SEI Stockholm Environment Institute

SEI Asia Centre

Training on Low Emissions Analysis Platform

Day 2: 20 October 2021

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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 2

https://tinyurl.com/SEIAsiaLEAPtraining-1450

Password: Day02#

Workshop connection information

Web meetings

https://tinyurl.com/SEIAsiaLEAPtraining

Zoom meeting ID: 872 2041 5222
Zoom passcode: 353649

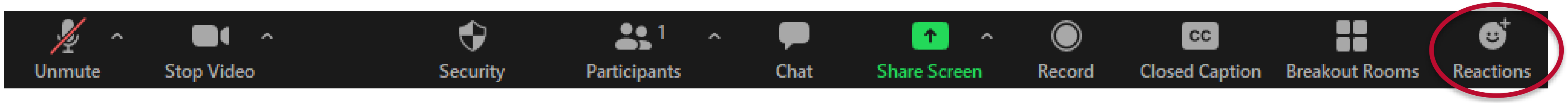
Shared files

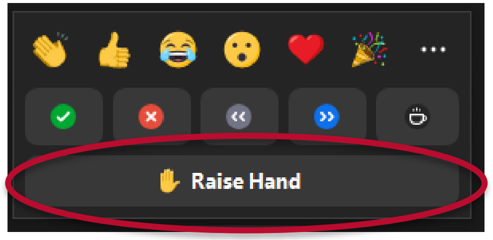
https://tinyurl.com/SEIAsiaLEAPMaterials

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**



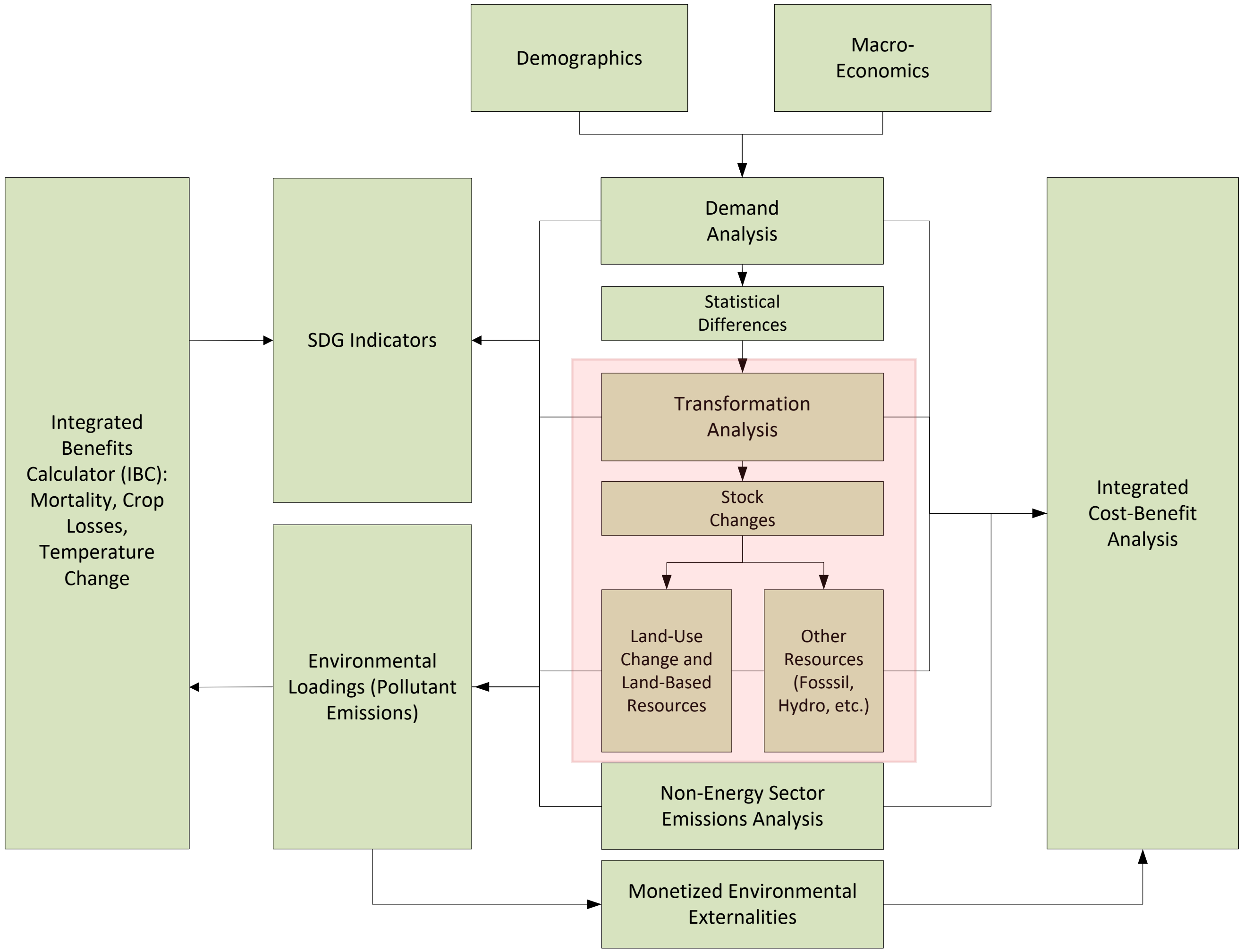


Workshop overview

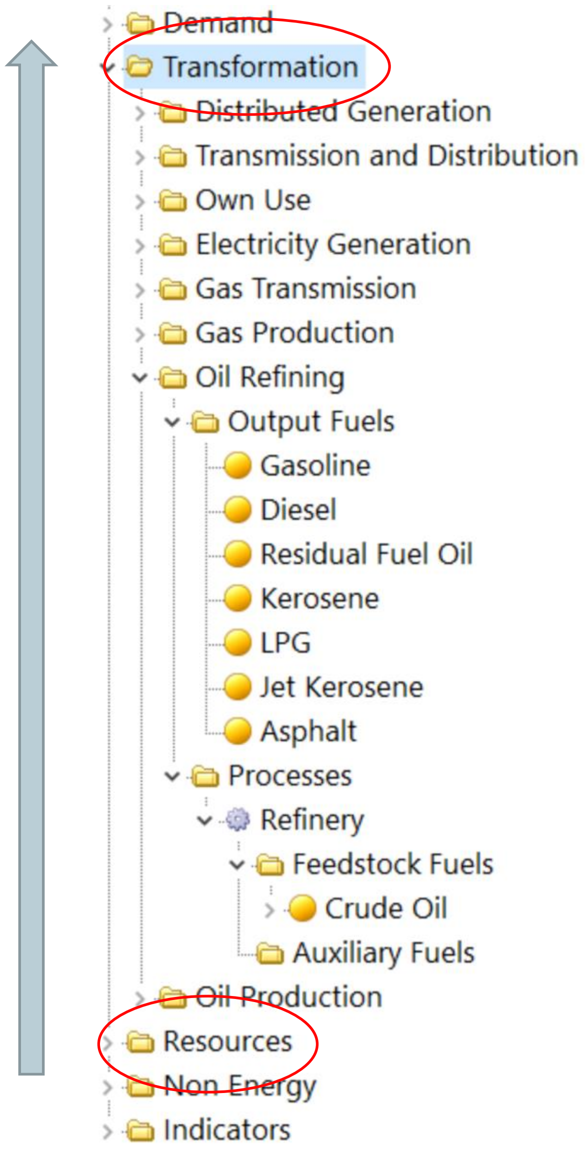
- **Day 1:** Introduction to LEAP and energy demand modeling
- **Day 2:** Energy supply and emissions modeling
- **Day 3:** Cost-benefit analysis and optimization modeling
- **Day 4:** Linking LEAP and WEAP and other advanced topics

Modeling energy supply with LEAP

Structure of a representative LEAP analysis

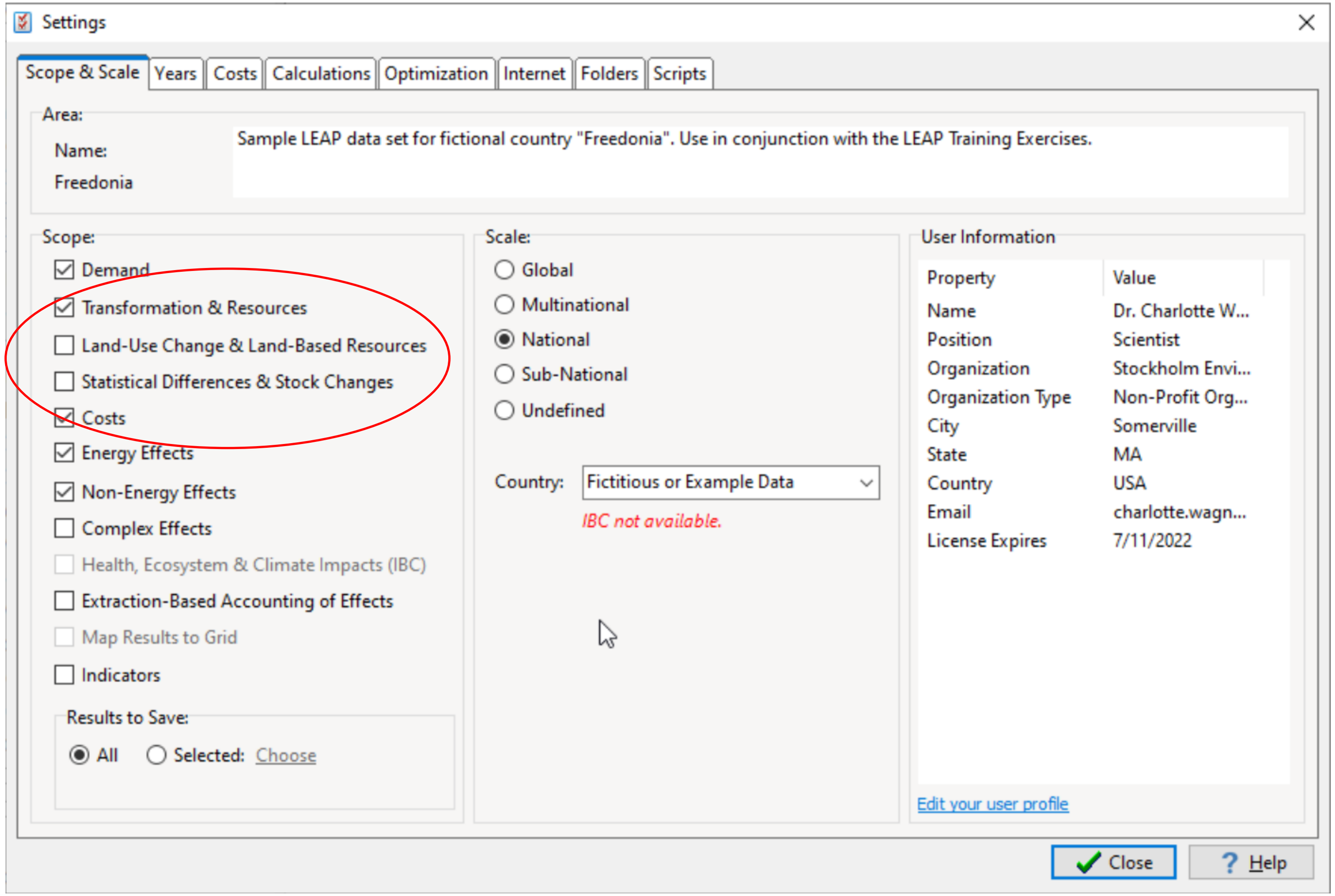


Supply modeling overview

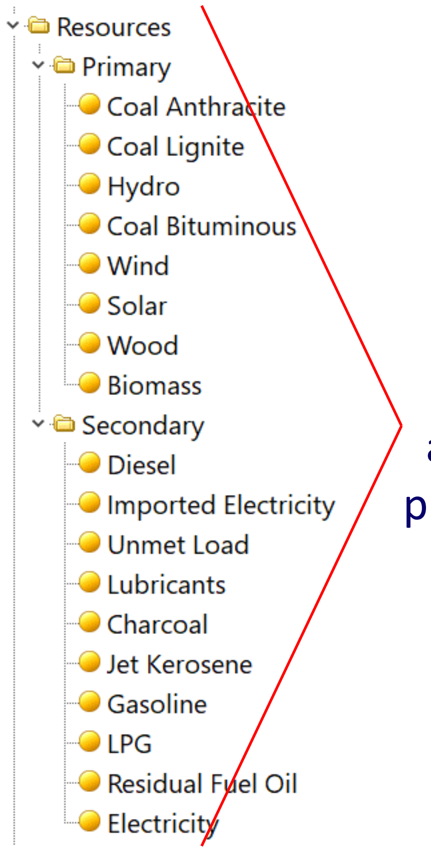


- LEAP supports **modeling all links in the energy supply chain**, from **resource extraction** to **energy trade, energy conversion,** and **delivery to end users**
- **Demand-driven**, engineering-based simulation
- Two main branches in LEAP tree: **Resources** and **Transformation**
  - Resources – 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 tracked in Resources
- Transformation structure: "**modules**" (energy-producing sectors), each containing one or more "**processes**"
  - Processes use feedstock (input) fuels to produce output fuels
- Transformation modeling allows for simulation of **process capacity: expansion** and **dispatch**
  - Choice of two overall methodologies: **rules-based simulation** and **optimization**
- **Cost-benefit and emissions accounting** can be integrated throughout supply model

