SEI Stockholm Environment Institute

SEI Asia Centre

Training on Low Emissions Analysis Platform

Day 4: 22 October 2021

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SWEDISH INTERNATIONAL
DEVELOPMENT COOPERATION AGENCY

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 4

https://tinyurl.com/SEIAsiaLEAPtraining-3905

Password: Day04%

Workshop connection information

Web meetings

https://tinyurl.com/SEIAsiaLEAPtraining

Zoom meeting ID: 872 2041 5222

Zoom passcode: 353649

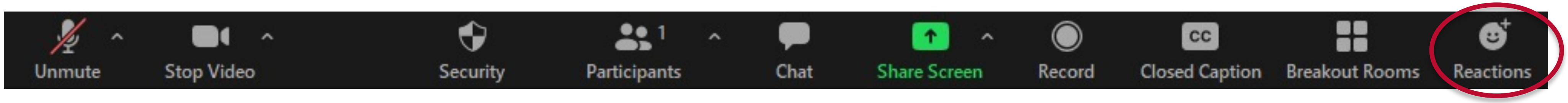
Shared files

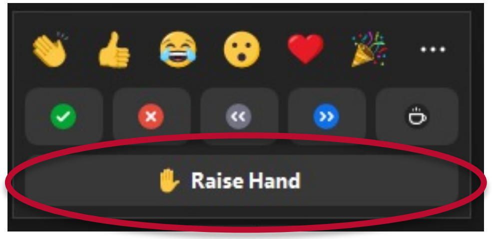
https://tinyurl.com/SEIAsiaLEAPMaterials

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**



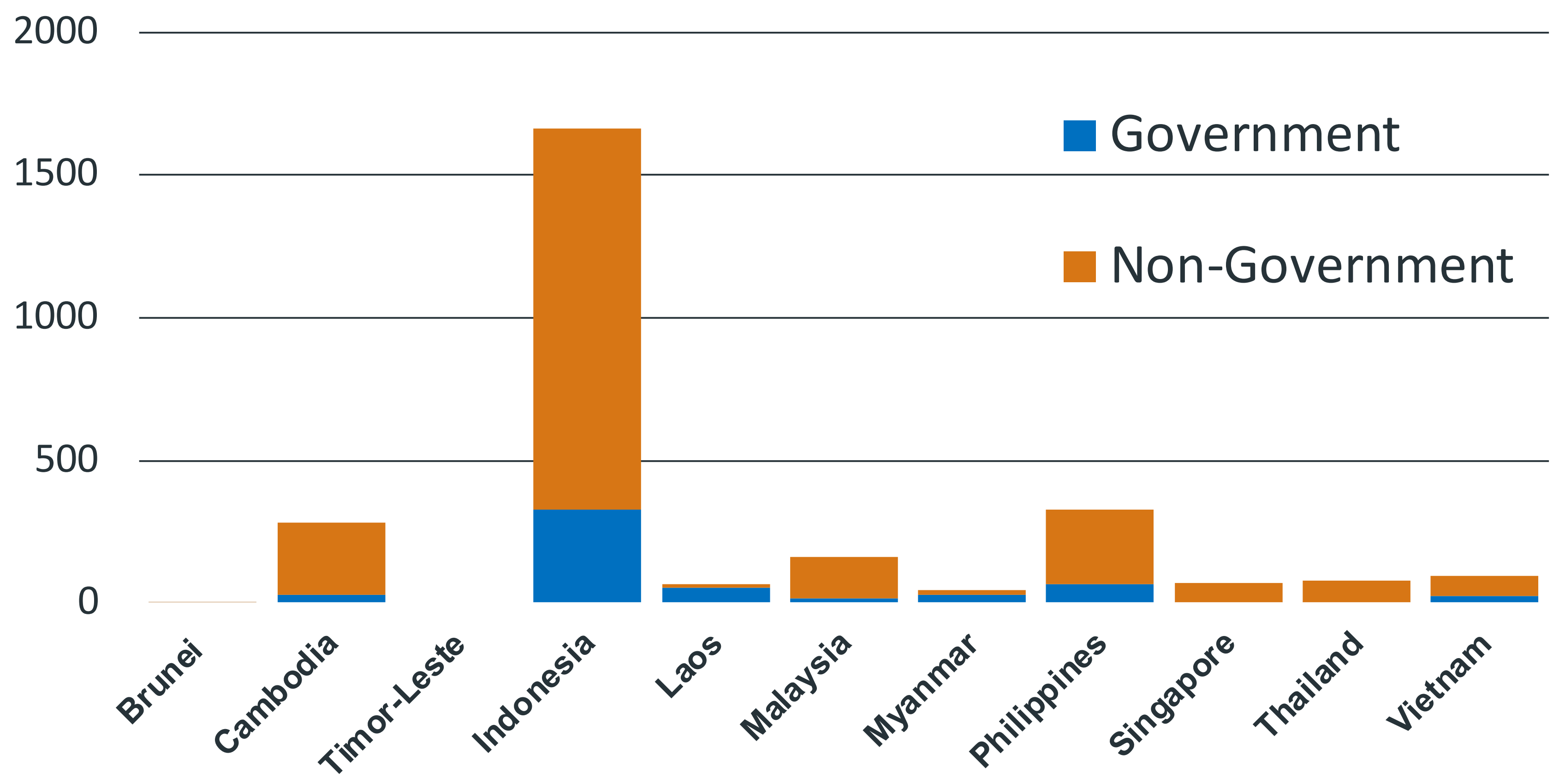


Workshop overview

- **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

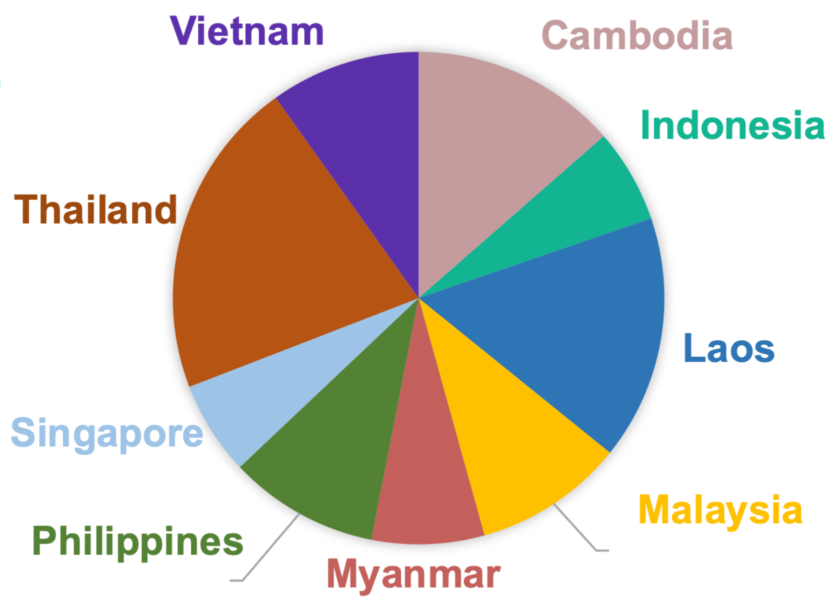
LEAP use in Southeast Asia

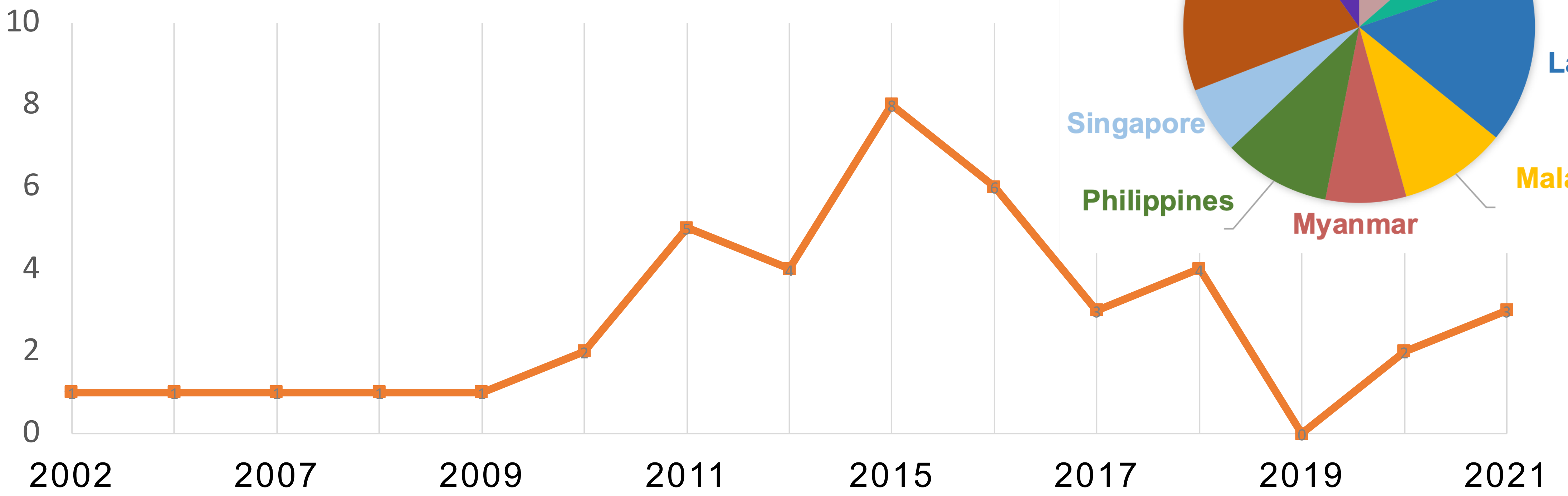
Users in ASEAN



Total number of users: 2805

Scientific publications





Total number of publications since 2002: 42*

*partial count for Thailand, Laos, and Indonesia

Major themes of publications

Intent of studies

- **Evaluation of *status quo***

  f.e. national and regional energy balances (APEC), sectoral analyses

- **Evaluation of (new) technologies / policy intervention**

  f.e. solar PV, hydrogen, biomass, impact of economic restructuring on energy system

