Introduction of GREET1.7 Excel Model

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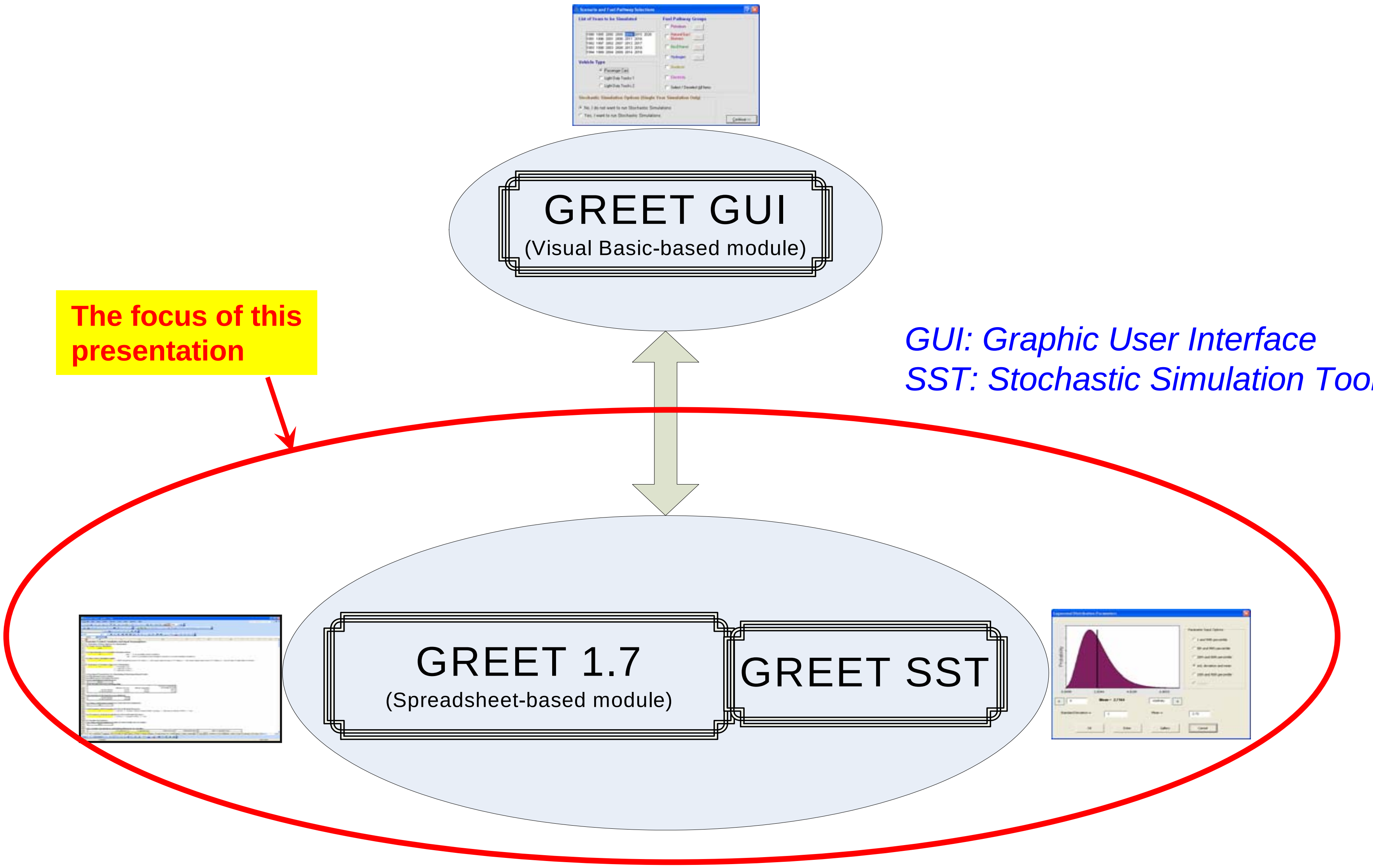
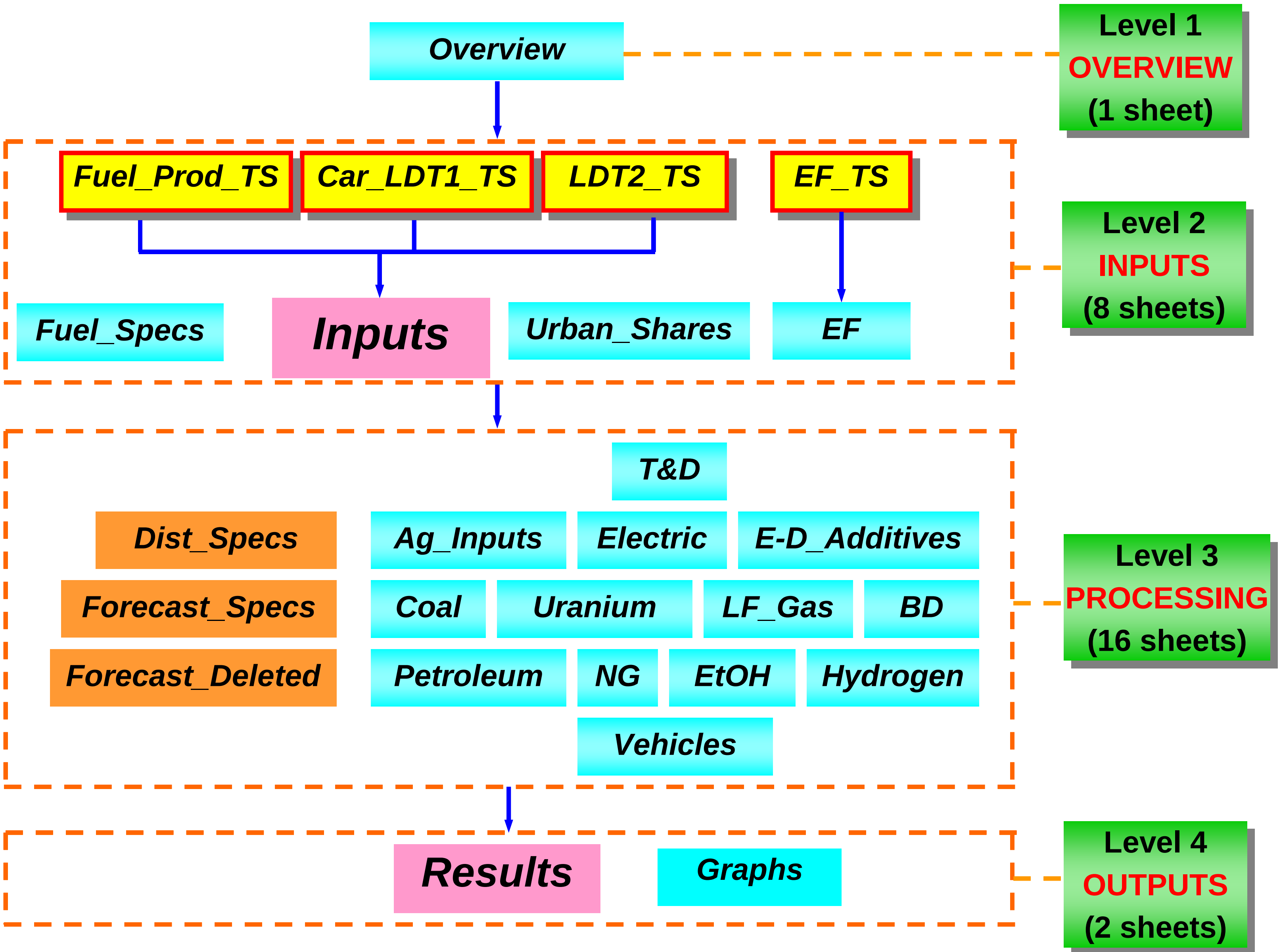
The Most Recent GREET 1.7 Model Includes 3 Modules



GREET1.7 Consists of 27 Microsoft® Excel Sheets



Brief Description of 27 Sheets in GREET1.7

- *Overview*: GREET copyright statement. It also presents a brief summary of each worksheet in GREET and is intended to provide brief introduction to the functions of each sheet.
- *Inputs*: Key input parameters that users can specify for GREET simulations. If users use the GREET GUI program, the GUI input values interact mostly with values in this sheet.
- *EF_TS*: Time-series tables for emission factors of combustion technologies applied to stationary sources.
- *EF*: Emission factors of combustion technologies by fuel type. This sheet interacts with EF_TS sheet.
- *Fuel_Specs*: Specifications (e.g., heating value, density, etc.) of individual fuels and global warming potentials of GHGs.
- *T&D*: Calculations of energy use and emissions for transportation and distribution of energy feedstocks and fuels.
- *Urban_Shares*: Share of urban emissions out of total emissions of criteria pollutants for major GREET simulated activities.
- *Fuel_Prod_TS*: Time-series tables for key parametric assumptions for well-to-pump fuel production processes. This sheet interacts with Inputs and other fuel production sheets.
- *Petroleum*: Calculations of well-to-pump energy use and emissions for petroleum-based fuels (including production of oxygenates).

Brief Description of 27 Sheets in GREET1.7 (Cont'd.)

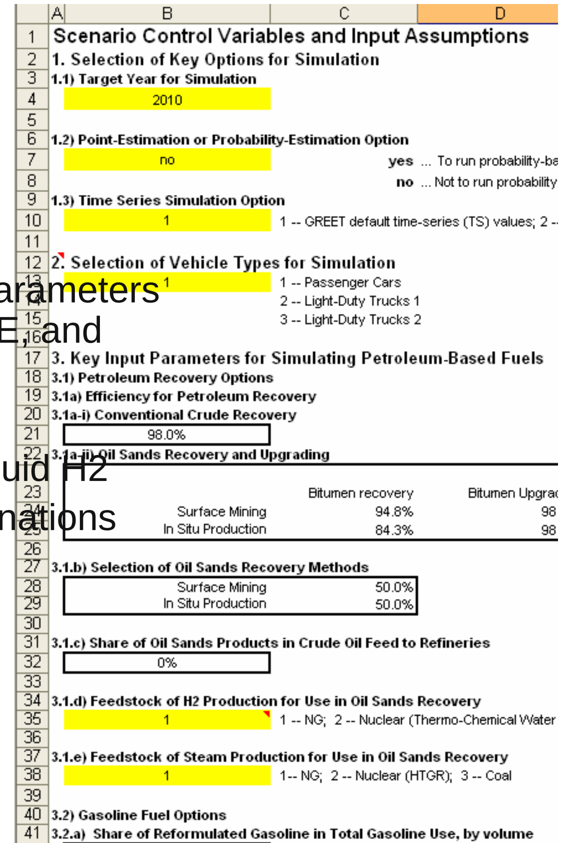
- *NG*: Calculations of well-to-pump energy use and emissions for NG-based fuels (plus flared gas to liquid fuels; landfill gas to methanol; and biomass to methanol, DME, and FT fuels).
- *Hydrogen*: Calculations of well-to-pump energy use and emissions for hydrogen production pathways.
- *Ag_Inputs*: Calculations of energy use and emissions for manufacturing agricutural inputs including fertilizers, herbicides, and insecticides.
- *EtOH*: Calculations of well-to-pump energy use and emissions for producing ethanol from corn and cellulosic biomass.
- *E-D_Additives*: Calculations of well-to-pump energy use and emissions for additives to blend ethanol in diesel fuel.
- *BD*: Calculations of well-to-pump energy use and emissions for biodiesel from soybeans.
- *Coal*: Calculations of energy use and emissions for coal mining.
- *Uranium*: Calculations of energy use and emissions for uranium ore mining and uranium fuel production.
- *LF_Gas*: Calculations of energy use and emissions for landfill gas recovery.

Brief Description of 27 Sheets in GREET1.7 (Cont'd.)

- *Electric*: Calculations of energy use and emissions for electricity generation.
- *Car_LDT1_TS*: Time-series tables of fuel economy and emission rates/changes associated with vehicle operations for passenger cars and light duty truck 1.
- *LDT2_TS*: Time-series tables of fuel economy and emission rates/changes associated with vehicle operations for light duty truck 2.
- *Vehicles*: Calculations of energy use and emissions for vehicle operations.
- *Results*: Well-to-pump and well-to-wheels energy use and emissions results for vehicle/fuel technology combinations.
- *Graphs*: Graphic presentation of energy use and emissions for various vehicle/fuel technology combinations.
- *Dist_Specs*: Detailed specifications of the input parameters built with distribution functions. The user is cautioned against making any changes to this sheet.
- *Forecast_Specs*: Detailed information of defined forecast items for a particular stochastic simulation run. The user is cautioned against making any changes to this sheet.
- *Forecast_Deleted*: List of the forecast items that were deleted, if any, as specified by the user. The user is cautioned against making any changes to this sheet.

