Introduction to FFCA and the CA-GREET Model

California Air Resources Board
California Energy Commission

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8:30-9:00	Introduction
9:00-11:00	Full Fuel Cycle Overview
11:00-12:00	CA GREET Pathways
12:00-1:00	Lunch
1:00-1:30	CA GREET Structure
1:30-2:00	Running the CA-GREET Model
2:00-4:00	Detailed Look at CA RFG and EtOH Pathways
4:00-4:30	Updates to CA-GREET Model

Thank You For Coming Today

- Full Fuel Cycle Analysis (FFCA) is **COMPLICATED**
  - It is easy to confuse complexity with lack of transparency
  - The learning process is not easy
  - Important to understand analysis because FFCA is the only way to compare alternative transportation fuels on a level field
- TIAX has been doing FFCA for a number of years, most recently for CEC in support of their AB1007 effort
  - Modified GREET 1.7 (latest version at time) (CA GREET)
  - Evaluated 12 finished fuels with CA specific inputs
  - 80 fuel/feedstock combinations
  - Quantified energy use and emissions associated with producing and using these transportation fuels
- CA GREET is being updated
  - Adding pathways
  - Enhancing transparency
  - Refining data inputs and calculations as needed
  - Compatibility with LUC modeling

Goals for Today's Training Session:

1. Understand what's included in Fuel Cycle Analysis
2. Understand CA-GREET model
   - Computation Methodology
   - Current Pathways
   - Limitations of the CA-GREET model
   - Planned updates
3. Ability to run existing CA-GREET default pathways and view the key input assumptions for these cases
4. Any other goals from participants?

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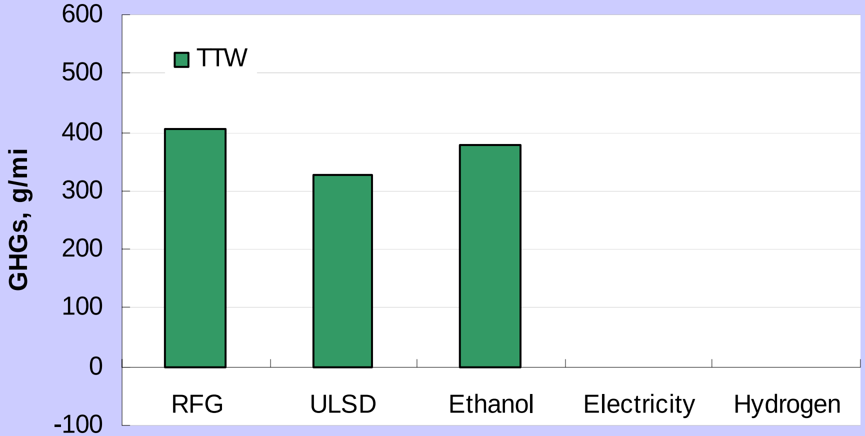
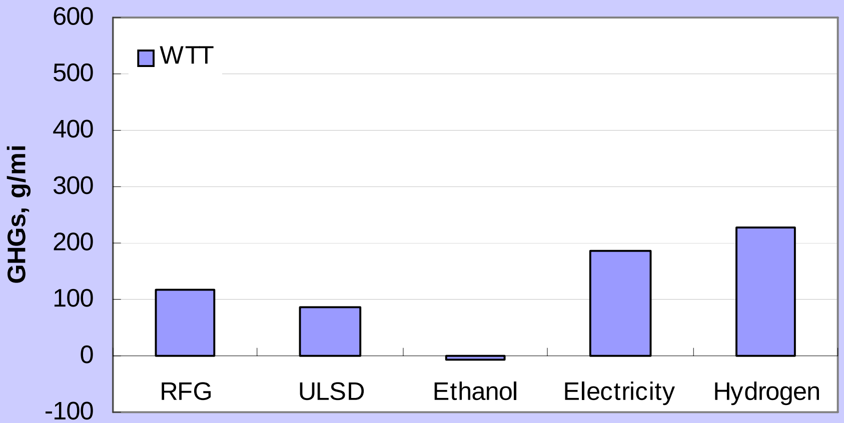
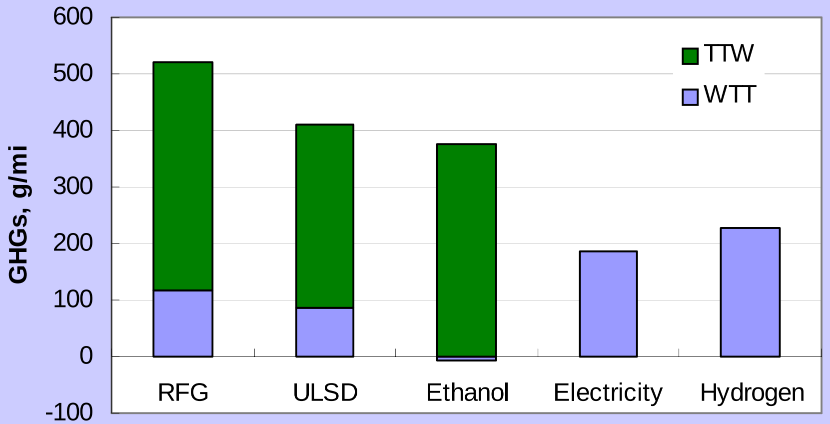
Why do a fuel cycle assessment...? The global nature of GHG emissions.