Scale

- **National/regional**

  f.e numerous country-level analyses, comparison between Lao PDR and Thailand, APEC

- **Hyper local**

  f.e. improved cooking stoves and small biogas digesters in a rural Thai village

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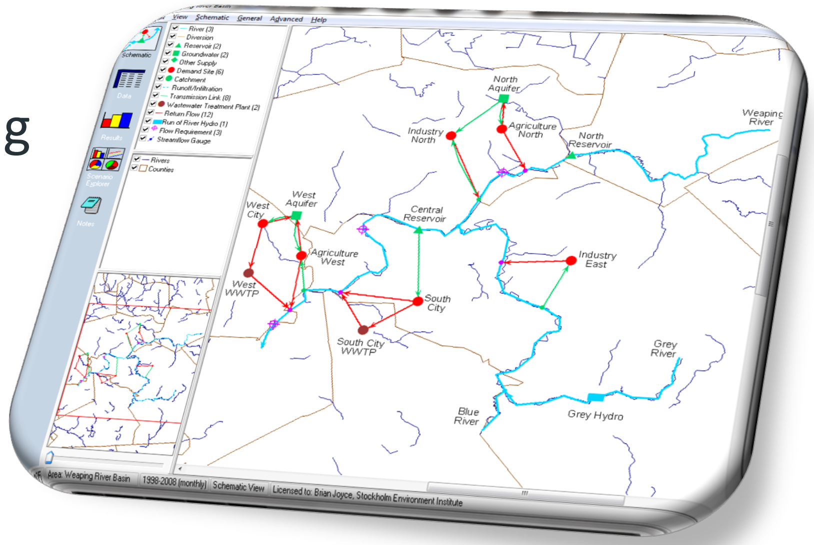
Linking
LEAP and WEAP

WEAP: Water Evaluation And Planning system

Water resources management modeling platform

- Integrated hydrology and water planning model
- GIS-based, graphical drag & drop interface
- Physical simulation of demands and supplies
- Additional simulation modeling: user-created variables, modeling equations and links to spreadsheets & other models (e.g., water quality, environmental flows, groundwater, and economics)
- Scenario management capabilities

Water Evaluation And Planning system
weap.sei.org



Approaches to connecting WEAP and LEAP

1. WEAP-LEAP connector
2. Program your own WEAP-LEAP integration
3. Manual integration

WEAP

Water Evaluation And Planning system
weap.sei.org

LEAP

Low Emissions Analysis Platform
leap.sei.org

Approaches to connecting WEAP and LEAP

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Approaches to connecting WEAP and LEAP

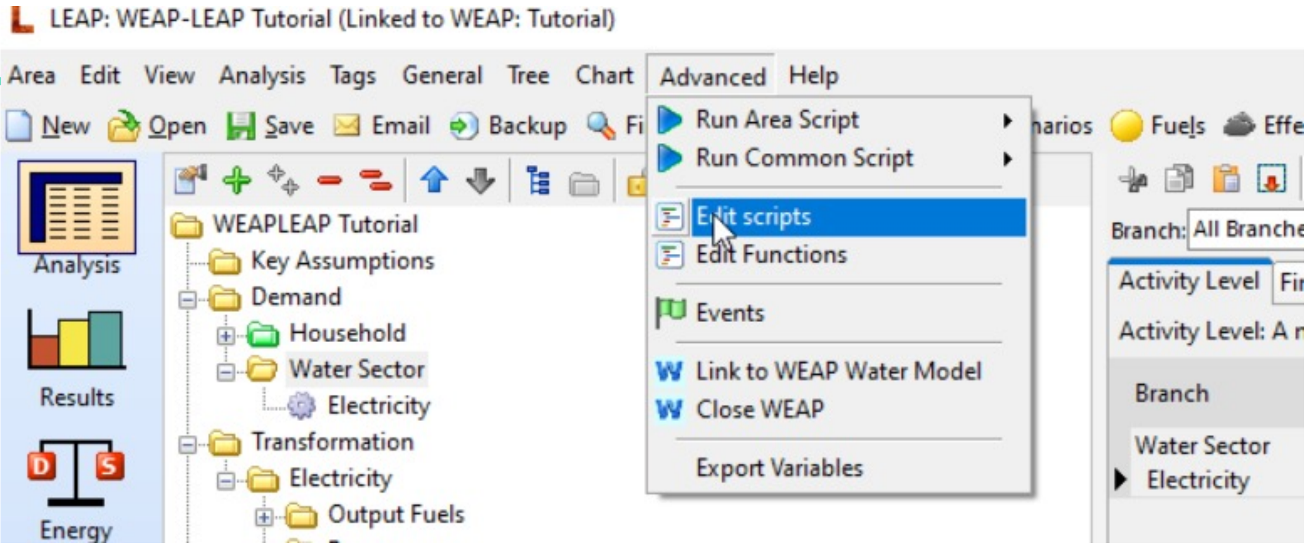
1. ~~WEAP-LEAP connector~~ (discontinued)
2. Program your own WEAP-LEAP integration
3. Manual integration
    1. Overview
    2. Demo
4. Important take-aways

Integration process

Steps:

1. **Identify WEAP-LEAP input variables**
2. **Identify directionality**
3. **Match time slicing**
4. **Exchange results between WEAP and LEAP**

Program your own WEAP-LEAP connection



Requirements:
COM-compatible scripting tool

Steps:

- Use LEAP API and script editor to create your own connector
- Control WEAP/LEAP from general scripting environment (e.g., Python)
- Example workflow:

A

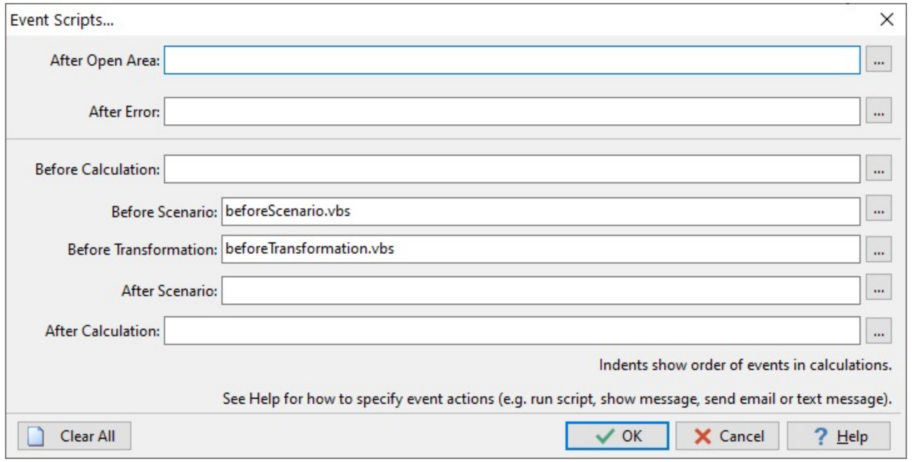
Calculate WEAP → Write out variable to excel → Read into LEAP → Calculate LEAP → Write out variable to excel → Read into WEAP → Calculate WEAP

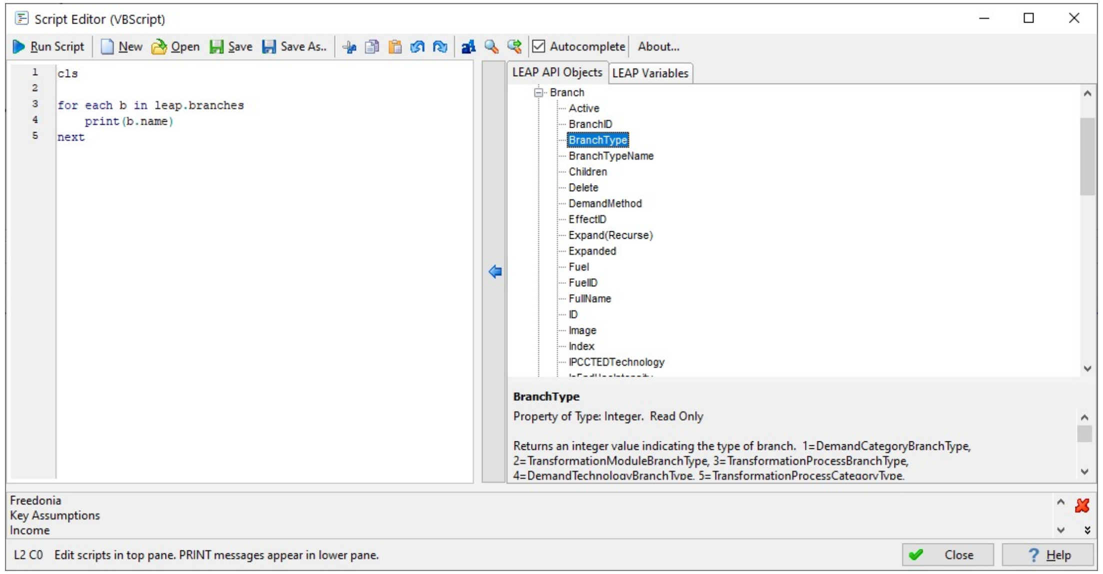
B

Calculate WEAP → Modify LEAP variables via API → Calculate LEAP → Update WEAP variables via API → Calculate WEAP

Application programming interface (API)

- LEAP includes a component object model (COM)-based API that allows integration with other software
- API can be exploited through scripts and other programs (e.g., pywin32, .NET COM)
    - LEAP scripting engine supports VBScript, Jscript, Python, Perl
- LEAP provides a basic script editor (Advanced => Edit Scripts) with an API object browser
- Scripts can be attached to LEAP events (Advanced => Events) to run at pre-defined points
- API documentation available in LEAP's help