The Inputs Sheet Contains Key Variables and Options for Each WTW Stage

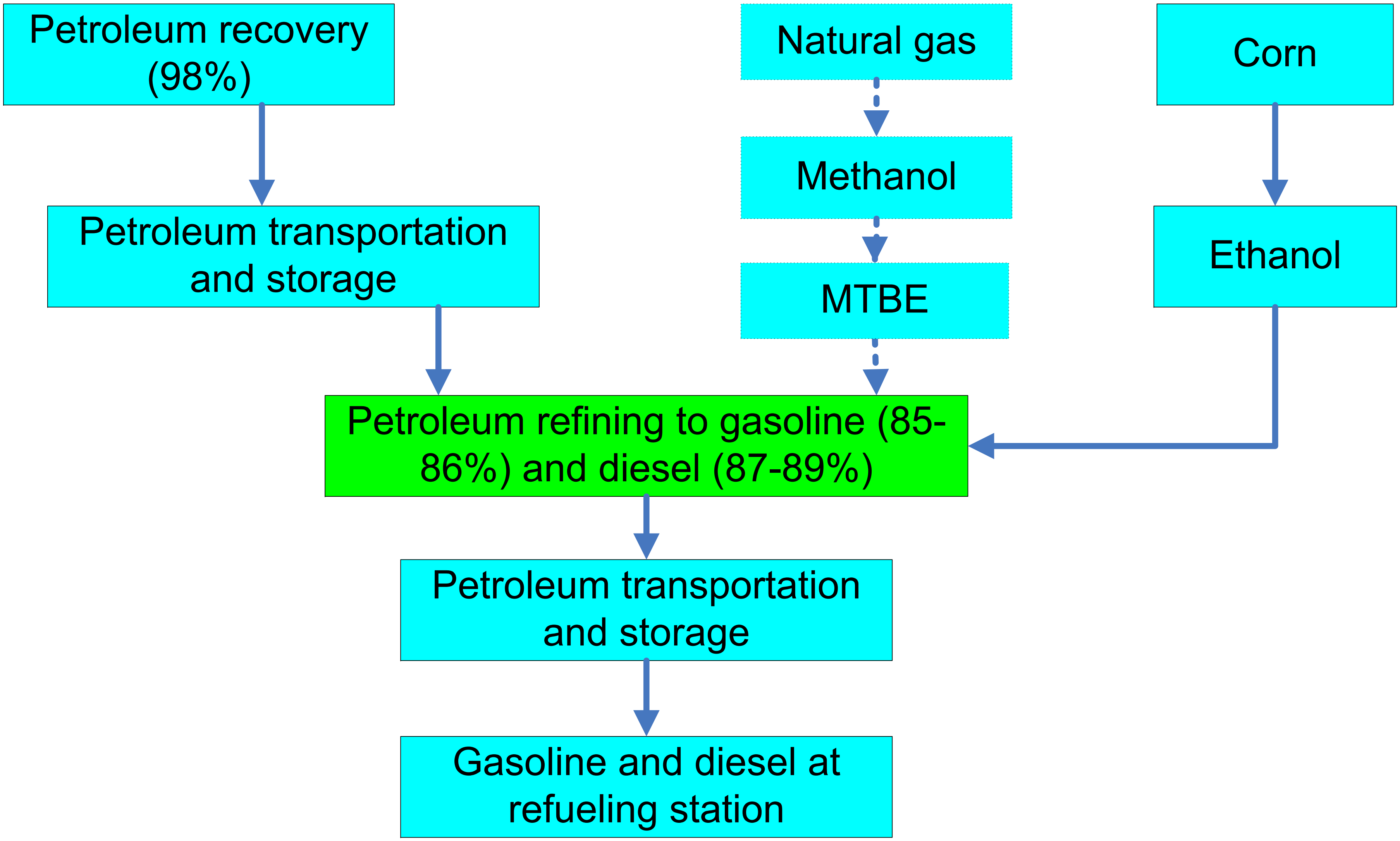
- This sheet presents key variables for various WTP and PTW scenarios, and specifies key parametric assumptions for GREET simulations
- This sheet is separated into fourteen sections:
  - Selection of key options for simulation
  - Selection of vehicle types for simulation
  - Key input parameters for simulating petroleum-based fuels
  - Key input parameters for simulating natural gas-based fuels (Input parameters for feedstocks [e.g., biomass] other than NG for simulating FTD, DME, and MeOH are also included in this section.)
  - Key input parameters for simulating hydrogen
  - Assumptions regarding boil-off effects of liquefied natural gas and liquid H_2
  - Transportation distance from feedstock production sites to final destinations
  - Key input parameters for simulating fuel ethanol
  - Key input parameters for simulating soybean-based biodiesel
  - Key input parameters for simulating electricity generation
  - Key input parameters for simulating vehicle operations
  - Key GREET default assumptions for WTP activities
  - Fuel economy and emission rates of baseline vehicles
  - Fuel economy and emission changes by alternative-fueled vehicles and advanced vehicle technologies
- This sheet serves as a bridge between the GREETGUI program and the GREET spreadsheet model running in the background, when users use the GREETGUI program to run the GREET model



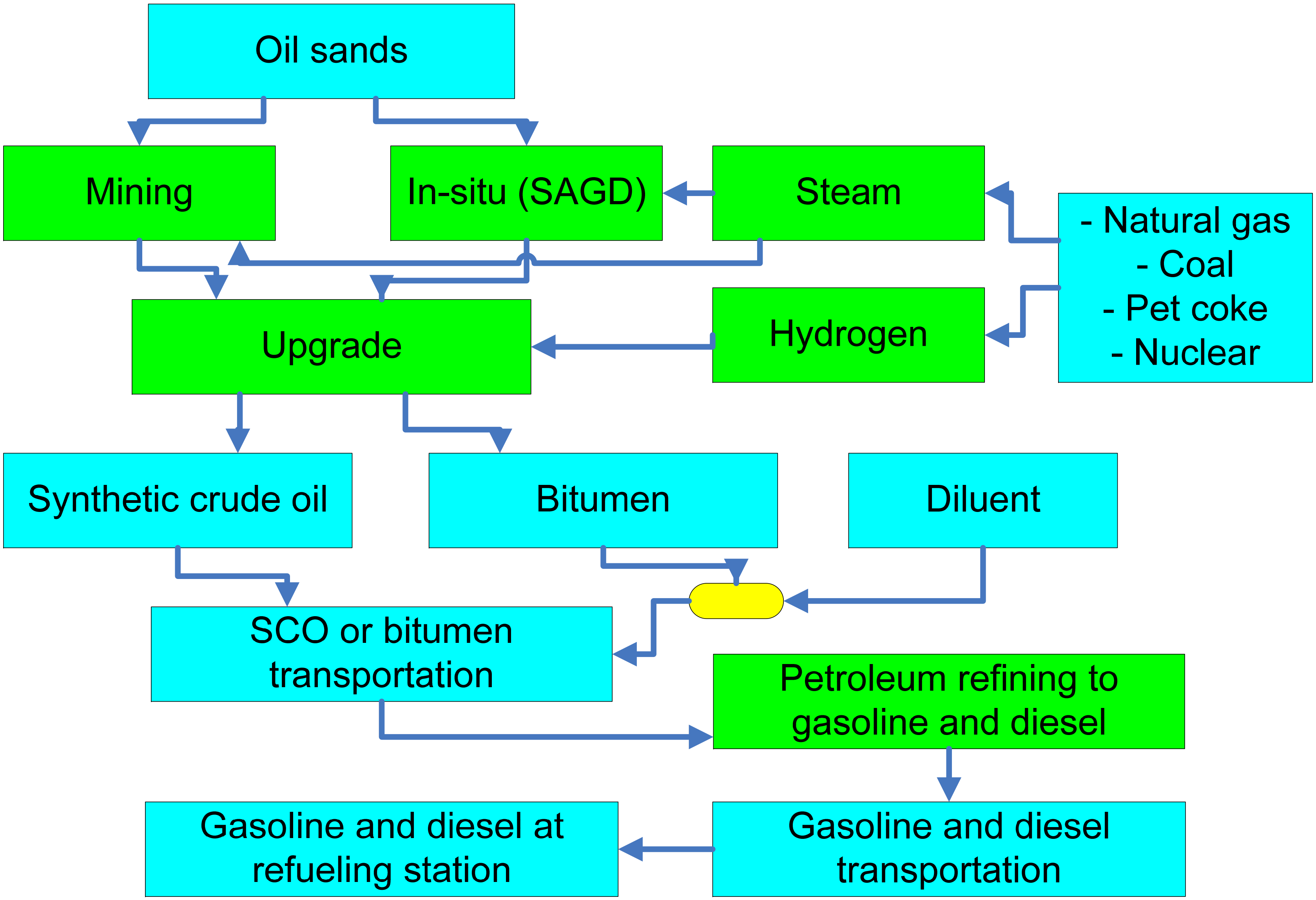
The Petroleum Sheet Serves as the Key Sheet to Calculate WTP Energy Use and Emissions Related to Petroleum-based Fuels

- This sheet calculates WTP energy use and emission rates for the following eight petroleum-based fuels:
  - Conventional gasoline (CG)
  - Reformulated gasoline (RFG)
  - California reformulated gasoline (CARFG)
  - Conventional diesel (CD)
  - Low-sulfur diesel (LSD)
  - Liquefied petroleum gas (LPG)
  - Crude naphtha
  - Residual oil
- The feedstock sources for petroleum fuels in GREET include conventional crude oil and oil sands from Canada.
- This sheet also presents calculations for MTBE, ETBE, and TAME, which can be used as oxygenates for the Federal RFG and CARFG fuels.
- This worksheet consists of the following five sections:
  - ***Scenario control and key input parameters*****.** The values in this section derive primarily from the *Inputs* sheet.
  - ***Shares of combustion processes for each stage*****,** which are used for emission calculations.
  - ***Calculation of energy use and emissions for individual stages*****.** In this section, GREET calculates energy use and emissions for each individual stage by considering energy efficiency, fuel use by type, fuel use by combustion technology, etc.
  - ***Calculation of energy use and emissions of oxygenate production***.
  - ***Summary of energy use and emissions*****.** Other sheets use the summary results from this sheet for individual vehicle/fuel WTW calculations.

Petroleum Refining Is the Key Energy Conversion Step for Gasoline and Diesel From Conventional Crude



The Pathway of Oil Sands to Gasoline and Diesel Requires A Large Amount of Steam and H_2



The Key Logic and Formula in Calculations of Energy Consumption and Emissions for Each Process Stage

- The ***energy efficiency*** is defined as [energy output]/[energy input].
- The ***energy use by each process fuel type i*** is calculated by:

$$EnergyUse_i = 1{,}000{,}000 \times \left(\frac{1}{EnergyEfficiency} - 1\right) \times Shares_i$$

- The ***total energy use*** calculates all the energy consumption (fossil energy plus renewable energy) for a given stage.
- The ***fossil energy use*** calculates fossil energy consumption (coal, NG and petroleum) for a given stage, which is a subset of ***total energy use***.
- The ***coal energy use*** calculates coal consumption for a given stage, which is a subset of ***fossil energy use***.
- The ***natural gas energy use*** calculates NG consumption for a given stage, which is a subset of ***fossil energy use***.
- The ***petroleum energy use*** calculates petroleum consumption for a given stage, which is a subset of ***fossil energy use***.

