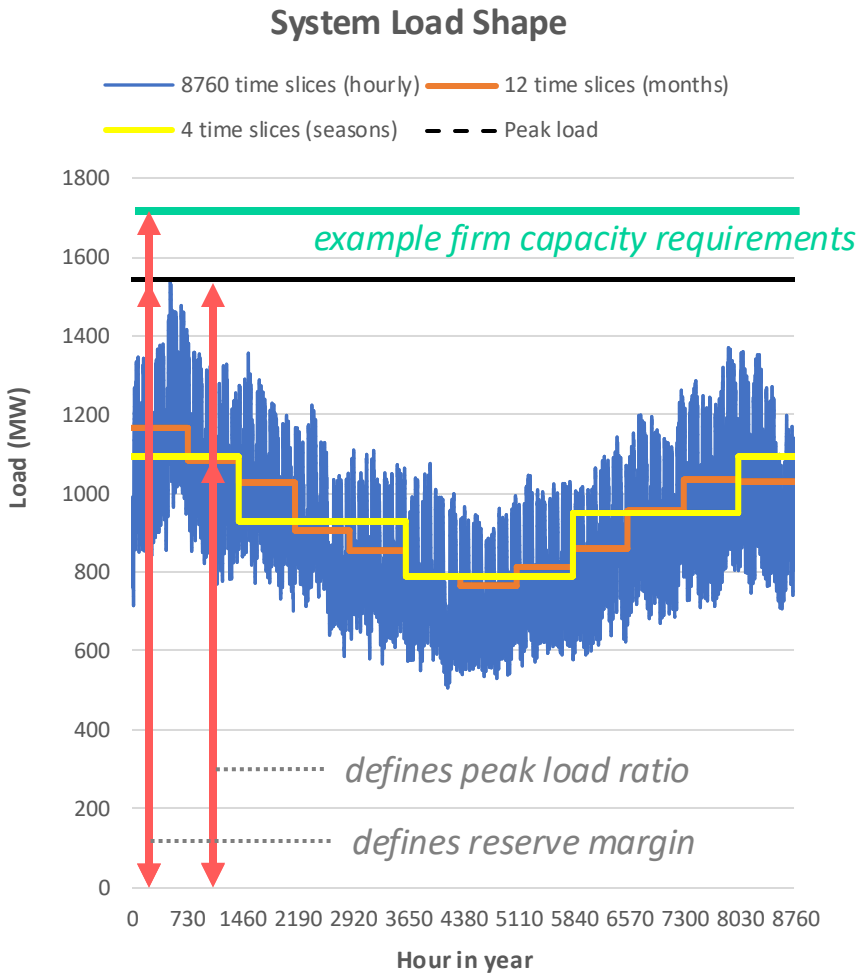
In each year:

$$\underbrace{\frac{firm\ capacity\ -peak\ load}{peak\ load}}_{reserve\ margin} \geq planning\ reserve\ margin$$

where:

$$peak\ load = (load\ in\ highest{-}load\ time\ slice)/(peak\ load\ ratio)$$

$$firm\ capacity = \sum_{p}(installed\ capacity)_p(capacity\ credit)_p$$



Calculating the Reserve Margin

Important inputs include:

- **Peak Load Ratio**, which may be entered manually or determined endogenously using LEAP's PeakLoadValueFromYearlyShape() function
- **Capacity Credit** captures characteristics of individual processes; should be defined in a way consistent with LEAP's calculation of reserve margin
  - Assignment of capacity credits can be subjective
  - In general, dispatchable generators often assigned a higher capacity credit than non-dispatchable generators, not to exceed generators' annual average maximum availability