Manual WEAP-LEAP integration

Steps:

- Identify **WEAP input variables** for LEAP (f.e. maximum hydro availability)
- **Match time slicing** for realistic integration (f.e. monthly)
- **Extract results (usually from WEAP)** to identify monthly water availability for hydropower based on water flow and other water needs
- **Apply availability constraint to LEAP** via excel export from WEAP and *Readfromexcel*-function in LEAP

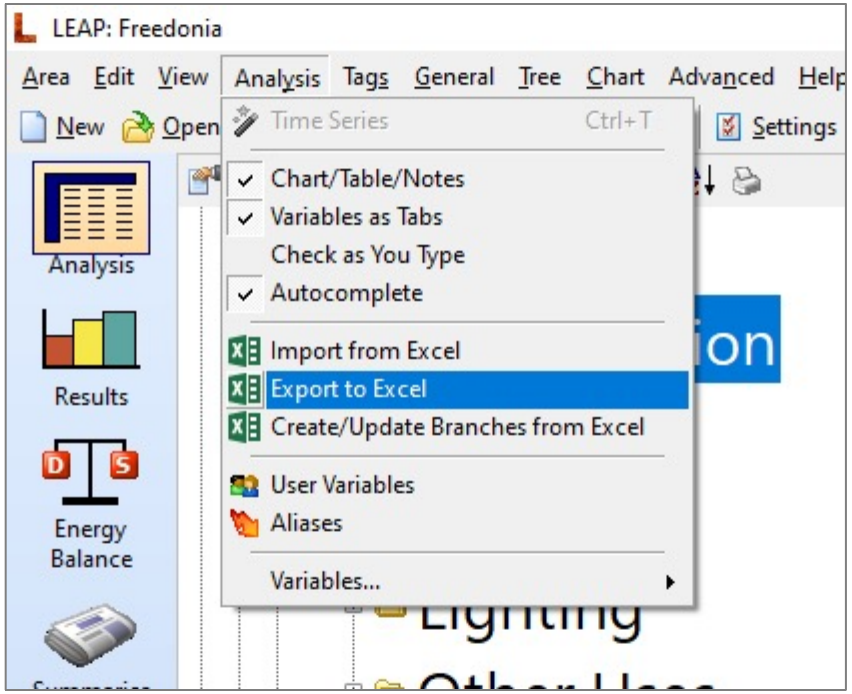
Important take-aways

- What time slices make most sense (i.e. monthly, seasonal)? - Time slicing in LEAP and WEAP need to match
- Not every year needs to be specified, LEAP will interpolate
- WEAP-LEAP linkage is not dynamic, finding optimal paths may require several iterations/scenario exploration

Advanced topics in LEAP modeling

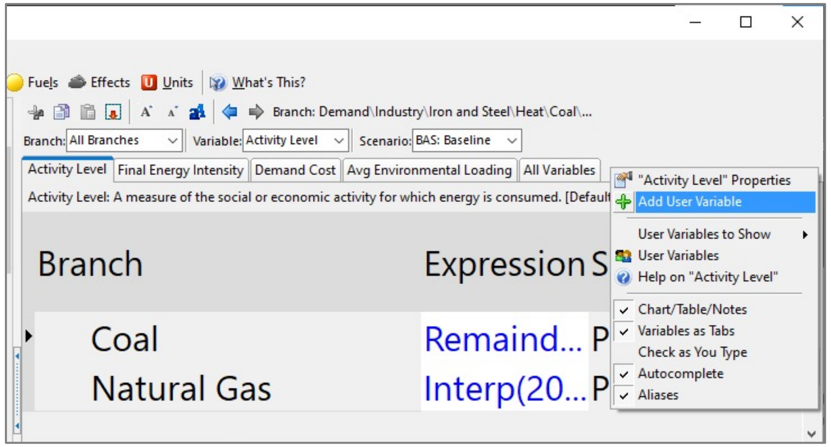
Exporting and importing data

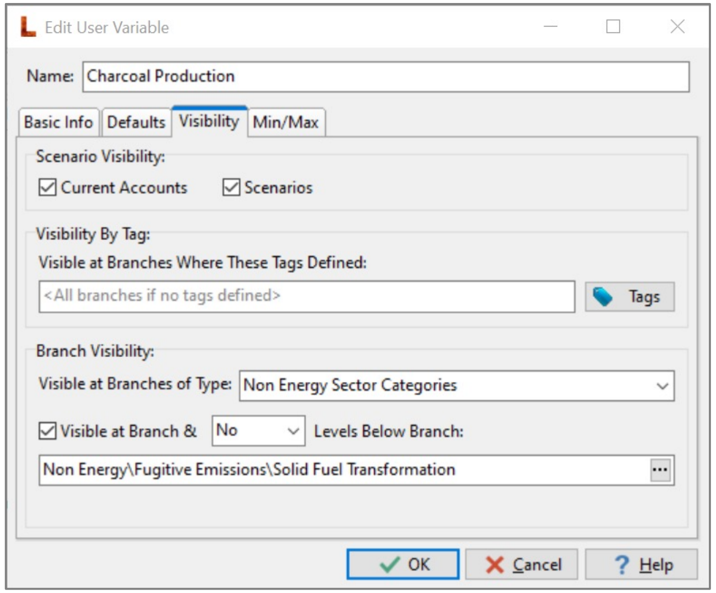
- Exporting to/importing from Excel provide a powerful platform for bulk loading data in LEAP models
- Export to Excel => extracts expressions or variable values from a model and pushes them to a specially formatted (LEAP-formatted) spreadsheet
- Import from Excel => imports into a model expressions or values in a LEAP-formatted spreadsheet
- Expressions and values segmented by branch, variable, scenario, and region in spreadsheets
- Typical pattern: export => revise spreadsheet => import
- First several columns in exported spreadsheets are hidden – make sure to include them when sorting!



Key assumptions ( ) and user variables

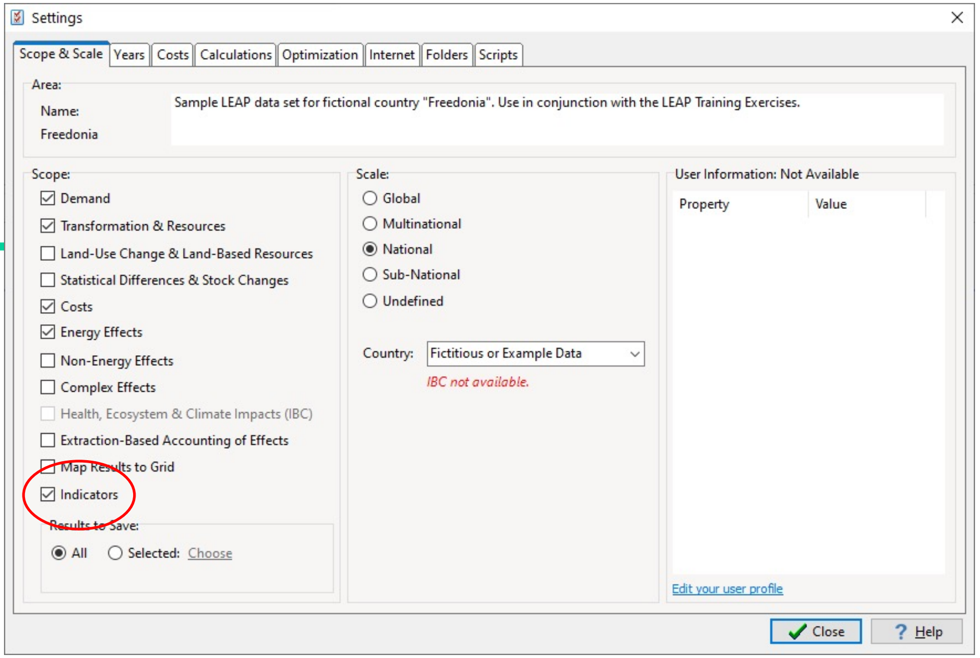
- LEAP provides two ways to create custom input variables for a model: key assumptions and user variables
- **Key assumptions**
  - Added as branches in tree's top-level Key Assumptions category (can be grouped in folders within Key Assumptions)
  - Each key assumptions branch includes a Key Assumption (Activity Level) variable
  - No limit on number of key assumption branches in a model
  - Generally used for cross-cutting inputs – variables needed in multiple different parts of tree
- **User variables**
  - Added to existing branches via Analysis menu or by right clicking on variable tabs in Analysis view
  - Up to 400 user variables allowed per model
  - Visibility properties control where user variables are displayed
  - Generally used for variables needed in one or a few branches
- For both key assumptions and user variables, user defines the unit – LEAP does not automatically perform unit conversions
- Values for key assumptions and user variables are specified using LEAP expressions – as for any other model input

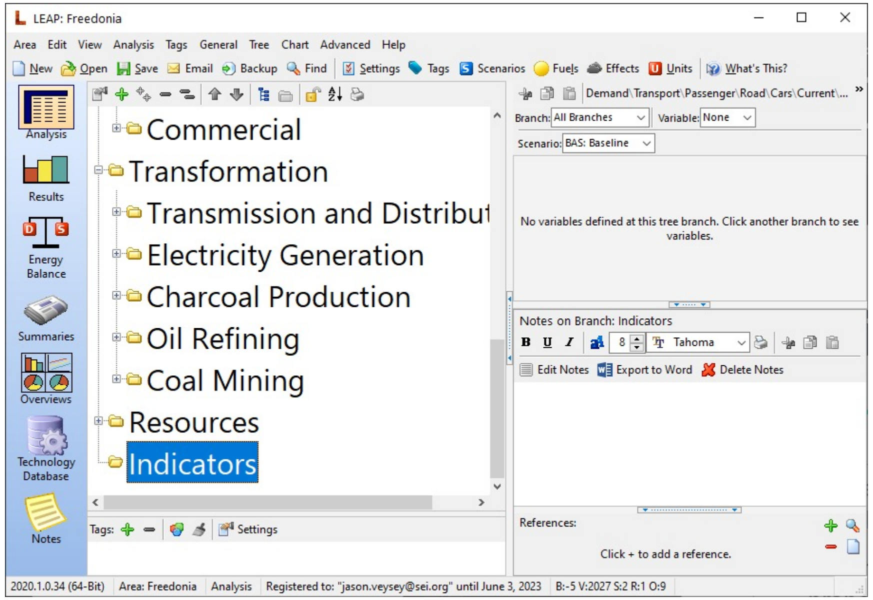




Indicators ( )