31	3) Calculations of Energy Consumption and Emissions for Petroleu				
32		Crude Oil			
33		Recovery	Transportation to U.S. Refineries	Transportation to CA Refineries	Storage
34	**Energy efficiency**	98.0%			
35	**Urban emission share**	2.0%	32.5%	47.5%	80.0%
36	**Loss factor**	1.000	1.000	1.000	1.000
37	**Shares of process fuels**				
38	Crude oil	1.0%			
39	Residual oil	1.0%			
40	Diesel fuel	15.0%			
41	Gasoline	2.0%			
42	Natural gas	61.9%			
43	Coal	0.0%			
44	Electricity	19.0%			
45	Refinery still gas	0.0%			
46	Feed loss	0.1%			
47	**Energy use: Btu/mmBtu of fuel throughput**				
48	Crude oil	204			
49	Residual oil	204			
50	Diesel fuel	3,057			
51	Gasoline	408			
52	Natural gas	12,635			
53	Coal				
54	Electricity	3,872			
55	Feed loss	28	62	62	0
56	Refinery still gas				
57	Natural gas flared	[illegible]			
58	Total energy	28,311	9,950	3,387	0
59	Fossil fuels	27,002	9,830	3,372	0
60	Coal	6,464	641	92	0
61	Natural gas	15,826	1,760	227	0
62	Petroleum	4,712	7,429	3,053	0
63	**Total emissions: grams/mmBtu of fuel throughput**				
64	VOC	0.654	0.546	0.273	
65	CO	3.957	2.543	1.217	
66	NOx	11.428	13.000	6.827	

Overview / Inputs / EF_TS / EF / Fuel_Specs / T&D / Urban_Shares / Fuel_Prod

The Key Logic and Formula in Calculations of Energy Consumption and Emissions for Each Process Stage (Cont'd)

- The ***total emissions*** for a given stage is calculated by:

$$EM_i = \left(\sum_j (EM_{cm,i,j} + EF_{up,i,j}) \times EC_j\right) \div 1{,}000{,}000$$

where

EM_i= Emissions of pollutant i in g/10^6 Btu of fuel throughput from a given stage;

$EM_{cm,i,j}$=Combustion emissions of pollutant i in g/10^6 Btu of process fuel j burned;

$EF_{up,i,j}$=Upstream emissions of pollutant i in g/10^6 Btu of process fuel j to produce and distribute the process fuel to the stage (considered within GREET through circular calculation programming); and

EC_j=Energy consumption of fuel j during the stage

- ***Shares of combustion processes*** for a given stage plays a key role in emissions calculations because different combustion processes may result in significantly different emission profiles.
- The calculation of ***urban emissions*** for a given stage involves one more factor: ***urban emission share***.

	3) Calculations of Energy Consumption and Emissions for Petrole				
32		Crude Oil			
33		Recovery	Transportation to U.S. Refineries	Transportation to CA Refineries	Storage
34	Energy efficiency	[illegible]			
35	Urban emission share	2.0%	32.5%	47.5%	80.0%
36	Loss factor	[illegible]	1.000	1.000	1.000
37	Shares of process fuels				
38	Crude oil	1.0%			
39	Residual oil	1.0%			
40	Diesel fuel	15.0%			
47	Energy use: Btu/mmBtu of fuel throughput				
48	Crude oil	[illegible]			
49	Residual oil	204			
50	Diesel fuel	3,057			
63	Total emissions: grams/mmBtu of fuel throughput				
64	VOC	0.654			
65	CO	3.957			
66	NOx	11.428			
67	PM10	1.449			
68	PM2.5	0.576			
69	SOx	2.387	5.927	3.950	
70	CH4: combustion	7.178	1.231	0.332	
71	N2O	0.055	0.019	0.006	
72	CO2	[illegible]	[illegible]	277	
73	VOC from bulk terminal	0.702	1.534	[illegible]	
74	VOC from ref. Station				
75	CH4: non-combustion	13.152	69.536	[illegible]	
76	Urban emissions: grams/mmBtu of fuel throughput				
77	VOC	0.046	0.539	0.752	0.000
78	CO	0.132	0.141	0.089	0.000
79	NOx	0.404	0.686	0.485	0.000
80	PM10	0.022	0.023	0.016	0.000
81	PM2.5	0.015	0.016	0.012	0.000
82	SOx	0.392	0.346	0.288	0.000

	2) Shares of Combustion Processes fo		
17		Crude Recovery	Oil Sands Recovery
18	Residual oil industrial or co	100.0%	100.0%
19	Diesel commercial boiler	25.0%	0.0%
20	Diesel stationary engine	50.0%	0.0%
21	Diesel turbine	25.0%	0.0%
22	Diesel locomotive		
23	Diesel HDE truck		100.0%
24	NG engine	50.0%	0.0%
25	NG large turbine	0.0%	0.0%
26	NG large industrial boiler	0.0%	100.0%
27	NG small industrial boiler	50.0%	0.0%
28	NG pipeline turbine		
29	Coal industrial boiler		100.0%

- The ***non-combustion emission*** items (e.g., evaporative VOC/CH4) are direct inputs in GREET.

The Key Logic and Formula in Calculations of Energy Consumption and Emissions for Each Process Stage (Cont'd)

Consideration of energy use and emissions of upstream stages for a fuel cycle involves circular calculation

$$EM_i = \left(\sum_j (EM_{cm\,i,j} + EF_{up\,i,j}) \times EC_j\right) \div 1{,}000{,}000$$

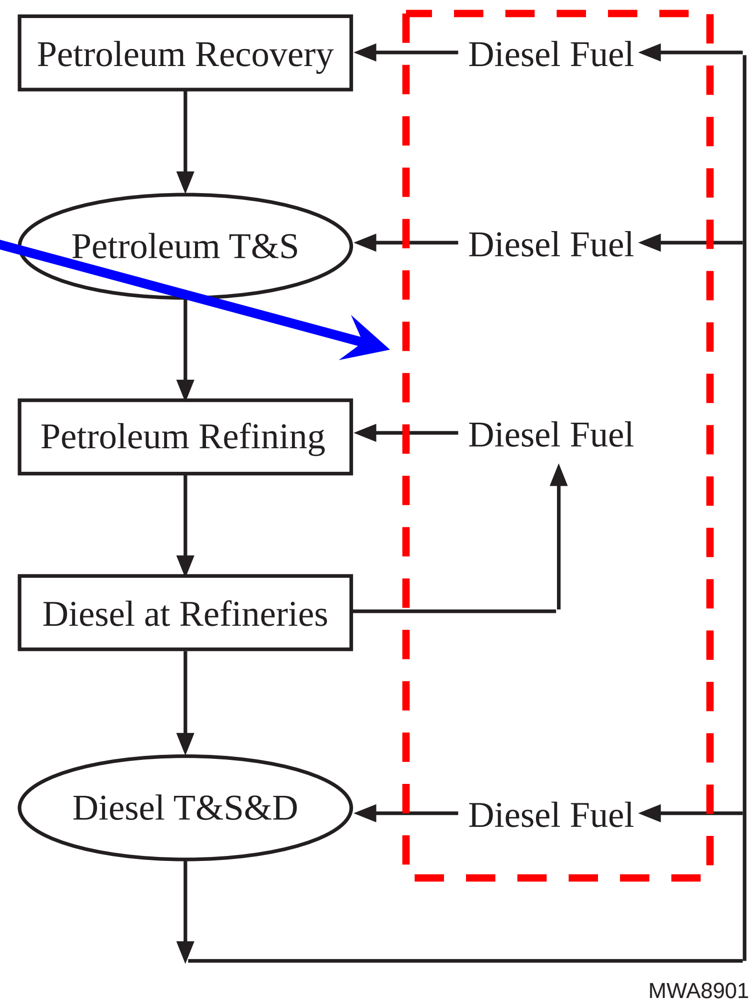
where

EM_i= Emissions of pollutant i in g/10^6 Btu of fuel throughput from a given stage;

$EM_{cm,i,j}$=Combustion emissions of pollutant i in g/10^6 Btu of process fuel j burned;

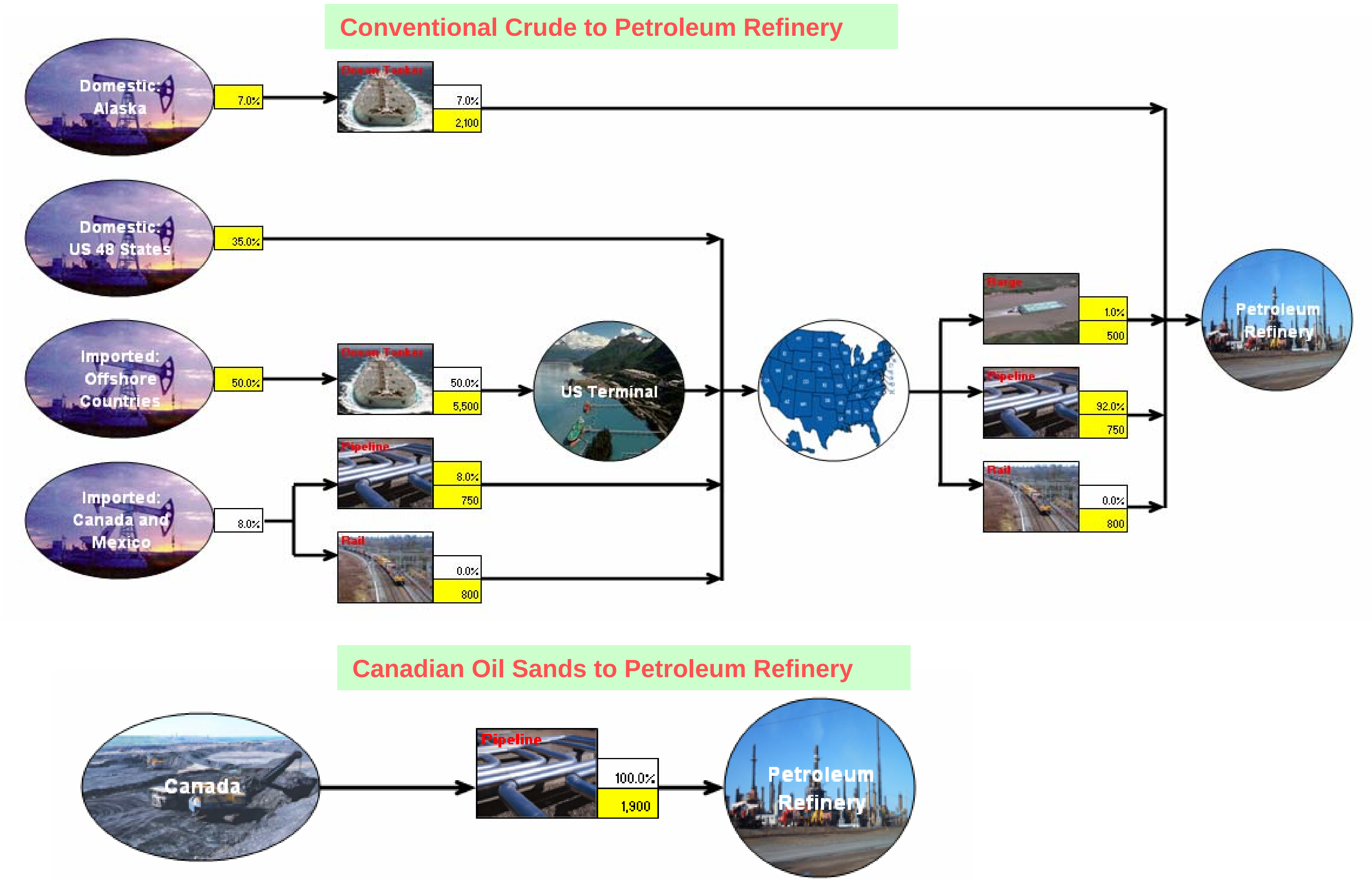
$EF_{up,i,j}$=Upstream emissions of pollutant i in g/10^6 Btu of process fuel j to produce and distribute the process fuel to the stage (considered within GREET through circular calculation programming); and

