Project Drawdown

Model Description for Code/Earth Hackathon

Overall Description of Modelling Effort

The models developed by project drawdown each examine the emissions and financial effect of aggressive adoption of a specific solution to climate change. Project Drawdown's models are developed in Microsoft Excel using standard templates that allow easier integration since integration is critical to the bottom-up approach used. Two main templates were used: Reduction and Replacement Solutions (RRS) model for energy reduction and replacement and the Biological Sequestration (Land) model for extracting carbon dioxide out of the atmosphere via natural processes (e.g. Afforestation). A third model type was used for food demand where specific country-level consumption patterns were used. For the Hackathon, we will focus on the RRS model.

Model Structure

Each model compares a conventional approach or technology to the solution. This therefore required that the conventional be clearly defined and delimited. For urban transport, this was typically private internal combustion engine (ICE) car travel, and for electricity generation, the conventional generation distribution of coal, oil and gas. Some solutions differed from these appropriately.

The adoptions of both conventional and solution were projected for each of several scenarios from 2015 to 2050 and the comparison of these scenarios (for the 2020-2050 segment[1]) is what constituted the published results. The scenarios compared are the baseline "Reference" (REF) and the "Project Drawdown Scenario" (PDS). There are at least three PDS scenarios for each solution, and these are all compared to the REF. In other words, published results equal the difference between the total costs or emissions (for the conventional and solution) in the PDS and the total costs or emissions in the REF scenario for the period 2020-2050.

All non-land solution and conventional adoption is assumed bounded by the total addressable market (TAM) which is specifically defined for each solution but may be shared across several competing solutions (such as all the electricity generation solutions and conventional technologies using the same TAM). The adoption and TAM's are defined in units of functional demand, which is the most natural unit of demand supplied by the competing technologies and is often defined according to the ISO standards[2]. For many solutions, the functional unit is obvious, such as tera-Watt-hours (TWh) of electricity for all electricity generation solutions, and passenger-km for passenger transportation solutions. Others were more challenging to define, and the research team selected units that could best allow a measurement of adoption, could be compared to existing literature, and could be used in other calculations throughout the model such as normalizing input and secondary variables. Actual implementation of solutions and conventional approaches was measured with implementation units defined for each, and this was the unit on which first costs and fixed operating costs depended. As an illustration, for electric vehicles, this was "car", and for all land solutions, it was million hectare.

[1] For most results, only the differences between scenarios, summed over 2020-2050 were presented, but for the net first cost, the position was taken that to achieve the adoptions in 2020, growth must first happen from 2015 to 2020, and that growth comes at a cost which should be accounted for, hence net first cost results represent the period 2015-2050.

[2] ISO refers to the standards defined by the International Standard Organization which includes units for measurement. ISO includes all of the SI (International System) units common in international scientific literature (also called the metric system) and is in contrast to the imperial system and US customary units.

Summary of Model Sheets/ Modules

The table below describes the main modules used for calculation of each solution's impact. An obvious theme from the descriptions below should be the need for transparency in all operations (i.e. record of processes done). Individual solutions may have additional Excel sheets for custom calculations required for that solution only, but these are chiefly used to store additional data and pre-process data for input into the modules below. These additional should be considered low priority. Note: CO2- carbon dioxide, CH4 – methane, N2O – nitrous oxide, PPM parts per million (concentration metric).