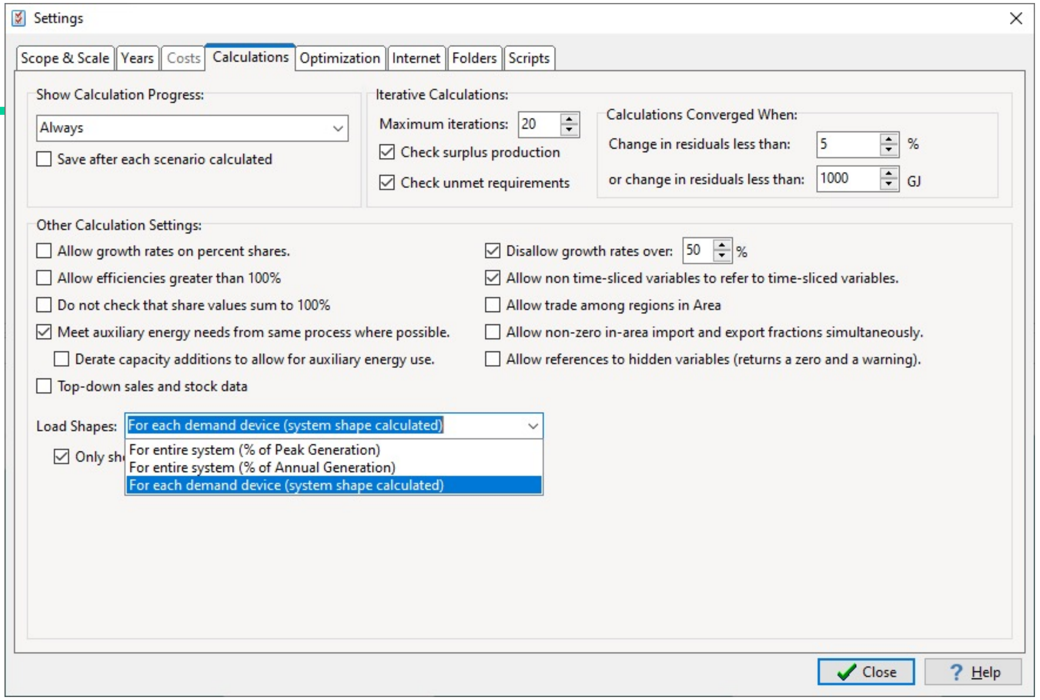
- Indicators are custom outputs (results) in a LEAP model
- Defined in Indicators branch – last top-level branch in tree
- LEAP calculates indicators last (after all other outputs). Therefore, unlike regular variables, indicators can include direct (non-lagged) references to standard results
- Depending on their complexity, indicators can be slow to calculate. To improve performance, Indicators branch can be turned off (all defined indicators will be retained and shown again when branch is reactivated)

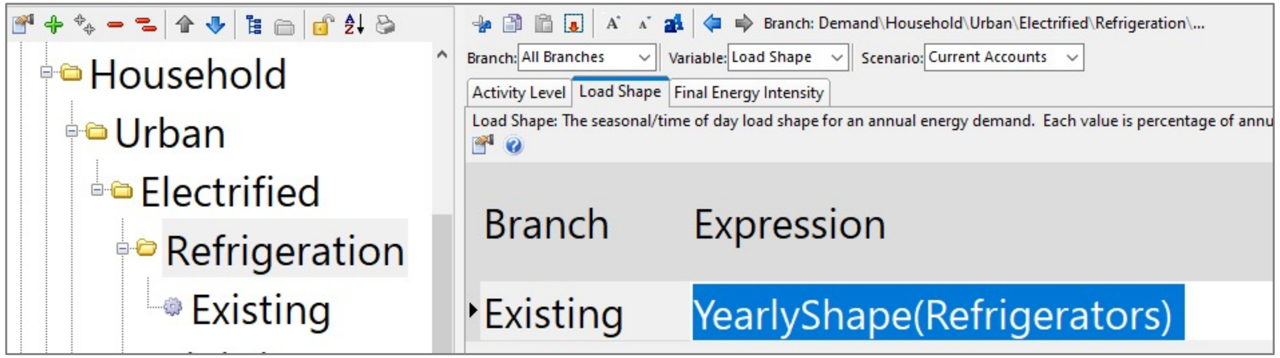




Demand-side load curves

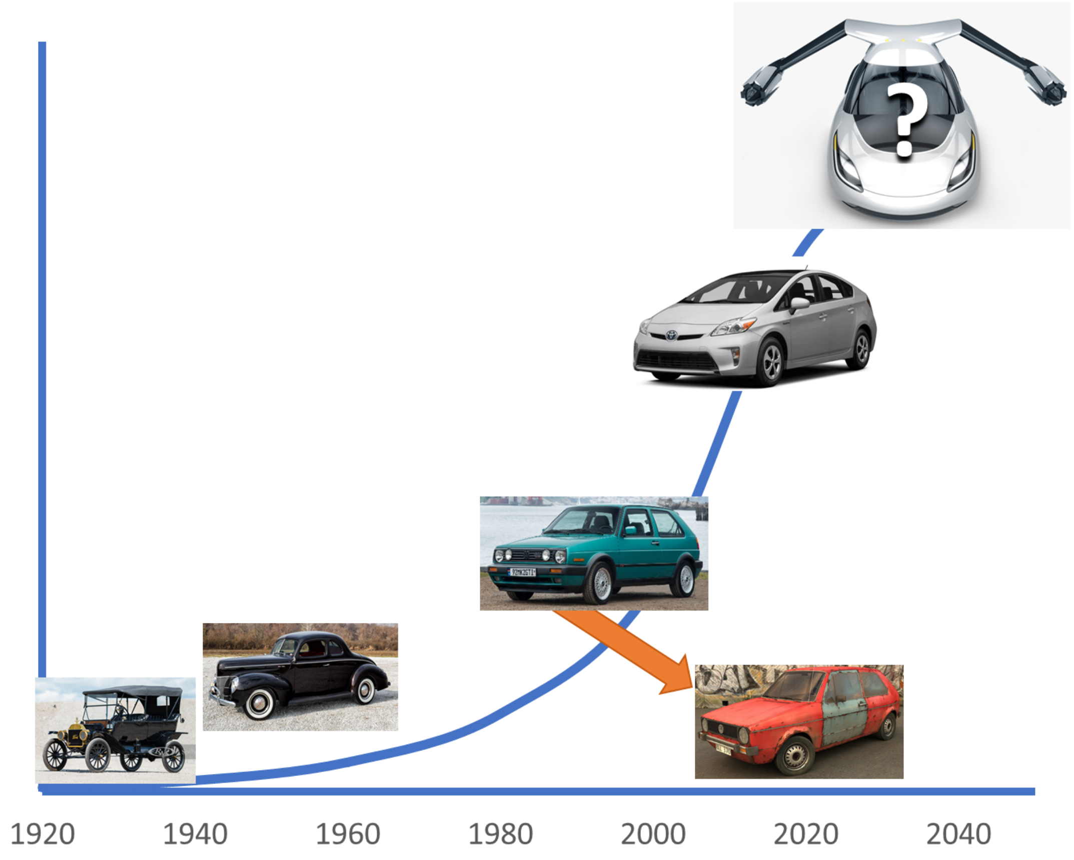
- Load shapes can be attached to demand technologies in LEAP, causing system-wide load curves for fuels to be calculated endogenously (by summing across technologies)
- Feature enabled in Settings
- LEAP provides Load Shape variable for demand technologies; it can be populated with a yearly shape or other time-sliced data (% of annual energy demand)





Transport stock turnover modeling

- Enabled with transport technologies
- LEAP tracks vintages for each transport technology
  - Vintage = all vehicles sold in a year
- Size of a vintage depends on initial number sold, time elapsed since sales year, and technology's survival profile
- Starting/historical stock of a technology (and age distribution of stock) can also be specified
- Energy consumption depends on number of vehicles, fuel economy, mileage, and device (fuel) shares
- Vehicle characteristics can evolve over time:
  - Fuel economy
  - Mileage
  - Emission factors
- Several variables also available to simulate scrappage
- Stock turnover approach is particularly useful for examining policies that target new vehicles – e.g., emission standards, fuel economy standards, introduction of EVs



