User's Guide for California PATHWAYS model version 2.4.0

Prepared for: California Air Resources Board

Prepared by: Energy and Environmental Economics, Inc. (E3)

Date: January 2017

Energy+Environmental Economics

Table of Contents

1. Intro to California PATHWAYS

1.1 Purpose

California PATHWAYS (CA PATHWAYS) was originally designed by Energy & Environmental Economics with support from Lawrence Berkeley National Labs (LBNL). This version has been updated for the California Air Resources Board (ARB). The purpose of the model is to evaluate the feasibility and cost of a range of GHG reduction cases in California within the context of complying with California's long-term greenhouse gas (GHG) emission reduction goals.

This user's guide is designed to provide a basic overview of how to open the model and run and evaluate cases using the Analytica-based California PATHWAYS tool. For a description of the model structure, please see the supporting model documentation. For more information about how to use the Analytica platform generally, please see the online tutorials developed by Lumina, as described in Section 2.5.

1.2 Version

Version 2.4.0 is the current version of the CA PATHWAYS model. This model replaces the prior version 2.3.2 which was released in February 2016.

1.3 Modeling Approach

CA PATHWAYS is a California-wide, economy-wide infrastructure-based GHG and cost analysis tool. Components include:

- Equipment stock turn-over for many sectors, with rates based on lifetime of equipment; energy use determined as service demand is met by the stock of equipment in each year
- Tracking of energy and energy infrastructure costs
- Bottom up forecast of service demand by end use, driven by variables including population, residential and commercial square footage, space heating/cooling, water heating, lighting, etc.
- Hourly electricity demand and supply detail, simulating required planning, system operation, and cost
- CA PATHWAYS is not an optimization model: the user is in full control of the outcomes.

2. Installation of California PATHWAYS and Analytica

2.1 Installing Analytica

The software platform Analytica by Lumina Systems is required to run CA PATHWAYS. Once Analytica is installed on your computer, opening CA PATHWAYS does not require any further installation steps. This

section is designed to guide the user through the download and installation of Analytica and CA PATHWAYS.

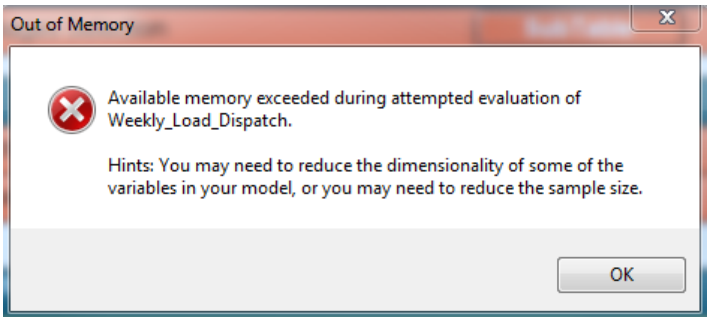
System Requirements

To use Analytica for CA PATHWAYS, the following minimum system requirements apply:

- Minimum 16GB of RAM (24 GB or more recommended)
- Windows 7 or later, dual core 64 bit processor

Running 1 case on a computer meeting the minimum requirements above can take 20-30 minutes.

In general, a faster CPU and more RAM will lead to CA PATHWAYS cases running more quickly. With the minimum requirements listed above it is not recommended to run more than one case simultaneously; on more powerful computers, running 2-3 cases simultaneously is possible. Running too many cases simultaneously or not meeting system requirements may lead to an Out of Memory error or computer crash. An example of the Out of Memory error is displayed below:



2.2 Recommended Versions of Analytica

Free 101 edition of Analytica: For users who would like to run existing cases, obtain results from the CA PATHWAYS model, or create and save new cases using the pre-existing model structure. This version of the software can be downloaded as described below.

The purchase of a Professional Analytica license is required to edit variables in the code and an Enterprise or Optimizer license in required to read and write data files into or out of the Analytica platform.

Currently, the latest version of Analytica is 4.6. Lumina issues periodic updates to its software. PATHWAYS version 2.4.0 is compatible with Analytica version 4.6. For future Analytica software updates, there are no guarantees that the new software will be compatible with PATHWAYS 2.4.0 and in some cases updates may result in new errors. It is recommended that users do not use new updates unless notified by E3 that the new update is compatible with CA PATHWAYS version 2.4.0.

2.3 Licenses

A license is needed to use Analytica. The Analytica Free Player license is automatically included when the software is downloaded, and can be used by anyone.

2.4 Downloading Analytica Free Player

Step 1. Go to Lumina's website and download the Analytica free player at:
http://www.lumina.com/support/downloads/

Click on "Ana64Setup.exe" to begin downloading the 64-bit version of Analytica. The 32-bit version of the software is not compatible with CA PATHWAYS. After downloading, double click on the file to begin the installation process. Once installed you do not need an activation key to run the free version of Analytica.

Step 2. Follow Instructions on the Lumina website to download and Install Analytica software.

2.5 User Guide & Tutorials

Details about how to use the Analytica software are available in the Analytica User Guide, available at:

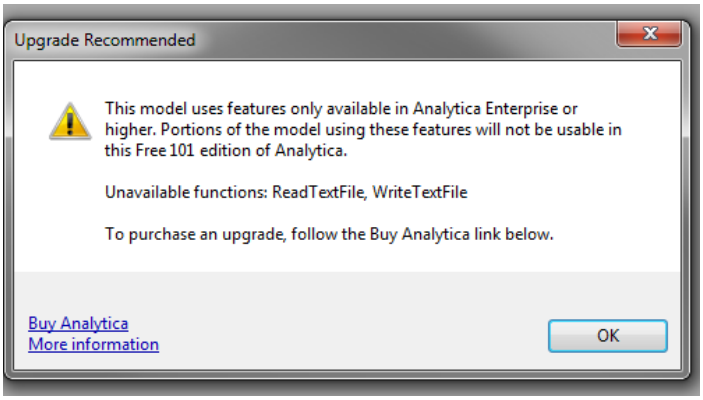
http://www.lumina.com/support/downloads/

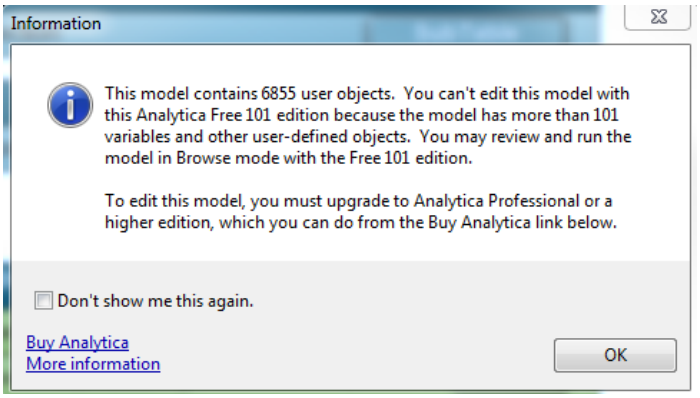
Lumina also provides tutorials in written and video versions. Tutorials contain further information about installing Analytica (pg. 4-6) and information on creating and editing models in Analytica, available at the same link as above.