Follow Along

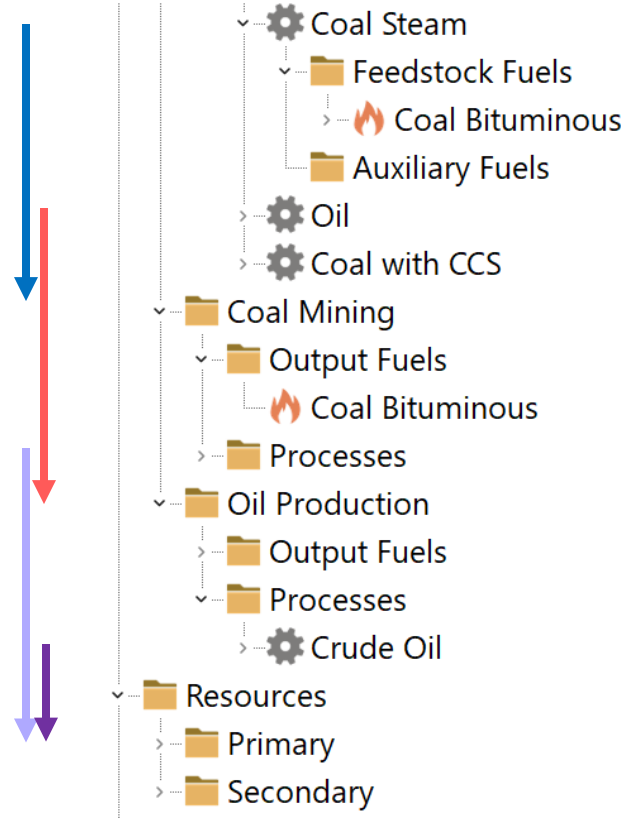
1. Continue using **follow_along_1.leap** in the Shared Materials directory.
2. How are the model's time slices established? How many time slices are used?
3. What is the name of the time slice that contains the highest load? What percentage of peak load is this?

The Resources Branch

Energy requirements that originate as final demands, and are transformed through supply processes, must terminate *somewhere*.

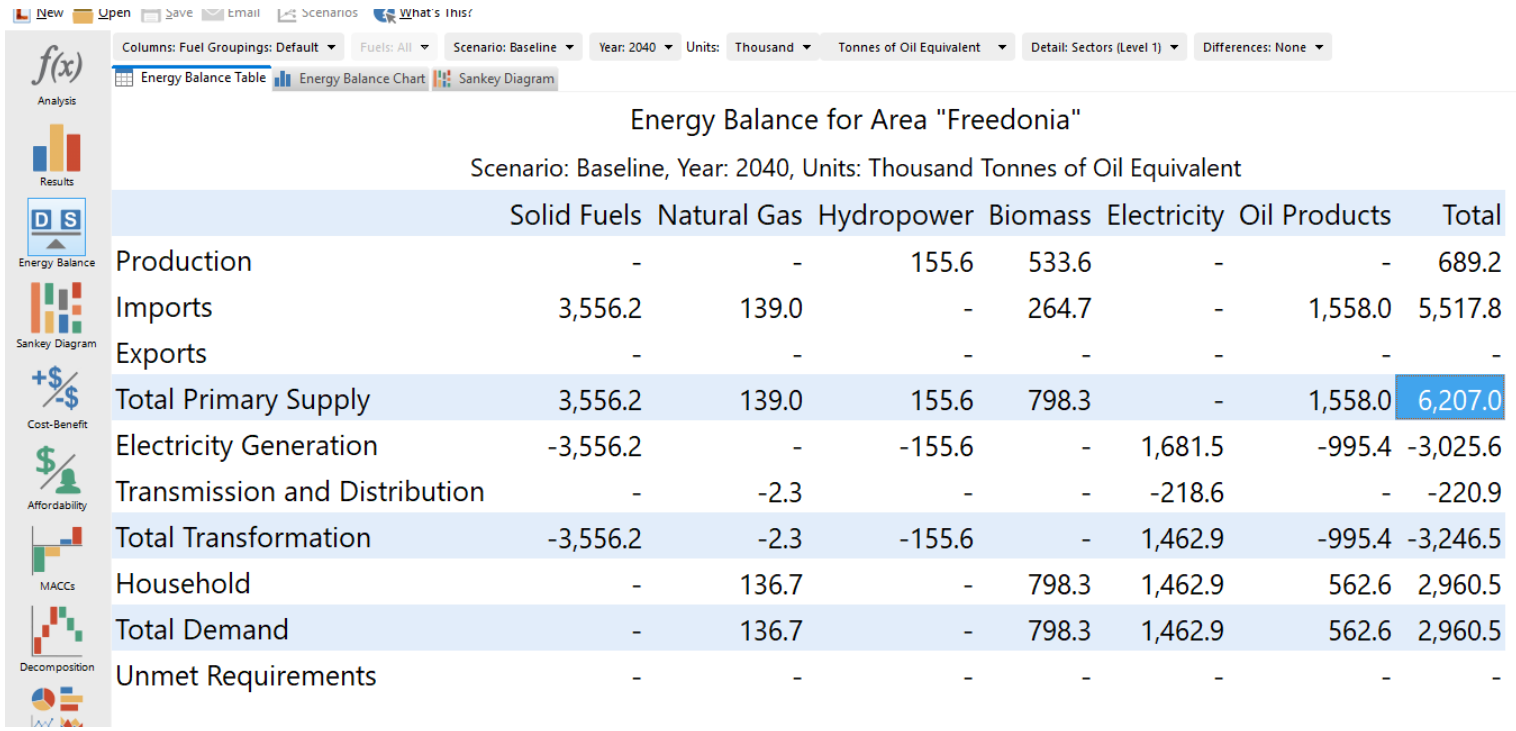
LEAP's Resources branches allow users to choose what happens at the bottom of the tree. Are these fuel requirements:

- Produced or extracted domestically?
- Imported?
- Simply designated "unmet"?



Energy Balances

An energy balance is an **annual reporting format** that shows the **production**, **conversion** and **consumption** of **energy commodities** in an economy, obeying physical accounting rules.



Energy Balance for Area "Freedonia"

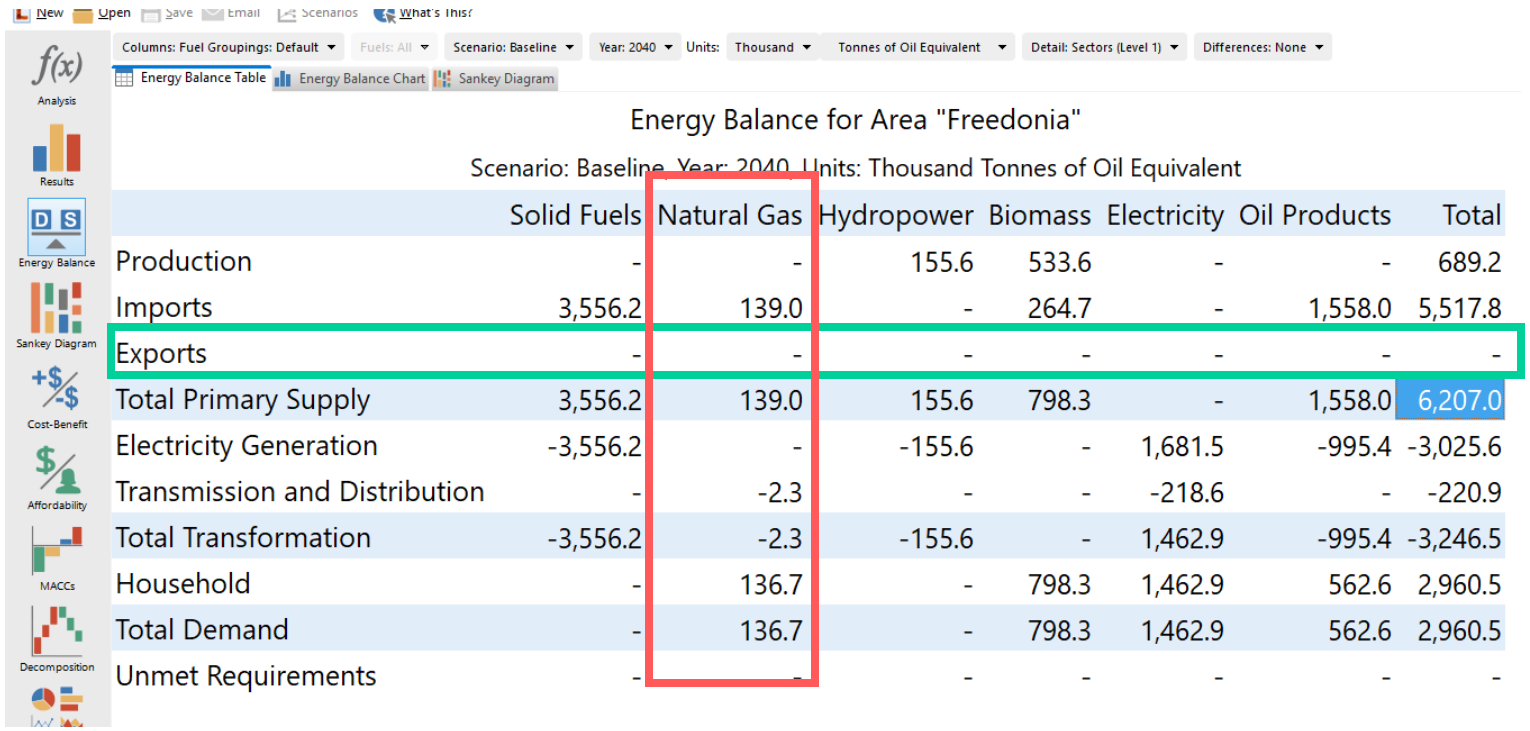
Scenario: Baseline, Year: 2040, Units: Thousand Tonnes of Oil Equivalent