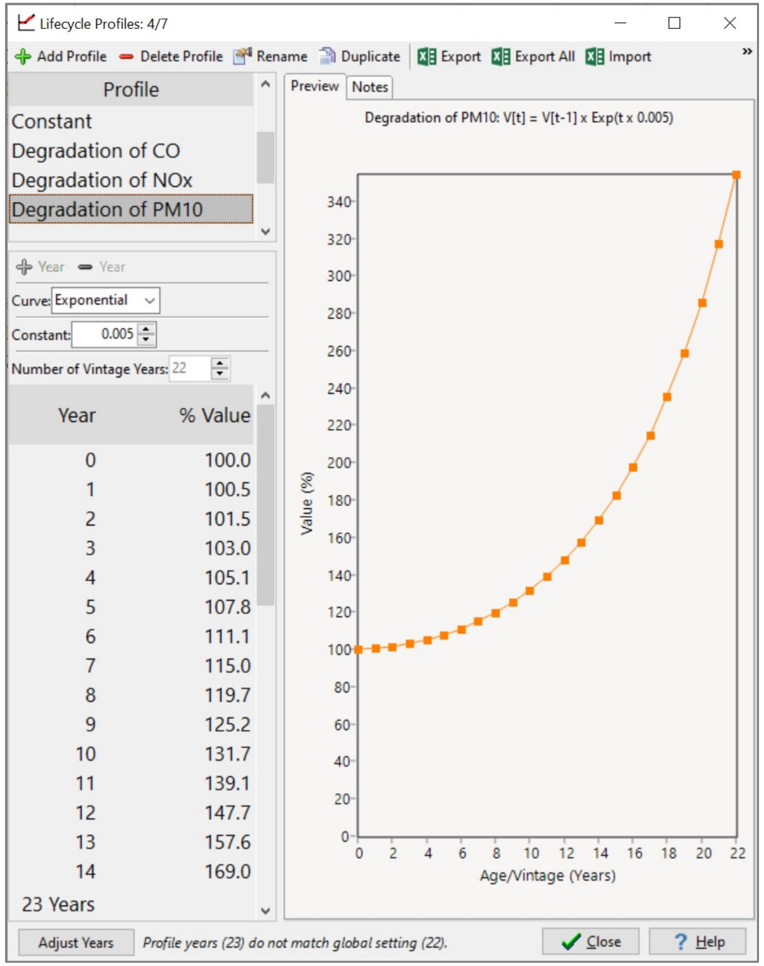
Transport stock turnover dynamics

Key points to consider:

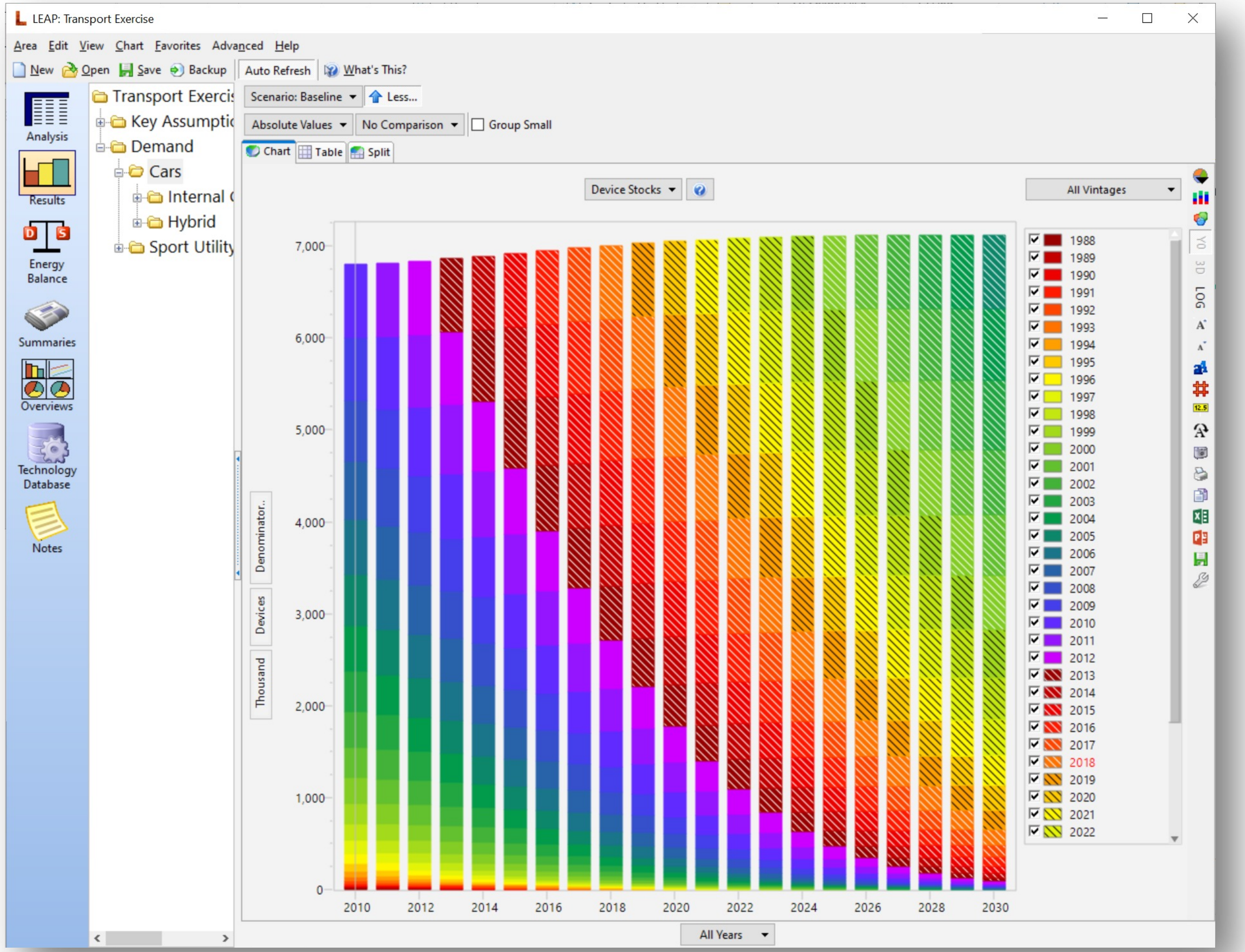
- How characteristics of new vehicles might evolve (e.g., due to new regulations). These changes are specified from year to year using LEAP's standard expressions (Interp, Growth, etc.)
- How characteristics of existing vehicles change as they get older. These changes are specified by vehicle age (vintage) from new to old (0, 1, 2, years, etc.) using special lifecycle profiles
- Specific policies affecting stocks in future years (such as a scrappage/replacement policy)

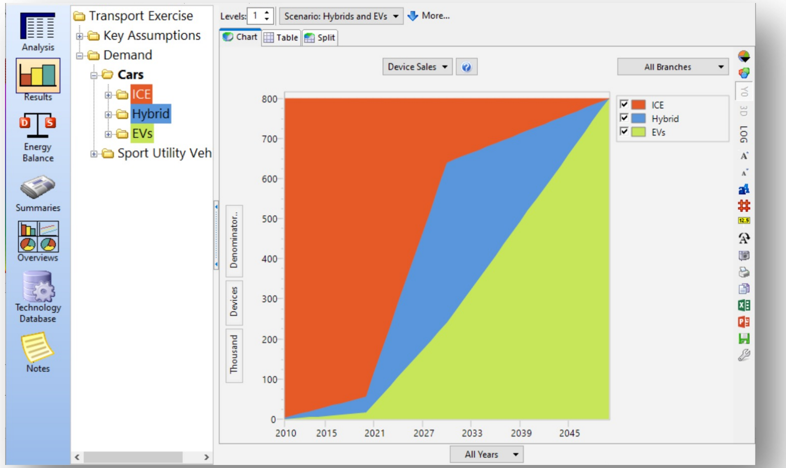
Transport stock turnover lifecycle profiles

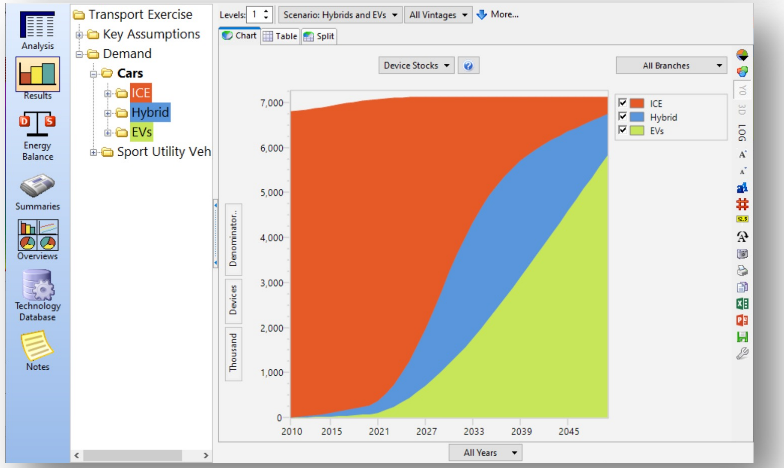
- In LEAP, lifecycle profiles are used to describe how vehicle characteristics change as they get older
  - Emissions degradation
  - Mileage degradation
  - Fuel economy degradation
  - Vehicle survival
- Typically start from value of 100% (the characteristic of a new vehicle)
- Can be specified using data values or an exponential curve, or imported from Excel