Enabling supply modeling

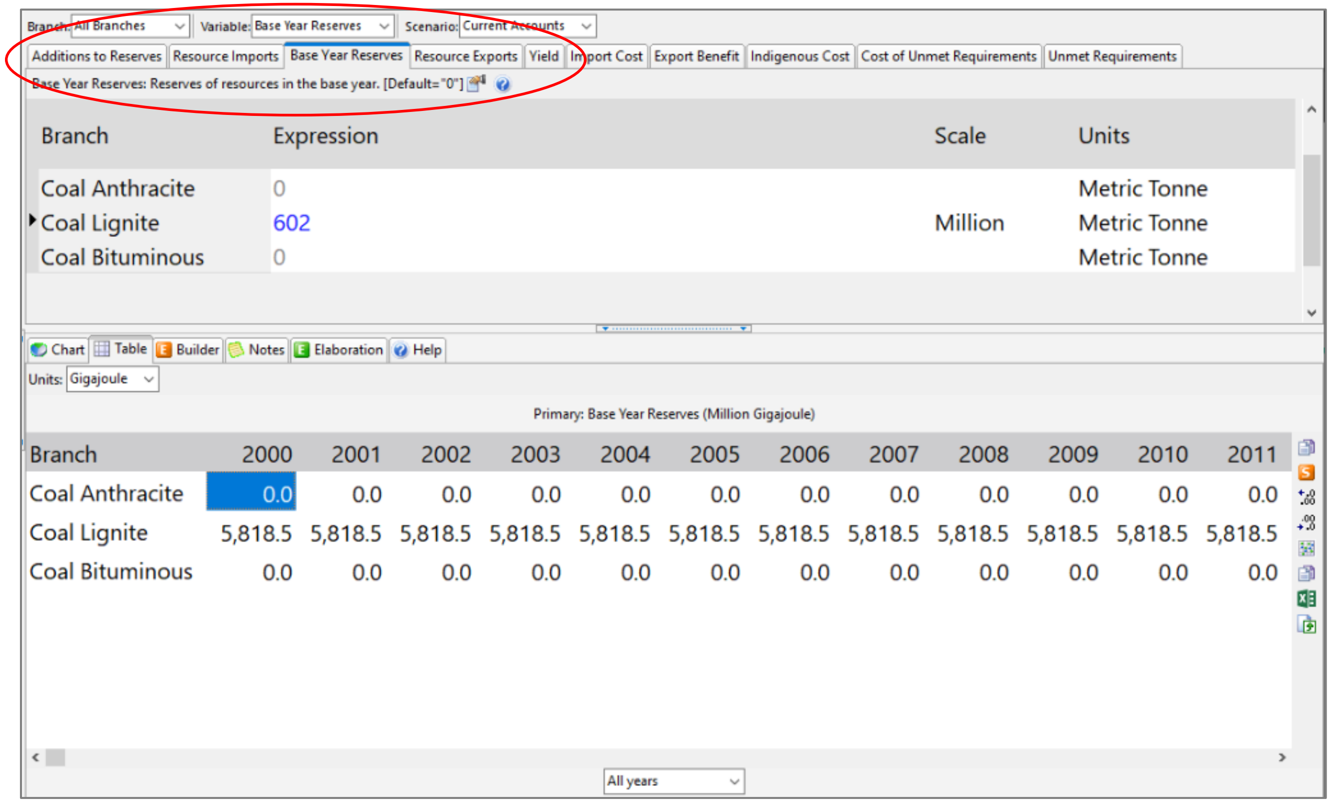


Resources branch

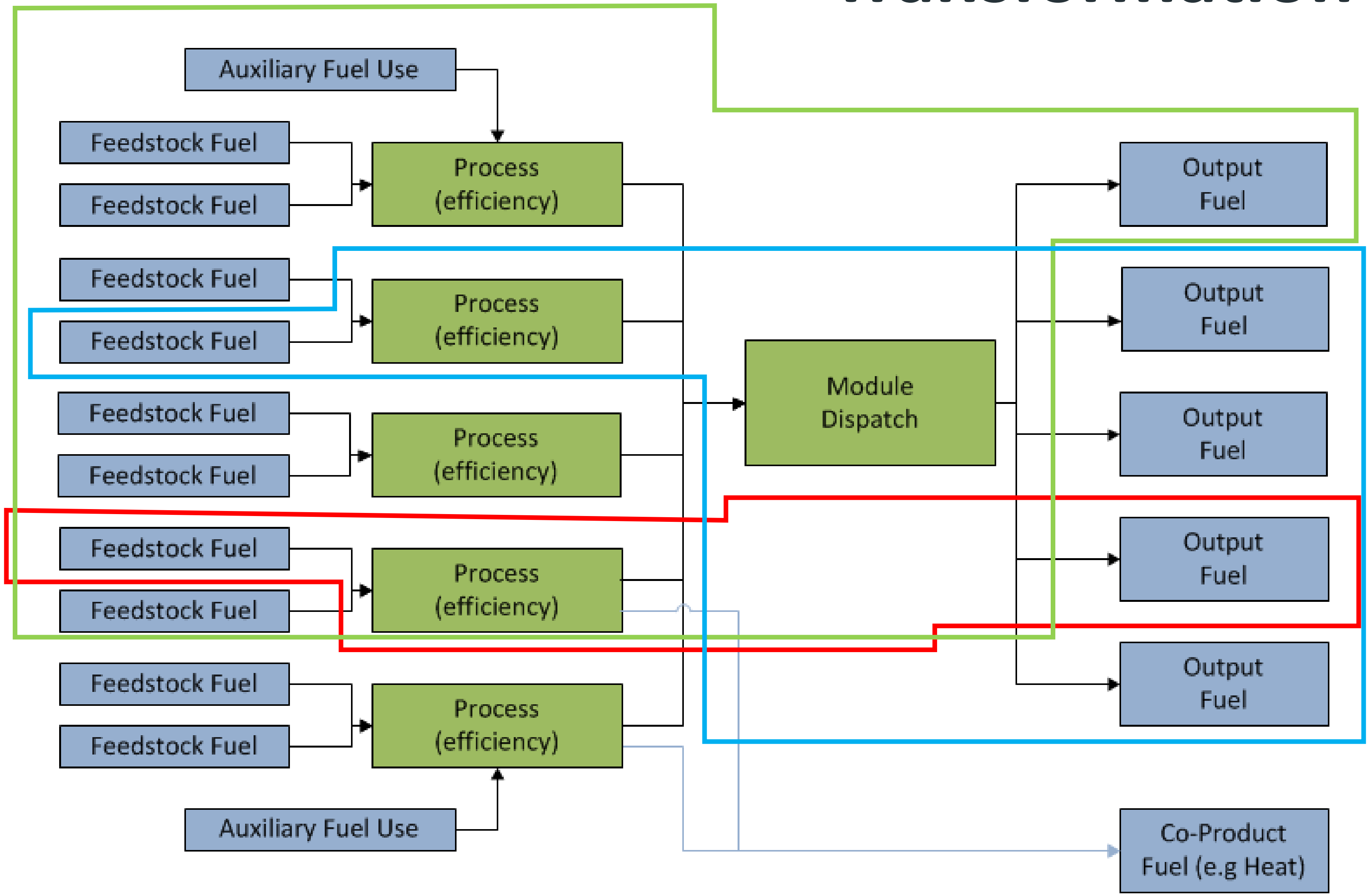


LEAP automatically adds branches for all primary and secondary fuels used in model

Variables in Analysis View for specifying reserves, yields, required imports and exports

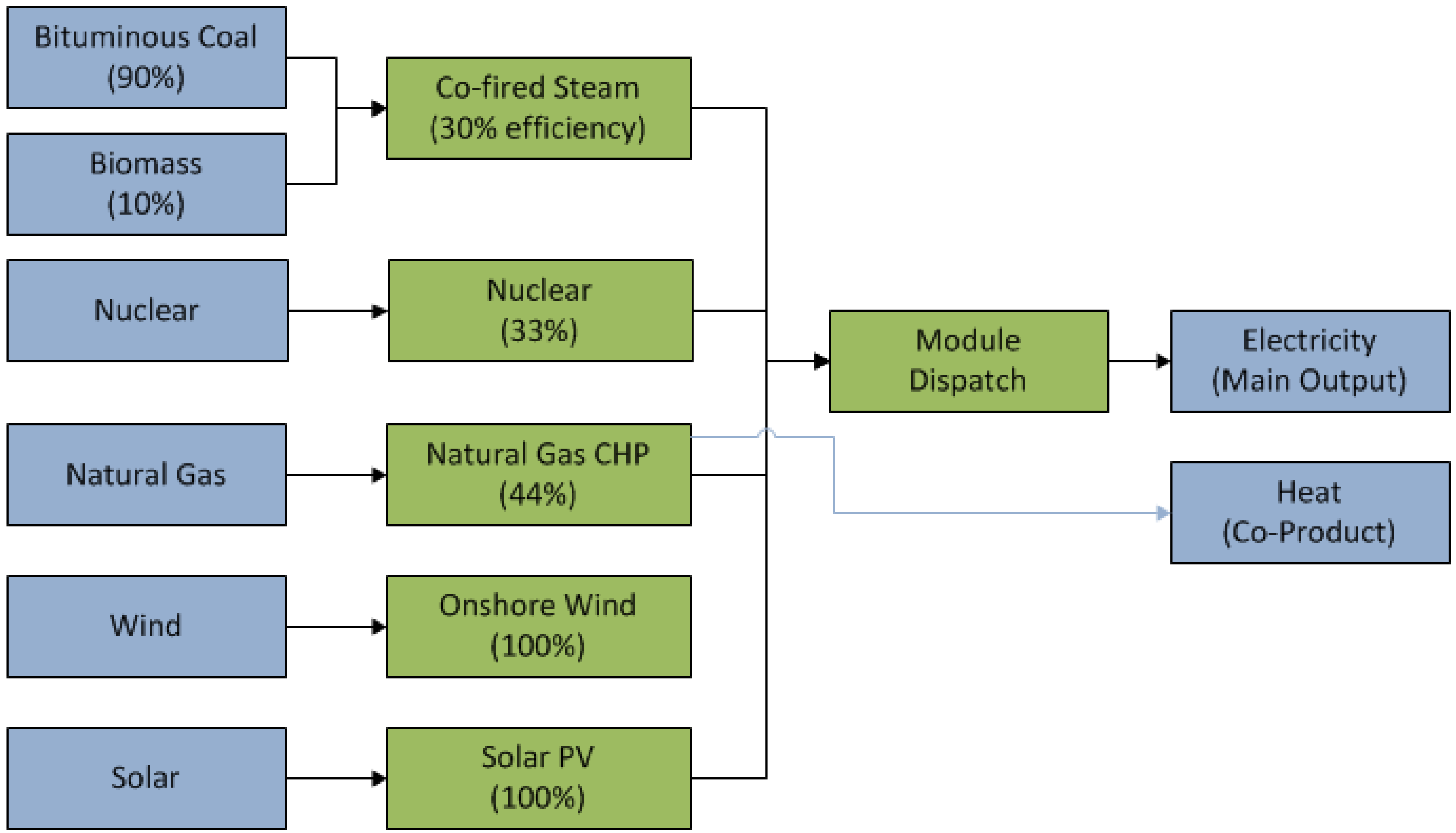


Transformation module layout

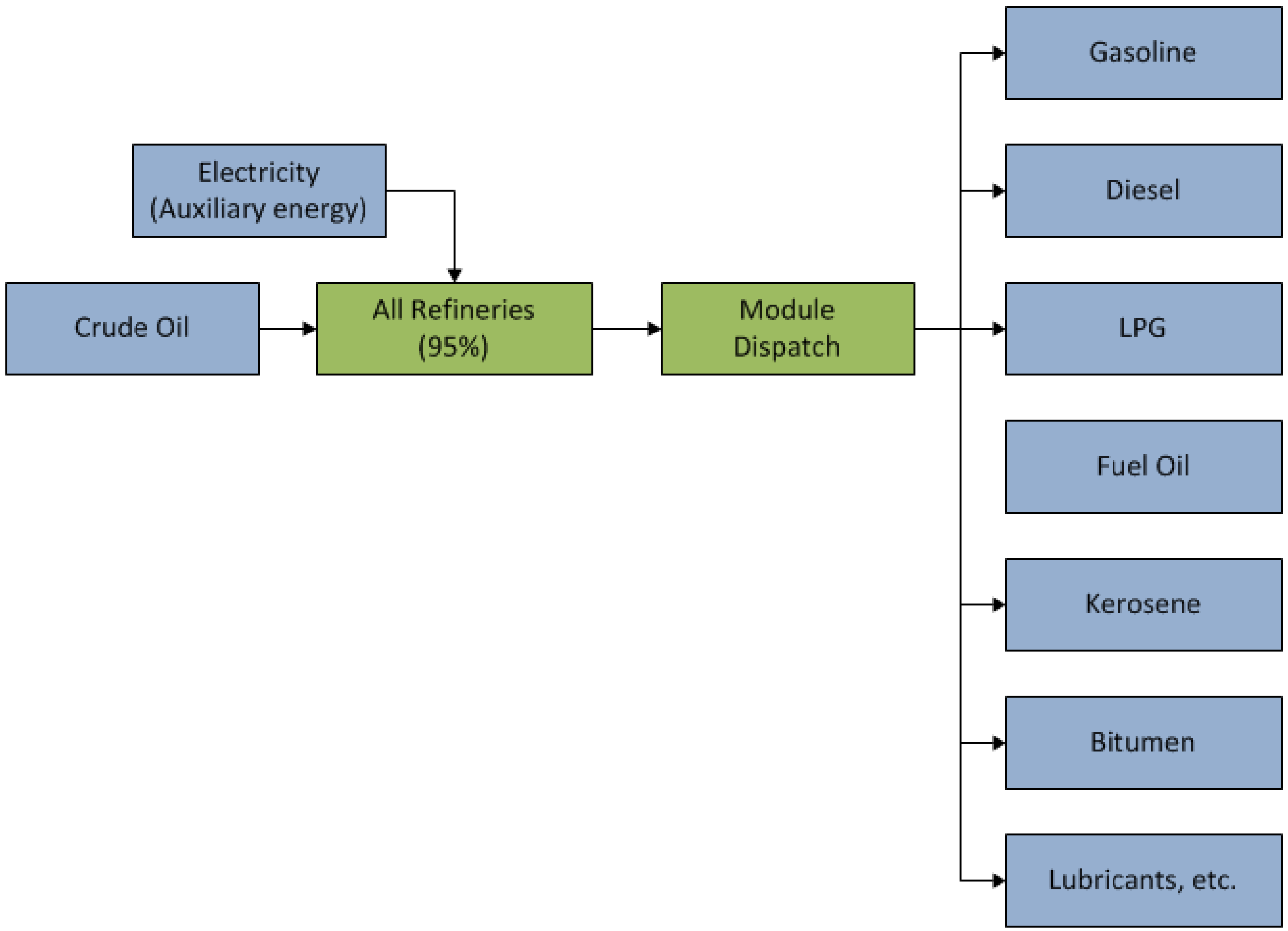


- Simple (e.g., transmission lines)
- Multi-output (e.g., petroleum refining)
- Multi-process (e.g., electricity generation)

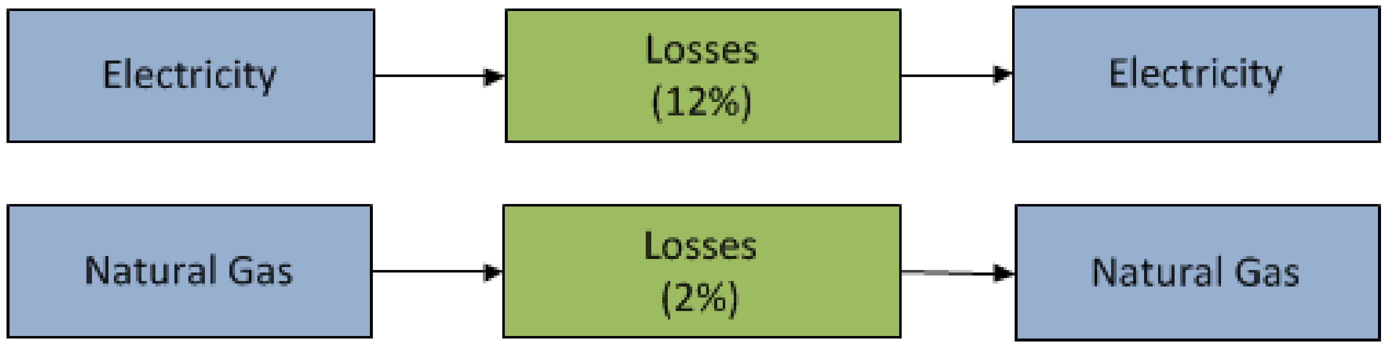
An electricity generation module



A petroleum refining module



Simple, non-dispatched transformation modules



Steps for a supply analysis in LEAP

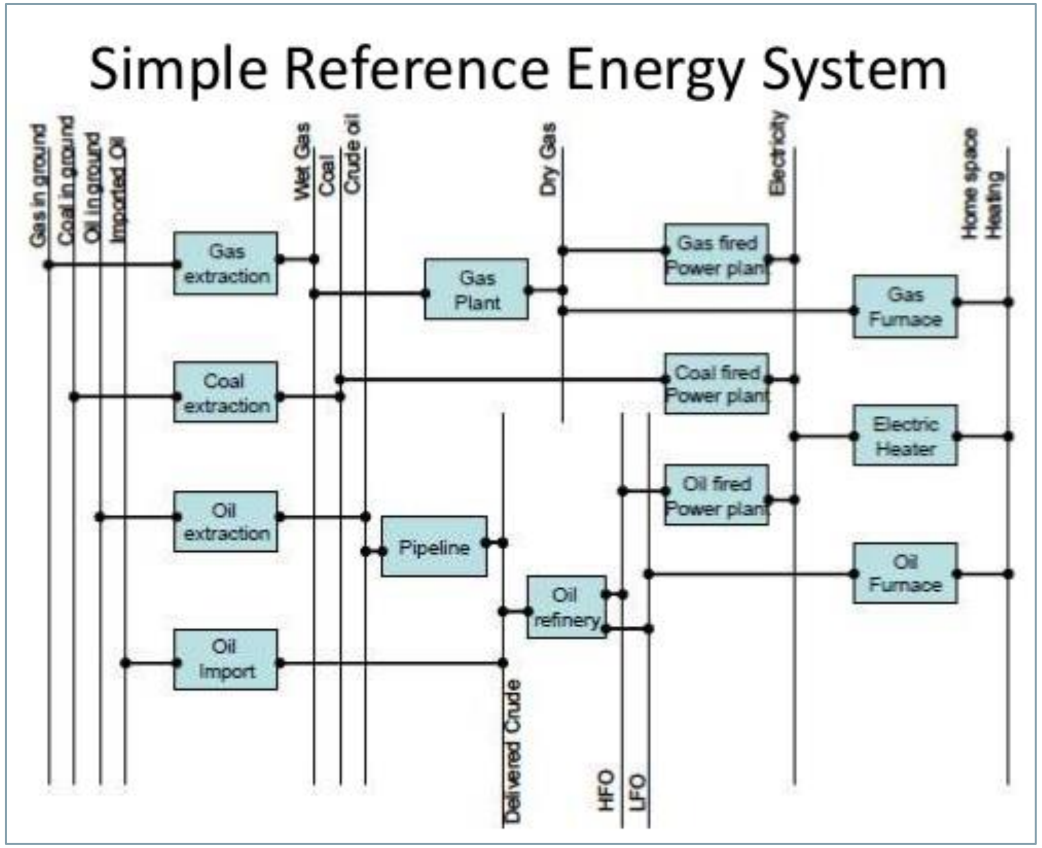
- Map components of supply system to Transformation and Resources branches
- Sequence transformation modules
- Set transformation module properties, specify output fuels, and enter process data
- Enter data in Resources branch