3. Running & Evaluating Pre-Defined Cases

3.1 Opening CA PATHWAYS in the Free Player Version of Analytica

Once Analytica is downloaded a user can open CA PATHWAYS. Opening the model in the Free Player version of Analytica will result in the following two messages after the model loads:

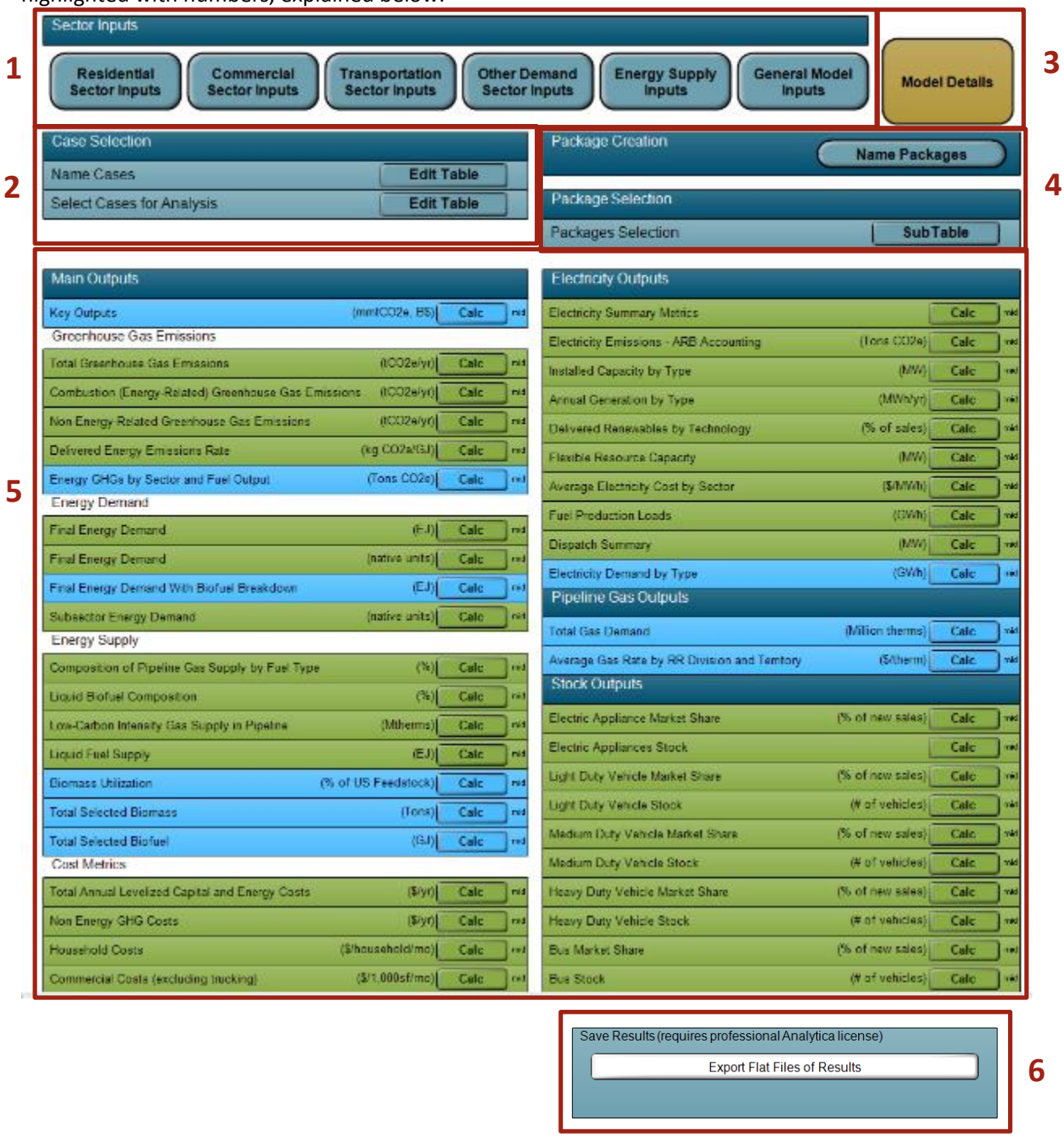




Unless you wish to purchase an upgraded version of Analytica, click “OK” on both of these screens.

3.2 User Interface

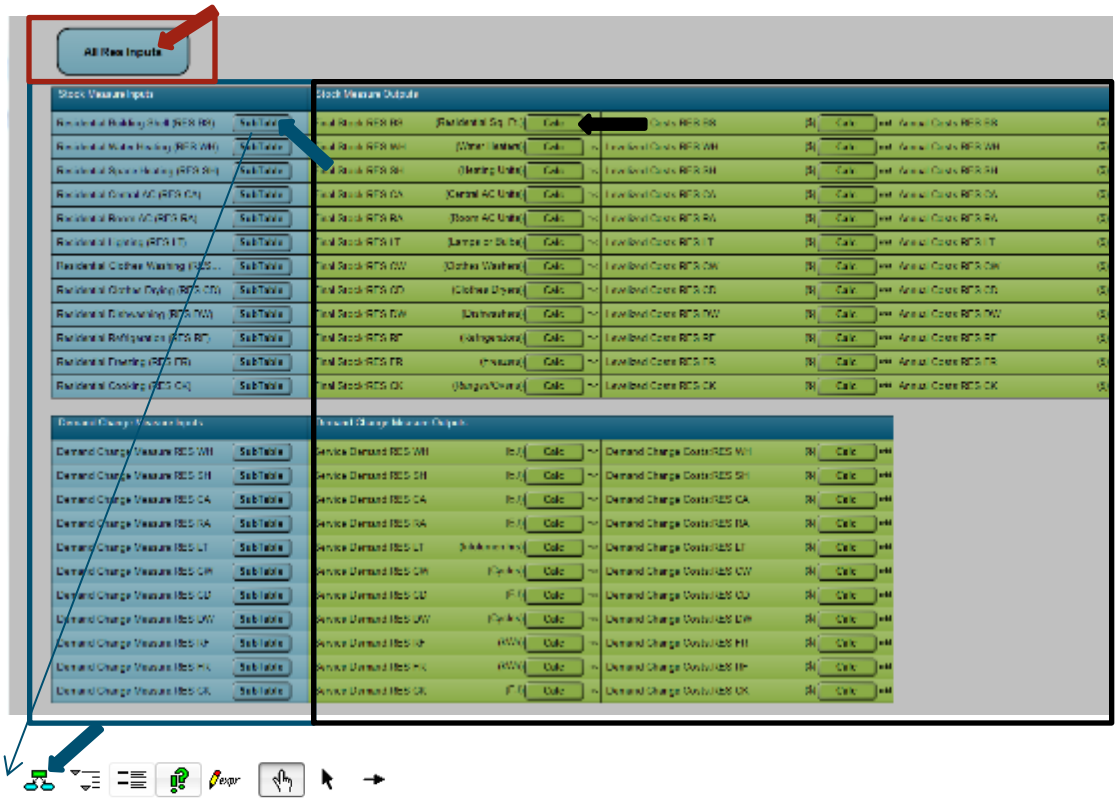
The main user interface for CA PATHWAYS is pictured below. Sections of the model are highlighted with numbers, explained below.