EC_j=Energy consumption of fuel j during the stage



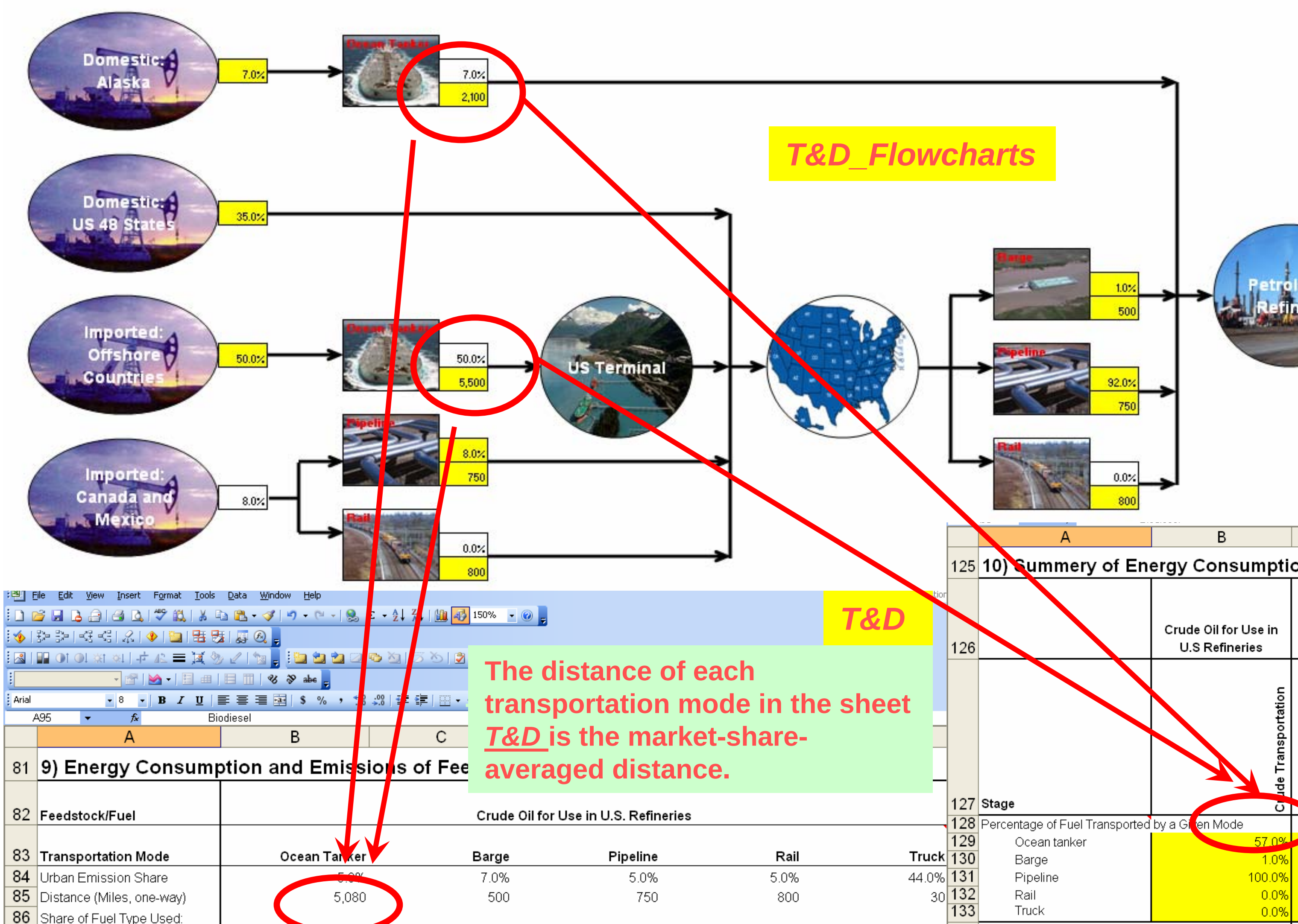
The GREET model applied Excel iteration calculation feature to perform circular calculations.

Transportation Modes and Distance Are Two Key Factors Affecting a Given WTP Transportation Activity



A New Sheet Presenting the T&D Flowcharts Is to Be Included in the Upcoming New GREET1.7 Version This Summer

Example :Conventional Crude to Petroleum Refinery



The distance of each transportation mode in the sheet *T&D* is the market-share-averaged distance.

The share of each transportation mode in the sheet *T&D* may not be the exactly 100% since not all the sources are transported by that mode.

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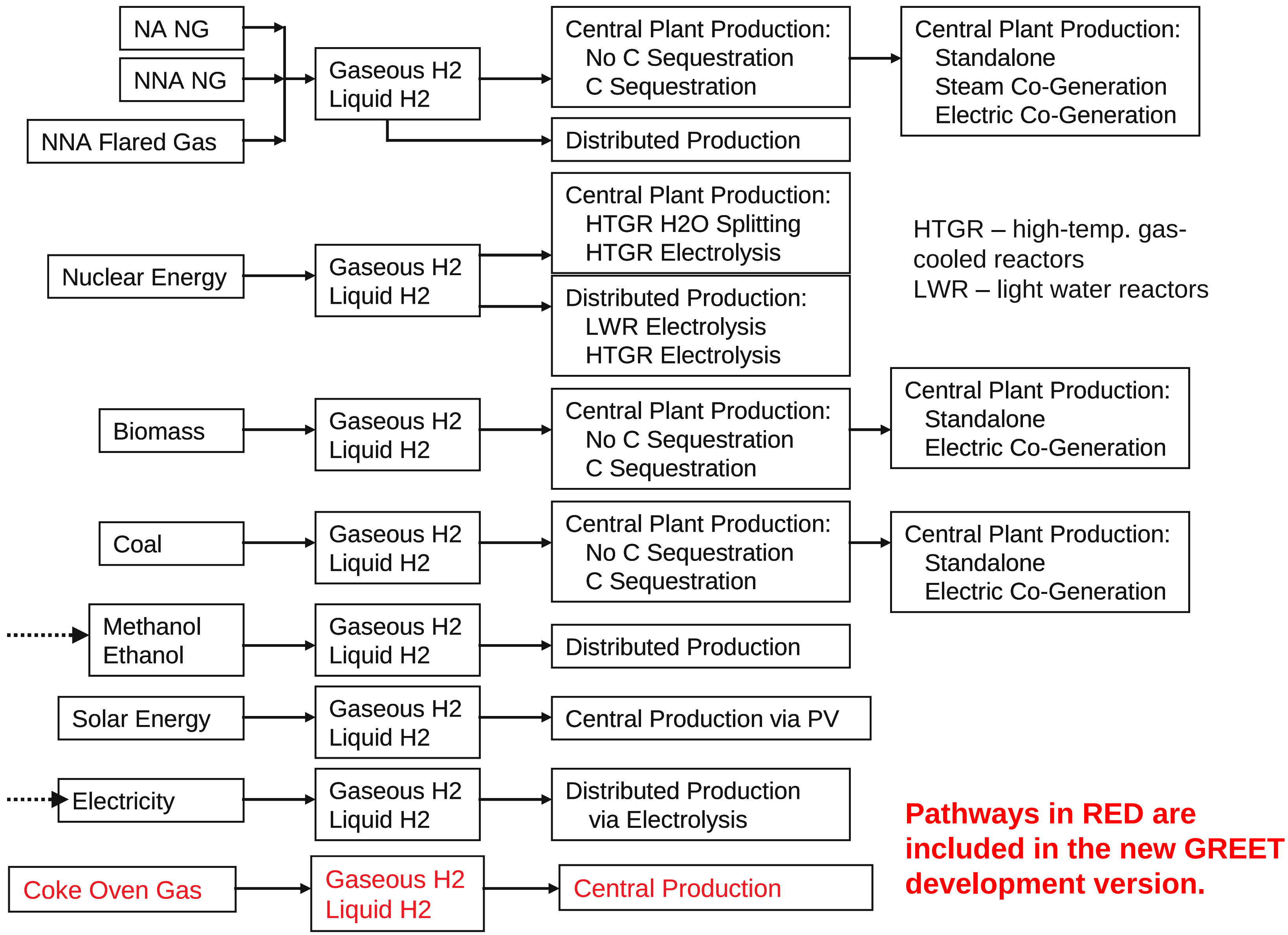
GREET Includes a Varity of Hydrogen Production Pathways

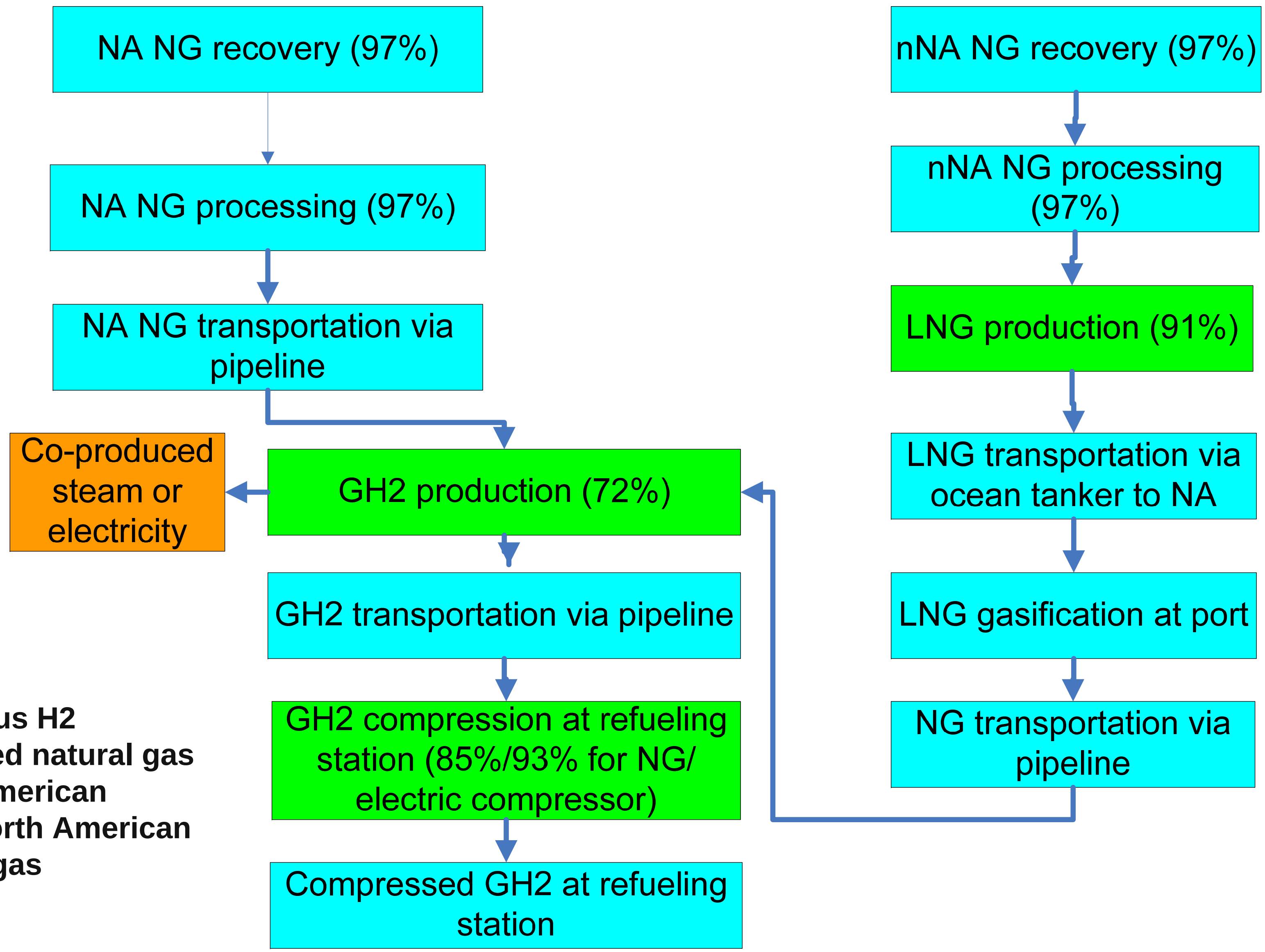


The <u>Hydrogen</u> Sheet Serves as the Key Sheet to Calculate Energy Use and Emission Rates for H2 Production Pathways

- **This worksheet consists of the following four sections:**
  - ***Scenario control and key input parameters*****.** The values in this section derive primarily from the *Inputs* sheet.
  - ***Shares of combustion processes for each stage*****,** which are used for emission calculations.
  - ***Calculation of energy use and emissions for individual stages*****.** In this section, GREET calculates energy use and emissions for each individual stage by considering energy efficiency, fuel use by type, fuel use by combustion technology, etc.
  - ***Summary of energy use and emissions*****.** Other sheets use the summary results from this sheet for individual vehicle/fuel WTW calculations.