Mapping supply system components

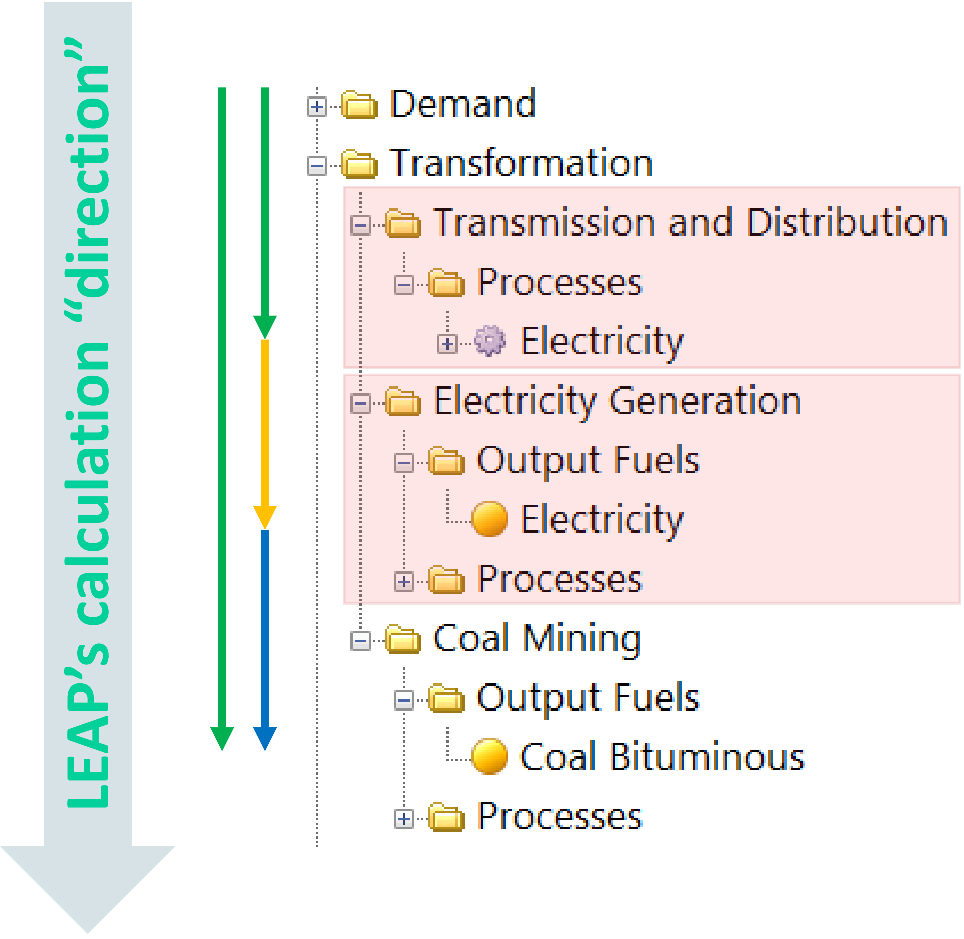
- **Ensure every supply source and activity is appropriately represented** in LEAP
- Key question: **system boundary**

Transformation module or Resources branch?

- **Transformation** – use to model energy conversion, energy losses, production capacity, dispatch of multiple production options, intra-annual variation in demand & supply, disaggregated production costs (e.g., capital, O&M)
- **Resources** – use to model production of primary energy resources or required fuel imports and exports where none of Transformation conditions apply



Module ordering

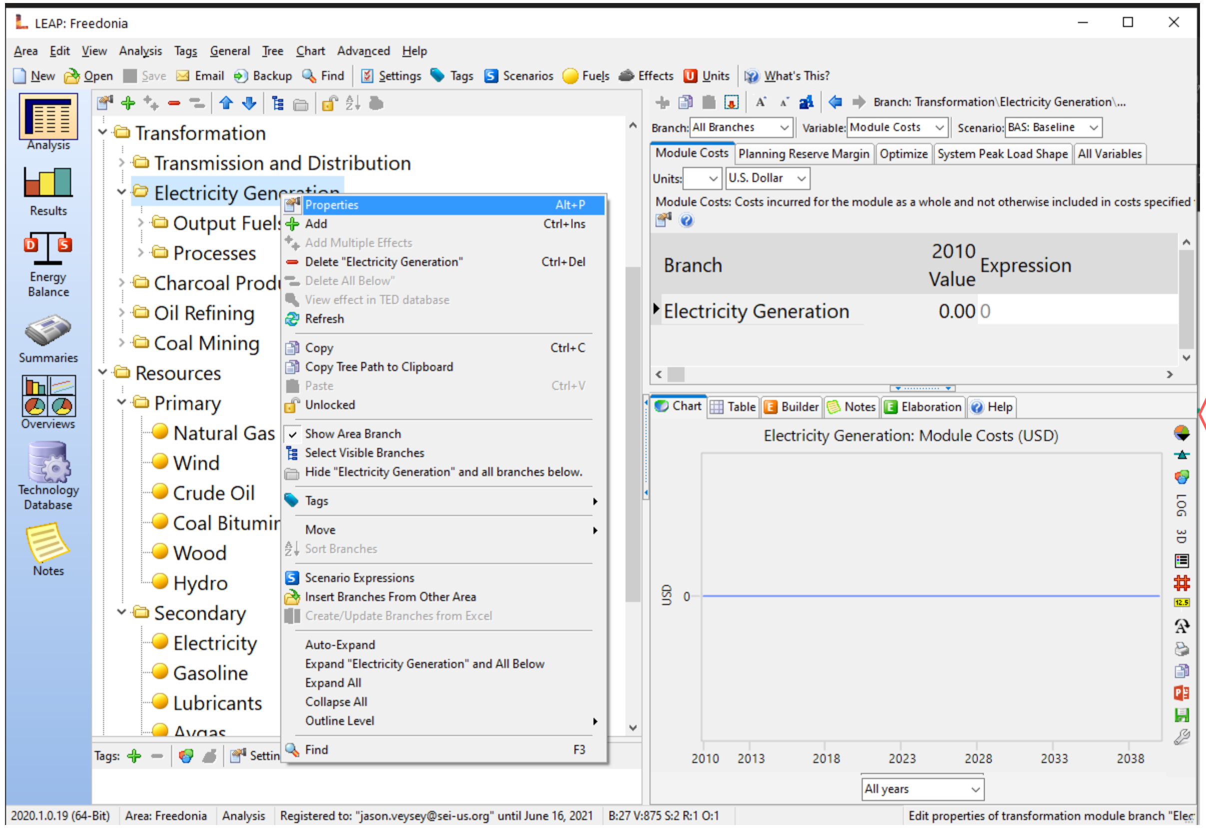


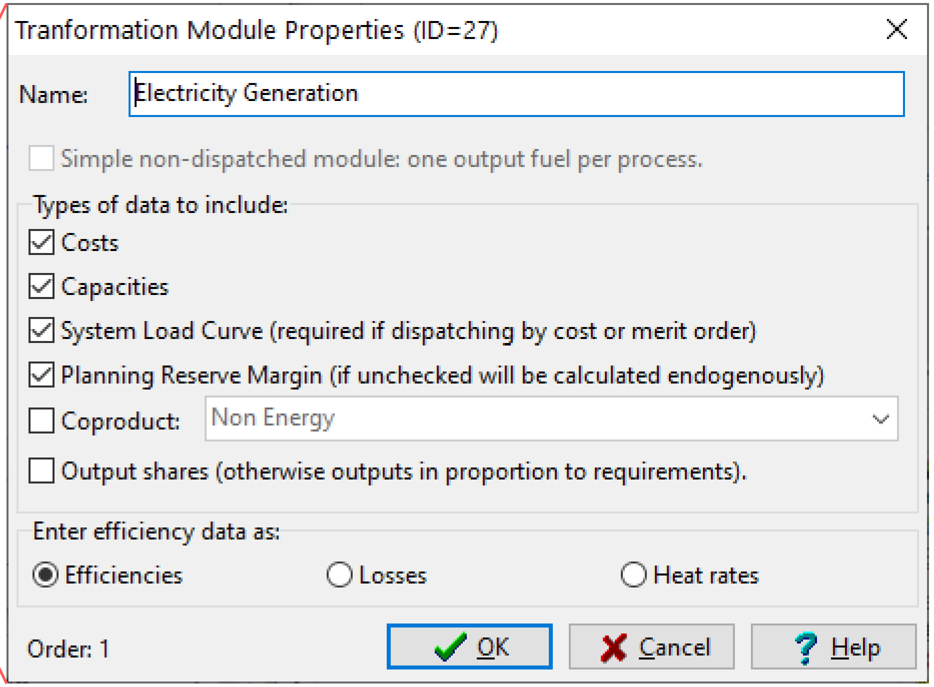
Energy requirements are imposed on transformation modules from higher-level branches, starting with final energy demand

Modules satisfy all requirements imposed on them, subject to capacity limits

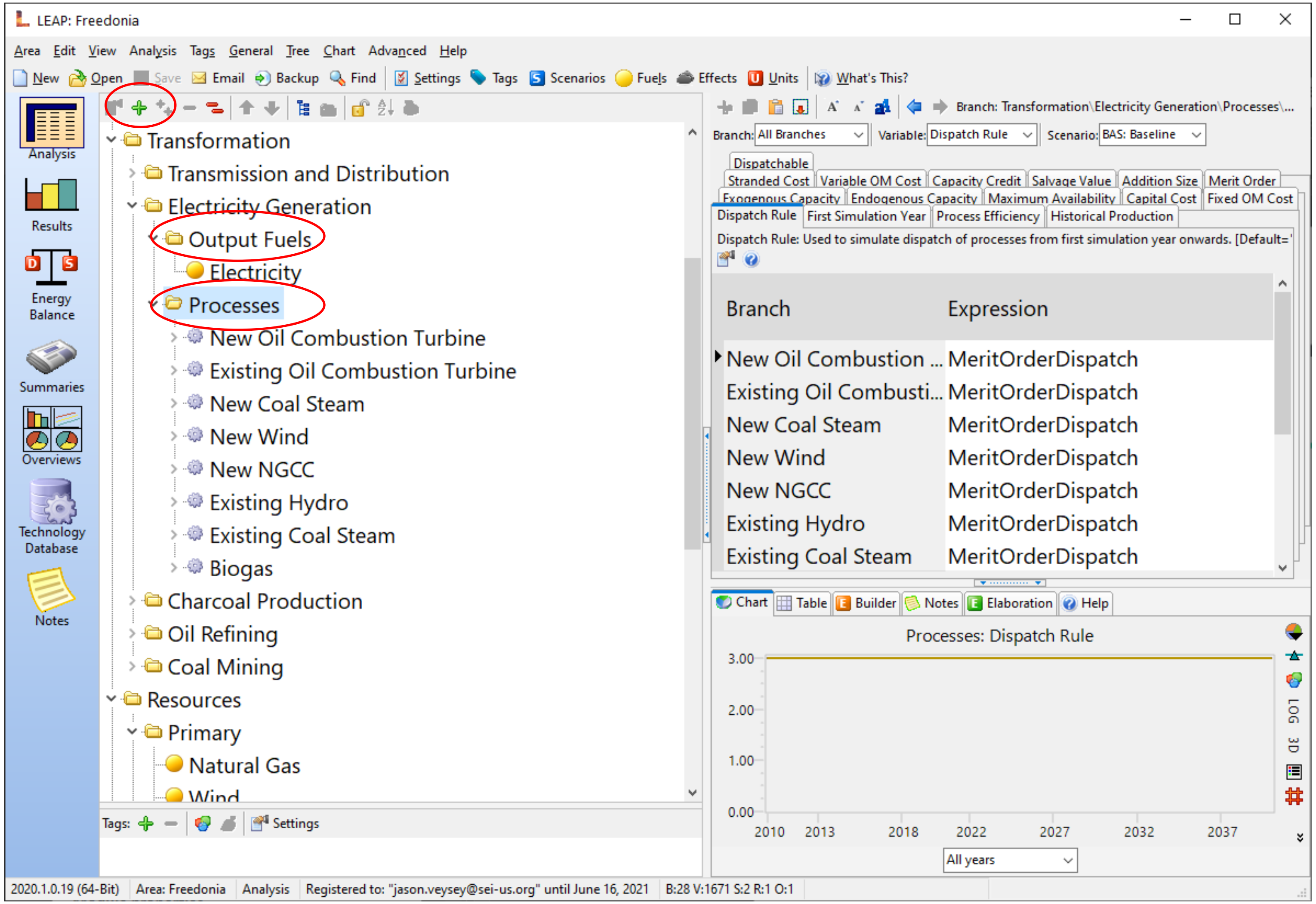
Multiple modules can produce same fuel

Module properties





Module outputs and processes



LEAP automatically creates categories (folder branches) for output fuels and processes

User decides which outputs and processes to add to categories – i.e., what's going to be modeled

Modeling process capacity

Two major issues to consider:

Capacity expansion	Dispatch
• How much capacity to build and when? (MW)	• Once built, how should capacity be operated? (MWh)

Capacity modeling methods

- **Two main methods** for modeling capacity expansion and process dispatch in LEAP
  - **Rules-based simulation** => user defines **prioritization rules**
  - **Optimization** => user defines cost and performance parameters, model finds **least-cost solution**
- Optimization is more data-intensive and difficult to calibrate, but it expands functional possibilities – e.g., **energy storage** and **transmission power flow**

Rules-based capacity expansion

- **Exogenous capacity** – assumed to exist in specified years
- **Endogenous capacity** – prioritized options that LEAP may build if needed to maintain reserve margin
  - User specifies reserve margin target and order and addition size for endogenous capacity options

Addition Order	Build Order	Process	Addition Size Expression
1	0	New Coal Steam	500
2	0	New Oil Combustion Turbine	300

Reserve margin:
available capacity when system is at peak load

Rules-based capacity expansion

- **Exogenous capacity** – assumed to exist in specified years
- **Endogenous capacity** – prioritized options that LEAP may build if neede
  - User s … or endogenous capacity options

Reserve margin

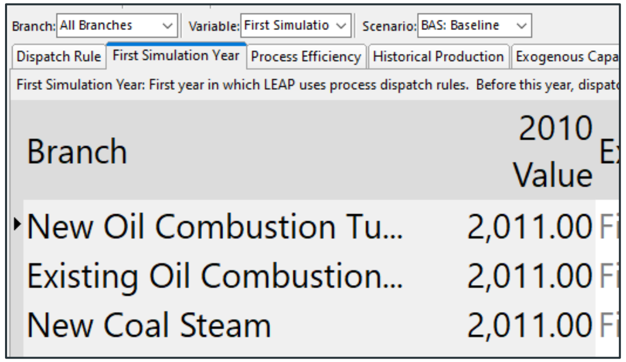
$$\frac{\sum(capacity \times capacity\ credit) - peak\ load}{peak\ load} \times 100$$