1. **Sector Inputs:** Double clicking on any of the six input tabs displays a list of inputs and some outputs associated with that sector. From that view, further detail is available for some sectors by clicking “All [Sector] Inputs.” Subtables display model inputs, which may also be

represented graphically (see Section 3.4) or as diagrams by clicking the “Diagram Window” button once viewing a subtable.

An example of this process is shown below for the Residential Sector Inputs button. Double clicking the button where the **red** box and arrow are shown displays all Residential Inputs. Clicking any of the subtable buttons (**blue** box and arrow) will display input sub-tables as shown below. Clicking any of the “Calc” buttons in **black** will run all calculations in the model necessary to provide that value, but will not run the full model.



Edit Table of Residential Building Shell (RES BS)

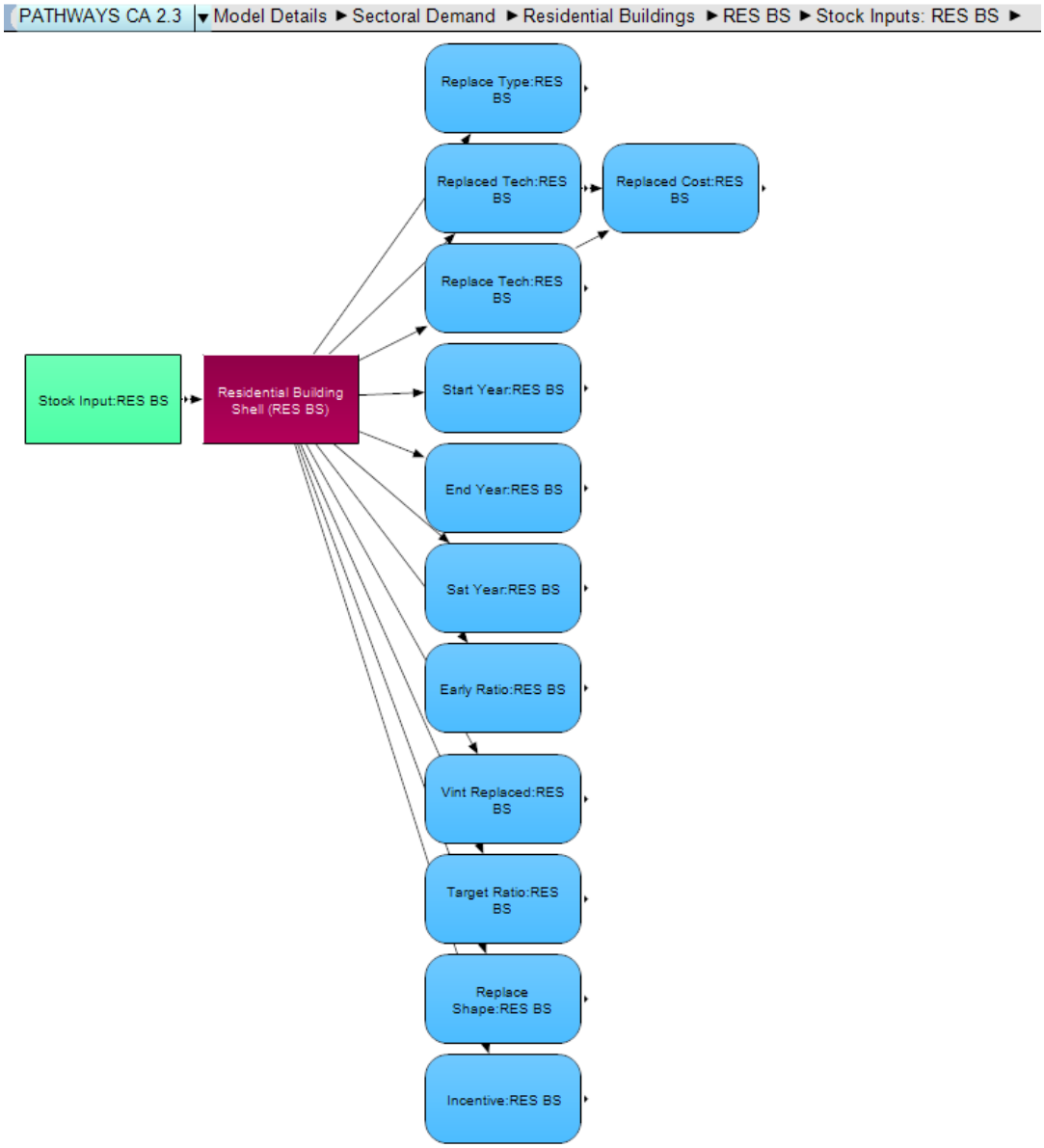
Active Packages: RES Reference

A Measure Index

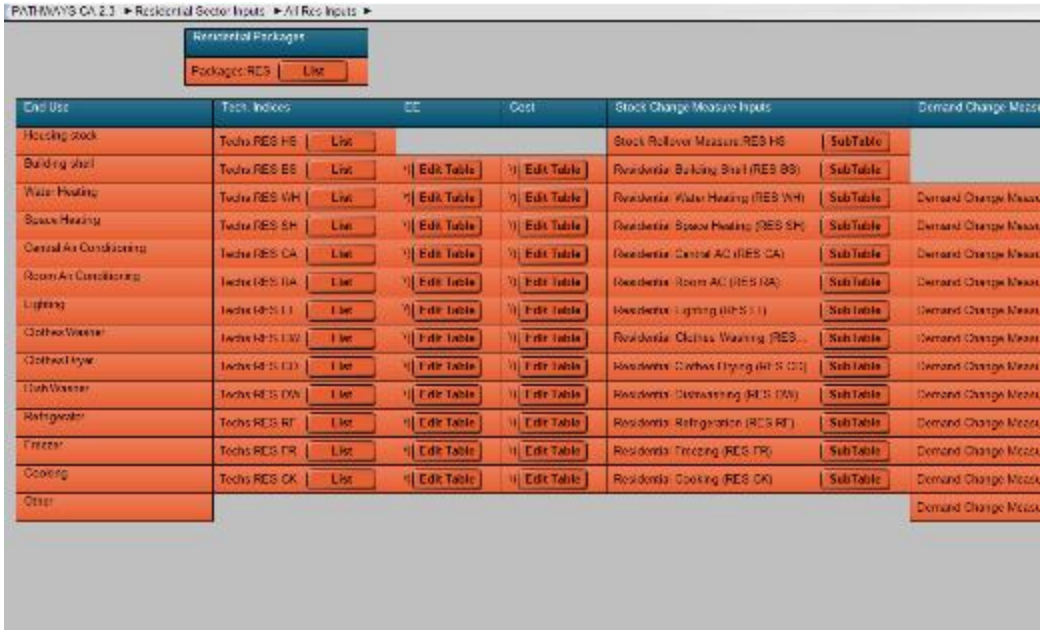
Input:RES BS

	Replacement Type	Technology	Technology Replaced	Measure Start Year	Measure Saturation Year	Measure End Year
Measure 1	Natural Replacement	IECC 2000	Reference	2014	2014	2050
Measure 2	Natural Replacement	Reference	Reference	2014	2014	2050
Measure 3	Natural Replacement	Reference	Reference	2014	2014	2050
Measure 4	Natural Replacement	Reference	Reference	2014	2014	2050
Measure 5	Natural Replacement	Reference	Reference	2014	2014	2050
Measure 6	Natural Replacement	Reference	Reference	2014	2014	2050