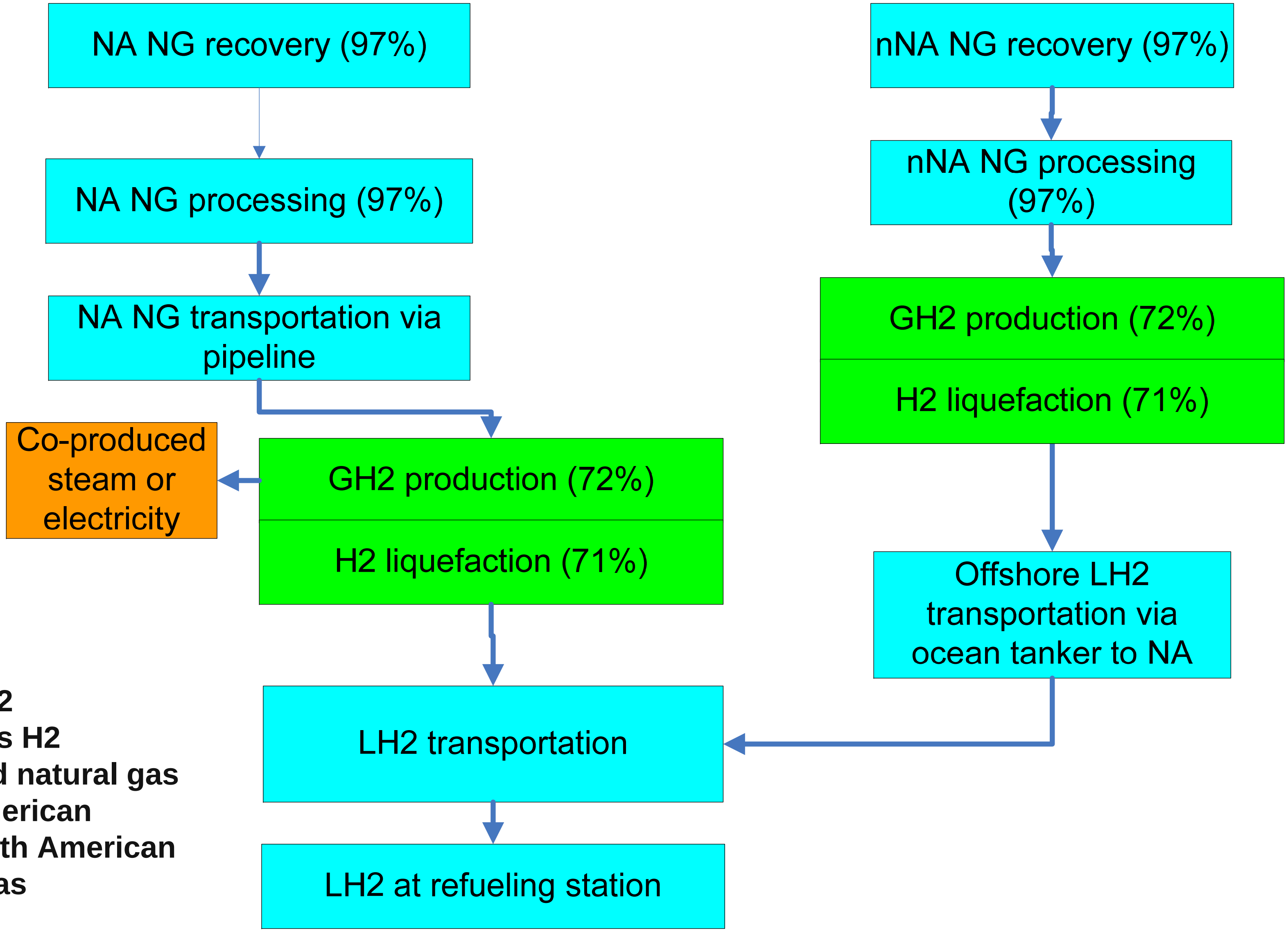
2	**Hydrogen Production Pathways: from NG, Electrolysis, Solar Photovotaics, Nuclear Energy, Coal, Biomass, Ethanol, and Methanol**												
3													
4	**1) Scenario Control and Key Input Parameters (from the *Inputs* sheet)**												
5		Transportation Fuel Application										Stationary Fuel Application	
6	Hydrogen Production Facility	Central Plant: NG	Central Plant: Solar Energy	Central Plant: Nuclear (water cracking)	Central Plant: Electrolysis (HTGR)	Central Plant: Coal	Central Plant: Biomass	Refueling Station: NG	Refueling Station: Electrolysis	Refueling Station: EtOH	Refueling Station: MeOH	Central Plant: NG	Central Plant: Solar Energy
7	Share of H2 Production: G.H2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	100.0%	0.0%
8	Share of H2 Production: L.H2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	100.0%	0.0%
9	CO2 Sequestration in Central H2 Plants: Percentage of CO2 to Be Captured											Gaseous	Liquid
10		G.H2	L.H2									100.0%	0.0%
11	NG-to-H2 Plant	0.0%	0.0%										
12	Coal-to-H2 Plant	0.0%	0.0%										
13	Biomass-to-H2 Plant	0.0%	0.0%										
14	Conversion factor for HTGR (MWh of electricity or H2 per gram of U-235)												
15	8.7												
16													
17	**Types of Electricity Displaced by Co-Produced Electricity in NG-based H2 Plants for Export**												
18	2	1-- Electricity generation mix (Could be U.S. mix, NE U.S. mix, CA mix, or user defined mix, which is consistent with the option of user selection of electricity generation mix for stationary use)											
19		2-- NGCC electricity											
20		3-- Coal IGCC electricity											
21		4-- Biomass IGCC electricity											
22	**Types of Electricity Displaced by Co-Produced Electricity in Biomass-Based H2 Plants for Export**												
23	1	1-- Electricity generation mix (Could be U.S. mix, NE U.S. mix, CA mix, or user defined mix, which is consistent with the option of user selection of electricity generation mix for stationary use)											
24		2-- NGCC electricity											
25		3-- Biomass IGCC electricity											
26	**Types of Electricity Displaced by Co-Produced Electricity in Coal-Based H2 Plants for Export**												
27	1	1-- Electricity generation mix (Could be U.S. mix, NE U.S. mix, CA mix, or user defined mix, which is consistent with the option of user selection of electricity generation mix for stationary use)											
28		2-- NGCC electricity											
29		3-- Coal IGCC electricity											
30													
31	**Selection of Electricity Generation Mix for H2 liquifaction in Central Plants**												

Production and Compression Are Key Steps for Central Gaseous H_2 Production



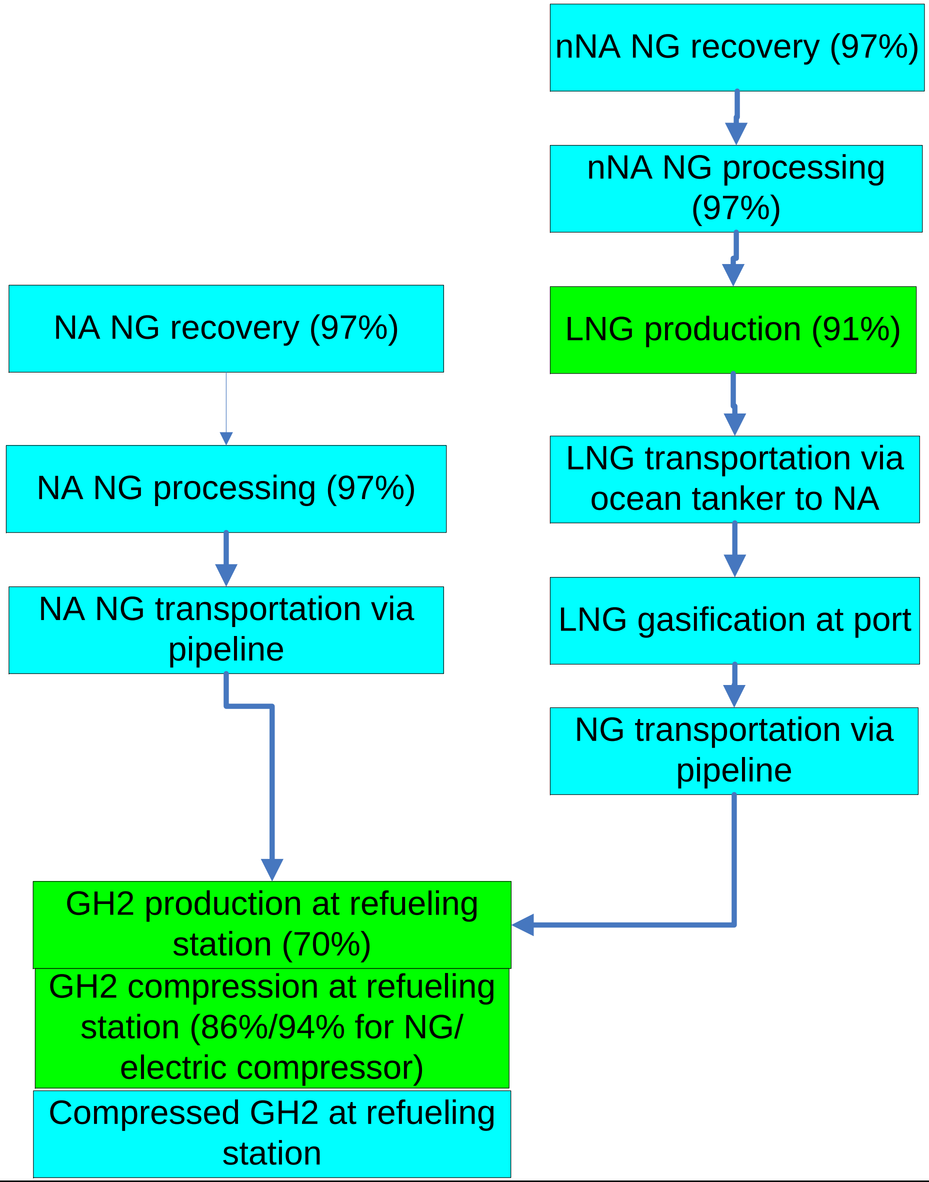
G.H2: gaseous H2
LNG: liquefied natural gas
NA: North American
nNA: non-North American
NG: natural gas

H_2 Liquefaction Has Higher Energy Losses Than H_2 Compression



L.H2: liquid H2
G.H2: gaseous H2
LNG: liquefied natural gas
NA: North American
nNA: non-North American
NG: natural gas

To Avoid Expensive H2 Distribution Infrastructure, Distributed NG SMR Serves as an Intermediate Transition Pathway

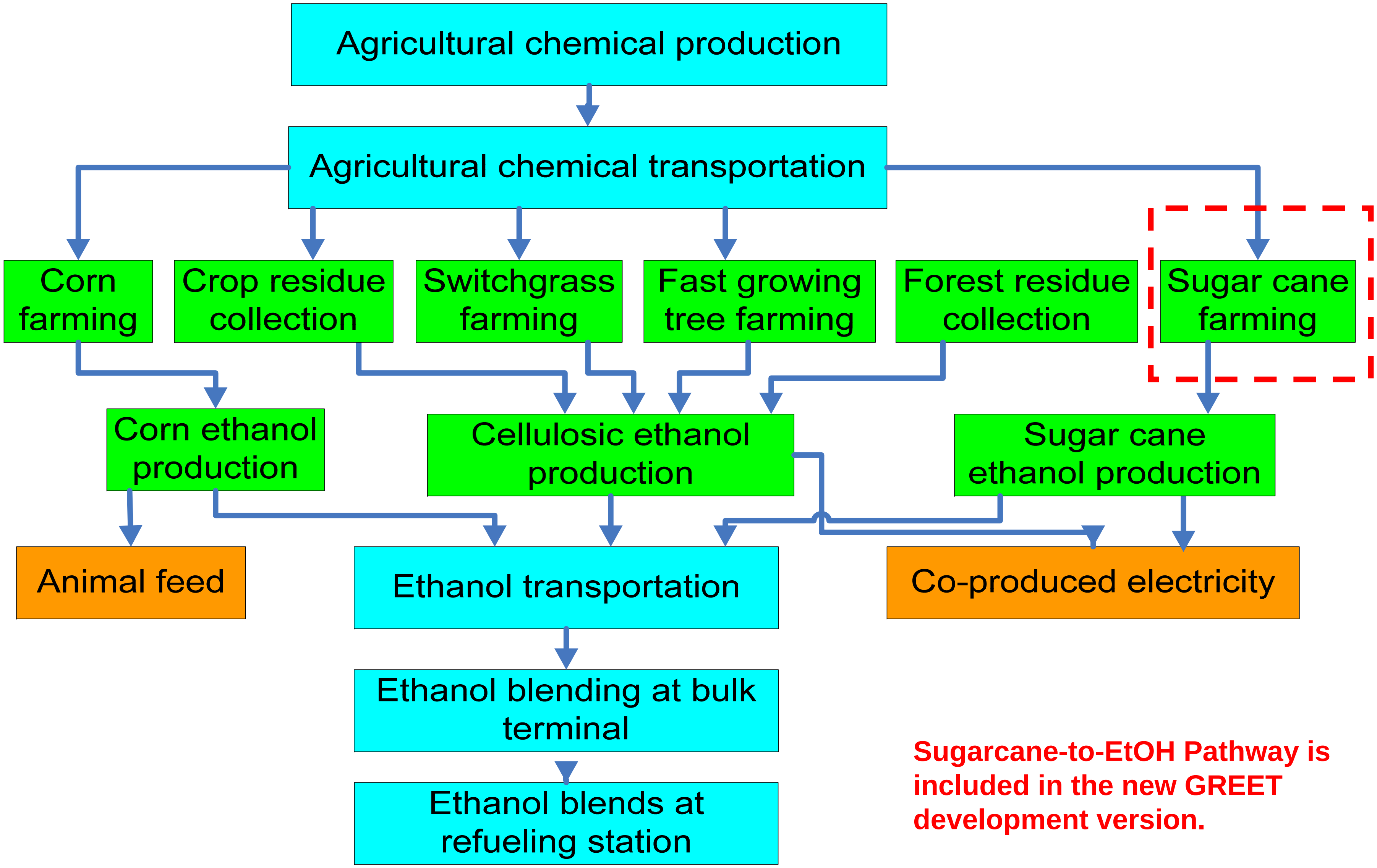


G.H2: gaseous H2
LNG: liquefied natural gas
NA: North American
nNA: non-North American
NG: natural gas