Addition Order	Build Order	Process	Addition Size Expression
1	0	New Coal Steam	500
2	0	New Oil Combustion Turbine	300

Reserve margin:
available capacity when system is at peak load

Rules-based process dispatch

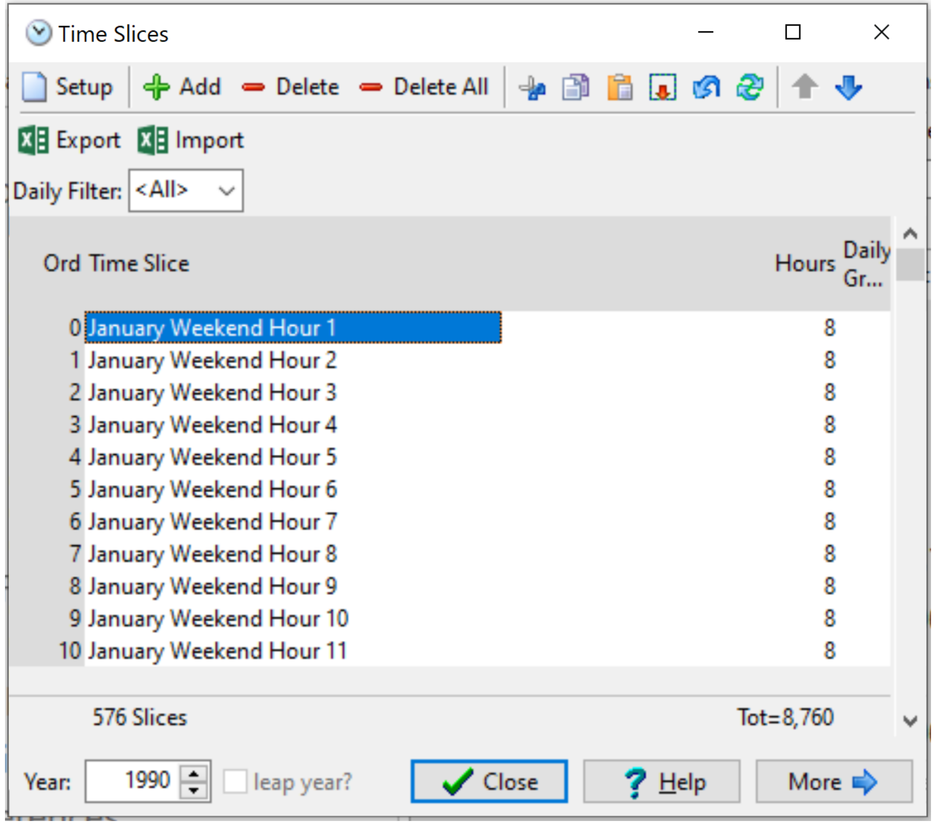
- Before **first simulation year – historical production**
- In and after first simulation year – **dispatch rule**
  - Merit order – user-assigned priorities
  - Full capacity – 100% of available capacity (capacity x maximum availability)
  - Percent share – % of module output requirements
  - Running cost – in order of variable O&M + fuel cost
  - Proportional to capacity – output shares determined by available capacity



Dispatch in and after first simulation year attempts to meet demand (MWh) and load (MW) in each year and time slice, given available capacity

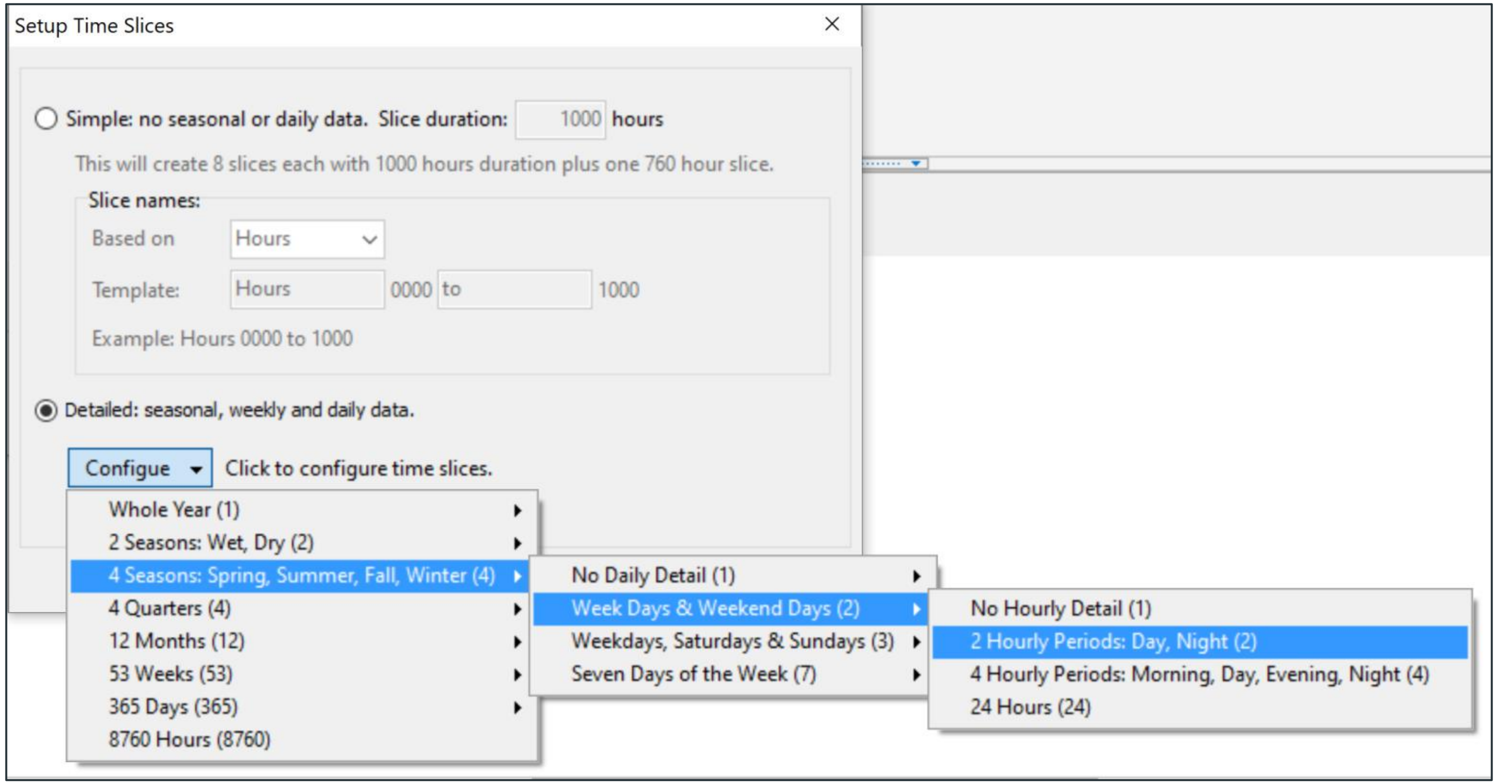
Time slicing

- Time slices **divide the year into sub-annual periods**
- Used to model **additional temporal detail** in supply and demand of particular fuels (e.g., electricity)
- **One set of time slices per model** – configure in General -> Time Slices
- **Various variables can be time sliced** (e.g., maximum availability, merit order, key assumptions)
- **Module output requirements can also be time sliced**
  - Exogenous – load shape attached to module
  - Endogenous – load shape attached to each final energy demand, LEAP sums demand shapes
- If module requirements are not time sliced, dispatch is for an entire year at a time

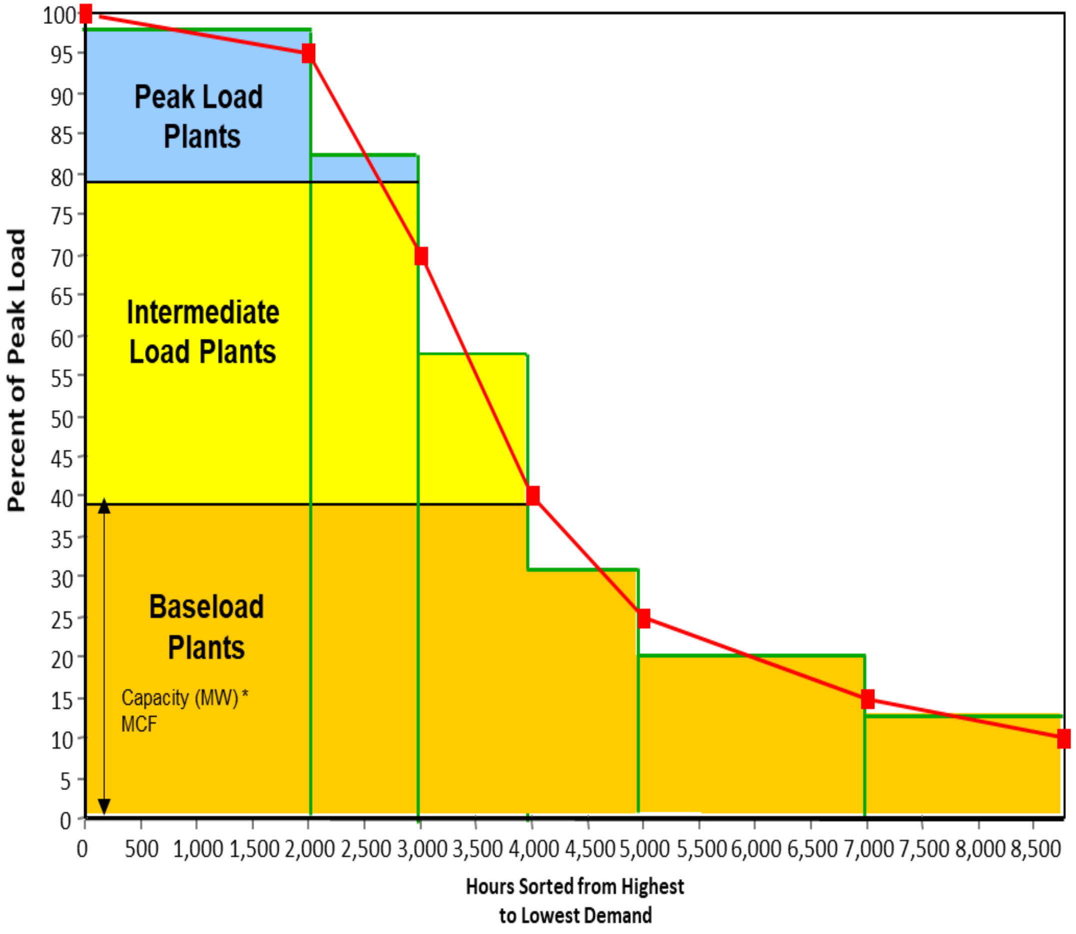


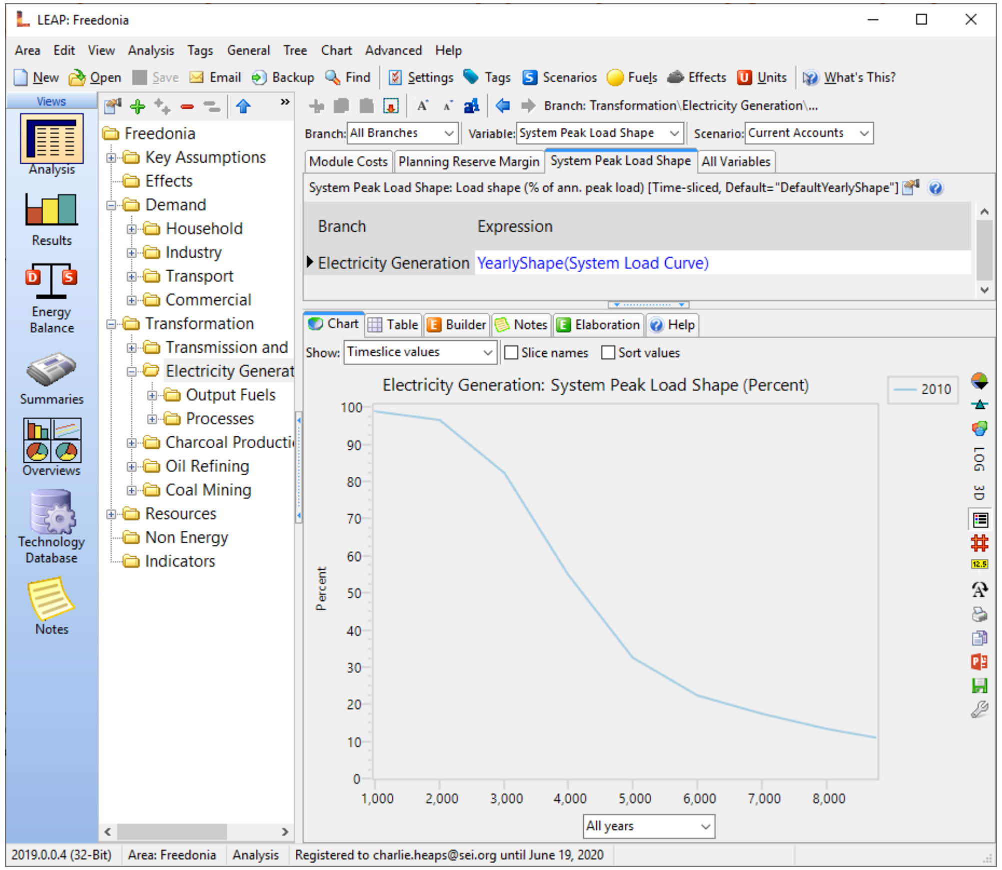
Time slice options

- **LEAP streamlines creation of various time slice configurations**
- If time-sliced **inputs are entered with hourly resolution**, LEAP aggregates them by time slice
    - Load shapes, process maximum availabilities, etc.
- Time slice configuration can then be modified, and LEAP will automatically re-aggregate all time-sliced inputs => this makes it **extremely easy to change time slices**



Load shapes and dispatch





A quantitative example

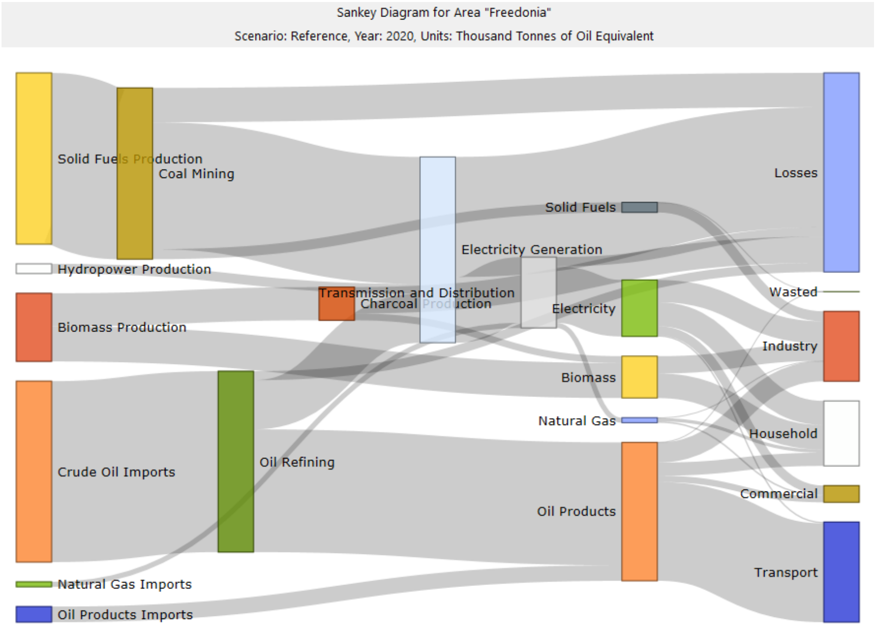
- Two time slices: winter (40% of year) and summer (60% of year)
- Annual demand = 100 GWh
- Load shape: 70% of demand in winter, 30% in summer
- Time sliced demands
    - Winter = 70% x 100 GWh = 70 GWh
    - Summer = 30% x 100 GWh = 30 GWh
- Time sliced loads
    - Winter = 70 GWh / (8760h x 40%) = 20.0 MW
    - Summer = 30 GWh / (8760h x 60%) = 5.7 MW
- Peak load = 20.0 MW