- Tailpipe emissions only represent a portion of the overall emissions related to vehicular fuel-use
- Full fuel cycle analysis looks at "well-to-tank" and "tank-to-wheel" emissions (WTT & TTW)
- Significance of WTT portion depends on a feedstock, processing, etc.





RFG (G2): California average crude refined in CA - ULSD (D3): California average crude refined in CA - Ethanol (et3): MW corn produced in MW dry mill facilities using NG and DDGS - Electricity (e11): California average mix - Hydrogen (h11): On-site natural gas steam reforming

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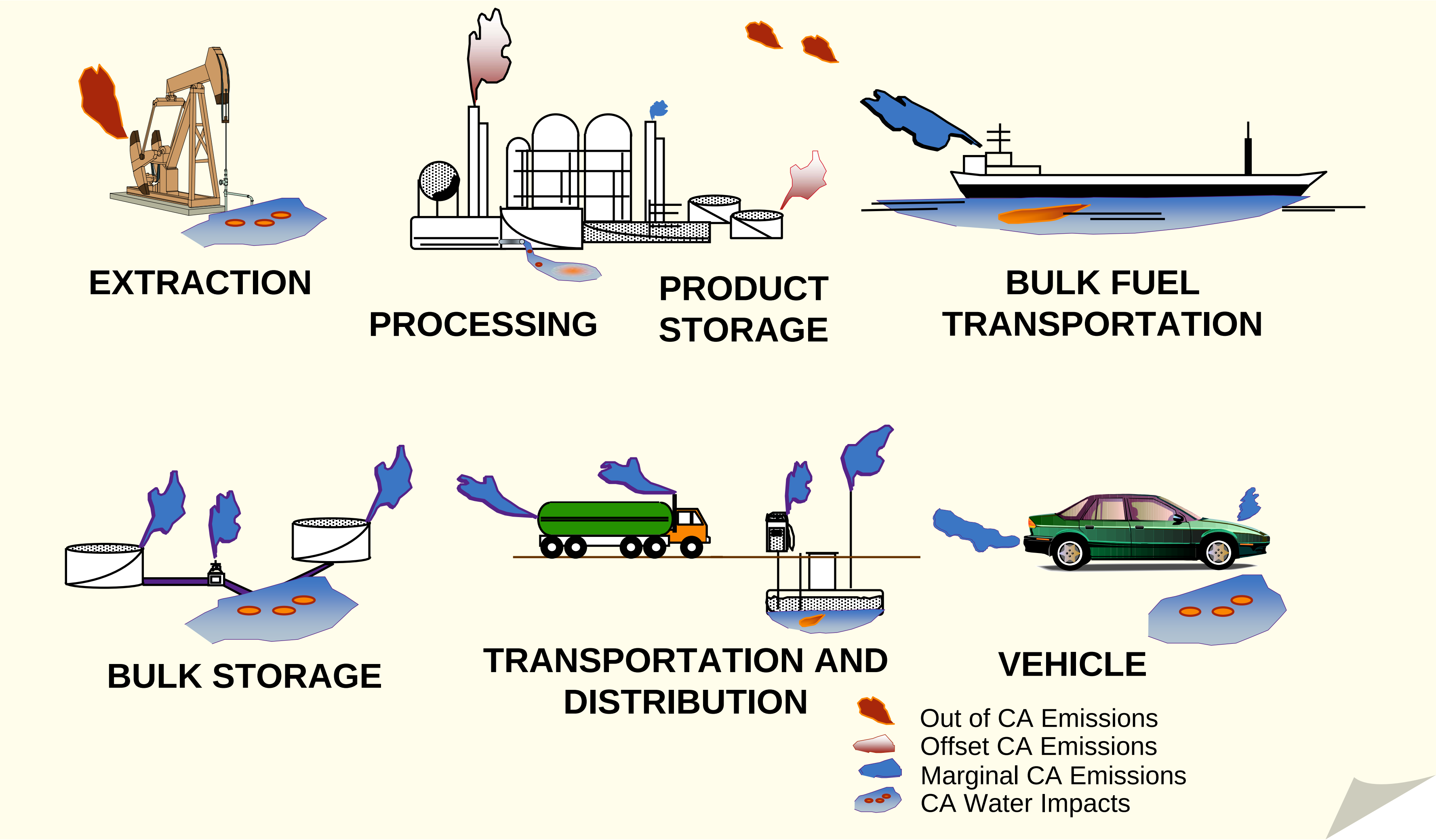
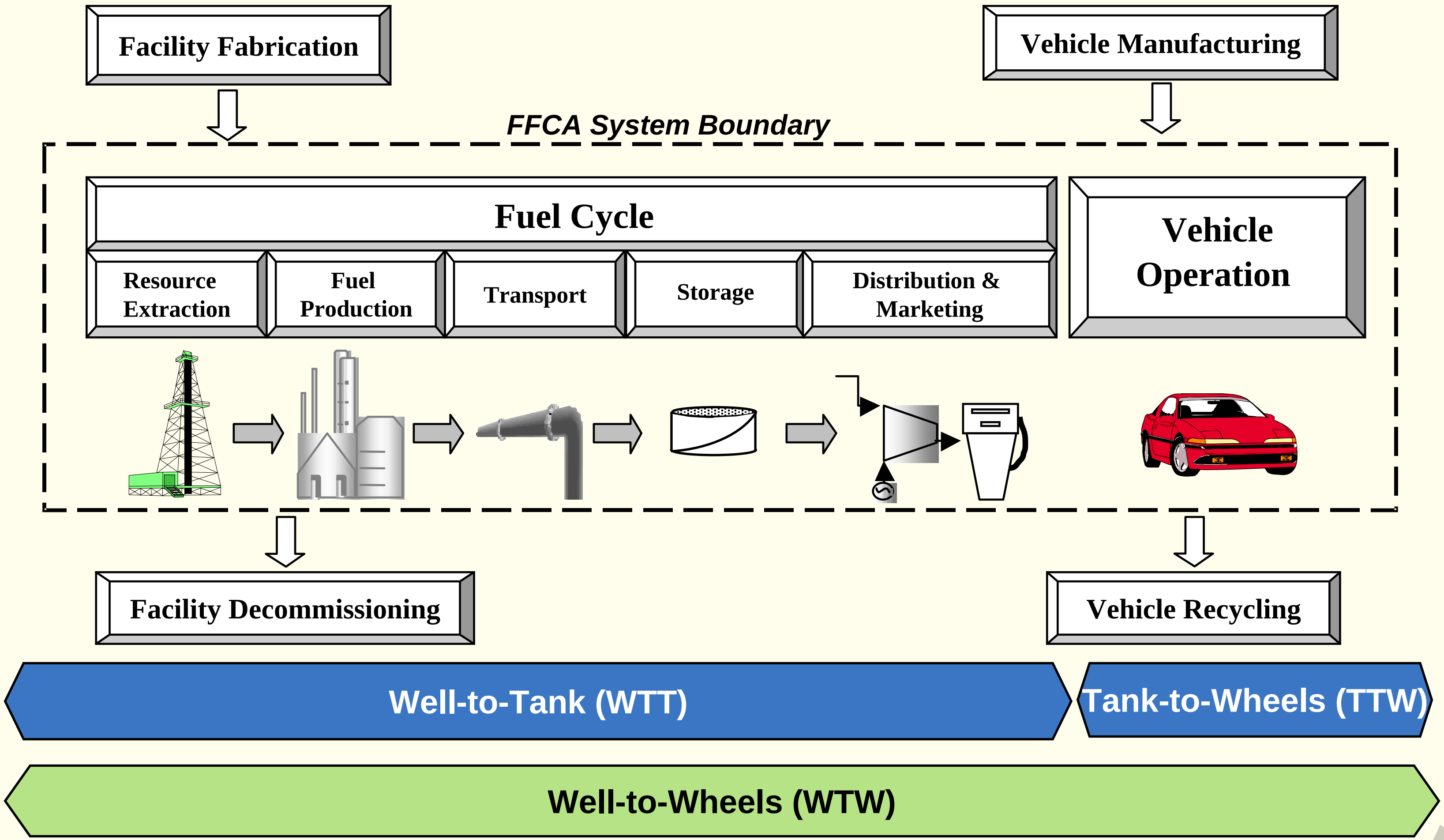
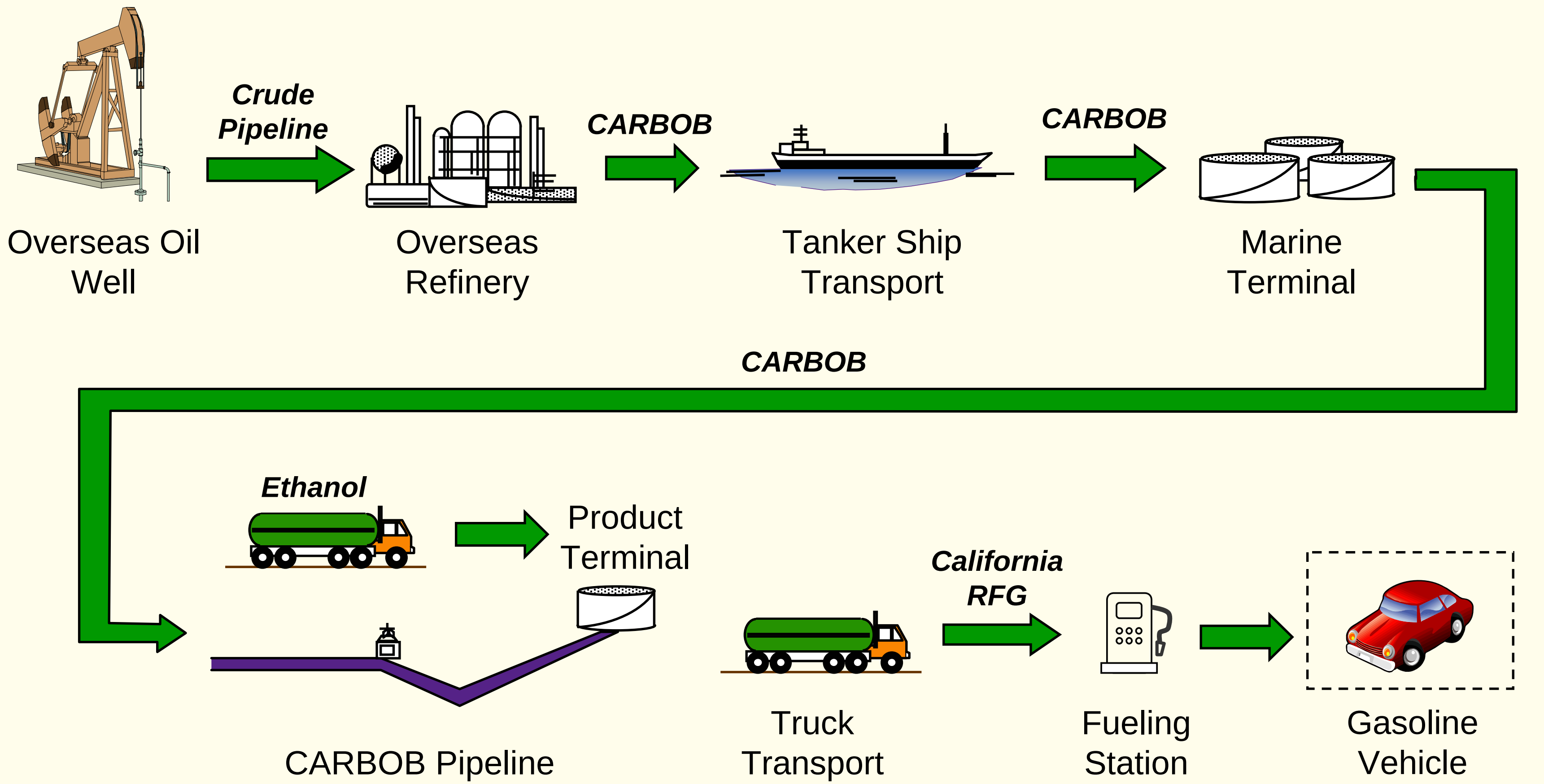
Processes Included in the Full Fuel Cycle Assessment