The EtOH Sheet Serves as the Key Sheet to Calculate Energy Use and Emission Rates for Ethanol Produced from Various Biomass Feedstocks

- **This worksheet consists of the following four sections:**
  - ***Scenario control and key input parameters*****.** The values in this section derive primarily from the *Inputs* sheet.
  - ***Shares of combustion processes for each stage*****,** which are used for emission calculations.
  - ***Calculation of energy use and emissions for individual stages*****.** In this section, GREET calculates energy use and emissions for each individual stage by considering energy efficiency, fuel use by type, fuel use by combustion technology, etc.
  - ***Summary of energy use and emissions*****.** Other sheets use the summary results from this sheet for individual vehicle/fuel WTW calculations.
- **Production of agricultural chemicals (fertilizers and pesticides) are simulated in the *Ag_Inputs* sheet, and the results are linked to the *EtOH* sheet.**
- **CO2 emissions need to be carefully examined in the biofuel pathways: e.g., CO2 credit/emissions during land use change, CO2 sequestration via photosynthesis during biomass growth, etc.**
- **Dealing with the co-products is a key for biofuel pathways: displacement method vs. market value method vs. other methods.**

Ethanol WTP Pathways Include Activities from Fertilizer to Ethanol at Stations

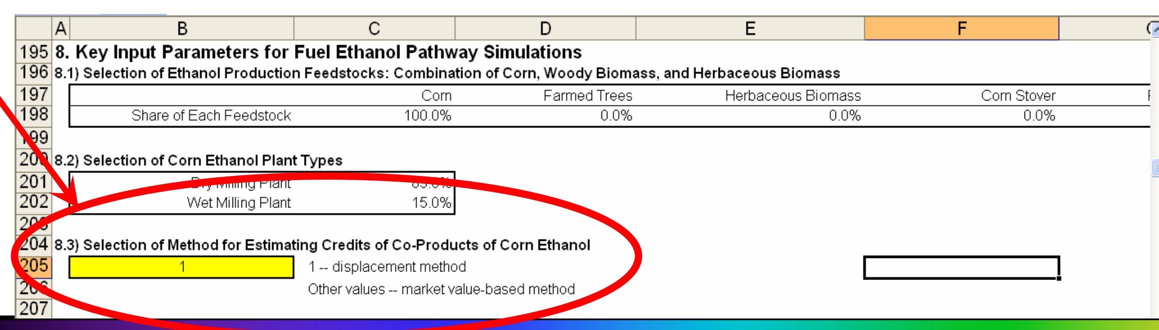


Sugarcane-to-EtOH Pathway is included in the new GREET development version.

Accounting for Animal Feed Is a Critical Factor in Ethanol's Lifecycle Analysis

Allocation Method	Wet milling	Dry milling
Weight	52%	51%
Energy content	43%	39%
Process energy	36%	41%
Market value	30%	24%
Displacement	~16%	~20%

Argonne uses the displacement method, the most conservative approach.



Vehicle Technologies Simulated in the Current Version of GREET

- **Only light-duty vehicles are simulated in GREET :**
  - Passenger cars (PC): GREET sets mid-size car as default.
  - Light-duty trucks 1 (LDT1) with a gross vehicle weight (GVW) less than 6000 lbs: GREET sets mid-size SUV as default.
  - Light-duty trucks 2 (LDT2) with a GVW between 6000 and 8500 lbs: GREET sets mid-size pick-up truck as default.
- **Among the 75+ vehicle/fuel systems, the spark-ignition vehicle fueled with gasoline, and the compression-ignition direct-injections vehicle fueled with diesel are considered as baseline vehicles.**
- **All other vehicles are considered alternative-fueled vehicles (AFVs) or advanced vehicle technologies (AVTs). The users need to specify the change rates of:**
  - fuel economy (relative to the baseline SI gasoline vehicle).
  - emission factors (SI technologies relative to the baseline SI gasoline vehicle and CIDI technologies relative to the baseline CIDI diesel vehicle).
- **Many vehicle technologies are for use in the future, not yet available in the historical U.S. market. In GREET, these vehicle technology options: (1) H2 SI ICE vehicles, (2) SIDI vehicles, (3) GI SI HEVs, (4) GC SI HEVs, (5) GI CIDI HEVs, (6) GC CIDI HEVs, and (7) Fuel-cell vehicles, can be only simulated for model-year 2005 and after.**

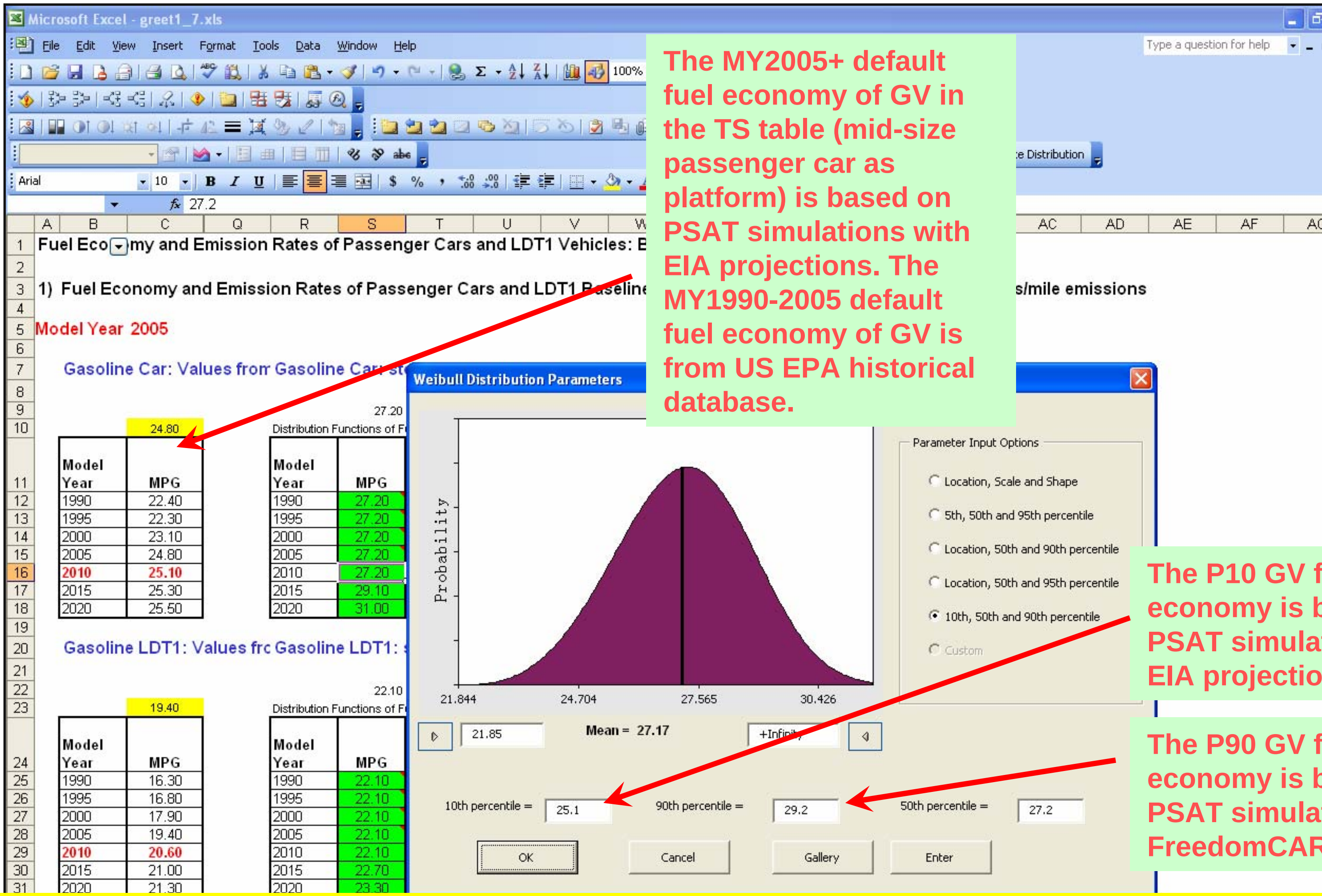
Fuel Economy and Emissions Rates Are Key Input Parameters for the Vehicle Operation Stage

Pump-to-Wheels Data Sources

- **Fuel economy**
  - Open literature
  - Vehicle simulations with models such as Argonne's PSAT model
  - Lab-tested fuel economy data are adjusted to reflect the on-road deterioration
- **Vehicle operation emissions**
  - Open literature
  - Emission testing results
  - EPA MOBILE6.2 model
  - CARB EMFAC2002 model

The fuel economy and emission factor values in the TS tables of the two sheets Car_LDT1_TS and LDT2_TS are based on each five-model-year instead of calendar-year (i.e., target year). Because emission rates of vehicle operations will deteriorate over time, the data of the lifetime mileage midpoint for a typical model-year vehicle should be applied for simulation. The GREET model was designed to do so. On average, half lifetime of a light-duty vehicle is about five years in the U.S. That means in GREET, for example, simulation for calendar year 2010 uses the values for model-year 2005 vehicles.

Argonne's PSAT Model Is An Important Tool to Simulate Vehicle Fuel Economy



The MY2005+ default fuel economy of GV in the TS table (mid-size passenger car as platform) is based on PSAT simulations with EIA projections. The MY1990-2005 default fuel economy of GV is from US EPA historical database.

The P10 GV fuel economy is based on PSAT simulations with EIA projections.

The P90 GV fuel economy is based on PSAT simulations with FreedomCAR goals.

Original PSAT simulation results are lab-tested fuel economy data. In GREET, PSAT results are adjusted with US EPA's on-road deterioration factor (downward by 10% for city estimates and by 22% for highway estimates) to reflect the on-road MPG.