Table 1 Summary of Modules of Project Drawdowns RRS Model

Priority	Sheet Name	Description and Purpose	Inputs	Outputs
		INPUT DATA MODULES		
High	**Variable Meta-Analysis (and Variable Meta-Analysis-Open)**	This sheet is used for collecting data on the various key assumptions that feed the controls used to calculate the key results. All variables used in the analysis are documented here. By entering data in the appropriate cells, a basic sensitivity analysis will be conducted based on standard deviations (S.D.) around the mean of all data collected. The results are reported as Mean, High, and Low, and appear on the **Advanced Controls** Sheet as reference values when deciding on the key inputs for the model. The second version (**Variable Meta-analysis-Open**) will normally remain blank when the model is released to the public, with the main version storing all the data collected by Project Drawdown but with raw values removed to avoid Copyright issues. The aim is to record the full information needed to determine variable sources to include or not in analysis, ensure conversion consistency (same conversion factors) and transparency and to record all data collected for potential future use. Models are presented with a hidden internal version where the raw data are expunged for copyright risk management, and a public empty sheet where users can enter their own data. On **Advanced Controls**, users can select which data source to use for statistics of each variable. This sheet also calculates learning rates at the bottom.	Some generic unit conversion factor data stored on sheet. User inputs the raw data and much meta-data about each datapoint used with full reference information including direct links to online sources. Module Inputs: **Advanced Controls** (for key settings, common units, learning rate information, first costs, technology lifetimes), **Helper Tables** (for adoptions – learning rate calculations)	Statistical summaries of model variables. Used by Modules: **Advanced Controls**, **Variable Summary**

Priority	Sheet Name	Description and Purpose	Inputs	Outputs
High	**TAM Data**	Provides an area for users to input various future market growth scenarios found in the literature for each Drawdown Region. Automatically analyses the market growth scenarios provided and uses various regression fits (least squares, 2nd and 3rd degree polynomial, exponential) to estimate annual values for high, medium, and low market growth scenarios.	User inputs the projected market data (TAM) from varied sources, possibly after interpolating the sources using the **Data Interpolator**. Module Inputs: **Advanced Controls** (for key variables and settings)	Grouped and combined annual market estimates over analysis period, including interpolations of same. Used by Modules: **Unit Adoption Calculations**,
		ADOPTION CALCULATION MODULES		
High	**Adoption Data**	Provides an area for users to input various existing future adoption scenarios for each found in the literature for each Drawdown Region. Allows easy visualization of the projections for comparison and classification. Generates a meta-analysis of the adoption scenarios provided and uses various regression fits (least squares, 2 and 3 degree polynomial, exponential) to estimate annual values for high, medium, and low adoption scenarios. For statistical reasons, each input projection should have data for all years, and so interpolation is often performed on the raw data. For Copyright reasons, this raw data should not be in the public version of the model.	User input of data from published sources. Often the data is not in exactly the form required, and pre-processing happens, which uses the **Data Interpolator** sheet or additional sheets for custom calculations.	Grouped and combined adoption projection estimates over analysis period, including interpolations of same. Used by Modules: **Advanced Controls**, **Helper Tables**,
High	**Custom PDS Adoption**	Allows recording of customized PDS adoption scenarios based on the analysis of existing growth prognostications. Any custom process can be used to calculate the adoption, and it is stored here along with extensive documentation of the procedure followed.	User inputs the data which may be copied or linked to other sheets in the model. Module Inputs: **Unit Adoption Calculations** (for the TAM)	Projections of adoption developed by Project Drawdown researchers with full documentation. Used by Modules: **Helper Tables**, **Advanced Controls**,

Priority	Sheet Name	Description and Purpose	Inputs	Outputs
Medium	**S-Curve Adoption**	Provides tools for calculating several types of S-Curve to represent PDS adoption (including Logistic, Bass Diffusion Model and combinations of polynomials)	User enters the parameters of the chosen S-Curve method including the fully custom S-Curve Module Inputs: **Advanced Controls** (for key variables and settings, TAM)	S-Curve based adoptions of solution by region. Used by Modules: **Helper Tables**,
Medium	**Data Interpolator**	Here users can interpolate and extrapolate data (TAM, Adoption) for missing years before entering into model. The sheet is designed to support finding the best fit curve visually (which is normally easy in Excel, except for the hack added: Logistic S-Curve, which requires that a separate parameter is changed by Excel optimization tools). Additionally, the module allows application of an assumption that older data can be adjusted to the base year by scaling according to population ("Population Harmonization")	Sheet stores UN Population division's historical projections of global and regional populations (hidden). User selects settings and pastes in available data then chooses the best interpolation fit from the available options.	Best-fit curves for each projection of adoption or TAM with missing years (in range 2014-2050). Used by Modules: **Adoption Data**, **TAM Data**,
		INTERNAL CALCULATION MODULES		