Viewing results for stock turnover models







Overviews

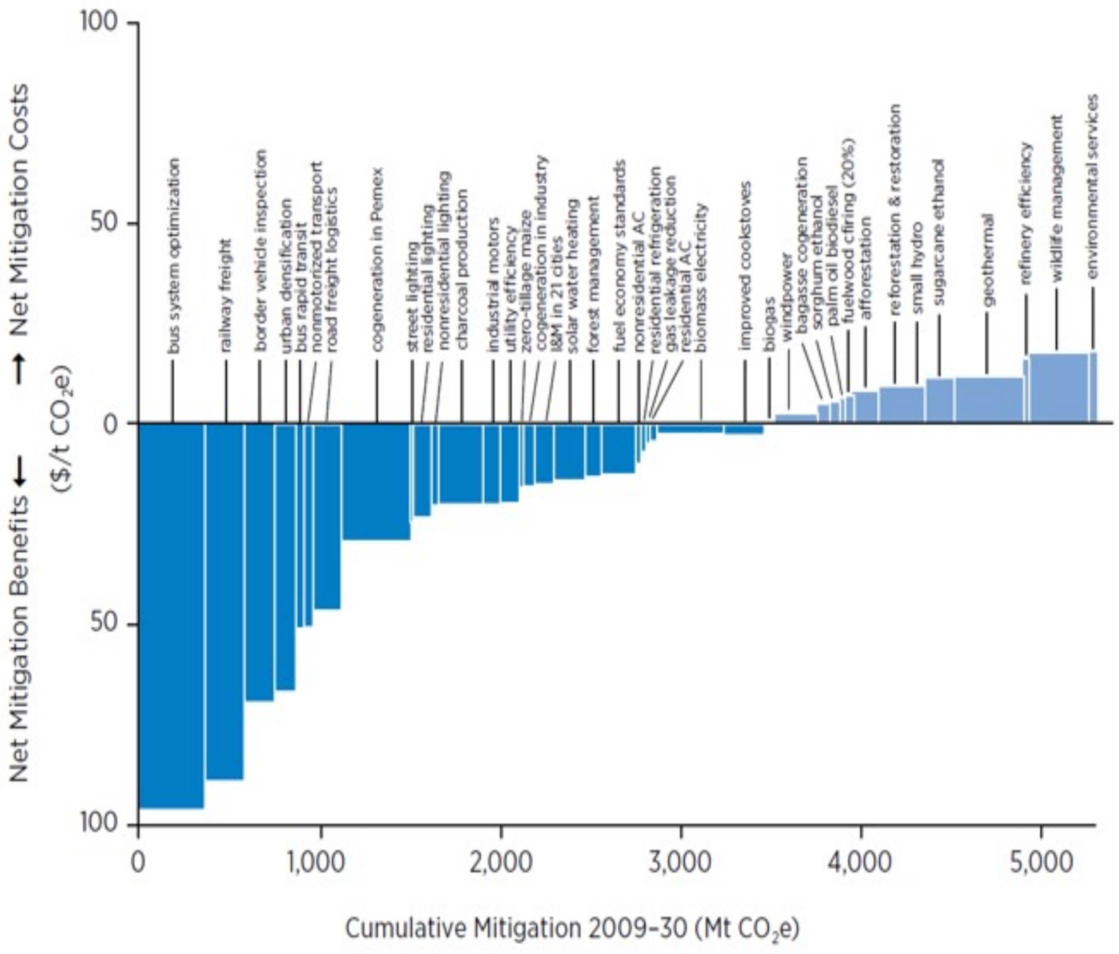
- LEAP's Overviews view shows multiple favorite charts in an interactive dashboard
- Overviews can optionally include key parameters (policy levers) with sliders – allows users to explore alternate values for major drivers without interacting with LEAP's equations
- Intended for stakeholder engagement

Overviews

LEAP: Caritrain Overviews
Area Edit View Advanced Help
New Open Save Auto Refresh Refresh Scenarios Manage Overviews Scenario Explorer Scenario: <From Favorites> What's This?
Analysis
Results
Energy Balance
Summaries
Overviews
Technology Database
Notes
Scenarios
LT_GDP_Growth
Oil Price Growth (%/Yr)
Solar Cap Cost Decline (%/Yr)
Wind Cap Cost Decline (%/Yr)
EV Share 2050
Baseline
Mitigation
My Scenario
Chart
Table
Energy Demand by Scenario
Thousand Tonnes of Oil Equivalents
Generation Mix 2050 (2050)
Gigawatt-Hours
Installed Capacity 2050 (2050)
Megawatts
Utility solar
Wind farms
Distributed solar
Hydro
Landfill gas ICE
Geothermal
Diesel
Storage
Cumulative Mit Cost
Cumulative $/Tonne
Self Sufficiency
GWP by Sector 2050 (2050)
Thousand Metric Tonnes CO2 Equivalent
Net Value
Agriculture
Charcoal Production
Commercial
Electricity Generation
Fugitive Emissions
IPPU
Industrial
LULUCF
Residential
Transportation
Waste

Marginal abatement cost curves

- Marginal abatement cost curves (MACCs) help assess cost and abatement potential of mitigation options and can be used in prioritizing implementation of measures
- MACCs plot cumulative emissions reductions from successive options (e.g., tonnes of GHGs avoided) against incremental cost per unit of emission reduction (e.g., \$/t CO_2e)
- Both costs and emissions can be discounted (costs typically are)
- For any given set of options, the area enclosed by a MACC equals the cumulative cost of those options
- Options below Y=0 are negative-cost (i.e., create cost savings)
- MACCs makes it easy to see which options are low or negative cost and which have largest mitigation potential (widest bars)



A typical example of a MACC
Source: Mexico Low Carbon Country Case Study, World Bank ESMAP

Cost discounting

A way to express costs incurred at different times in common terms

$$\boldsymbol{discounted\ cost} = \frac{\boldsymbol{nominal\ cost}}{(\boldsymbol{1} + \boldsymbol{discount\ rate})^{(\boldsymbol{year\ of\ nominal\ cost} - \boldsymbol{monetary\ year})}}$$

- Accounts for time value of money (intertemporal valuation)
- Example:
  - \$100 cost incurred in 2025
  - 5% discount rate
  - Monetary year = 2020

$$discounted\ cost = {}^{\$100}/_{1.055^5}$$
$$= \$78.4$$

Three approaches to calculating MACCs

1. **Partial approach:** Each option evaluated separately versus a baseline. Options ranked independently, ignoring possible interdependencies. Fast and simple but less thorough: may lead to misinterpretations.
2. **Retrospective approach:** Options first ranked independently with most cost-effective option plotted first. Next, all remaining options recalculated assuming implementation of the first option and 2nd most cost-effective option plotted. This continues until all options plotted. Retrospectively captures impact of prior (cheaper) options on later options but ignores how later options may affect cheaper options. Method also implies that once an option is included it will also be a permanent part of any strategy, including subsequently identified options.
3. **Integrated approach:** Requires use of an integrated energy system optimization model. Simultaneously takes into account all interdependencies within the system.

LEAP supports approaches #1 and #2. It also supports integrated planning, but currently does not plot MACCs for optimization scenarios. For more information on methods, see:

Sathaye, J. and Meyers, S. (1995). Mitigation Assessment of the Energy Sector: An Overview. In *Greenhouse Gas Mitigation Assessment: A Guidebook*. Springer. 21–53. http://unfccc.int/resource/cd_roms/na1/mitigation/Resource_materials/Greenhouse_Gas_Mitigation_Assessment_Guidebook_1995/chap03.pdf

Words of caution when interpreting MACCs

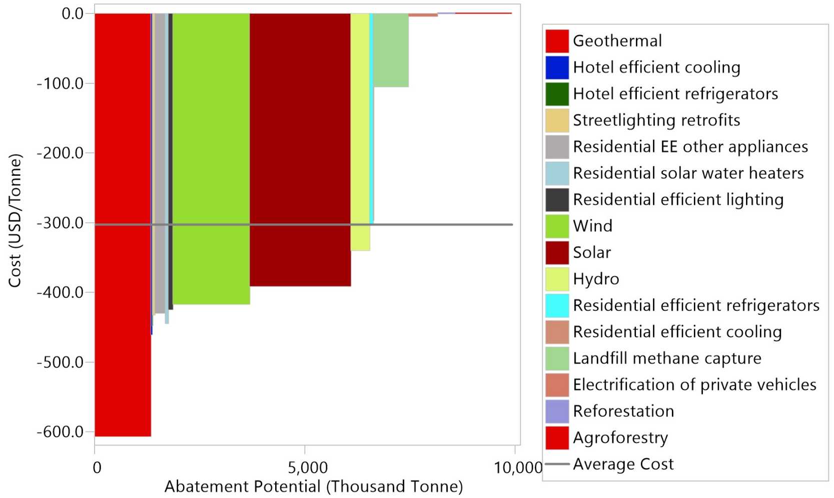
- Traditional climate policy suggests implementing cheapest opportunities first ("low hanging fruit"). This sounds like common sense, and is the thinking embodied in MACCs.
- But sometimes it makes sense to invest in options even if they are more expensive, especially if this helps to drive down costs or otherwise helps society to better prepare for long-term goals (e.g., a low carbon future).
- For example, electric vehicles (EVs) may not be a cost-effective GHG emission mitigation option now if electricity is generated from fossil fuels. But it may still make sense to prioritize EVs – both to drive down battery costs and to kick start start learning about charging networks and other required EV infrastructure. EVs will certainly be a crucial ingredient for achieving ambitious climate goals in concert with renewables and other CO_2-neutral electricity generation options.
- MACCs only show economic costs and GHG abatement. These are not the only topics that most countries care about! For example, the most cost-effective GHG mitigation options probably are not the most cost-effective options for air pollution abatement. One way to address this in MACCs is to include externality costs within the reported costs.