Measure 7	Natural Replacement	Reference	Reference	2014	2014	2050
Measure 8	Natural Replacement	Reference	Reference	2014	2014	2050
Measure 9	Natural Replacement	Reference	Reference	2014	2014	2050
Measure 10	Natural Replacement	Reference	Reference	2014	2014	2050

Clicking the Diagram window (**blue** arrow above) button then displays the influence diagram for the selected input. An example is shown below for Residential Building Shell.



Alternatively, clicking “All Res Inputs” on the first subtable screen above (**red** arrow) brings up the screen below, from which the user may then double click a desired list or table of Residential data.

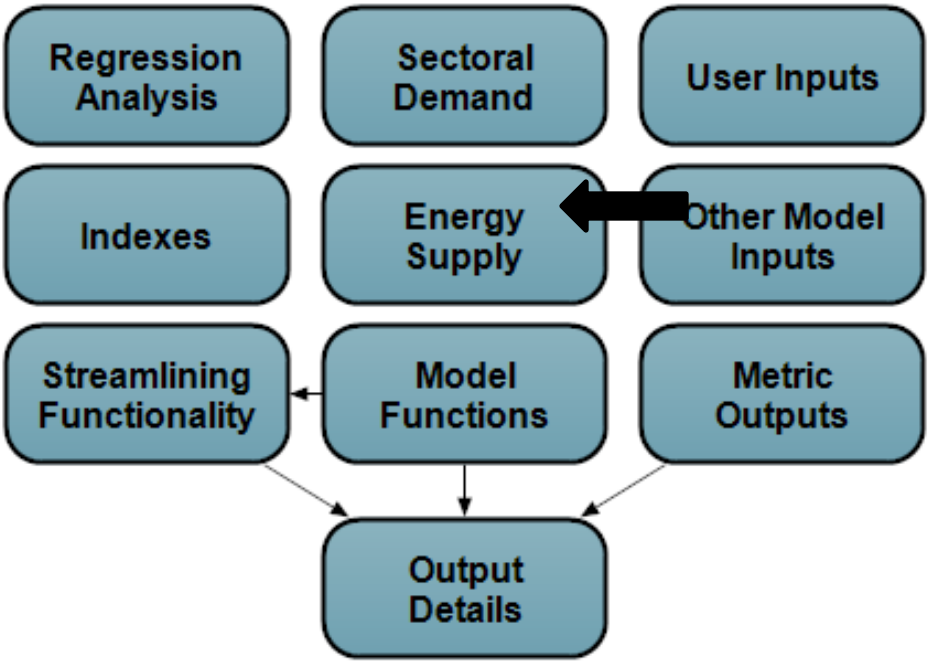


2. **Case Selection:** Choose which cases to run (Active Cases). See section 3.3 of this guide for more information.
3. **Model Details:** Brings up the main diagram window for the model. The user may then double click to display sectoral and sub-sectoral diagrams. Subsectoral diagrams (e.g. Model Details → Sectoral Demand →Transportation, Communication, and Utilities, or Model Details → Energy Supply → Fossil Energy) displays influence diagrams.[1] Clicking on variables within influence diagrams displays information about the variable. The variable can also be represented as a table or graph, see 3.4.

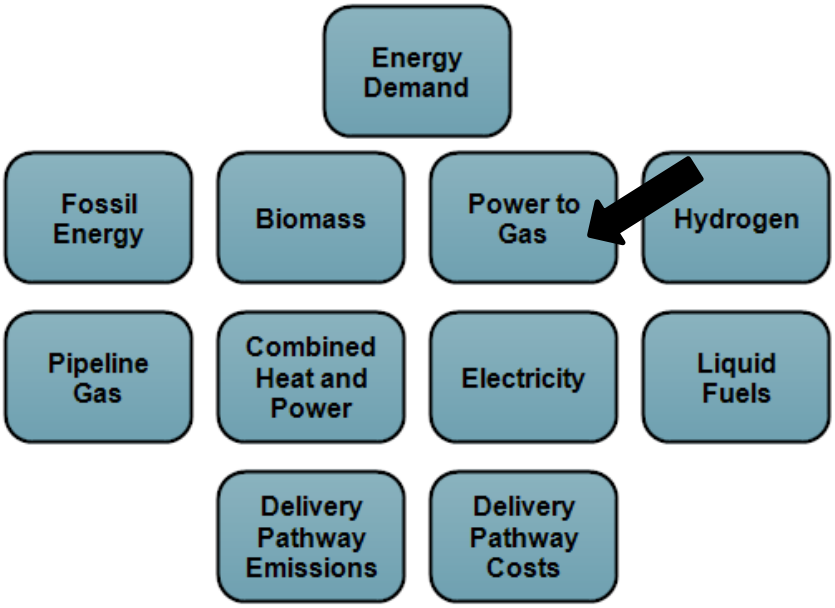
   An example of this process is shown below for the Power to Gas (P2G) influence diagram. Double Clicking the buttons highlighted with the black arrows allows the user to access the P2G influence diagram. Clicking other buttons allows access of other influence diagrams.