Priority	Sheet Name	Description and Purpose	Inputs	Outputs
High	**Unit Adoption Calculations**	Contains all principal calculations related to the TAM and adoption of the solution in both the PDS and REF scenarios. As the principal calculations sheet, users will not be using this sheet directly. In some cases, users will benefit from the some of the data contained on this sheet, (e.g. the population and GDP projections used in the PDS and REF scenarios). Almost all model results depend on calculations from this sheet.	Some data stored on sheet (population and GDP) Module Inputs: **Helper Tables** (for adoptions), **TAM Data** (for TAM), **Advanced Controls** (for key variables: years of analysis, conversions, energy consumption, direct and indirect emissions), **Emissions Factors** (for grid and fuel emissions factors)	Estimations of adoptions normalized in many ways: in annual and cumulative functional units, in annual and cumulative implementation units, in annual units of the PDS relative to the REF scenario. Additional outputs are calculated. Used by Modules: **Advanced Controls**, **Custom PDS Adoption**, **Custom REF Adoption**, **Operating Cost**, **First Cost**, **Net Profit Margin**, **CO2 Calcs**, **CH4 Calcs**,
High	**Helper Tables**	This sheet identifies the adoption (in functional units) selected of the numerous options available on various sheets and calculates or copies that adoption for use by all other sheets.	Module Inputs: **Advanced Controls** (key settings, selection of adoption source and parameters), **Adoption Data**, **S-Curve Adoption**, **Custom PDS Adoption**, **Custom REF Adoption**, **Unit Adoption Calculations** (for TAM data)	Adoption of solution in REF and PDS scenarios. Used by Modules: **Advanced Controls**, **Unit Adoption Calculations**, **Variable Meta-analysis**, **Variable Meta-analysis-Open**,

Priority	Sheet Name	Description and Purpose	Inputs	Outputs
High	**Operating Cost**	This sheet is used for calculating the comparative ongoing costs of the PDS scenario and the REF scenario (presented in many different ways like net cost, carbon dioxide abatement cost, payback period etc.). It provides placeholders for factoring and conversions for any data needed to determine the operating costs per functional unit of measure for both the solution and conventional technologies/ practices being replaced. For the most part, the user will not use this sheet; however, in cases where a customized operating cost is required (i.e. when creating weighted average prices, accounting for regional deviations, etc.), users should use the placeholders on this sheet to perform requisite calculations.	User may enter any converting factors that may be needed, as well as any custom operating costs calculations. Module Inputs: **Advanced Controls** (for key variables, unit operating costs (fixed, variable and fuel costs), discount rates, unit conversion factors, technology lifetime), **Unit Adoption Calculations** (for adoption in functional units, and in implementation units), **First Cost** (for total annual implementation cost)	Annual and total operating cost of the solution and conventional technologies taking into account differences in capacity, lifetime, implementation dates, adoption rates, different fixed and variable costs, discount rate. NPV of implementation units. Used by Modules: **Advanced Controls**, **Detailed Results**,
High	**First Cost**	This sheet is used to calculate the cost inputs related to acquisition, installation and implementation of the solution and conventional technologies/practices. The base assumptions include the learning rate, the combined acquisition/installation cost. This sheet also uses these assumptions to calculate the yearly (marginal) cost of installing new implementation units required to meet demand, the yearly (marginal) cost of installing replacement units, and a cumulative sum of all those costs for both the PDS scenario and the REF scenario. For the most part, the user will not use this sheet; however, in cases where a customized first cost is required (i.e. when creating weighted average prices, accounting for regional deviations, etc.), users should use the placeholders on this sheet to perform requisite calculations.	User expected to enter any conversion factors needed and customized calculation data if necessary. Module Inputs: **Advanced Controls** (for unit conversion factors, implementation unit costs, learning rates, discount rate, price drop settings), **Unit Adoption Calculations** (for adoptions in implementation units)	Annual and total implementation costs (outright and relative to conventional technology) considering discount rates, learning rates and adoption rates. Used by Modules: **Advanced Controls**, **Operating Cost**, **Net Profit Margin**,