Putting demand & supply together: energy balances

- Energy demand and supply results are combined in LEAP's integrated framework
- Results can be displayed 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 Demand and Transformation sectors/modules. Can optionally show sub-sectoral results
- Balances can be viewed in table, chart, and Sankey diagram formats

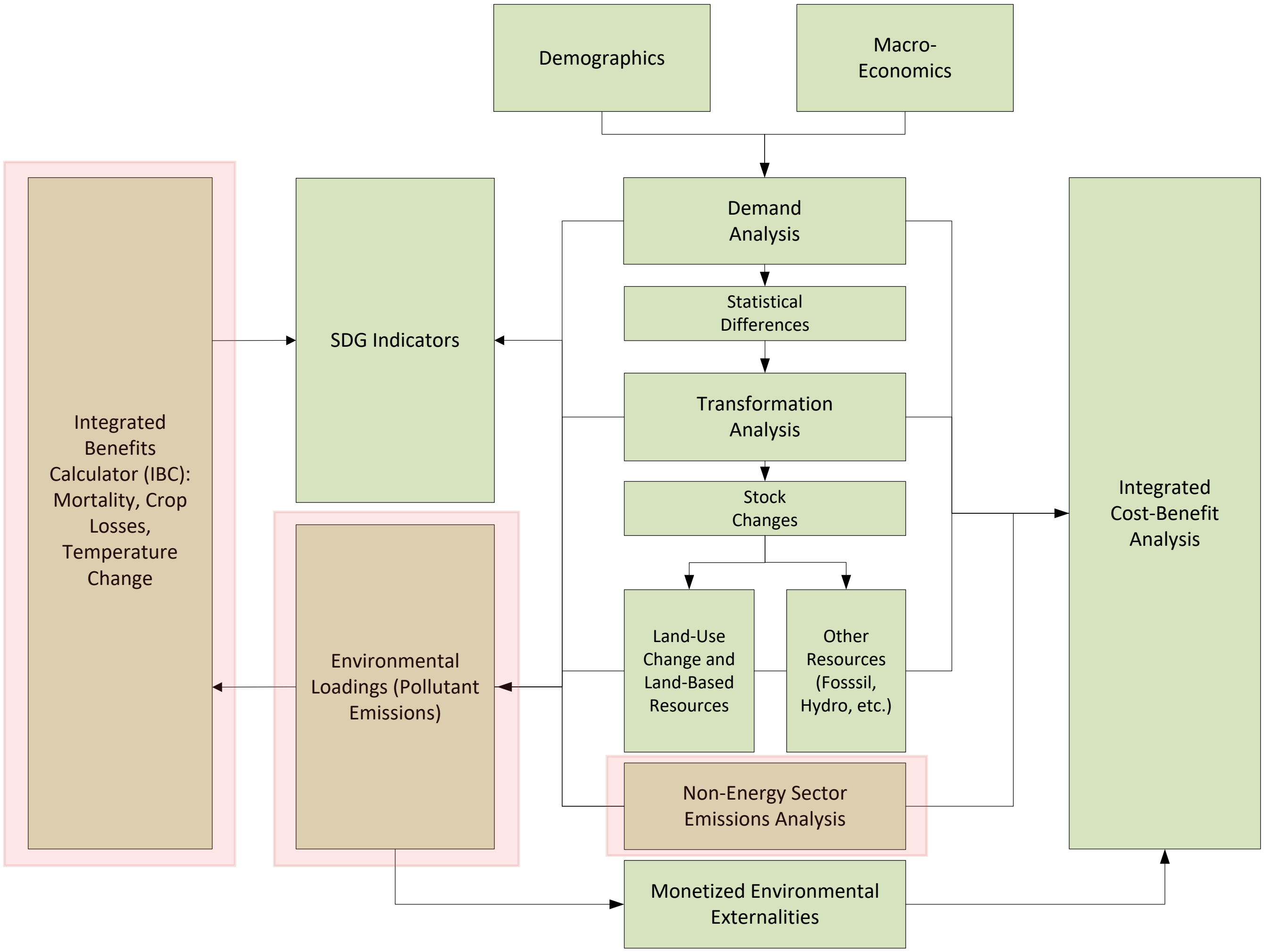
Energy Balance for Area "Freedonia"
Scenario: Reference, Year: 2020, Units: Thousand Tonnes of Oil Equivalent

	Solid Fuels	Natural Gas	Crude Oil	Hydropower	Biomass	Electricity	Oil Products	Total
Production	5,685	-	-	321	2,263	-	-	8,269
Imports	-	170	6,006	-	-	-	517	6,693
Exports	-	-	-	-	-	-	-	-
Total Primary Supply	5,685	170	6,006	321	2,263	-	517	14,962
Coal Mining	-1,137	-	-	-	-	-	-	-1,137
Oil Refining	-	-	-6,006	-	-	-	5,705	-300
Charcoal Production	-	-	-	-	-874	-	-	-874
Electricity Generation	-4,215	-	-	-321	-	2,182	-1,632	-3,986
Transmission and Distribution	-	-3	-	-	-	-306	-	-309
Total Transformation	-5,352	-3	-6,006	-321	-874	1,877	4,073	-6,606
Household	-	108	-	-	815	797	436	2,157
Industry	332	10	-	-	573	736	667	2,320
Transport	-	-	-	-	-	46	3,280	3,326
Commercial	-	49	-	-	-	297	207	554
Total Demand	332	167	-	-	1,389	1,877	4,590	8,356
Unmet Requirements	0	-	-	-	-	0	0	0

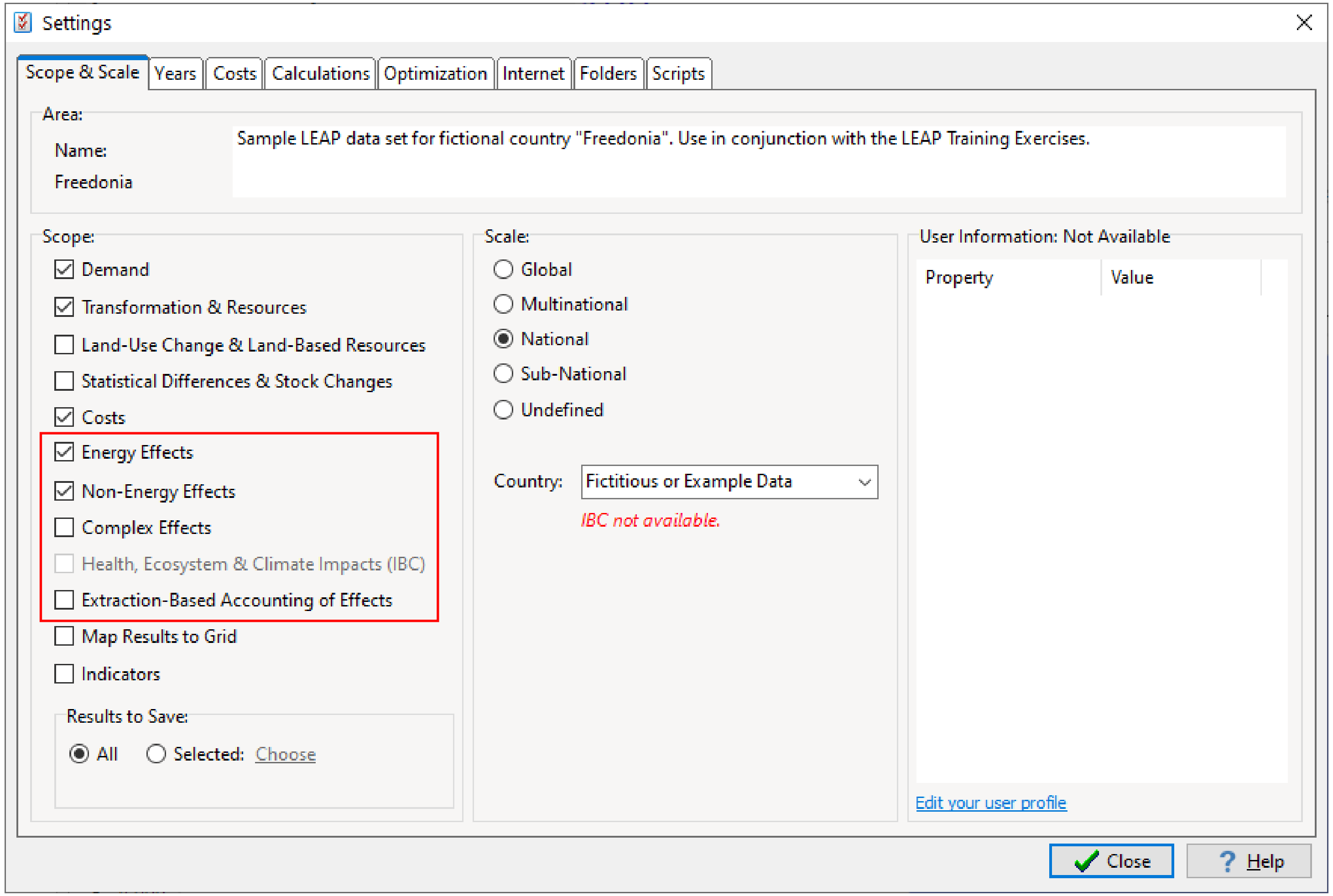


Modeling emissions with LEAP

Structure of a representative LEAP analysis

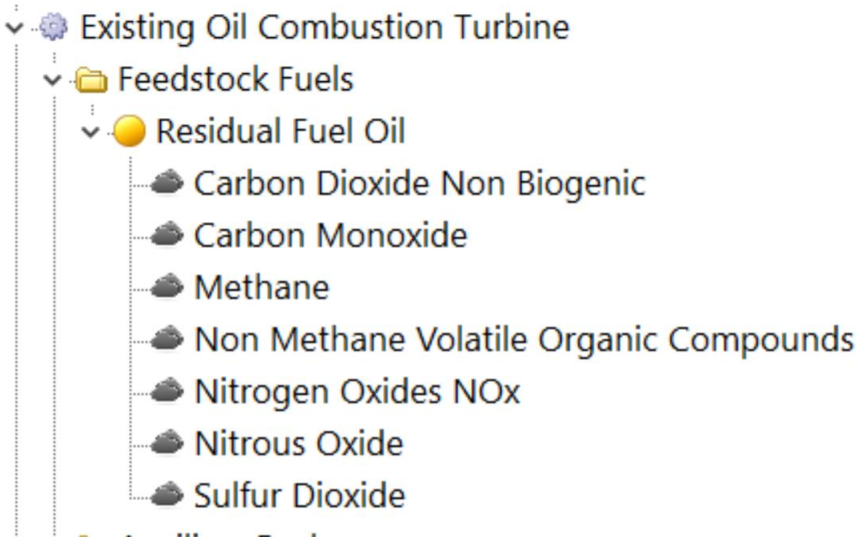


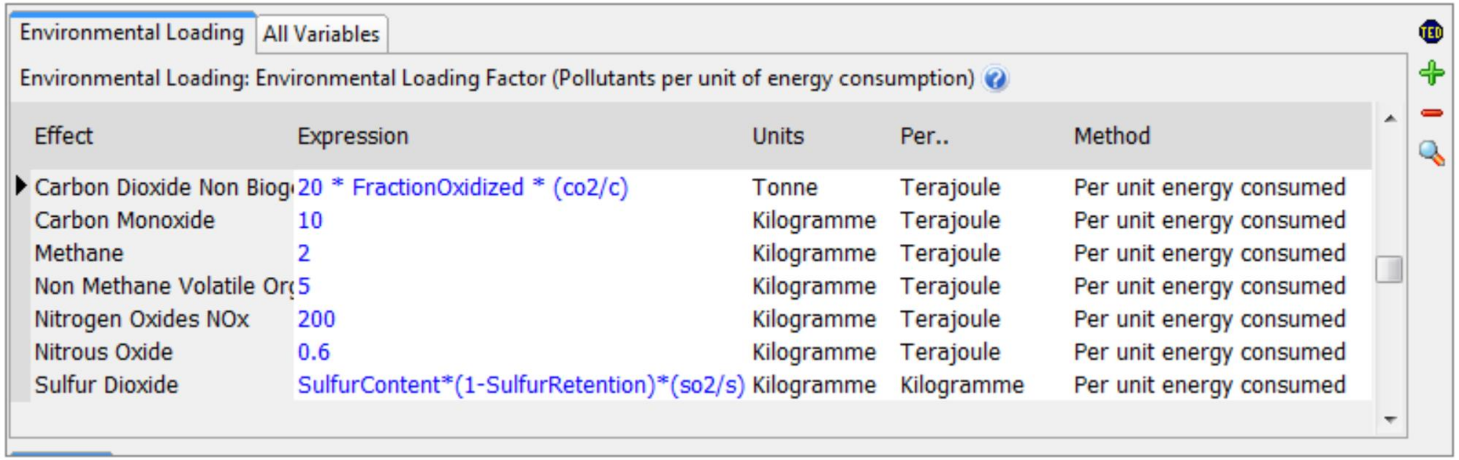
Enabling emissions modeling



Energy-related emissions

- **Energy-related emissions** in LEAP are based on **energy production or consumption** and **emission factors**
- Can specify factors for any greenhouse gas (GHG) or pollutant
  - Factors can be entered in any physical unit and denominated by units of energy consumption, energy production, or distance traveled for transport (e.g., kg/tonne coal consumed, grams/mile traveled)
  - Expressions for factors can reference chemical composition of fuels
- LEAP includes default IPCC Tier 1 emission factors in its Technology Database



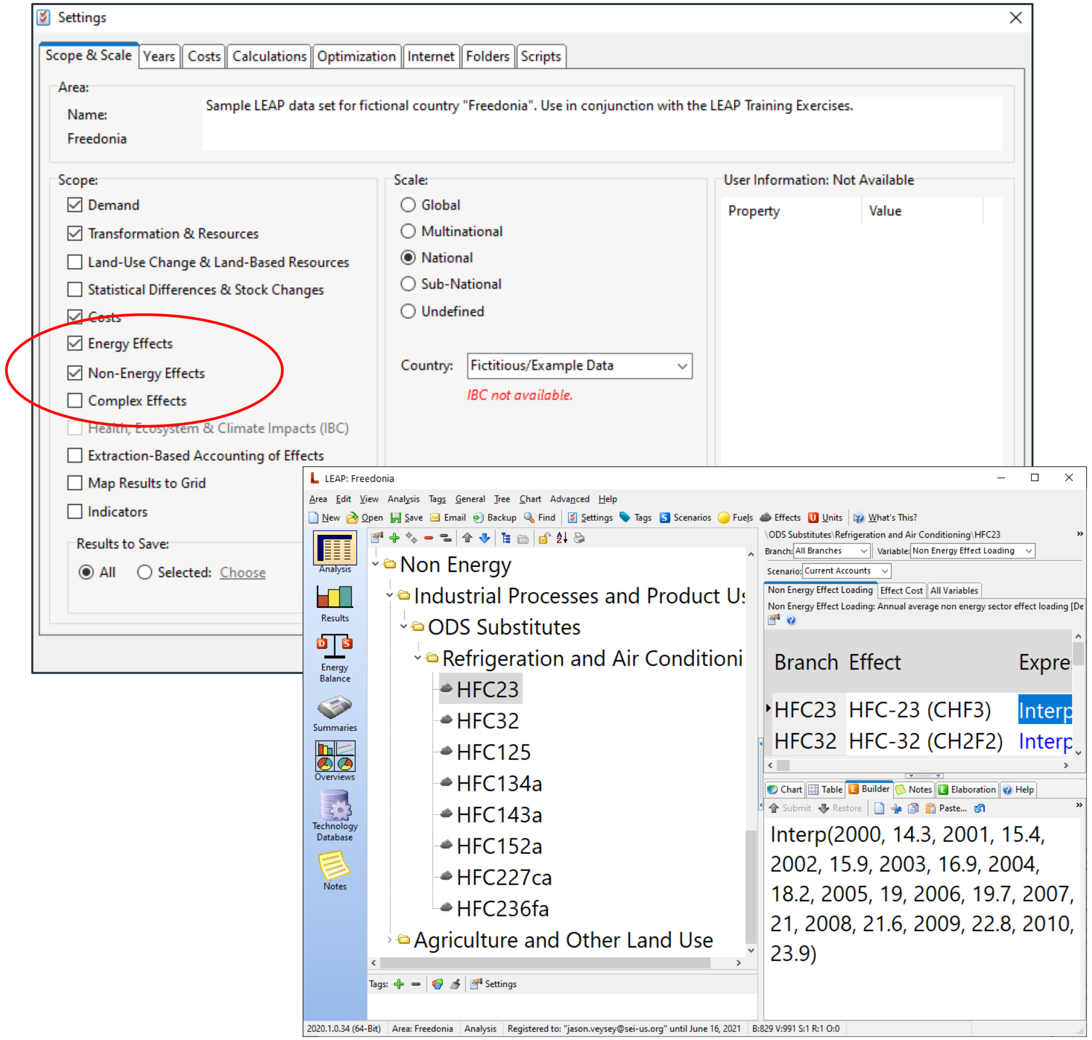

Environmental Loading | All Variables

Environmental Loading: Environmental Loading Factor (Pollutants per unit of energy consumption)