MACCs in LEAP

- MACCs are created in LEAP's Summaries view
- Requires a baseline scenario and a separate, freely combinable scenario for each measure to be plotted on the MACC (designate scenarios for MACC in Manage Scenarios window)
- Multiple MACCs can be defined; user can choose baseline scenario and emission and cost variables for each
- MACCs can be viewed as tables or charts with various color scheme options
- Retrospective MACCs take much longer to calculate than partial MACCs but are more thorough

Marginal Abatement Cost Curve Report: MACC
Compared to Scenario: Baseline, Retrospective Analysis

Scenario	Abatement Thousand Tonne	Cost Million USD	Cumulative Abatement Thousand Tonne	Cumulative Cost Million USD	Unit Cost USD/Tonne
Geothermal	1,338.0	-811.1	1,338.0	-811.1	-606.2
Hotel efficient cooling	32.2	-14.8	1,370.2	-825.9	-460.3
Hotel efficient refrigerators	5.1	-2.3	1,375.3	-828.2	-447.4
Streetlighting retrofits	58.7	-25.3	1,433.9	-853.5	-431.8
Residential EE other appliances	248.2	-106.6	1,682.2	-960.1	-429.4
Residential solar water heaters	72.0	-32.0	1,754.2	-992.1	-444.3
Residential efficient lighting	104.6	-44.4	1,858.8	-1,036.5	-424.3
Wind	1,823.3	-758.9	3,682.1	-1,795.4	-416.2
Solar	2,409.7	-942.2	6,091.7	-2,737.6	-391.0
Hydro	446.5	-151.6	6,538.2	-2,889.2	-339.6
Residential efficient refrigerators	84.4	-25.5	6,622.7	-2,914.7	-301.5
Residential efficient cooling	11.9	-3.5	6,634.6	-2,918.2	-296.4
Landfill methane capture	818.0	-85.9	7,452.6	-3,004.1	-105.0
Electrification of private vehicles	702.2	-2.9	8,154.8	-3,007.0	-4.2
Reforestation	415.5	0.5	8,570.4	-3,006.5	1.2
Agroforestry	1,348.3	1.8	9,918.7	-3,004.8	1.3
Average Unit Cost:					-302.9



Decomposition reports

- Decomposition reports can help decision makers understand underlying trends in scenarios by deconstructing trends into their component factors
- This type of report draws upon two well-known methodologies: IPAT and the Kaya identity
- IPAT refers to mathematical notation of a formula describing the impact of human activity on the environment:
  I = P × A x T
- The expression equates human impact (I) on the environment to a function of three factors: population (P), affluence (A), and technology (T). The Kaya identity is similar but refers specifically to emissions of carbon dioxide
- Decomposition reports, especially when displayed graphically in "waterfall" charts, are a powerful way of understanding challenges facing society in addressing overall social trends
- LEAP allows users to create IPAT and Kaya-type decomposition analyses and to further customize these approaches (e.g., to study other indicators such as air pollution or by including other factors)

Kaya identity is expressed in the form:

$$F = P \cdot \frac{G}{P} \cdot \frac{E}{G} \cdot \frac{F}{E}$$

Where:

- *F* is global CO2 emissions from human sources
- *P* is global population
- *G* is world GDP
- *E* is global energy consumption[3]

And:

- *G/P* is the GDP per capita
- *E/G* is the energy intensity of the GDP
- *F/E* is the carbon footprint of energy

The Kaya identity was developed by Yoichi Kaya. It is a variation of Paul Ehrlich & John Holdren's IPAT formula that describes the impact of human activity on the environment.

Using waterfall charts to visualize decomposition

- Waterfall charts show why a particular indicator (e.g., emissions) changes due to the impact of different factors
- For example, they can be used to show why GHG emissions change over time from the base year (2010) to the end year (2040) in a mitigation scenario (Figure 1)
- Or they can be used to show what factors caused emissions to be reduced in 2040 between a baseline and a mitigation scenario (Fig 2)
- The up and down "steps" in a waterfall chart indicate which factors caused the indicator to increase and which to decrease
- Waterfall decomposition charts can be created within LEAP, and color coded to make them easier to understand

TFC = total final energy consumption, TPS = total primary energy supply, GDP = gross domestic product

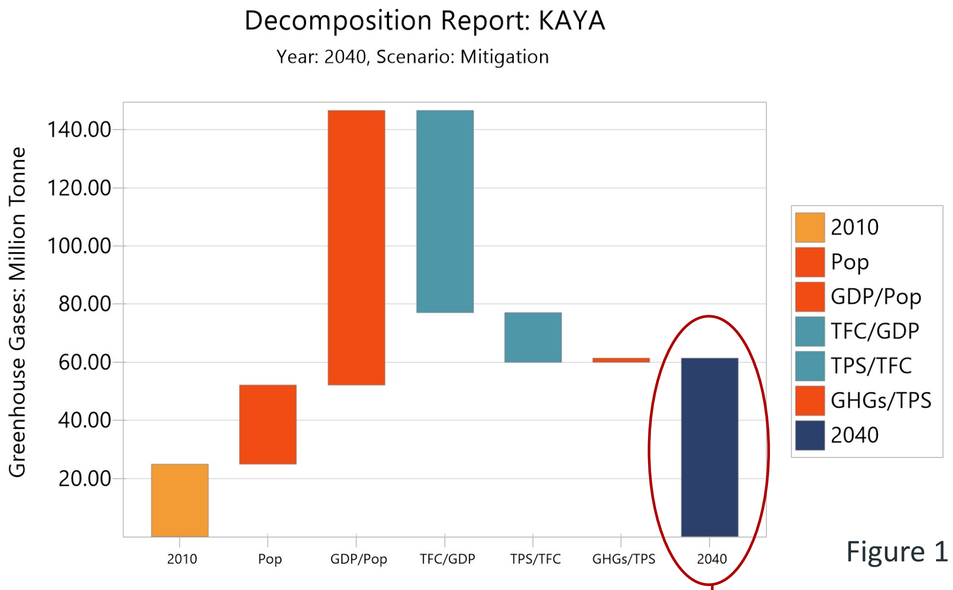


Figure 1

same

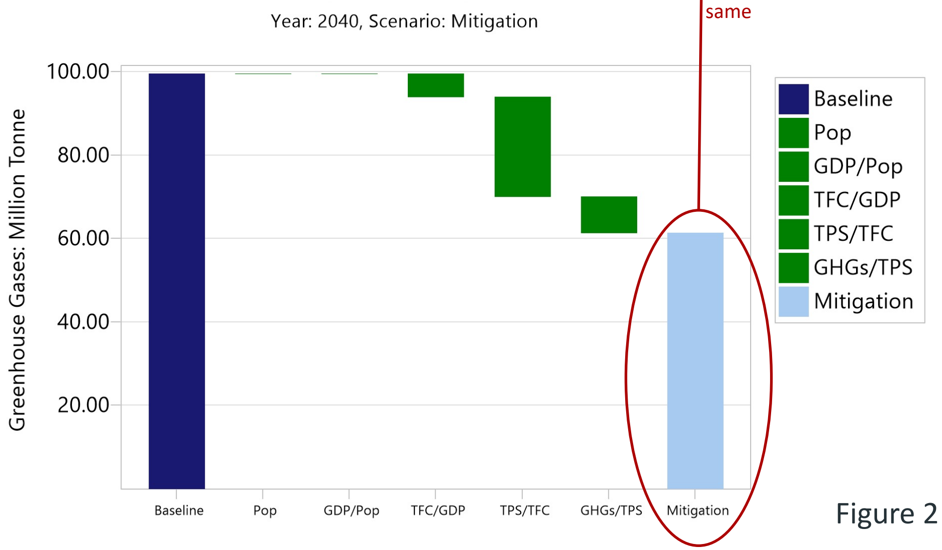
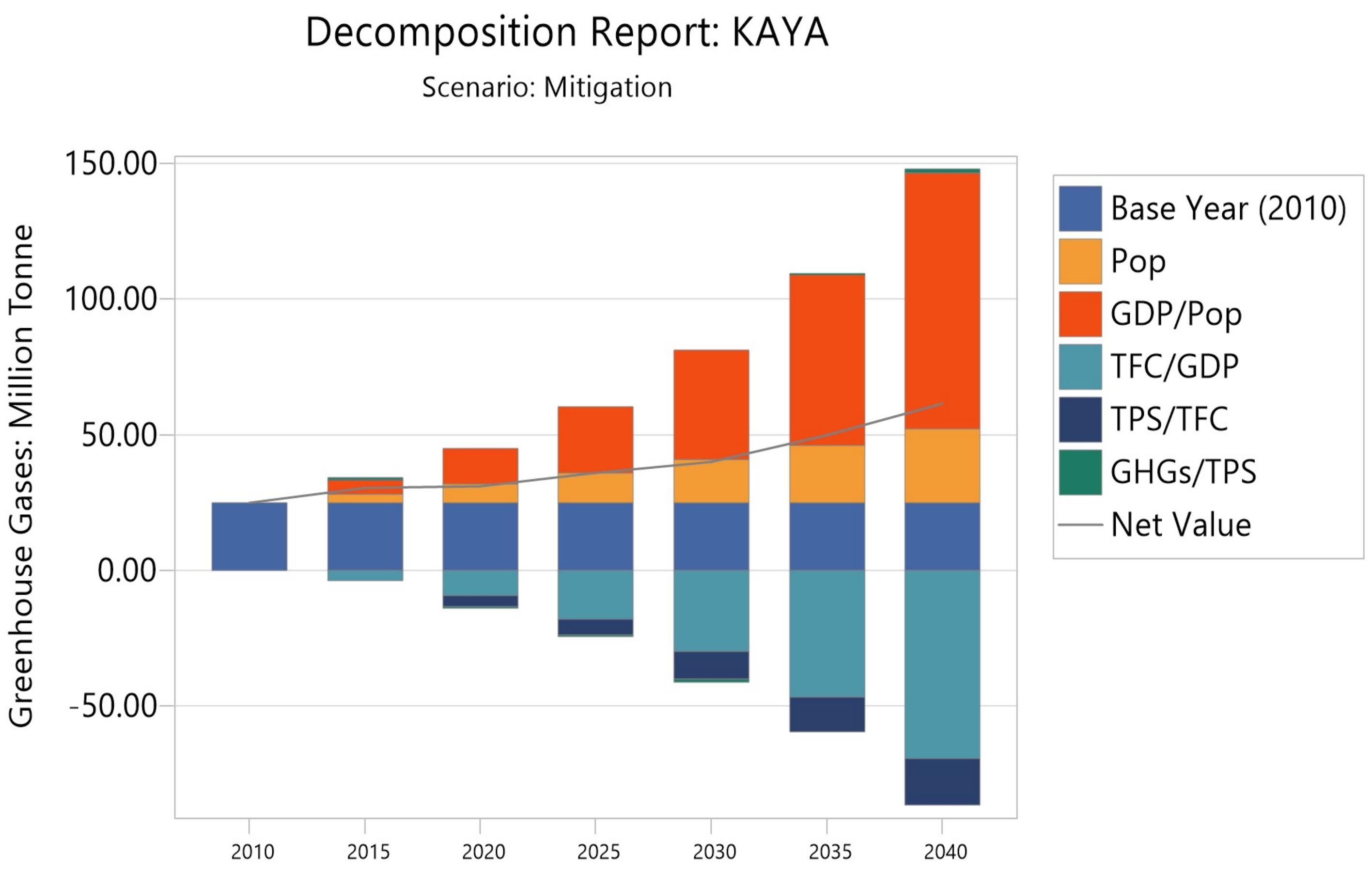