Priority	Sheet Name	Description and Purpose	Inputs	Outputs
High	**CO2 Calcs**	This sheet includes CO2 and other GHG metrics, including CO2 million metric tons (MMT) reduced by region and year, CO2-eq MMT by region and year, and parts per million (PPM) atmospheric CO2 avoided based on pulse-response functions that account for residence time of CO2. It combines CO2 and CH4 values provided into one ppm-CO2-eq value.	Sheet stores some base year assumed greenhouse gas concentrations for CO2, CH4 and N2O. Module Inputs: **Advanced Controls** (for key variables and settings), **CH4 Calcs** (for total CH4 reduction), **Emissions Factors** (for grid and fuel emissions factors), **Unit Adoption Calculations** (for adoption in functional and implementation units, and energy consumption reduced)	Emissions reduction broken out by year and by type (fuel, grid, other direct and indirect emissions), Greenhouse gas concentration reduction estimates from emissions reduction Used by Modules: **Advanced Controls**, **Detailed Results**, **Carbon Price Analysis**,
Medium	**Net Profit Margin**	This sheet is used for calculating the comparative ongoing profit of the PDS scenario and the REF scenario. It provides placeholders for factoring and conversions for any data needed to determine the profit per functional unit of measure for the solution and conventional technologies/ practices being replaced. For the most part, the user will not use this sheet; however, in cases where a customized profit is required users should use the placeholders on this sheet to perform requisite calculations. This follows the same structure as the **Operating Cost** sheet, with a few changes.	User may enter any converting factors that may be needed, as well as any custom operating costs calculations. Module Inputs: **Advanced Controls** (for key variables, unit operating costs (fixed, variable and fuel costs), discount rates, unit conversion factors, technology lifetime), **Unit Adoption Calculations** (for adoption in functional units, and in implementation units), **First Cost** (for total annual implementation cost)	Annual profit margin increase from implementing solution instead of conventional, estimate of profit-based Net Present Value of an implementation unit. Used by Modules: **Detailed Results**,

Priority	Sheet Name	Description and Purpose	Inputs	Outputs
Medium	**CH4 Calcs**	A sheet that includes CH4 metrics, including CH4 metric tons reduced by region and year and parts per billion atmospheric CH4 avoided based on pulse-response functions that account for residence time of CH4. This sheet is available but is currently not used in the model calculations.	Module Inputs: **Advanced Controls** (for key variables and settings), **Unit Adoption Calculations** (for adoptions in functional units)	Net CH4 reduction and concentration reduction Used by Modules: **CO2 Calcs**,
		USER DASHBOARD INTERFACE MODULE		