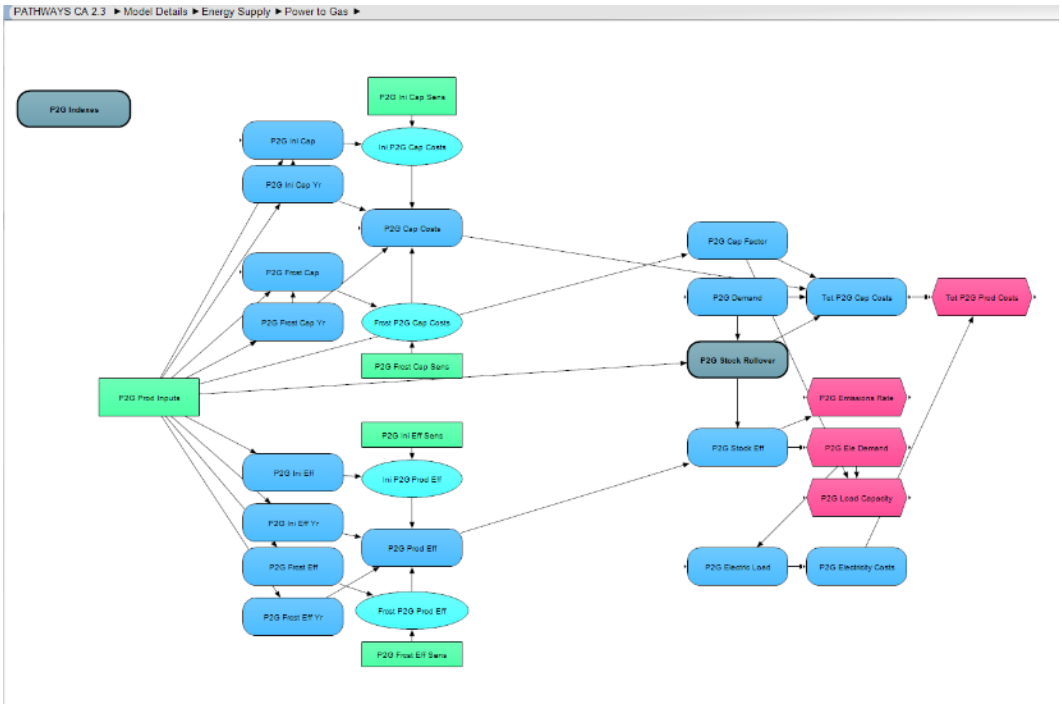
[1] For more on the shapes (variables) and functionalities of influence diagrams, see the Analytica tutorial on using influence diagrams, https://www.youtube.com/watch?v=dSzvuMGJTlk

PATHWAYS CA 2.3 ► Model Details ►



PATHWAYS CA 2.3 ► Model Details ► Energy Supply ►



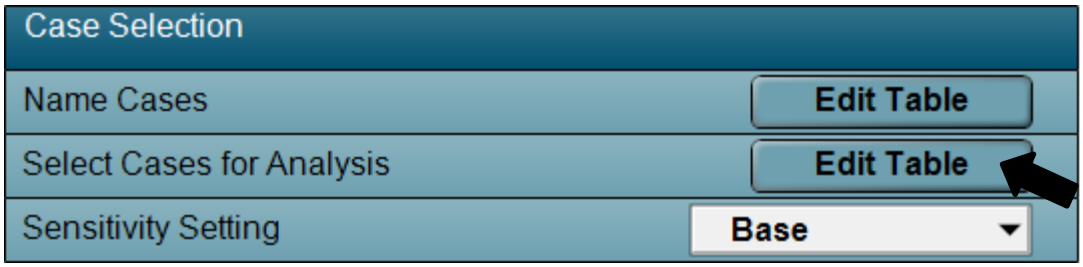


Once at the influence diagram level, double clicking on any variable allows the user to see how that variable is defined.

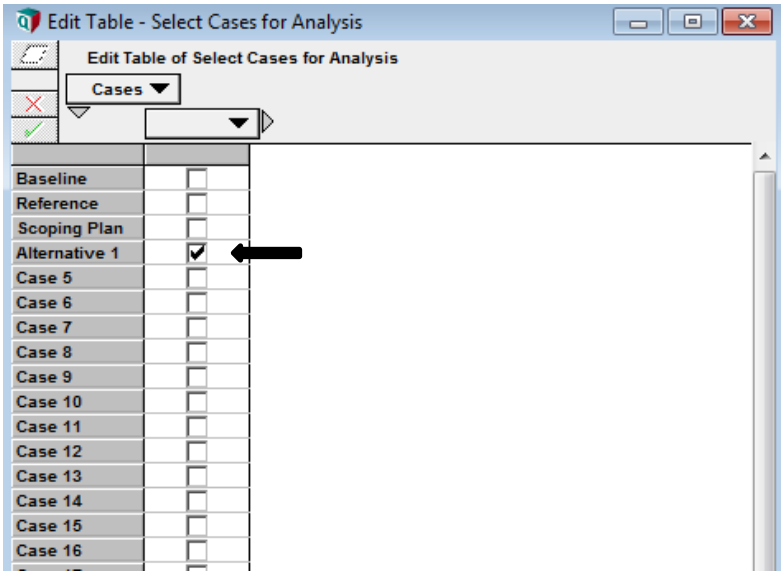
4. **Packages:** Packages define the set of input assumptions associated with each sector. Combinations of different packages are used to create economy-wide scenarios. This section of the model on package naming and selection is to create user-defined cases (see Section 4).
5. **Outputs:** Clicking "Calc" will run selected cases (see 3.3 on Selecting Cases). See Evaluating Results (3.4) for more information.
6. **Export Flat Output Files:** Exports categories of pre-defined results into flat files that can be viewed and manipulated in Excel. Requires professional or higher version of Analytica.

3.3 Selecting Cases

CA PATHWAYS contains three predefined cases: Reference (business as usual with pre-SB 350 mitigation policies); Scoping Plan (Proposed mitigation scenario with cap-and-trade); and Alternative 1 (no cap-and-trade mitigation scenario). See the January 2017 ARB Proposed Scoping Plan for more information about these scenarios. The model provides the option for creating additional user-defined cases (see Section 4). Cases are accessed by clicking on the "Edit Table" button next to "Select Cases for Analysis," toward the top left of the opening model interface screen.



Analytica will then bring up the case selection screen, where the user can check boxes for the cases they wish to run – these will become the Active Cases. After checking the desired boxes, the user may return to the main screen of the model to run the selected cases by exiting this screen using the "x" in the upper right corner of the dialogue box. It is not advisable to run more than one case simultaneously with a computer meeting the minimum system requirements.