Effect	Expression	Units	Per..	Method
Carbon Dioxide Non Biog	20 * FractionOxidized * (co2/c)	Tonne	Terajoule	Per unit energy consumed
Carbon Monoxide	10	Kilogramme	Terajoule	Per unit energy consumed
Methane	2	Kilogramme	Terajoule	Per unit energy consumed
Non Methane Volatile Or	5	Kilogramme	Terajoule	Per unit energy consumed
Nitrogen Oxides NOx	200	Kilogramme	Terajoule	Per unit energy consumed
Nitrous Oxide	0.6	Kilogramme	Terajoule	Per unit energy consumed
Sulfur Dioxide	SulfurContent*(1-SulfurRetention)*(so2/s)	Kilogramme	Kilogramme	Per unit energy consumed

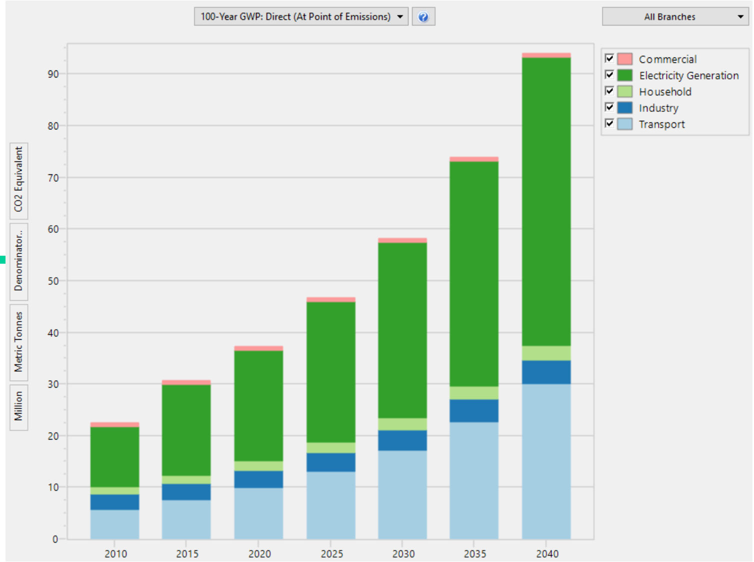
Non-energy emissions

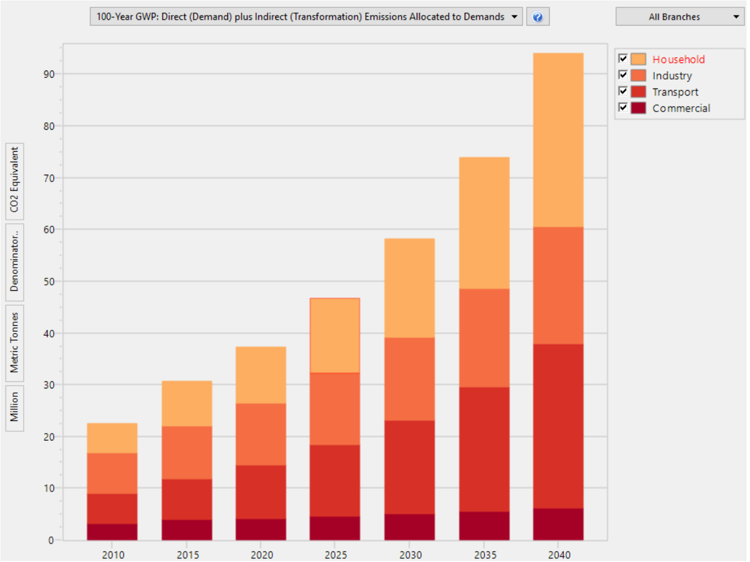
- LEAP models can optionally include emissions from non-energy sources
- This allows modeling of economy-wide emissions
- **Non-energy emissions** based on **user-defined expressions** (i.e., formulas that return total annual emissions)
- Expressions can reference other model variables (e.g., key assumptions) to ensure consistency across sectors



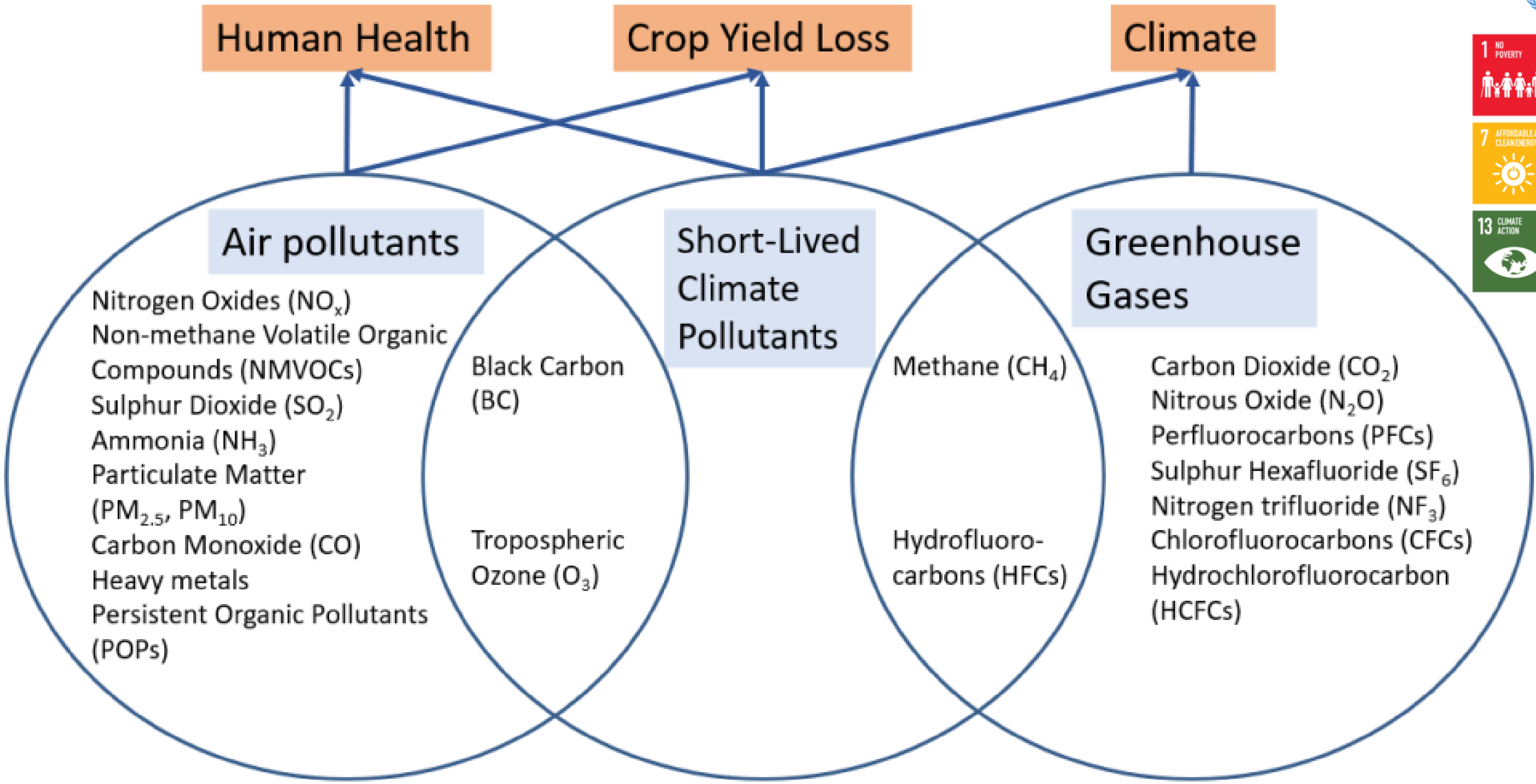
Emission results

- Results can be shown for **individual pollutants** or summed to show **overall global warming potential (GWP)**
- LEAP includes GWP conversion factors from all IPCC assessment reports
- **Direct emissions** from demand, supply, and non-energy branches can be displayed by branch, fuel, year, and other dimensions
- For demand branches, **indirect GHG emissions** (supply-side emissions attributable to final energy demands) can also be calculated
- In national models, projected air pollution emissions can be used in LEAP's Integrated Benefits Calculator (LEAP-IBC) to quantify impacts on human health, agriculture, and temperature

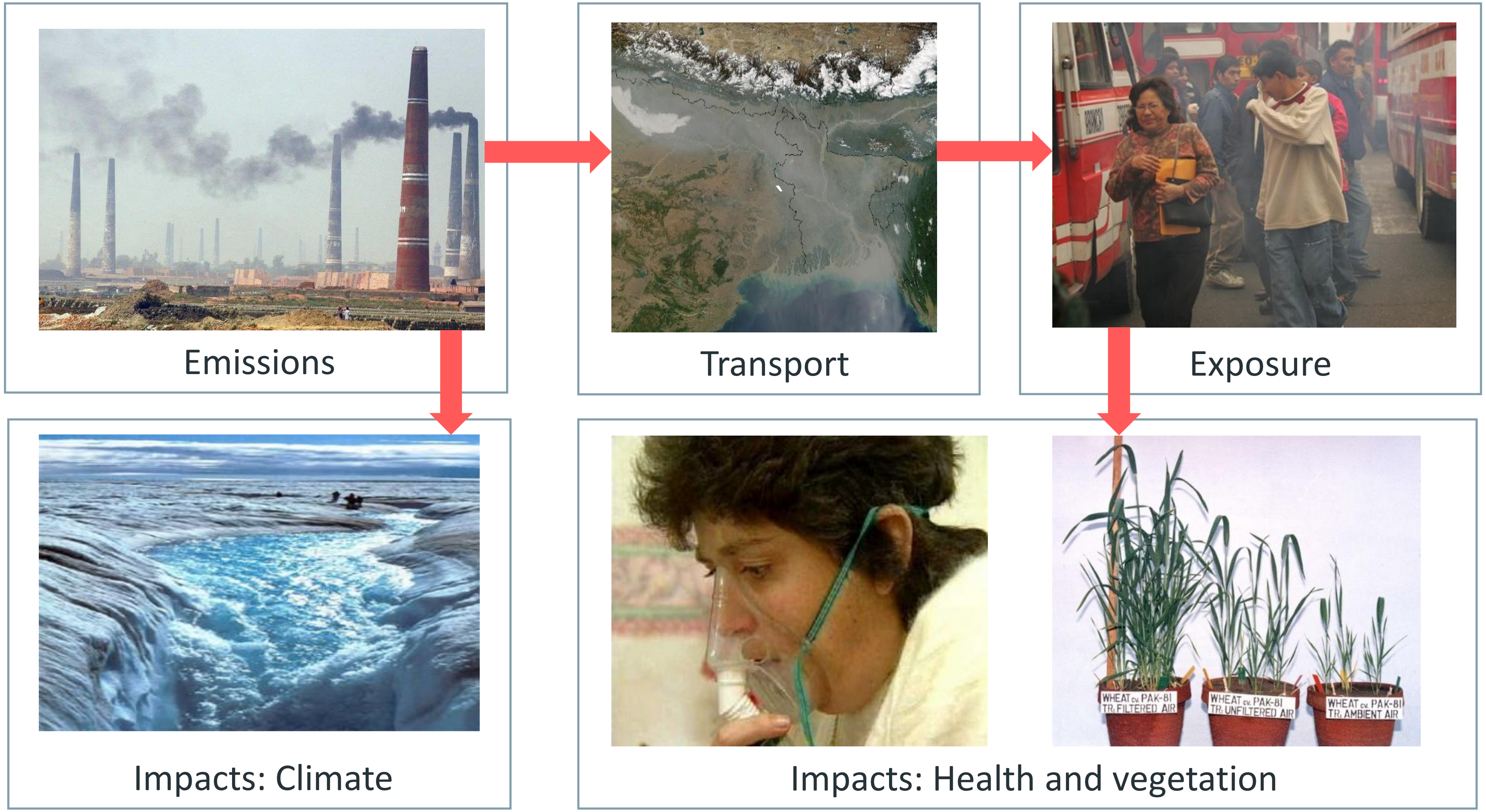




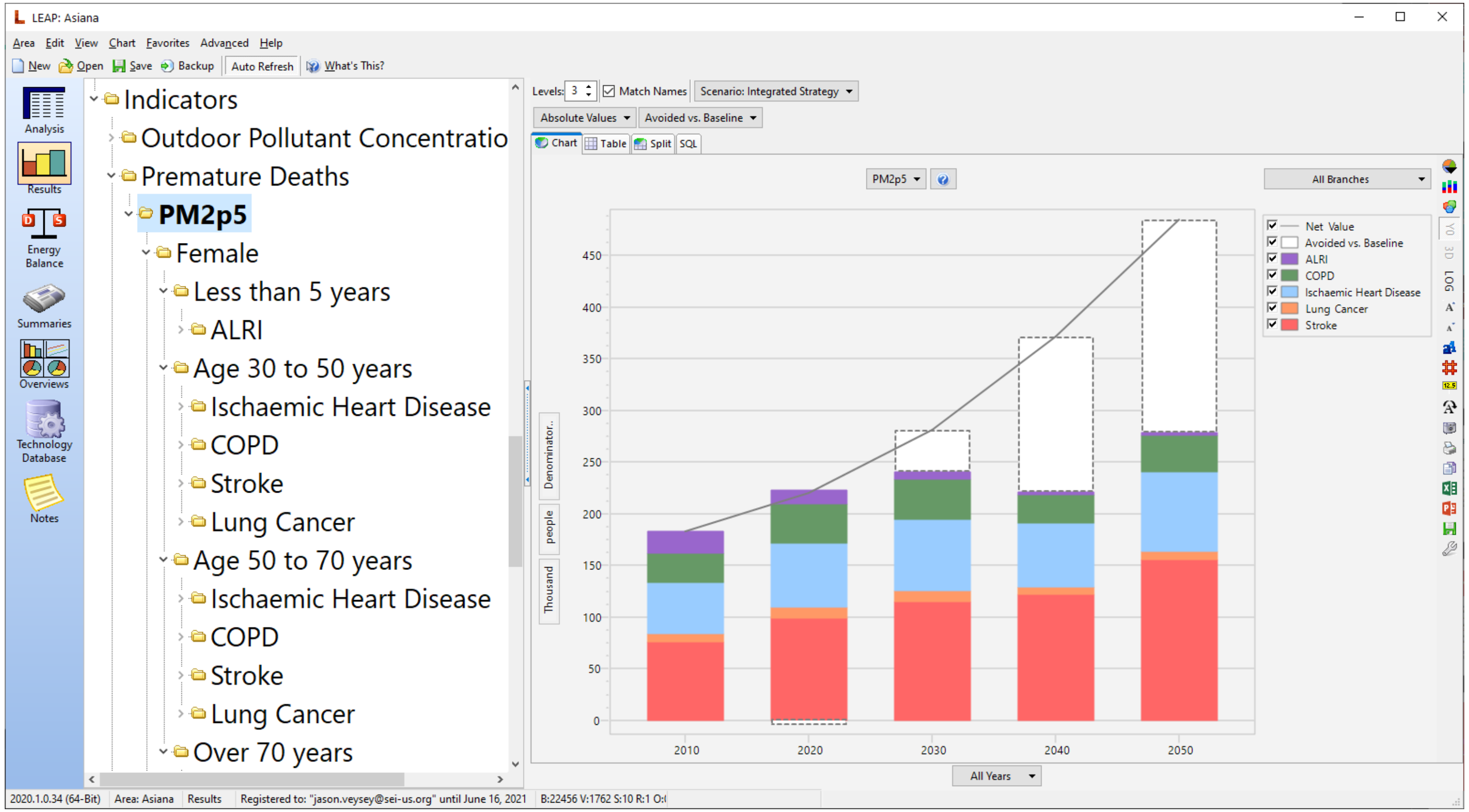
Motivation for LEAP-IBC: Integrated climate and air pollution assessments