Priority	Sheet Name	Description and Purpose	Inputs	Outputs
Medium	**Advanced Controls**	A sheet where the major "tweakable" parameters of the model are prominently displayed, along with many financial and GHG reduction results. This allows users of the model to easily change parameters and see their impact on results. These inputs represent the major assumptions used in the model, and can easily be over-written by users for using their own inputs or performing sensitivity analysis.	This sheets pulls data from almost every other sheet and allows user selections of model settings and inputs. It then sends these settings to the calculation sheets. Module Inputs: **Unit Adoption Calculations** (for TAM, adoptions in implementation unit and functional unit/results, fuel and electricity consumption reduced), **Adoption Data** (for adoption projections, and source names), **Variable Meta-Analysis** (for summary statistics of each variable), **Emissions Factors** (for fuel emissions factors and global warming potentials), **Custom PDS Adoption** (for scenario names), **Custom REF Adoption** (for scenario names), **Helper Tables** (for selected adoption), **First Cost** (for total implementation costs), **Operating Cost** (for total operating costs, payback period, lifetime cashflow NPV, abatement cost), **CO2 Calcs** (for total emissions reduction: direct and indirect, PPM values and rates)	Control over all key aspects of model. Key outputs. Used by Modules: **Variable Meta-analysis**, **Variable Meta-analysis-Open**, **TAM Data**, **Operating Costs**, **Net Profit Margin**, **First Cost**, **CO2 Calcs**, **Helper Tables**, **S-Curve Adoption**, **Basic Controls**, **Detailed Results**, **Variable Summary**, **Carbon Price Analysis**, **CH4 Calcs**,

Priority	Sheet Name	Description and Purpose	Inputs	Outputs
Low	**Basic Controls**	This is a very simplified version of the **Advanced Controls** sheet that automates some of the inputs . A sheet where the most commonly used parameters of the model are available for editing, along with the overall financial and GHG reduction results. This allows users of the model to easily change parameters and see their impact on results.	User is expected to enter the values, but the existing inputs to and results from the model come from the **Advanced Controls** sheet.	Control over most basic inputs of model. Most basic outputs. Used by Modules: N/A
		MODEL OUTPUT MODULE		
High	**Detailed Results**	presents a full set of results from the model including all those presented on **Advanced Controls**, possibly a few more and several plots of the outputs. The sheet also allows exporting of the results to a PDF.	Module Inputs: **Advanced Controls** (for key settings, variables and many outputs), **Operating Cost** (for cashflow NPV, annual operating costs, payback period: automatically recalculated by VBA), **Net Profit Margin** (for profit-based cashflow NPV and payback periods), **CO2 Calcs** (for annual CO2-eq reduction, CO2-eq concentration reductions)	A full set of model outputs for at least a single scenario, with trends and graphics where useful. Used by Modules: N/A
Low	**Variable Summary**	Shows the summary of the variables listed on **Variable Meta-Analysis** along with the values used in the model on **Advanced Controls**. This sheet is populated by pressing a button on the **Variable Meta-Analysis**, and although it comes filled with the summary of the data used by the Research Team, the user will only summarize the data on the sheet on which the button is pressed. The sheet also allows exporting the table to a PDF.	Module Inputs: **VBA code** scans the **Variable Meta-analysis** or V**ariable Meta-analysis-Open** sheet for any variable with data and extracts the statistical summary from that sheet then extracts the value entered in the model for that variable on the **Advanced Controls** Sheet.	A summary of all the key variables used in the model including a brief statistical summary. Used by Modules: N/A

Priority	Sheet Name	Description and Purpose	Inputs	Outputs
Low	**Custom REF Adoption**	Contains placeholders to construct customized REF adoption scenarios based on the analysis of existing reference prognostications.	User inputs the data which may be copied or linked to other sheets in the model. Module Inputs: **Unit Adoption Calculations** (for TAM)	A set of Drawdown-developed REF scenarios of solution adoption to replace the default REF scenario of fixed adoption in % terms. Used by Modules: **Advanced Controls**, **Helper Tables**,
Low	**Carbon Price Analysis**	Allows the user to simulate the change to the results shown on **Advanced Controls** when carbon prices are added to the economies represented by the results. Users can enter three cases of carbon prices than vary in simple or complex ways, and automatic calculators are added to calculate linear and fixed carbon price curves. *This sheet does not alter any other part of the model.*	User enters any Carbon-price specific data here including sources, full reference information and the actual curve of prices for carbon as they change over time. Module Input: **Advanced Controls** (for key outputs: implementation units, emissions reduction, marginal first cost, operating costs, abatement cost and cash flow NPV), **CO2 Calcs** (for direct and indirect emissions reduction)	An altered set of main model results taking into account the potential emissions impact of a price on carbon. Used by Modules: N/A
		DATA STORAGE MODULES		