	Solid Fuels	Natural Gas	Hydropower	Biomass	Electricity	Oil Products	Total
Production	-	-	155.6	533.6	-	-	689.2
Imports	3,556.2	139.0	-	264.7	-	1,558.0	5,517.8
Exports	-	-	-	-	-	-	-
Total Primary Supply	3,556.2	139.0	155.6	798.3	-	1,558.0	6,207.0
Electricity Generation	-3,556.2	-	-155.6	-	1,681.5	-995.4	-3,025.6
Transmission and Distribution	-	-2.3	-	-	-218.6	-	-220.9
Total Transformation	-3,556.2	-2.3	-155.6	-	1,462.9	-995.4	-3,246.5
Household	-	136.7	-	798.3	1,462.9	562.6	2,960.5
Total Demand	-	136.7	-	798.3	1,462.9	562.6	2,960.5
Unmet Requirements	-	-	-	-	-	-	-

Energy Balances

Commodity Flows (rows)

Commodities (columns)



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Total Demand	-	136.7	-	798.3	1,462.9	562.6	2,960.5
Unmet Requirements	-	-	-	-	-	-	-

Total Primary Energy Supply

Follow Along

1. Continue using **follow_along_1.leap** in the Shared Materials directory.
2. Using the Energy Balance View, find the total final electricity demand in the year 2030. Does it match what you found earlier?
3. In that year, how much electricity is lost at the Transmission and Distribution module? How would you calculate how much electricity is “transformed by” (input into) the Transmission and Distribution module?
4. How much bituminous coal is “transformed by” (input into) the Electricity Generation module?
5. What is the total primary energy supply of bituminous coal, in 2030? How much is produced domestically?

Afternoon Assignment

Learning goals:

- Learn to add new transformation modules, and why their ordering matters
- Understand the different uses of a module process
- Learn when to limit process capacity, and when not to bother

Afternoon Assignment

Steps:

1. Locate and open both **afternoon_exercise_1.leap** and **LEAP2024TrainingExercise.pdf** in the Shared Materials directory.

2. Beginning on page 43, follow the instructions.
   a) *3.1 Charcoal Production*: Add the module according to the instructions. We'll do this together.
   b) *3.2 Electricity Generation*: In Current Accounts, update the Exogenous Capacity and Historical Production variables using the information in the table.
   c) *3.3 Oil Refining*: Add the module according to the instructions. We'll begin this together.
   d) *3.4 Coal Mining*: Add the module according to the instructions.

Afternoon Assignment

Steps:

3. Section *3.5 Resources* describes how to add resource reserves or annual yields. You may skip this, as these steps have already been completed in the LEAP area.
4. Switch to the Energy Balance View, which will trigger your model to calculate.
   a) Can you generate the two tables shown on page 46?
   b) If your calculated values differ, how would you go about identifying the reason for the discrepancy?

We will briefly take up this assignment at the beginning of tomorrow's session.