LEAP-IBC calculation pathway



LEAP-IBC results

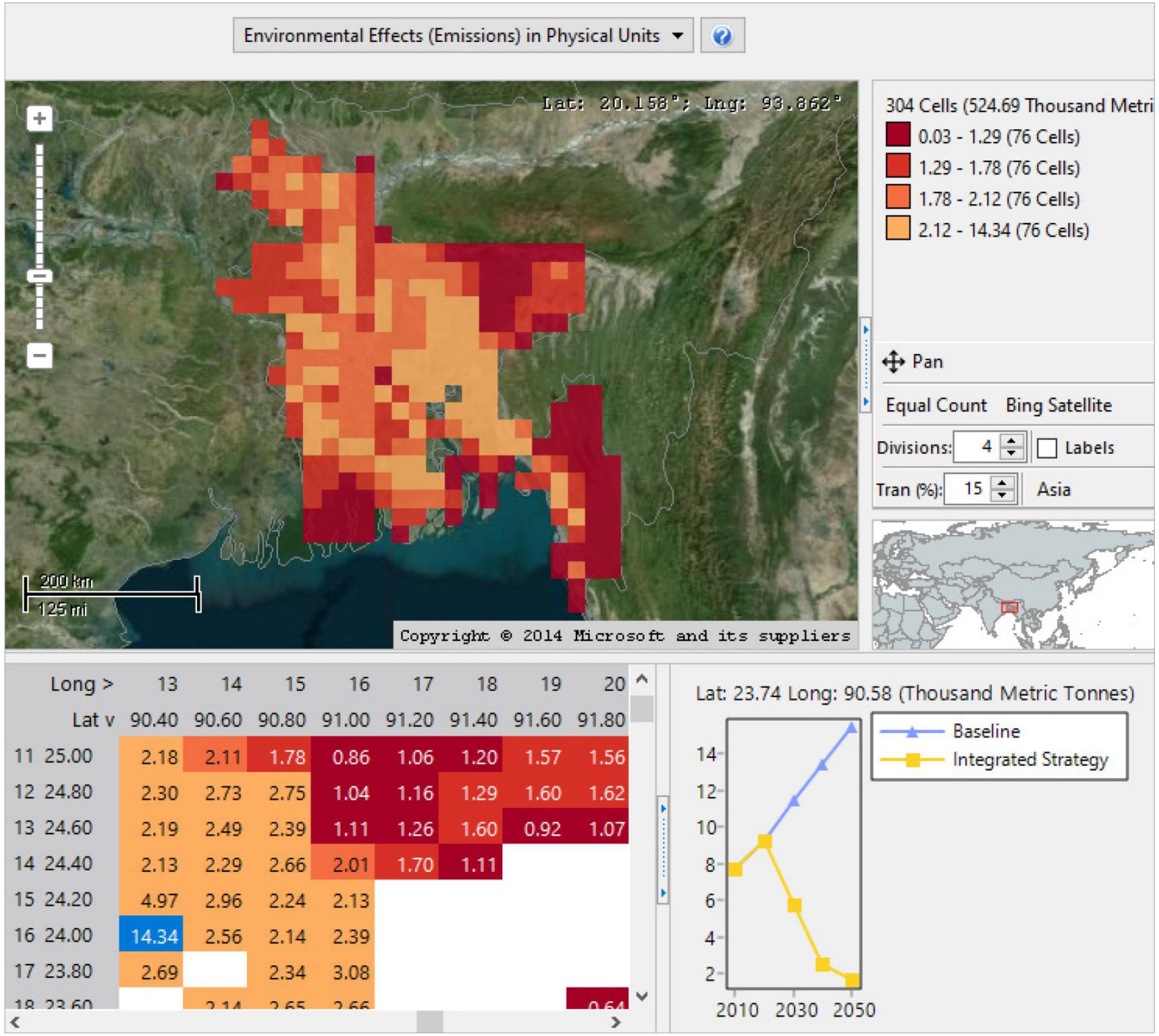


Key results include:

- **Air pollutant concentrations** by origin (natural background, national emissions, rest of world emissions)
- **Premature deaths** and years of life lost by pollutant, sex, age, disease, indoor vs. outdoor exposure, pollutant origin
- **Global temperature change** due to national emissions by pollutant
- **Economic costs of premature mortality**
- **Crop losses** due to pollutant concentrations (major cereal crops)

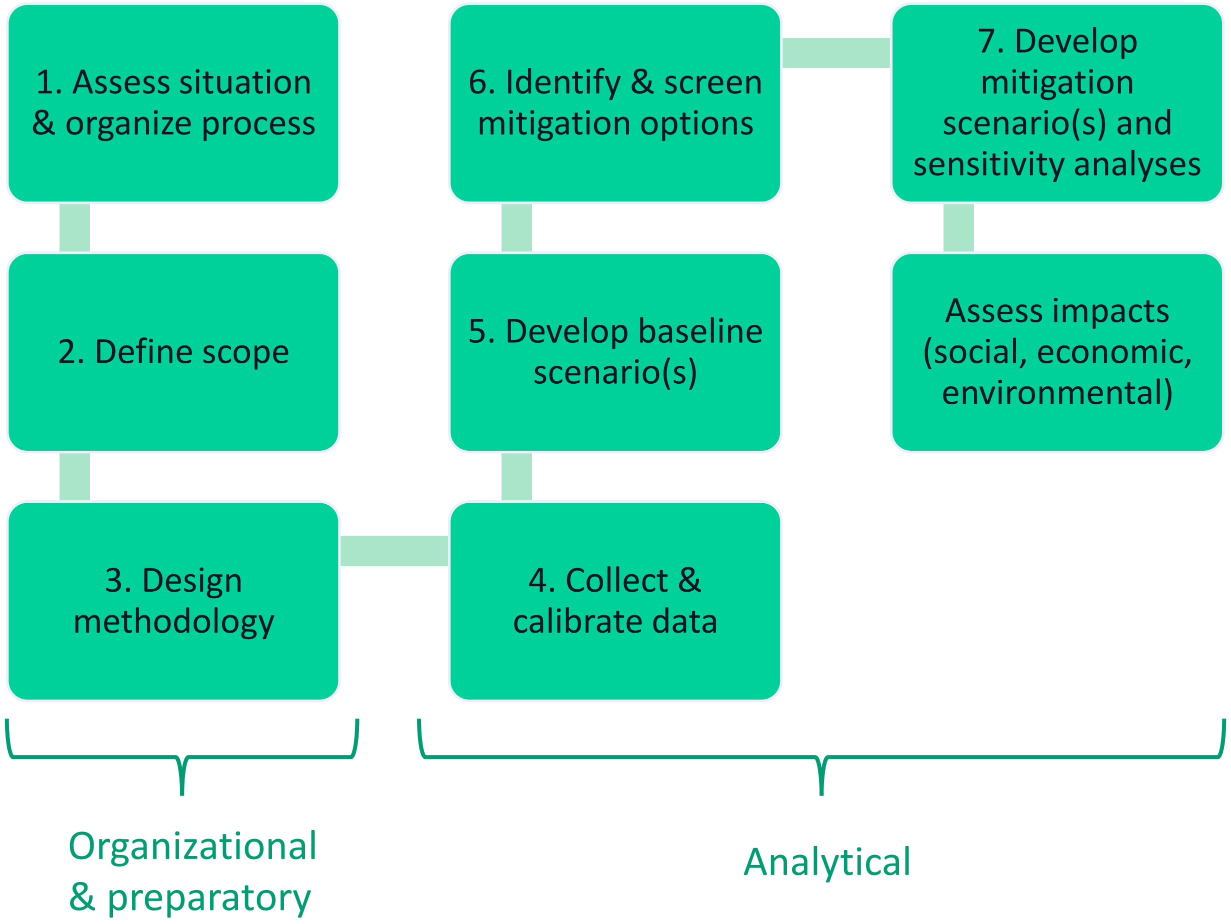
Mapping emissions

- In addition to using charts and tables to analyze emission results, users can optionally display them on maps
- This feature is useful for identifying **emerging emission hotspots** and for tracking and monitoring progress on **reducing emission burdens faced by different communities**

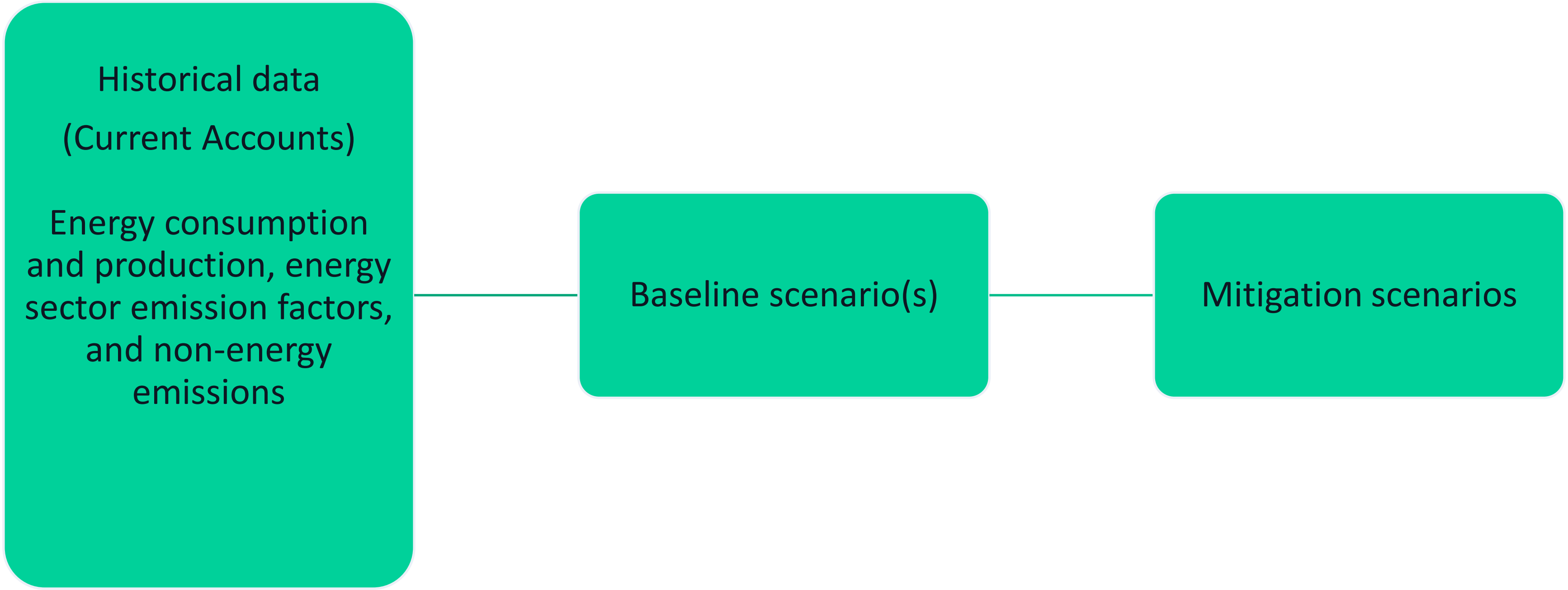


Emission mitigation assessment

- LEAP modeling can play a valuable role in emission mitigation assessment
- Supports analytical steps in assessment process, allowing quantification of impacts of mitigation strategies
- **LEAP's scenario-based architecture** aligns well with typical assessment framework: **comparing mitigation options to a baseline**



Using LEAP for mitigation assessment



Baseline scenarios

- Baseline scenarios are often termed “business-as-usual (BAU)” scenarios, but **BAU needs to be carefully defined**
  - Does it include anticipated future changes? Does it include policies recently enacted? Recently announced? Does it only include policies not specifically aimed at reducing emissions?
  - There is no single commonly accepted definition
- In principle, **a baseline scenario should provide a plausible and consistent description of future developments in the absence of explicit new mitigation policies**
  - Not a forecast of what will happen: future is inherently unpredictable
- Development of a baseline scenario is a critically important analytical and policy task
  - **Influences magnitude of emission benefits and relative cost of mitigation strategies**
  - It can be useful to have multiple baseline scenarios, e.g., with and without existing policies (to reveal their emission benefits)
- Not simply an extrapolation of past trends, a baseline scenario requires data and assumptions regarding factors such as:
  - Macroeconomic and demographic projections (e.g., population and GDP growth)
  - Structural shifts in the economy (e.g., relative growth of agricultural, industrial, and services sectors)
  - Planned investments and existing policies in individual sectors (e.g., power supply plans)
  - Evolution of technologies and practices, including saturation effects, fuel switching, and adoption rates of new technologies (e.g., share of households with air conditioning; use of combined heat and power in steel industry)

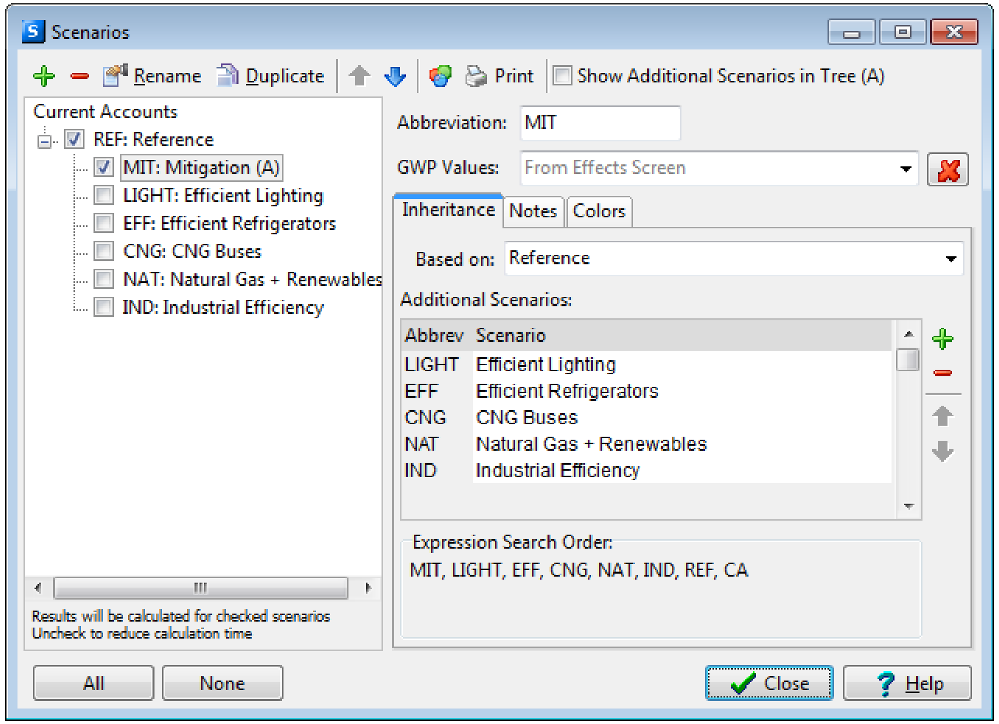
Developing mitigation scenarios

- Mitigation scenarios reflect a future in which **explicit policies and measures are adopted to reduce the sources (or enhance the sinks) of emissions**
- Mitigation scenarios should take into account:
  - Specific national and regional development priorities, objectives, and circumstances
  - Common but differentiated responsibilities of countries
- Mitigation scenarios should not simply reflect current plans. Instead, they should assess what would plausibly be achievable based on the goals of the scenario