Priority	Sheet Name	Description and Purpose	Inputs	Outputs
High	**Emissions Factors**	Contains the emission factors for the electric grid and primary fuel combustion. Emissions factors related to electricity generation (kg CO2 per kWh) for various regions and years for both CO2 and CO2-eq are derived from the projected energy generation mix and direct/indirect emissions factors by generation type taken from the IPCC AR5 Model Database, AMPERE v3 MESSAGE Base and 450 scenarios. Fuel emissions factors are calculated using the methodology recommended in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2, Annex 1. Changes should not be made here, and users should contact the Project Drawdown Research Team for more information on the calculations contained here.	Data on expected REF- (and placeholder PDS-) scenario global average electricity grid emissions factors are stored here. Fuel emissions factors (and background data) and costs are also stored on this sheet for a wide range of fuels of interest to Project Drawdown along with conversion factors for fuel energy content and Global Warming Potential (GWP) values	A record of all key fuel and grid emissions factors. Used by Modules: **Advanced Controls**, **CO2 Calcs**, **Unit Adoption Calculations**,
High	**ScenarioRecord**	Holds the inputs and outputs for each of the Project Drawdown Scenarios published in the Drawdown book and presented at www.drawdown.org. Advanced users can store and load their own scenarios. The goal is not just to hold a snapshot, but to allow a researcher to reload and adjust scenarios.	Full model input data and key output data are stored here to be able to recreate a specific set scenario of outputs of the model. User is required to add explanatory data on scenario. Module Inputs: **Advanced Controls** (for key variables, settings and outputs), **Detailed Results** (output values and graphs), **Unit Adoption Calculations** (for TAM), **Helper Tables** (for adoptions), **Operating Cost** (for annual operating costs), **CO2 Calcs** (for annual emissions reductions and concentration reductions),	A full record of the inputs and outputs of the model for any number of scenarios of interest to researchers, and possible tools for comparison of same. Used by Modules: **VBA Code**: for loading scenarios

Priority	Sheet Name	Description and Purpose	Inputs	Outputs
Low	**Regions-Countries Sorting**	A tool to help sort country-level data by the Drawdown Regions.	A list and regional classification of most countries and territories as used in Drawdown is stored here along with space to store data that is collected on a country-by-country basis.	A list of countries to allow easy sorting of datasets into Drawdown country groups. Used by Modules: possibly **TAM Data**, **Adoption Data**.
Low	**XLLANG**	This normally-hidden sheet stores Microsoft Office language codes which are used for storing and loading model scenarios which have formulae inputs. This is important since formulae are stored in the language of the Excel at the time of storage, and if opened in Excel with a different language, they may cause errors.	This sheet stores Microsoft language codes	A set of Microsoft language codes to provide easy access when stored scenarios are to be loaded. Used by Modules: **ScenarioRecord**,
		Modules With Data Storage or Input as a *Secondary* Purpose		
N/A	**Variable Meta-Analysis**	This sheet is chiefly in the Data input section of this table, but it does store some common conversion values including inflation factors and currency conversions to ensure consistency across Drawdown models.	(See above)	(See above)
N/A	**Adoption Data**	This sheet allows input of the adoption projections as noted above, but also stores all data collected.	(See above)	(See above)
N/A	**Advanced Controls**	This sheet is mainly the User Dashboard, as listed above, however is therefore stores the key inputs used in the model.	(See above)	(See above)
N/A	**Basic Controls**	As the secondary User Dashboard, this sheet also stores key inputs used in the model.	(See above)	(See above)
N/A	**Data Interpolator**	This sheet is mainly supporting the calculation of adoption and market trajectories, but in doing so, to ensure transparency in calculations, all interpolations are stored.	(See above)	(See above)
N/A	**Unit Adoption Calculations**	This sheet is mainly a calculation sheet as discussed earlier, but it also functions as a storage sheet for Population and GDP projections for all Drawdown Regions. These are used to scale other variables as necessary.	(See above)	(See above)