3.4 Evaluating Results

3.4.1 Calculating Results

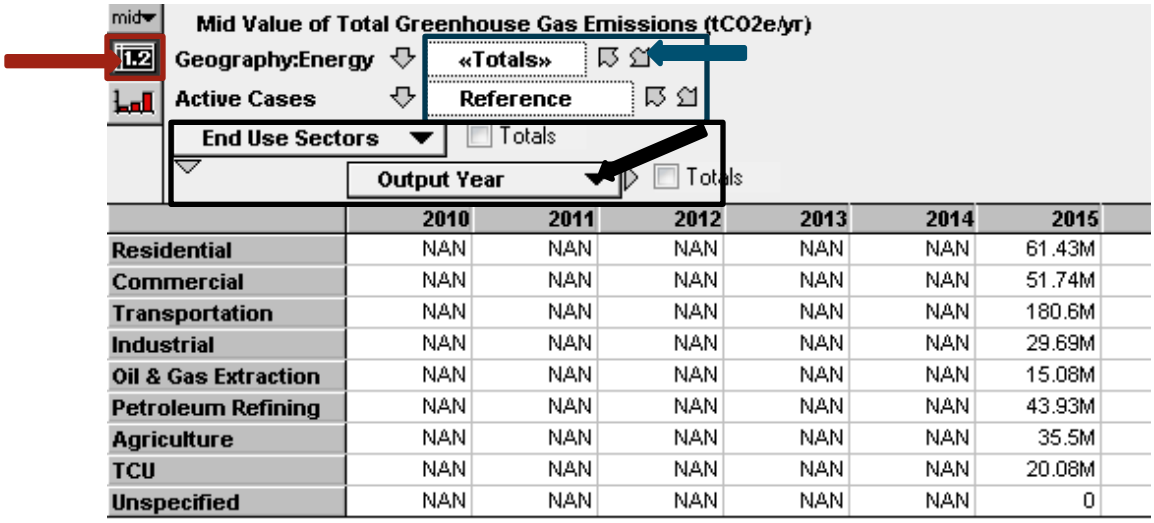
The model is run by clicking any of the green "Calc" buttons on the screen associated with every computed variable. Clicking "Calc" once will run the model through to the point in the model at which the result is available. Allow 20-30 minutes for the model to run 1 complete case for the first time, for example by clicking on "calc" for final CA wide GHG emissions. Subsequent calculations will generally require less evaluation time since the model will not need to recalculate all modules.

Model calculations can be stopped at any time by clicking the red "x" in the top dialogue box, shown below. The red X button appears once the user starts running the model.

To check memory usage and to ensure that the model is still calculating, click on "window" → "show memory usage" to view your computer's computational statistics.

3.4.2 Results Tables

After the model has finished calculating, the "Calc" button will change to a "Result" button. By double clicking on results, a data table or chart of results will be displayed. If a chart is displayed, the data table can be viewed by clicking on the table icon, shown by the **red** box and **red** arrow below.

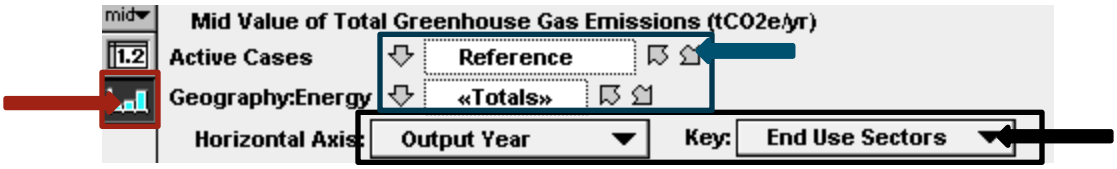


	2010	2011	2012	2013	2014	2015
Residential	NAN	NAN	NAN	NAN	NAN	61.43M
Commercial	NAN	NAN	NAN	NAN	NAN	51.74M
Transportation	NAN	NAN	NAN	NAN	NAN	180.6M
Industrial	NAN	NAN	NAN	NAN	NAN	29.69M
Oil & Gas Extraction	NAN	NAN	NAN	NAN	NAN	15.08M
Petroleum Refining	NAN	NAN	NAN	NAN	NAN	43.93M
Agriculture	NAN	NAN	NAN	NAN	NAN	35.5M
TCU	NAN	NAN	NAN	NAN	NAN	20.08M
Unspecified	NAN	NAN	NAN	NAN	NAN	0

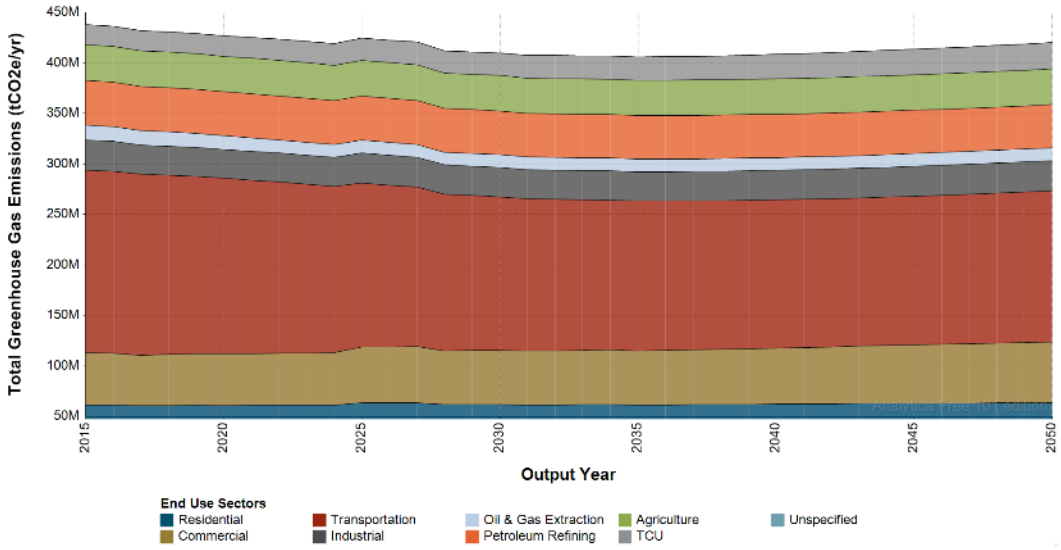
Different table axes are displayed by using the drop down lists on the buttons enclosed in **black** boxes and arrow above. The user may then toggle through what to display on the axes by toggling through the boxes enclosed in **blue** boxes and arrow above (e.g. "Active Cases" will give options to look at any cases that have been run). This allows the user to choose what to display in the table.

3.4.3 Results Graphs

After clicking into case results, a graph of the result can be displayed by clicking on the graph button, shown below with the red box and arrow. As was the case for tables, the black box and arrow below shows where drop-down menus allow the user to choose what will define the x-axis and key labeling for the graph. The blue box and arrow then determine what data will be displayed on the graph, e.g. from which case (Reference, Scoping Plan, or Alternative 1) data will be displayed.