Possible framing of scenarios

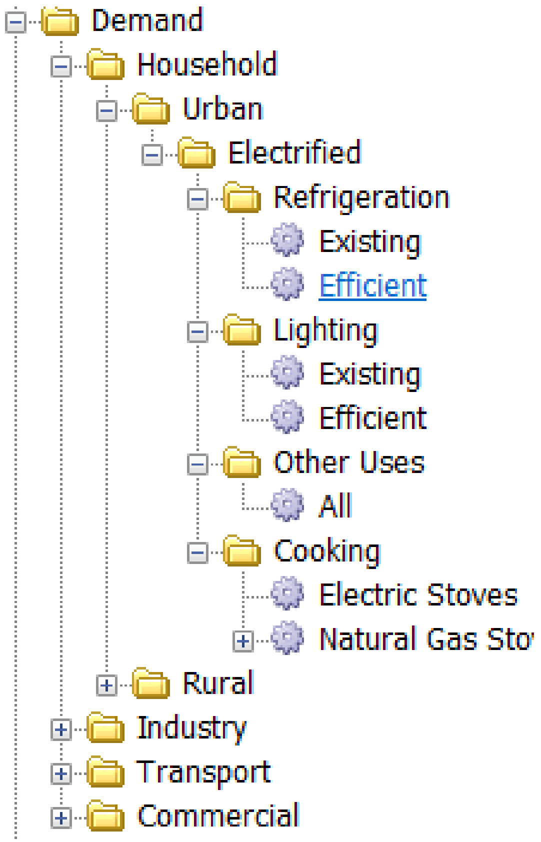
- An emission reduction target
- Specific options or technologies: included based on perceived technical and/or political feasibility
- All options up to a certain cost per unit of emissions reduction (equivalent to a carbon tax)
- "No regrets" (cost-effective) options only

Implementing mitigation scenarios in LEAP

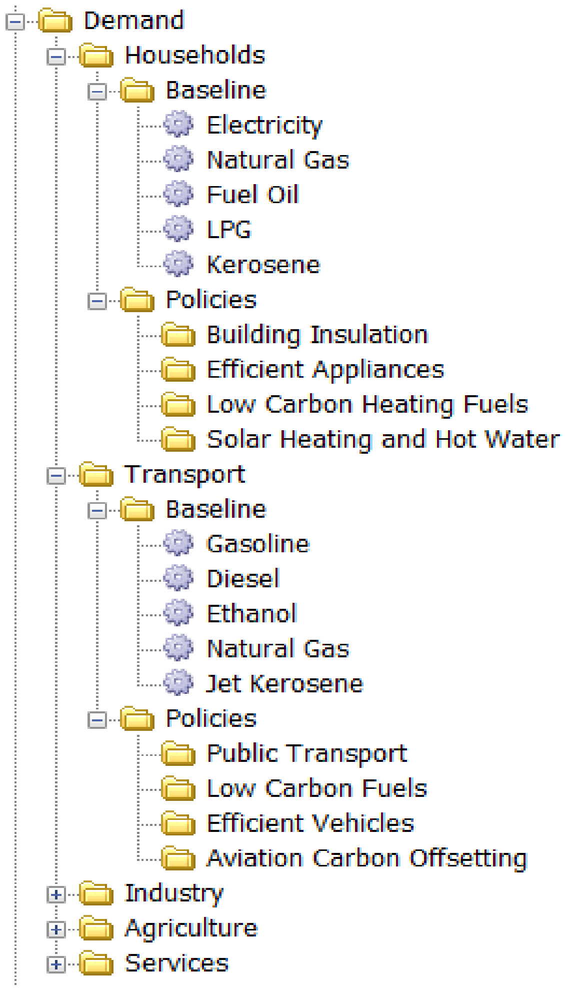


A common approach: measure-specific "mini" scenarios combined into overall mitigation strategies

Bottom-up / end-use



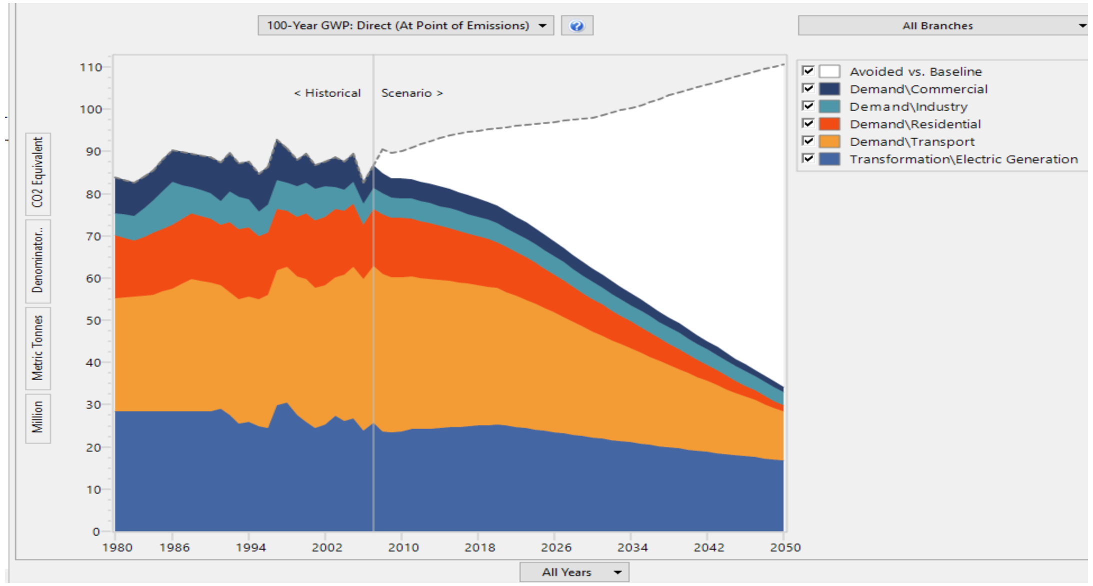
Hybrid / decoupled



Assessing impact of mitigation scenarios

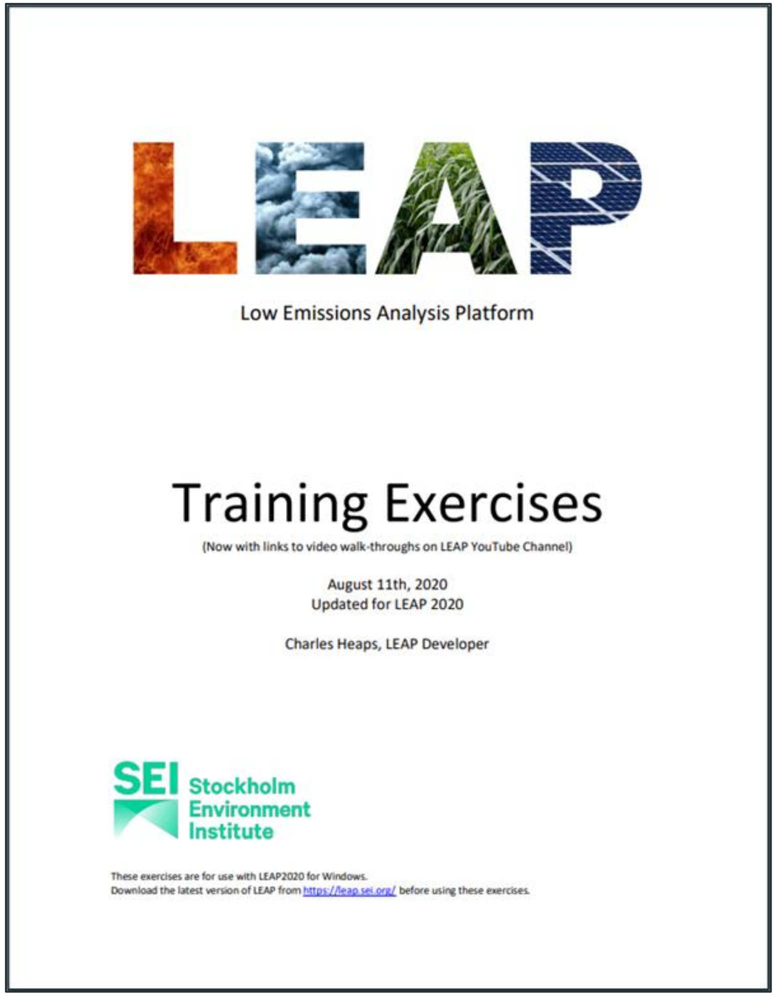
- Scenarios can be compared in terms of:
  - Emission savings
  - Impacts on energy security
  - Social impacts (e.g., development benefits or drawbacks)
  - Costs
  - Technical feasibility of options
  - Political plausibility

  …
- LEAP facilitates such comparisons in Results view



Exercise 2: Energy supply and emissions modeling

Freedonia


LEAP

Low Emissions Analysis Platform

Training Exercises

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

August 11th, 2020
Updated for LEAP 2020

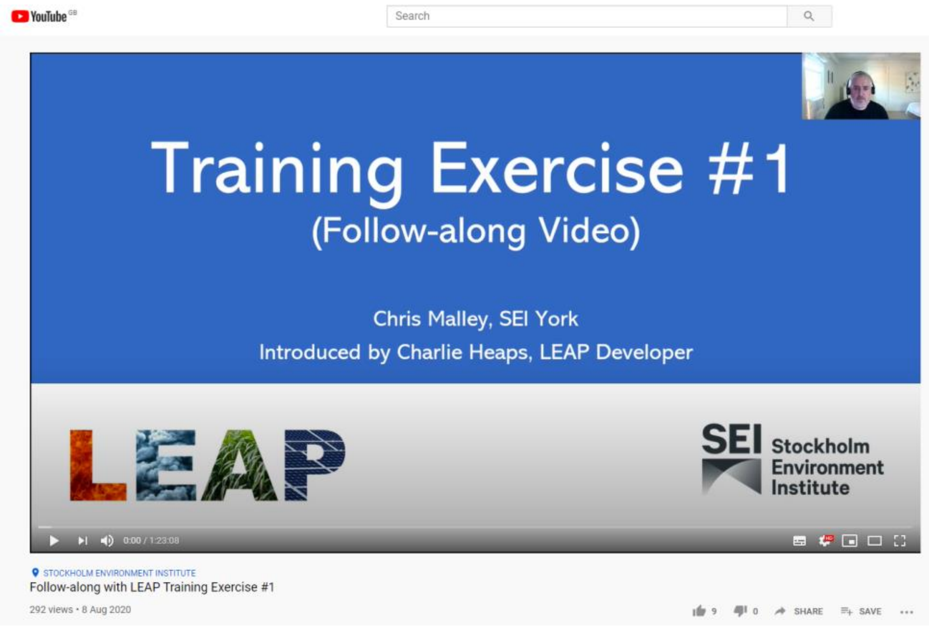
Charles Heaps, LEAP Developer

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



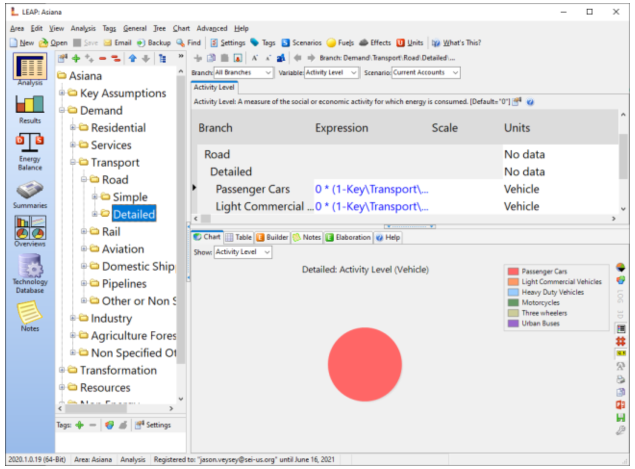
https://www.youtube.com/watch?v=cW87lWDABgc

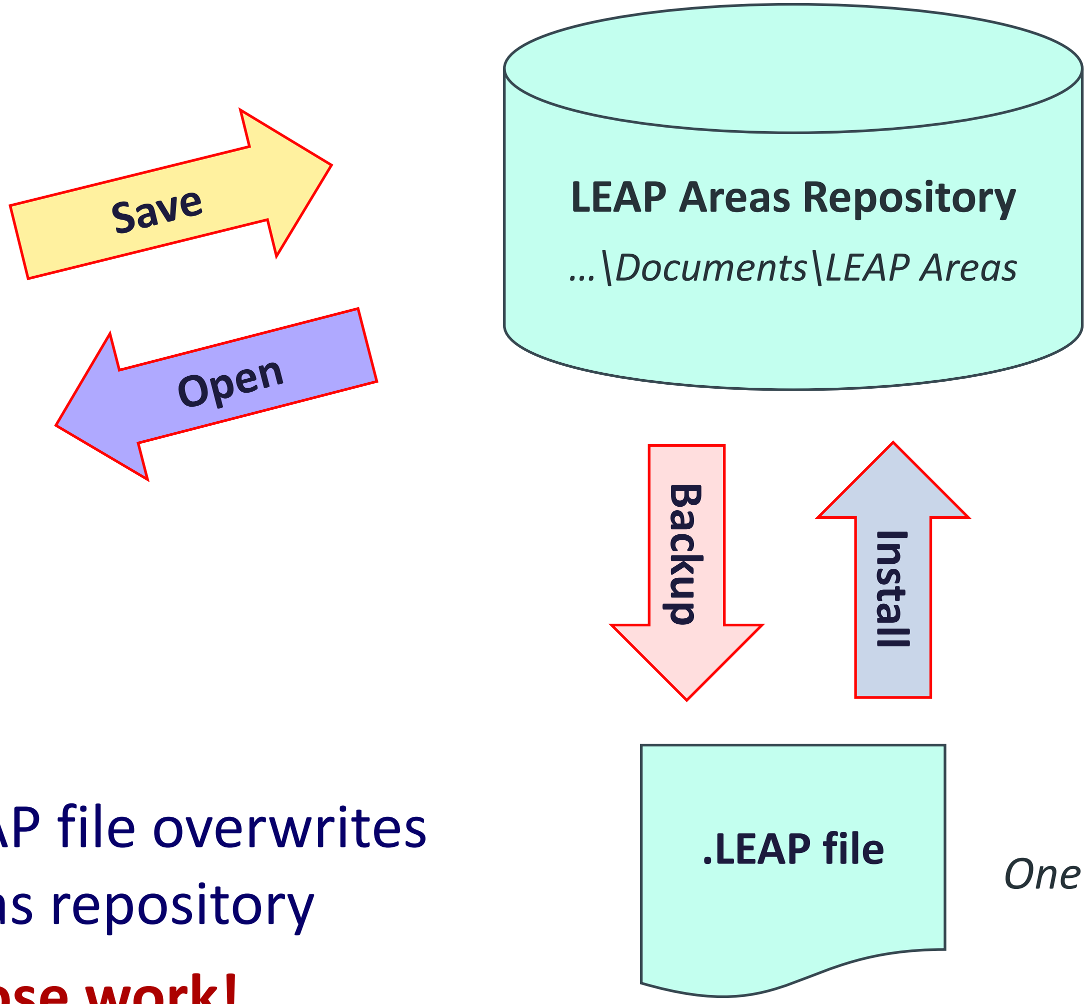
Freedonia

Exercise 2 (covers 1.4–1.6)

- **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

Saving and sharing models





One folder with multiple files per area

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!