Vehicle Emission Factors in GREET Reflect the Evolution of Emission Standards for Light Duty Vehicles: 1990-2010

Tier 0, Tier 1, and LEV Standards (PCs only, g/mi. for 50K miles)

	NMOG	CO	NO_X	PM
Tier 0 (MY1990)	0.34 (NMHC)	3.4	1.0	0.20 (DV)
Tier 1 (MY1995)	0.25 (NMHC)	3.4	0.4 (GV)/1.0 (DV)	0.08 (DV)
LEV (MY2000)	0.075	3.4	0.2	N/A

Tier 2 Standards (PCs and LDTs, Fully in Effect in 2009, g/mi. for 120K miles)

	NMOG	CO	NOx	PM	HCHO
Bin 10	0.156/0.230	4.2/6.4	0.6	0.08	0.018/0.027
Bin 9	0.090/0.180	4.2	0.3	0.06	0.018
Bin 8	0.125/0.156	4.2	0.20	0.02	0.018
Bin 7	0.090	4.2	0.15	0.02	0.018
Bin 6	0.090	4.2	0.10	0.01	0.018
Bin 5	0.090	4.2	0.07	0.01	0.018
Bin 4	0.070	2.1	0.04	0.01	0.011
Bin 3	0.055	2.1	0.03	0.01	0.011
Bin 2	0.010	2.1	0.02	0.01	0.004
Bin 1	0.000	0.0	0.00	0.00	0.000

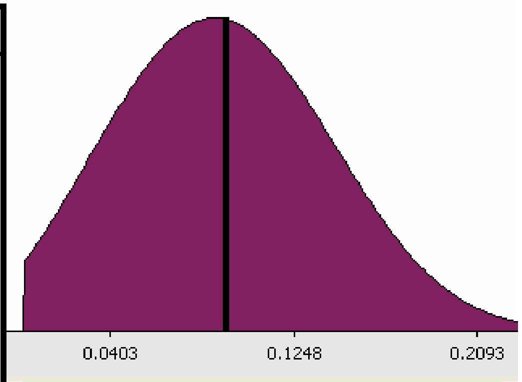
SULEVII (Bin 2) LEVII (Bin 5)

MOBILE6.2 and EMFAC2002 Are Applied to Simulate Exhaust and Evaporative Emission Factors

- Both models are feasible to simulate emission factors with single vehicle technology. For example:
  - MOBILE6.2: technology fractions are set to 100% Tier 2 Bin 5 vehicles
  - EMFAC2002: technology fractions are set to 100% LEVII vehicles
- For MY2010 vehicles, both models are run assuming CY 2016: the lifetime mileage midpoint of a 2010 MY vehicle. For example, passenger cars will have accumulated ~80K miles.
- GREET defaults are set to be the average of the results from the two models

	MOBILE6.2	EMFAC2002
Model Year	2010	2010
Calendar Year	2016	2016
Exhaust Technology	Tier 2 Bin 5	LEV II
Evaporative Technology	Tier 2 Evap	Near Zero Evap/OBD
RVP: winter	11.0	11.0
RVP: summer	6.8	6.8
I/M	OBD	OBD
Speed: mph	28 in average[a]	28 in average[b]
Temperature: winter	34F/46F	34F/46F
Temperature: summer	72F/92F	72F/92F

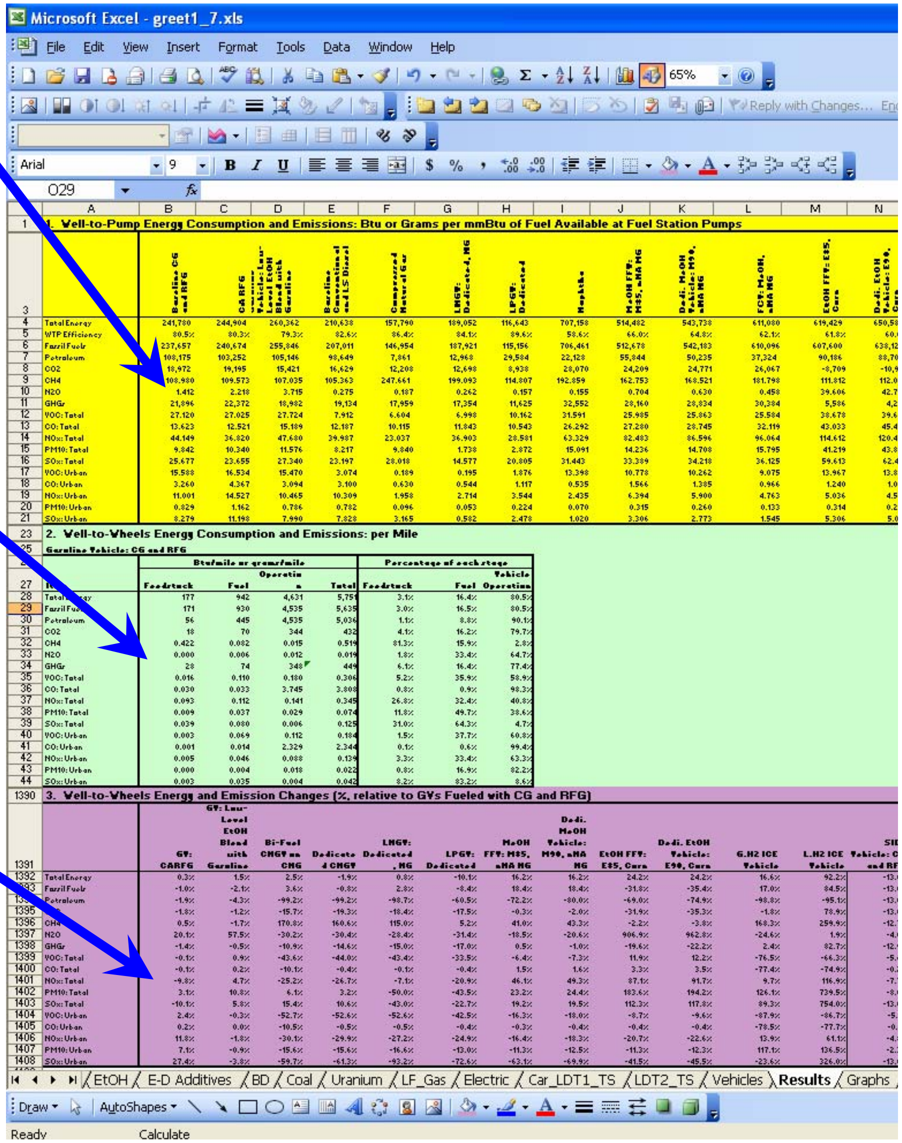
a: Speed allocation: 37mph:35mph:31mph:13mph=34%:3%:50%:13%
b: Speed allocation: 35mph:30mph:15mph=37%:50%:13%



This curve is a distribution function built for exhausted VOC emission factor of MY2010 mid-size passenger car in GREET based on two models' simulations.

WTW Results Are Summarized in the Results Sheet

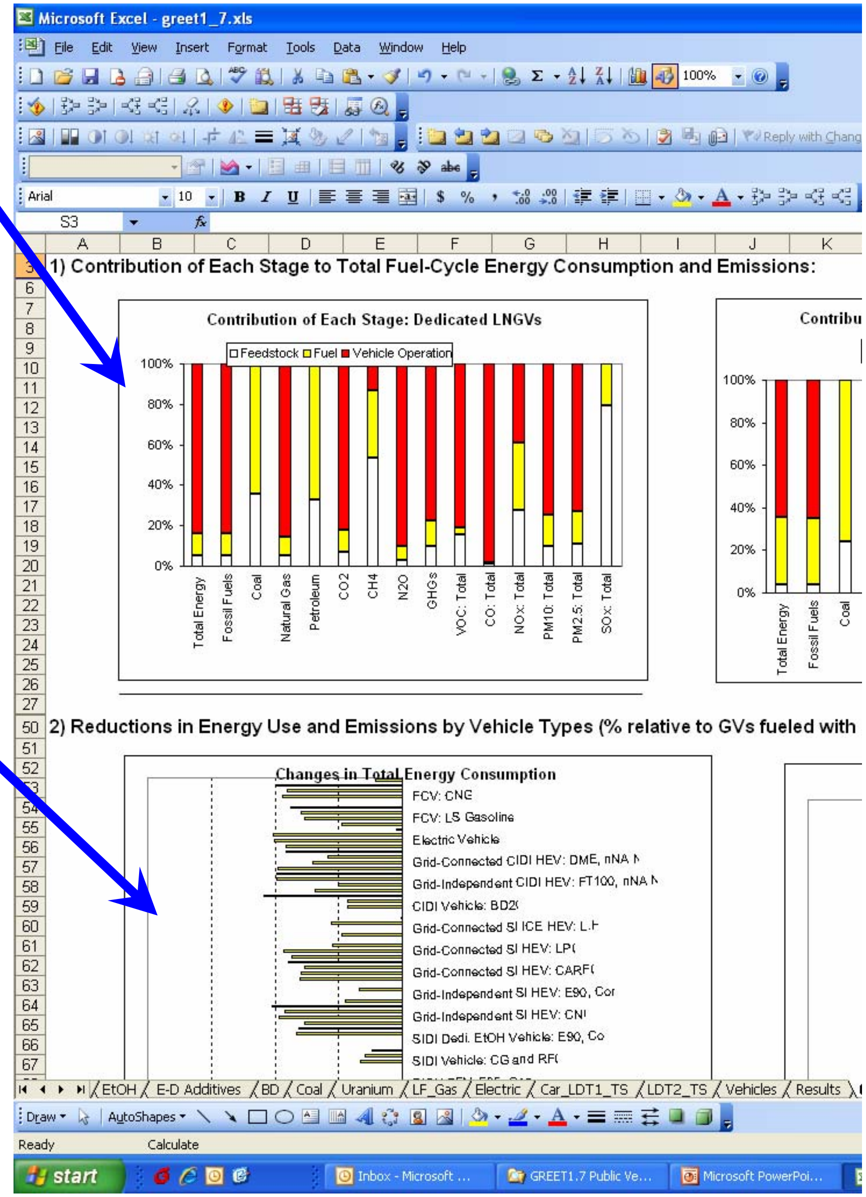
- The ***Well-to-Pump Energy Use and Emissions*** section presents energy and emission results from wells to refueling station pumps (in Btu or grams per mmBtu of fuel available at fuel pumps) for each transportation fuel.
- The ***Well-to-Wheels Energy Use and Emissions*** section calculates fuel-cycle energy use and emission rates for all vehicle/fuel options. For each option, results are separated into three stages: feedstock, fuel, and vehicle operation.
- The ***Well-to-Wheels Energy and Emission Changes*** section calculates changes in fuel-cycle energy use and emission rates for each alternative-fueled vehicle or advanced vehicle technology relative to baseline gasoline vehicle.



WTW Results Are Presented as Charts in the Graphs Sheet

- The ***first*** section presents the charts in terms of contribution of each stage to total fuel-cycle energy consumptions and emissions.

- The ***second*** section presents the charts in terms of reductions in energy use and emissions by vehicle types (% relative to GVs fueled with gasoline).



Time-Series Tables Were Designed in the GREET1.7 to Reflect the Technology Advancement over Time

- GREET1.7 can simulate a target year or multiple years (through GUI) between 1990 and 2020
  - Previous versions were based on two snap-shot simulations: near term vs. long term
  - Technology advancement over time is established with time-series look-up tables

0.069	
0.069	
5-year period	**LDGV: NOx**
1990	1.285
1995	0.656
2000	0.300
2005	0.141
2010	**0.069**
2015	0.069
2020	0.069

71.50%	
71.50%	
5-year period	**G.H2 Production Efficiency (Central, NA-NG, no export)**
1990	68.0%
1995	69.0%
2000	71.0%
2005	71.5%
2010	**71.5%**
2015	72.0%
2020	73.0%