Figure 2

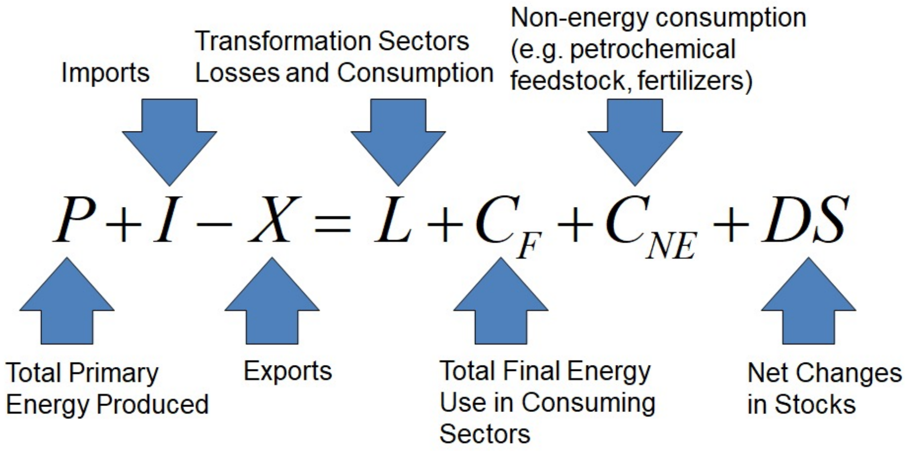
Using bar charts to visualize decomposition

- LEAP also allows scenario decompositions to be viewed as time-series bar charts
- For example, in this figure, overall emissions increase over time, with growth due to increasing population and income (wealth), partially mitigated by improvements in energy efficiency (TFC/GDP) and (TPS/TFC). However, there is no significant switch to lower carbon fuels (GHGs/TPS)
- The “net value” line shows the overall trend in emissions



Energy balances

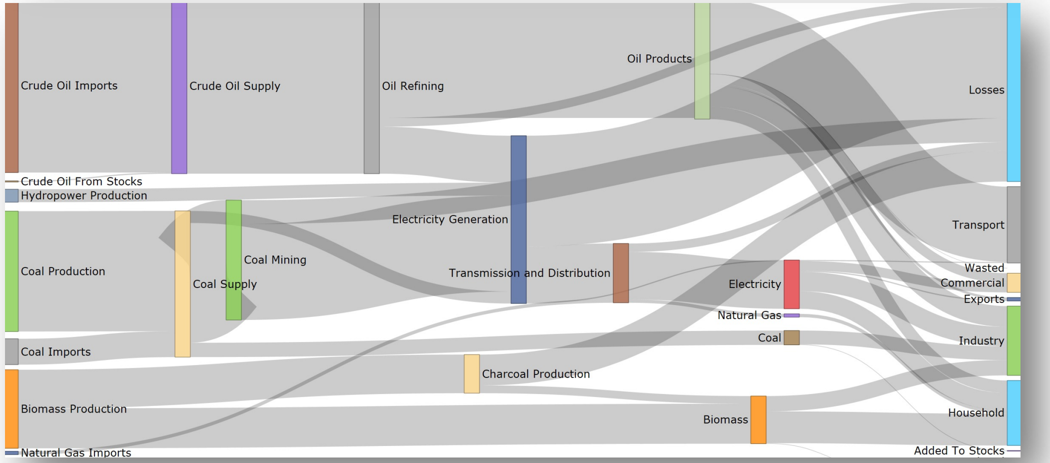
- Energy balances are accounting matrices that describe flows of energy through an economy during a period (typically a year)
- They can help to guide decision makers in planning investments in different sectors and inform where energy is being consumed, produced, lost, and traded
- Typically, they show both primary and final energy consumption. Some versions also show delivery of useful energy services
- Energy balances are usually given in one consistent energy unit (GJ, TOE, etc.)
- The term "balance" refers to the fact that quantities of primary energy produced must equal quantities consumed after accounting for changes in stocks, imports, and exports. Note that some energy balances also include an item for "statistical differences" to account for inconsistencies between data on energy consumption and production



Visualizations of energy balances

- Energy balances can be presented in LEAP in a variety of formats, including standard tables and Sankey diagrams
- In tabular form, they typically list energy sources as columns and sectors and activities as rows

	Coal	Natural Gas	Crude Oil	Hydropower	Biomass	Electricity	Oil Products	Total
Production	125.48	-	-	13.50	81.91	-	-	220.89
Imports	26.98	3.52	181.30	-	-	-	0.00	211.80
Exports	-	-	-	-	-	-1.20	-2.47	-3.67
From Stock Change	-0.56	-	1.20	-	-	-	-	0.64
Total Primary Supply	151.90	3.52	182.50	13.50	81.91	-1.20	-2.47	429.66
Coal Mining	-24.98	-	-	-	-	-	-	-24.98
Oil Refining	-	-	-182.50	-	-	-	173.38	-9.13
Charcoal Production	-	-	-	-	-32.22	-	-	-32.22
Electricity Generation	-112.52	-	-	-13.50	-	59.51	-49.01	-115.52
Transmission and Distribution	-	-0.07	-	-	-	-8.75	-	-8.82
Total Transformation	-137.50	-0.07	-182.50	-13.50	-32.22	50.76	124.37	-190.66
Statistical Differences	-	-	-	-	0.57	-	-1.20	-0.63
Household	-	3.45	-	-	33.12	18.26	12.95	67.78
Industry	14.40	-	-	-	16.00	20.22	21.60	72.22
Transport	-	-	-	-	-	1.08	78.55	79.63
Commercial	-	-	-	-	-	10.00	10.00	20.00
Total Demand	14.40	3.45	-	-	49.12	49.56	123.10	239.63



Enhanced energy balances

- LEAP can create projections of energy balances into the future and also allows balance formats to be adjusted interactively (e.g., changing units or showing years, regions, or detailed fuels data in columns)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Production	346.2	351.1	356.2	378.2	383.8	406.3	428.8	435.3	458.4	465.6
Imports	280.2	299.4	318.8	324.0	345.6	353.0	361.1	386.2	397.4	425.1
Exports	-	-	-	-	-	-	-	-	0.0	-
Total Primary Supply	626.4	650.5	675.0	702.2	729.4	759.2	789.9	821.5	855.9	890.7
Coal Mining	-47.6	-48.4	-49.3	-53.7	-54.7	-59.2	-63.7	-64.9	-69.5	-70.9
Oil Refining	-12.6	-12.6	-12.6	-12.6	-12.6	-12.6	-12.6	-12.6	-12.6	-12.6
Charcoal Production	-36.6	-37.0	-37.4	-37.7	-38.1	-38.5	-38.9	-39.2	-39.6	-40.0
Electricity Generation	-166.9	-176.4	-185.6	-193.2	-203.4	-212.1	-220.8	-232.8	-243.2	-256.4
Transmission and Distribution	-12.9	-13.4	-13.9	-14.4	-15.0	-15.5	-16.1	-16.7	-17.4	-18.0
Total Transformation	-276.6	-287.8	-298.7	-311.7	-323.8	-337.9	-352.1	-366.2	-382.3	-397.8
Household	90.3	93.1	95.9	98.9	102.0	105.3	108.7	112.3	116.0	119.9
Industry	97.1	98.9	100.7	102.6	104.6	106.6	108.7	110.9	113.2	115.5
Transport	139.2	147.3	155.8	164.8	174.3	184.3	195.0	206.3	218.2	230.8
Commercial	23.2	23.5	23.9	24.3	24.6	25.0	25.4	25.8	26.2	26.7
Total Demand	349.8	362.7	376.3	390.6	405.5	421.3	437.9	455.3	473.6	492.9

	Lat. America and Caribb	Mid East and N. Africa	North America	Pacific OECD	Other Pacific Asia	South Asia
Production	32.4	48.6	126.0	39.6	42.4	65.9
Imports from Beyond Area	0.4	0.7	1.2	0.5	0.6	1.5
Exports Beyond Area	0.0	-	0.0	0.0	-	-
Total Primary Supply	32.8	49.3	127.2	40.1	42.9	67.4
Liquefaction	-	-	0.0	-	0.0	-
Oil Refining	-0.8	-0.6	-0.6	-0.2	-0.2	-0.3
Electric Generation	-4.1	-8.7	-20.0	-9.6	-6.8	-17.2
CHP Production	0.0	0.0	-4.0	-0.4	-1.1	-0.6
Heat Production	-	-	0.0	0.0	-	-
Own Use during Energy Conversion	-3.7	-4.5	-7.9	-1.9	-3.0	-3.0
Distribution_Losses	-0.8	-1.0	-1.5	-0.4	-0.9	-2.6
Total Transformation	-9.5	-14.8	-33.9	-12.5	-12.1	-23.6
Households	4.5	6.5	12.7	3.3	9.1	9.9
Agricultural Energy Use	0.6	0.9	1.6	0.3	0.5	1.5
Services	1.1	1.6	10.0	3.8	1.2	0.8
Industrial Energy Use	7.6	10.8	24.0	8.9	11.2	20.0
Transportation	8.4	11.3	36.8	8.2	7.9	10.0