Priority	Sheet Name	Description and Purpose	Inputs	Outputs
N/A			(See above)	(See above)

Model Schematic

A visualization of the flow of data between the ***high priority*** model components is shown below. In that figure, we group certain modules together for simplicity and explain the sheets that comprise the groups.

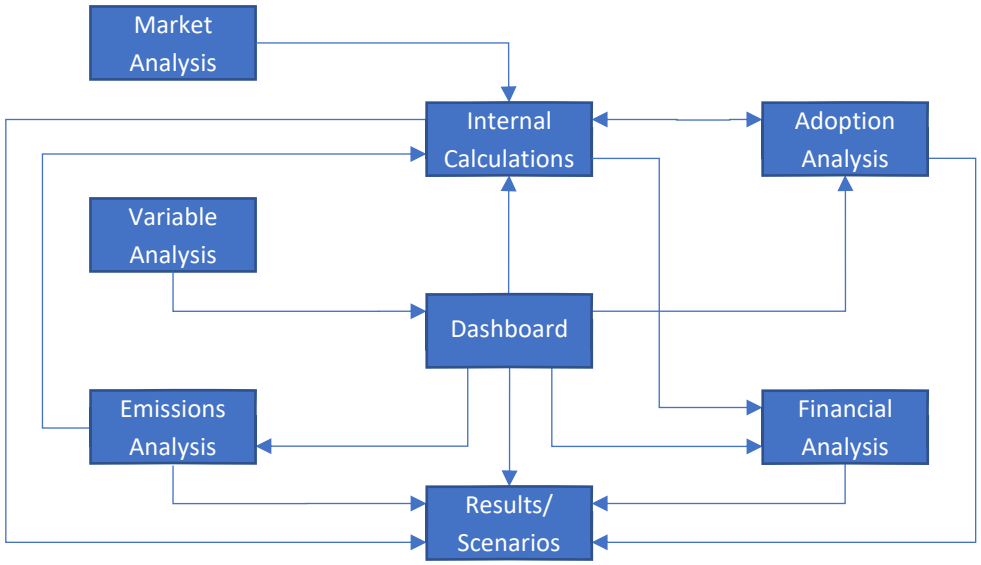

*Figure 1 Simplified Schematic of Connection Among various Components of Model. Note that: "Market Analysis" is **TAM Data**, "Internal Calculations" is **Units Adoption Calculations**, "Adoption Analysis" is **Adoption Data**, **Custom PDS Adoption** and **Helper Tables**, "Variable Analysis" is **Variable Meta-Analysis**, "Dashboard" is **Advanced Controls**, "Emissions Analysis" is **CO2 Calcs** and **Emissions Factors**, "Financial Analysis" is **Operations Costs** and **First Costs** and "Results/ Scenarios" is **Detailed Results** and **ScenarioRecord**.*

Code Order of Model Modules

Using the prioritization developed in the earlier table, and considering the dependencies between various modules as illustrated in the figure, the recommended order for modules coding (according to the groups of the figure) is as follows:

1. Variable Analysis: **Variable Meta-analysis**
2. Market Data: **TAM Data**
3. Adoption Analysis: **Adoption Data**, **Custom PDS Adoption**, **Helper Tables**
4. Internal Calculations: **Units Adoption Calculations**
5. Emissions Analysis: **CO2 Calcs**, **Emissions Factors**
6. Financial Analysis: **Operations Cost**, **First Cost**
7. Dashboard: **Advanced Controls**
8. Results/ Scenario: **Detailed Results**, **Scenariorecord**