Processes Included in the Full Fuel Cycle Assessment

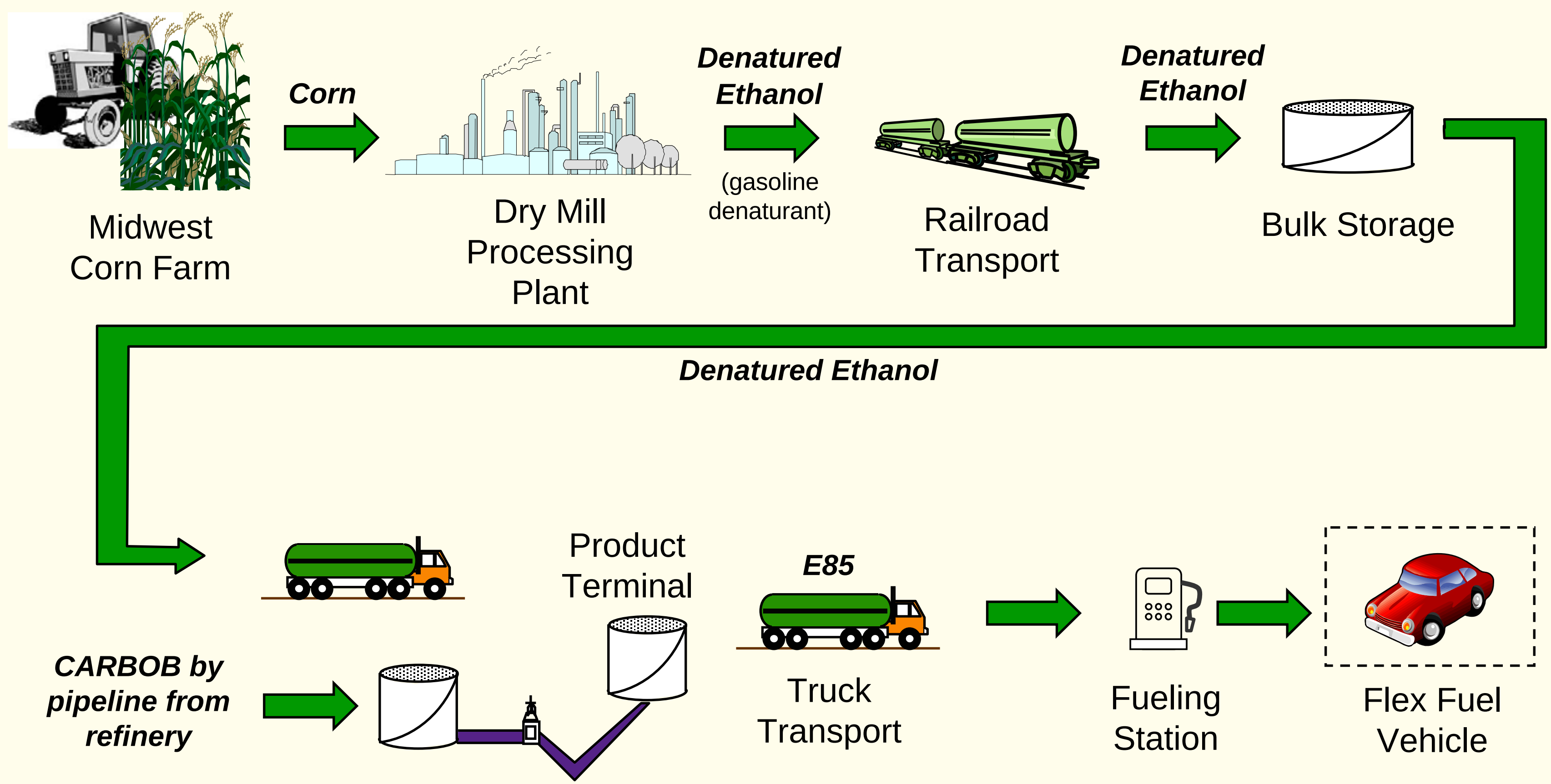


Example Pathway: Imported CARBOB from Middle East to California RFG



This schematic illustrates the sources of direct emissions and energy consumption, but the analysis also includes indirect emissions that are "upstream" of these sources.

Example Pathway: Midwest Corn Ethanol Pathway to E85



This schematic illustrates the sources of direct emissions and energy consumption, but the analysis also includes indirect emissions that are "upstream" of these sources.

How do WTT and TTW Components Combine to Yield WTW Emissions?

Five values are needed to estimate WTW GHG emissions:

1. **WTT** GHG Emissions, gCO2e/MJf
2. Fuel-Based CO2 Potential (**Fuel CO2**), gCO2e/MJf
3. Vehicle Energy Consumption (**VEC**), MJf/mi
4. Vehicle **N2O** emissions, gCO2e/mi
5. Vehicle **CH4** emissions, gCO2e/mi

WTT (g/mi) = **WTT GHG** (g/MJf) X **VEC** (MJf/mi)

TTW GHG (g/mi) = **Fuel CO2** (g/MJf) X **VEC** (MJf/mi) + **CH4** (g/mi) + **N2O** (g/mi)

WTW GHG (g/mi) = WTT GHG (g/mi) + TTW GHG (g/mi)

Value 1, WTT GHG, is what the CA-GREET model is designed to calculate

A number of FFCA models exist and each have their own attributes and drawbacks

- The most prominent FFCA (or LCA) models include:
  - GREET
  - LEM
  - GHG Genius
- There are a number of other models that may be used to support FFCA models by providing in-depth analysis for specific components
  - FASOM-GHG
  - FAPRI
  - BESS
- Both EPA and CEC chose the GREET model as their preferred platform
  - Heavily used, reviewed, referenced but analysts, industry, academia
  - Input from EPA, USDA, DOE, and industry
  - Full fuel cycle analysis for a large number of alternative fuels
  - Difference between models is generally results from different inputs, not methodology

How is CA-GREET Different From GREET 1.7?

– Added a User Interface – the Control Panel worksheet

- Drop down menus allow easy selection for analysis year and default pathways (80 pathways)
- Organized by fuel group: Petroleum, Natural Gas, Ethanol, Biodiesel, Electricity, Hydrogen, Synfuels
- Makes important assumptions easy to find and vary
- Allows cases to be re-run without having to modify each variable each time