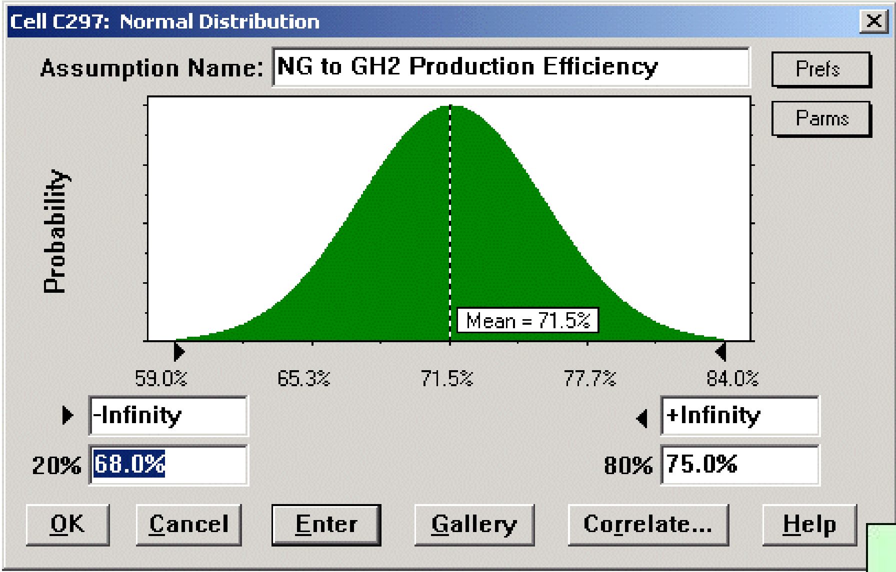
U.S. mix: Average

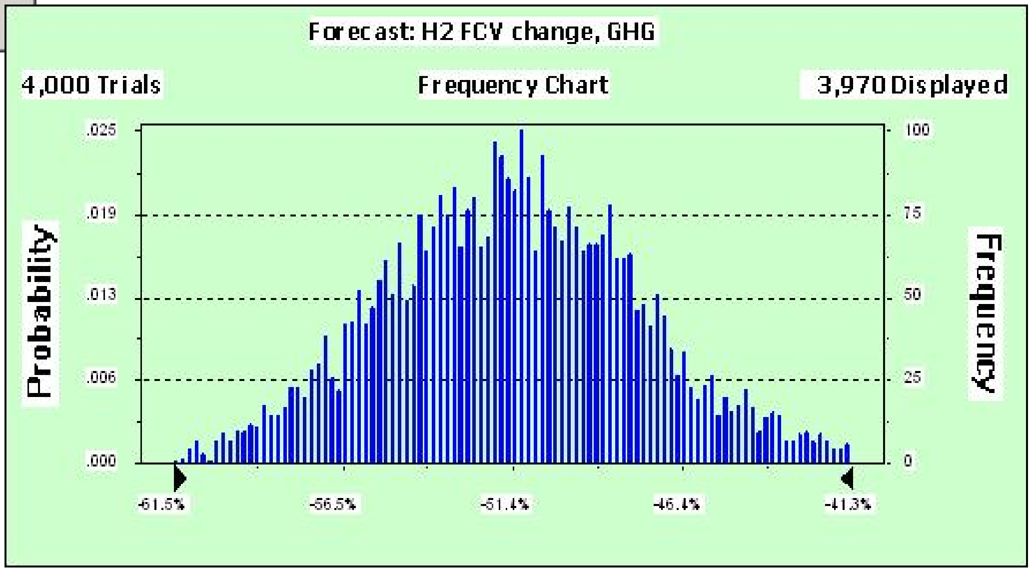
	1.7%	20.6%	50.2%	17.7%	9.8%
5-year period	**Residual Oil**	**Natural Gas**	**Coal**	**Nuclear**	**Others**
1990	4.2%	12.3%	52.5%	19.0%	12.0%
1995	2.2%	14.8%	51.0%	20.1%	11.9%
2000	2.9%	15.8%	51.7%	19.8%	9.8%
2005	1.7%	18.4%	50.3%	19.4%	10.2%
2010	**1.7%**	**20.6%**	**50.2%**	**17.7%**	**9.8%**
2015	2.5%	22.7%	48.6%	16.6%	9.6%
2020	1.9%	24.2%	49.2%	15.4%	9.3%

- For any simulation year between within a five-year interval listed in the TS tables, GREET uses a linear interpolation algorithm to calculate the estimate for that particular year
- Time-series look-up tables are located in four TS sheets in GREET: 1) ***Fuel_Prod_TS***; 2) ***EF_TS***; 3) ***Car_LDT1_TS***; and 4) ***LDT2_TS***.

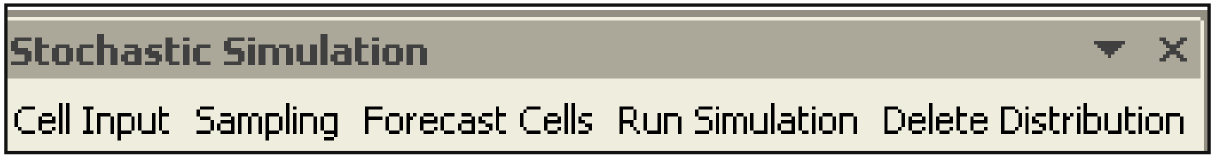
GREET Is Designed With Stochastic Simulations to Address Uncertainties

Distribution-Based Inputs Generate Distribution-Based Outputs



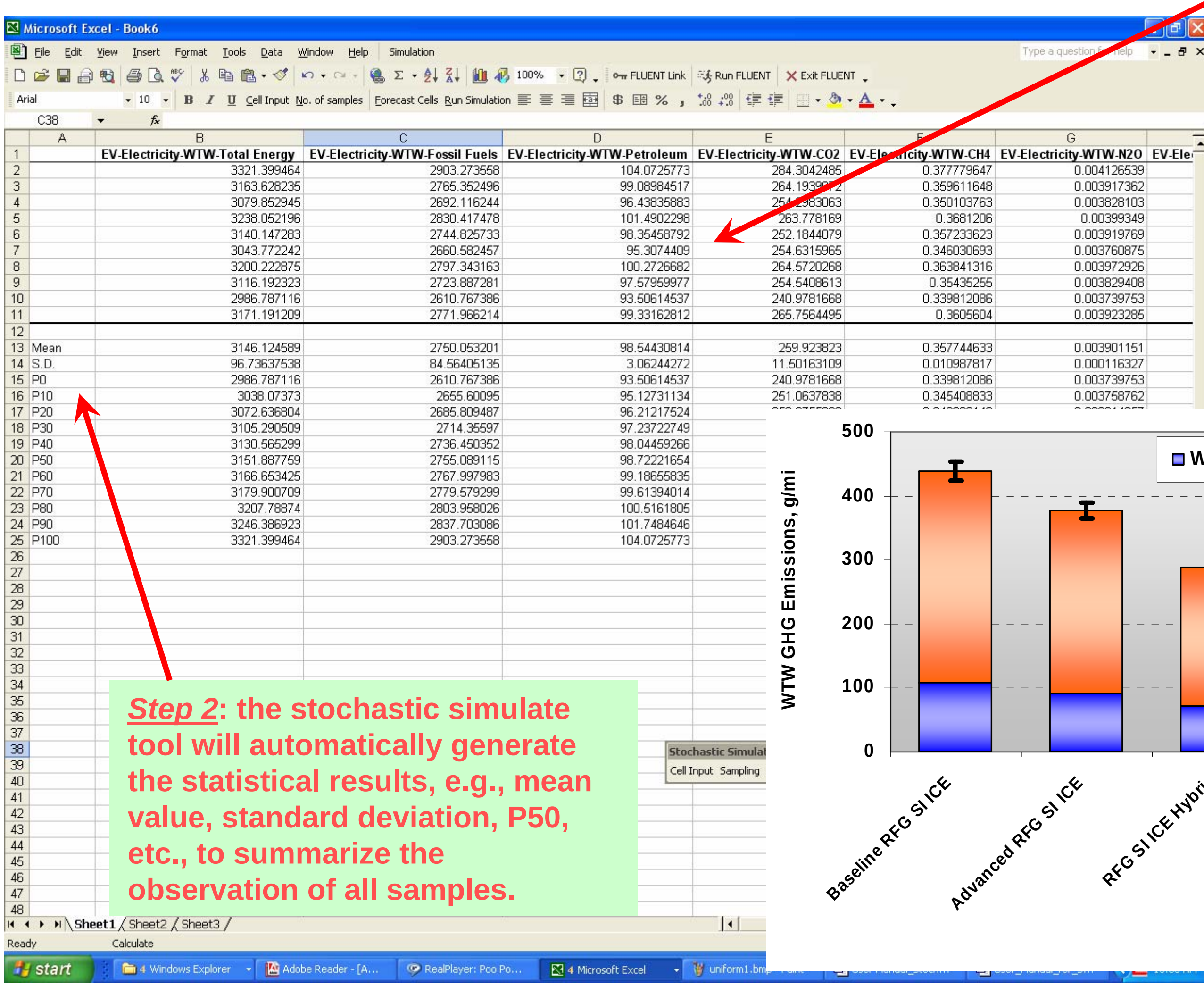


The Structure of the Stochastic Simulation Tool



- **Assign probability distribution functions to the input variables**
  - **GREET 1.7 includes ~1,000 key parameters with distribution functions**
  - **The tool includes as many as 11 probability distribution function types**
- **Specify the number of samples required and the sampling technique**
  - **Four sampling techniques are included in the tool**
- **Define the forecast variables**
  - **GREET 1.7 includes ~3,000 forecast variables**
- **Propagate the uncertainties**
- **Statistically analyze the outputs**

Statistically Analyzing the Outputs after Each Stochastic Simulation Run Is Required

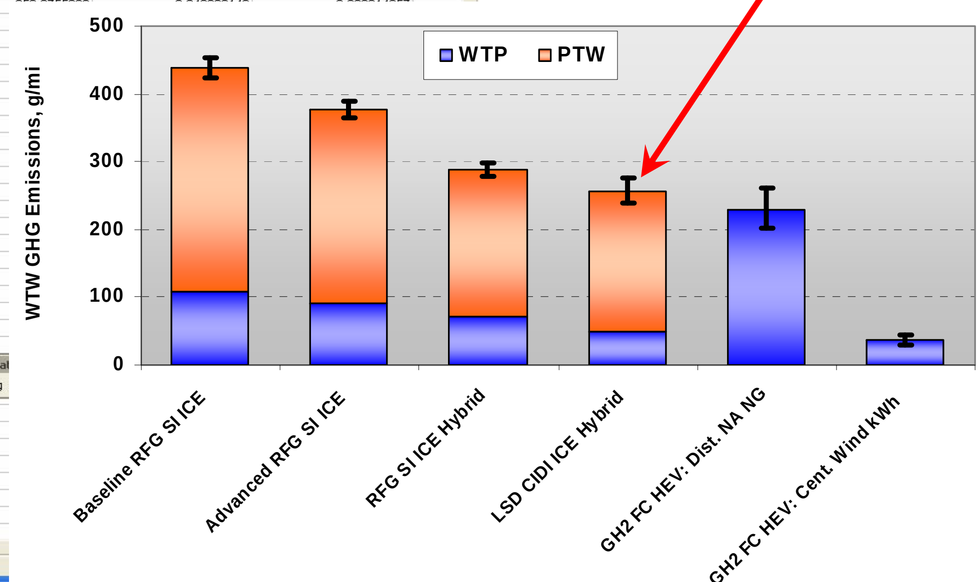


	A	B	C	D	E	F	G	H
1		EV-Electricity-WTW-Total Energy	EV-Electricity-WTW-Fossil Fuels	EV-Electricity-WTW-Petroleum	EV-Electricity-WTW-CO2	EV-Electricity-WTW-CH4	EV-Electricity-WTW-N2O	EV-Ele
2		3321.399464	2903.273558	104.0725773	284.3042485	0.377779647	0.004126539	
3		3163.628235	2765.352496	99.08984517	264.1939[illegible]	0.359611648	0.003917362	
4		3079.852945	2692.116244	96.43835883	254.2983063	0.350103763	0.003828103	
5		3238.052196	2830.417478	101.4902298	263.778169	0.3681206	0.00399349	
6		3140.147283	2744.825733	98.35458792	252.1844079	0.357233623	0.003919769	
7		3043.772242	2660.582457	95.3074409	254.6315965	0.346030693	0.003760875	
8		3200.222875	2797.343163	100.2726682	264.5720268	0.363841316	0.003972926	
9		3116.192323	2723.887281	97.57959977	254.5408613	0.35435255	0.003829408	
10		2986.787116	2610.767386	93.50614537	240.9781668	0.339812086	0.003739753	
11		3171.191209	2771.966214	99.33162812	265.7564495	0.3605604	0.003923285	
12								
13	Mean	3146.124589	2750.053201	98.54430814	259.923823	0.357744633	0.003901151	
14	S.D.	96.73637538	84.56405135	3.06244272	11.50163109	0.010987817	0.000116327	
15	P0	2986.787116	2610.767386	93.50614537	240.9781668	0.339812086	0.003739753	
16	P10	3038.07373	2655.60095	95.12731134	251.0637838	0.345408833	0.003758762	
17	P20	3072.636804	2685.809487	96.21217524				
18	P30	3105.290509	2714.35597	97.23722749				
19	P40	3130.565299	2736.450352	98.04459266				
20	P50	3151.887759	2755.089115	98.72221654				
21	P60	3166.653425	2767.997983	99.18655835				
22	P70	3179.900709	2779.579299	99.61394014				
23	P80	3207.78874	2803.958026	100.5161805				
24	P90	3246.386923	2837.703086	101.7484646				
25	P100	3321.399464	2903.273558	104.0725773				

Step 1: the stochastic simulate tool will automatically generate the results for each sample after the run is completed .

Step 2: the stochastic simulate tool will automatically generate the statistical results, e.g., mean value, standard deviation, P50, etc., to summarize the observation of all samples.

Step 3: with the statistical results, the user may manually draw graphs (e.g., the uncertainty range between the P10 and P90 values in the demo chart below).



It may take several minutes to more than an hour to finish a particular stochastic simulation run depending on many factors, such as the number of forecast cells selected, the number of samples selected, and the hardware configuration of your computer.