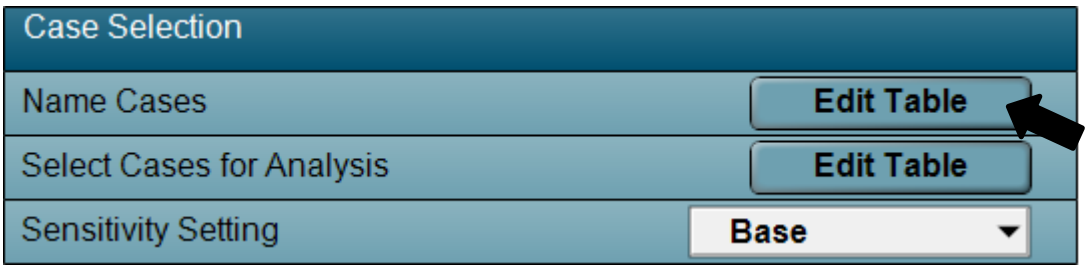
An example graph for GHG emissions by output year for the Reference case is displayed below.



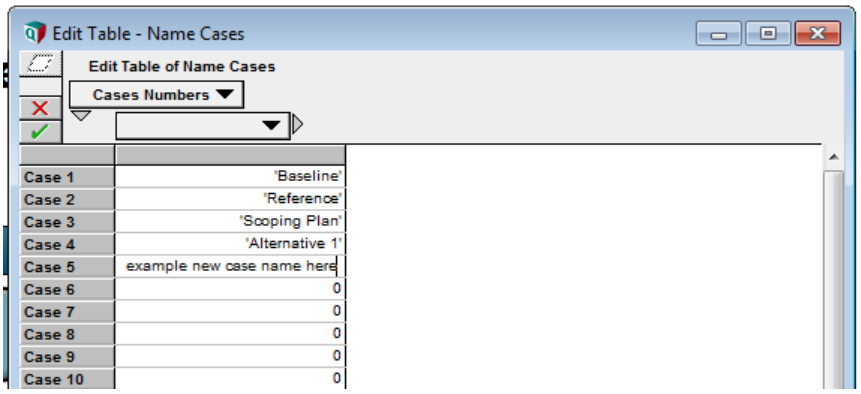
4. User-Defined Cases

4.1 Naming a User-Defined Case

To create a new case, first give your case a new name. The user should begin by clicking "Edit Table" next to the "Name Cases" label on the main user interface.



This will bring up the table of pre-defined and available case names. Any unnamed cases are available to be named by the user. Existing cases can also be re-named if desired. An example is shown below.



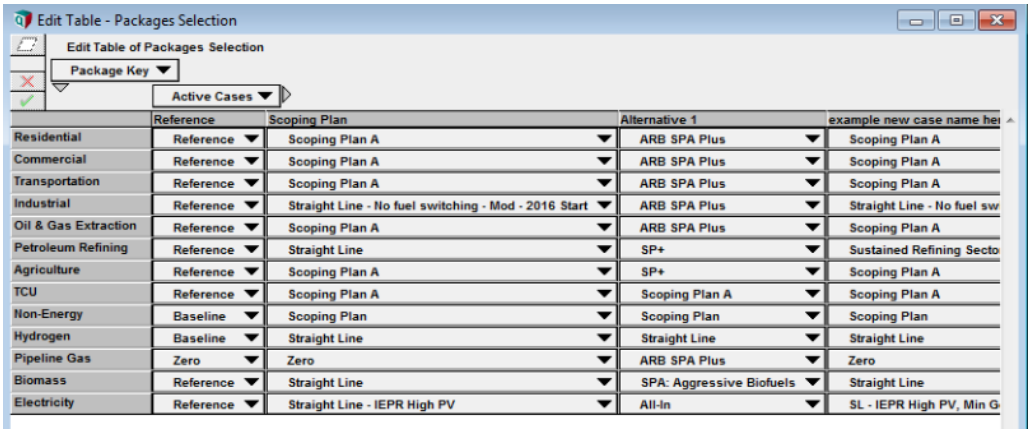
Double clicking in these boxes allows the user to edit the name of the case. New cases will have arbitrary packages assigned by default. The user must change this assignment by creating new packages or selecting different packages (see 4.2 and 4.3).

4.2 Selecting Packages

Once the user has selected their newly named case for analysis, the packages associated with that case must be changed from the default by double clicking the "Subtable" label next to Packages Selection.

The user may then select which package to associate with each sector (Residential, Commercial, Transportation, Industrial, Oil & Gas Extraction, Petroleum Refining, Agriculture, TCU, Non-Energy, Hydrogen, Pipeline Gas, Biomass, Electricity) using drop-down menus. This functionality allows the user to combine packages in ways that are not covered by pre-defined cases.

Below is an example of packages associated with scenarios (Case names listed across top row, Sectors in far left column).



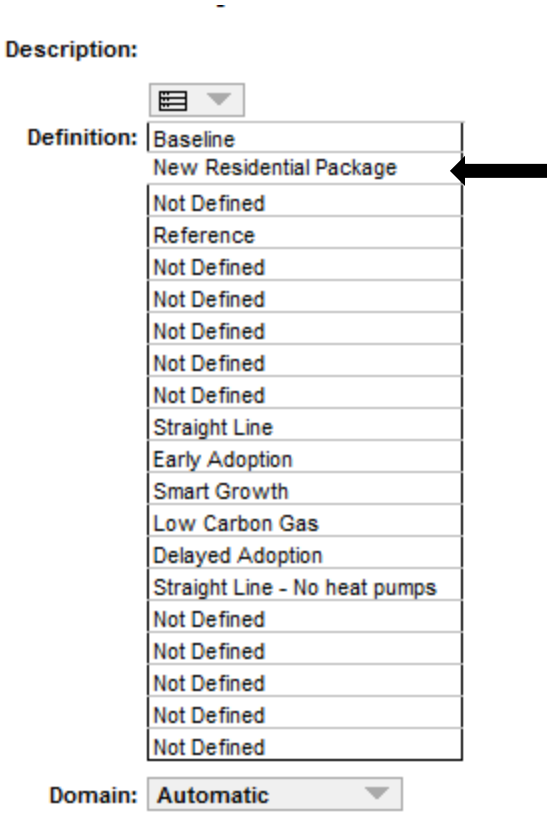
	Reference	Scoping Plan	Alternative 1	example new case name he
Residential	Reference	Scoping Plan A	ARB SPA Plus	Scoping Plan A
Commercial	Reference	Scoping Plan A	ARB SPA Plus	Scoping Plan A
Transportation	Reference	Scoping Plan A	ARB SPA Plus	Scoping Plan A
Industrial	Reference	Straight Line - No fuel switching - Mod - 2016 Start	ARB SPA Plus	Straight Line - No fuel sw
Oil & Gas Extraction	Reference	Scoping Plan A	ARB SPA Plus	Scoping Plan A
Petroleum Refining	Reference	Straight Line	SP+	Sustained Refining Secto
Agriculture	Reference	Scoping Plan A	SP+	Scoping Plan A
TCU	Reference	Scoping Plan A	Scoping Plan A	Scoping Plan A
Non-Energy	Baseline	Scoping Plan	Scoping Plan	Scoping Plan
Hydrogen	Baseline	Straight Line	Straight Line	Straight Line
Pipeline Gas	Zero	Zero	ARB SPA Plus	Zero
Biomass	Reference	Straight Line	SPA: Aggressive Biofuels	Straight Line
Electricity	Reference	Straight Line - IEPR High PV	All-In	SL - IEPR High PV, Min G

4.3 Creating New Packages

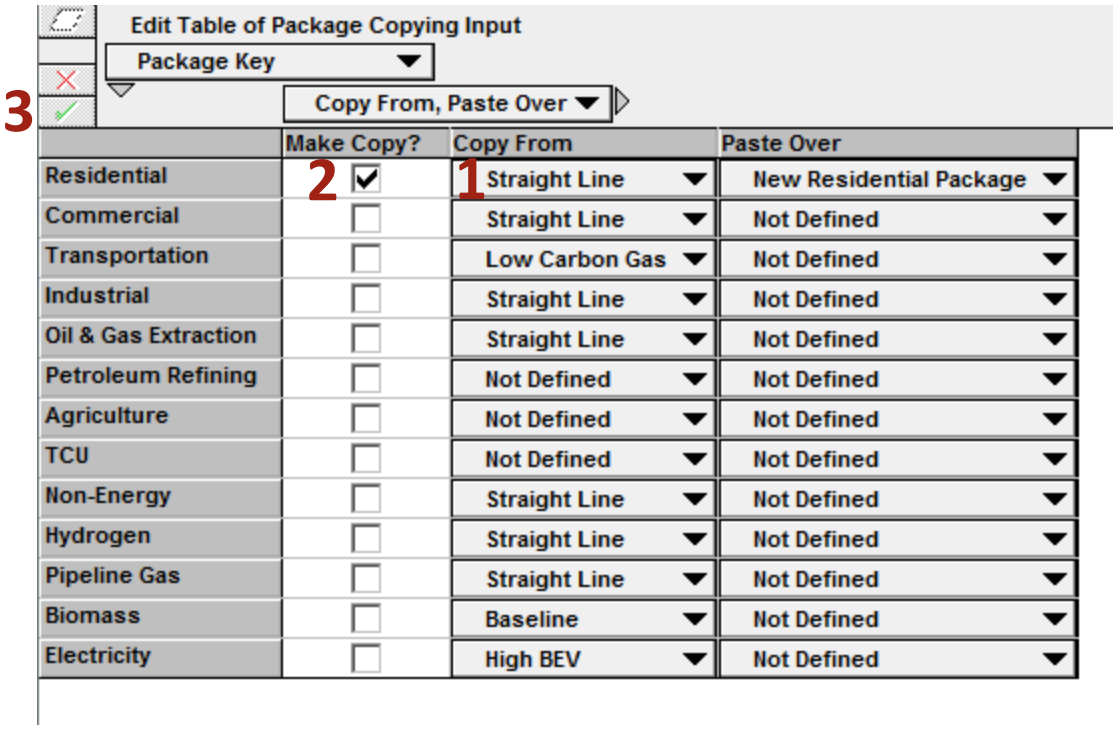
To begin the process of creating a new package, click the “Name Packages” button shown below on the opening CA PATHWAYS screen.

The user may then select which sector they would like to create a new package for. The **black** arrow below on the Main Package Screen points to the Residential Sector packages as an example.

The user may then name their new package by retitling any of packages not associated with the pre-defined cases.

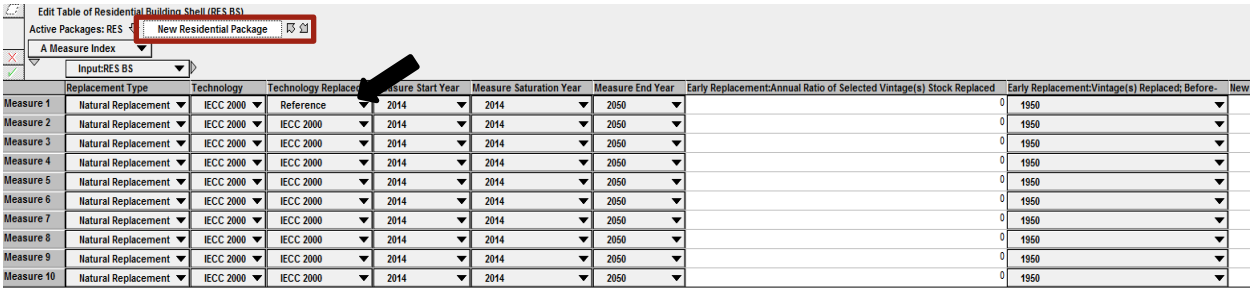


Next, the user can copy over data from one of the pre-existing packages to this new package by clicking "Package copying input: edit table" where the **blue** arrow is shown two figures above on the Main Package Screen. Then, on the screen displayed below, the user (1) chooses which package to copy from to their new package, (2) checks the box, and (3) hits the green check mark. It is very important that the user ensure they **DO NOT** choose to copy from one pre-existing package over another, as that **WILL** change the contents of the other package, leaving it mislabeled. Please ensure you have checked only the boxes to copy over your newly created package. Note: the package copying tool is not currently implemented for biomass packages, and attempts to copy / edit biomass packages may result in errors or incorrect results.



The user can then finish the new package copying process by clicking “Copy New Package” on the Main Package Screen, as pointed to three figures above by the **red** arrow.

The user may now edit this new package by changing any of its underlying measures, equations, etc. For example, for the “New Residential Package” created above, the user may select this case as one to be evaluated (see Section 3.3), then change e.g. measures associated with that package by entering one of the associated sectoral tables, as shown below. The user should ensure they change the correct package by toggling to the name of their newly created package on the “Active Packages” list in the red box below. By selecting any of the drop down menus (example pointed to by black arrow), the user can then change the package’s measures.



Finally, the user can associate this package with a scenario by creating a new scenario (see 4.1) and selecting this package as one of the packages associated with that scenario (see 4.2).

4.4 Evaluating Results

Results of a user-defined case are obtained and evaluated in the same way as results of a pre-defined case. See section 3.3-3.5.