3	**Select Year Here**					Fed RFG	CA RFG	ULSD	NG, CNG	LNG	LPG
4	2012			Total Energy	J/J	0.23	0.27	0.22	0.07	0.18	0
5				WTP eta	%	81.3%	78.5%	82.3%	93.1%	84.8%	88.
6	1	Land Use Change Toggle		Fossil Fuels	J/J	0.23	0.27	0.21	0.07	0.18	0
7		1=w/o; 2=with		Coal	J/J	0.04	0.02	0.02	0.00	0.01	0.
8				Natural Gas	J/J	0.08	0.12	0.09	0.07	0.17	0.
9				Petroleum	J/J	0.11	0.13	0.11	0.00	0.00	0.
10				CO2	g/MJ	18.02	17.05	15.69	5.25	11.27	9.
11				CH4	g/MJ	0.10	0.10	0.10	0.13	0.20	0
12				N2O	g/MJ	0.00	0.00	0.00	0.00	0.00	0.
13	**Select Fuel Pathway Here**			**GHGs**	**g/MJ**	20.33	19.96	17.98	8.31	15.82	12
14	Et3			VOC: Total	g/GJf	11.21	13.85	10.92	6.23	6.41	78.
15	E85, Corn, MW NG	ok		CO: Total	g/GJf	19.05	25.21	17.96	11.48	13.95	14.
16				NOx: Total	g/GJf	32.94	59.50	52.45	22.67	32.10	25.
17				PM10: Total	g/GJf	8.46	8.62	7.02	0.87	1.63	4
18				PM2.5 Total	g/GJf	3.05	4.44	3.83	0.50	0.91	1.
19		**Group**	**Region**	SOx: Total	g/GJf	7.87	17.22	15.63	10.25	11.33	14.
20	**Active Case**	ETOH	1	VOC: Urban	g/GJf	4.28	4.89	3.52	0.13	0.03	70.
21	Petroluem	PET	4	CO: Urban	g/GJf	0.03	0.51	0.45	0.27	0.06	0.
22	Nat Gas	NG	3	NOx: Urban	g/GJf	0.08	2.11	1.44	0.84	0.18	2.
23	Syn Fuel	SF	4	PM10: Urban	g/GJf	0.00	0.10	0.06	0.01	0.00	0.
24	Ren Diesel	RD	4	PM2.5 Urban	g/GJf	0.00	0.09	0.05	0.01	0.00	0.
25	Ethanol	ETOH	1	SOx: Urban	g/GJf	0.00	0.17	0.03	0.00	0.00	0.
26	Electricity	EL	3			Fed RFG	CARFG	ULSD	CNG	LNG	LPG
27	Hydrogen	H2	3								

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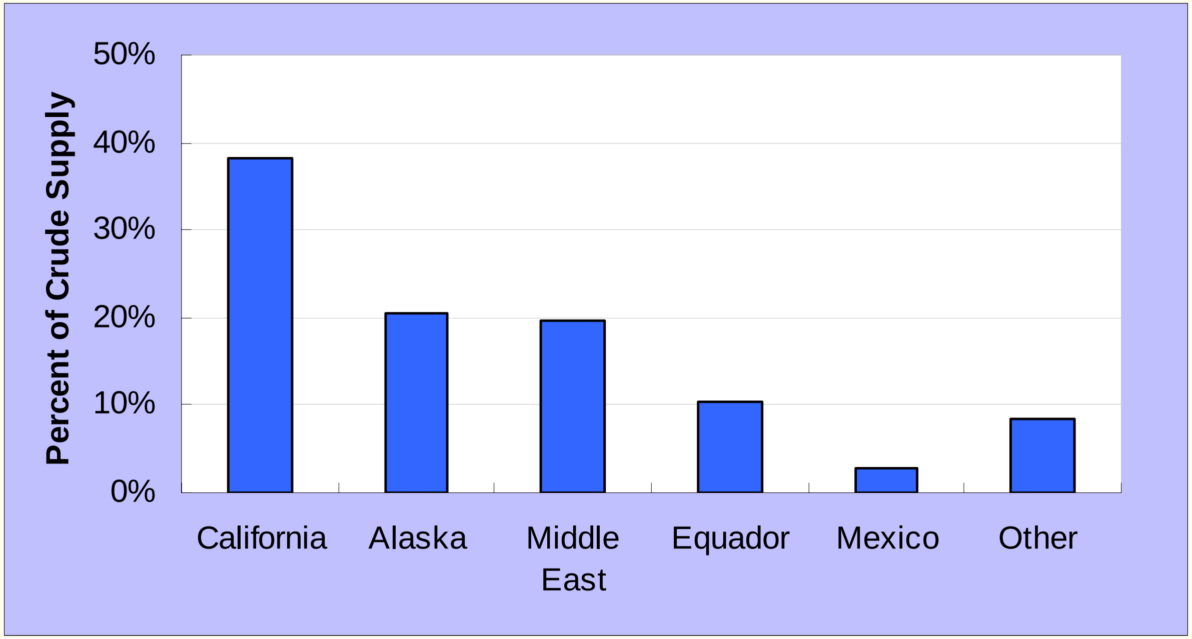
How is CA-GREET Different From GREET 1.7?

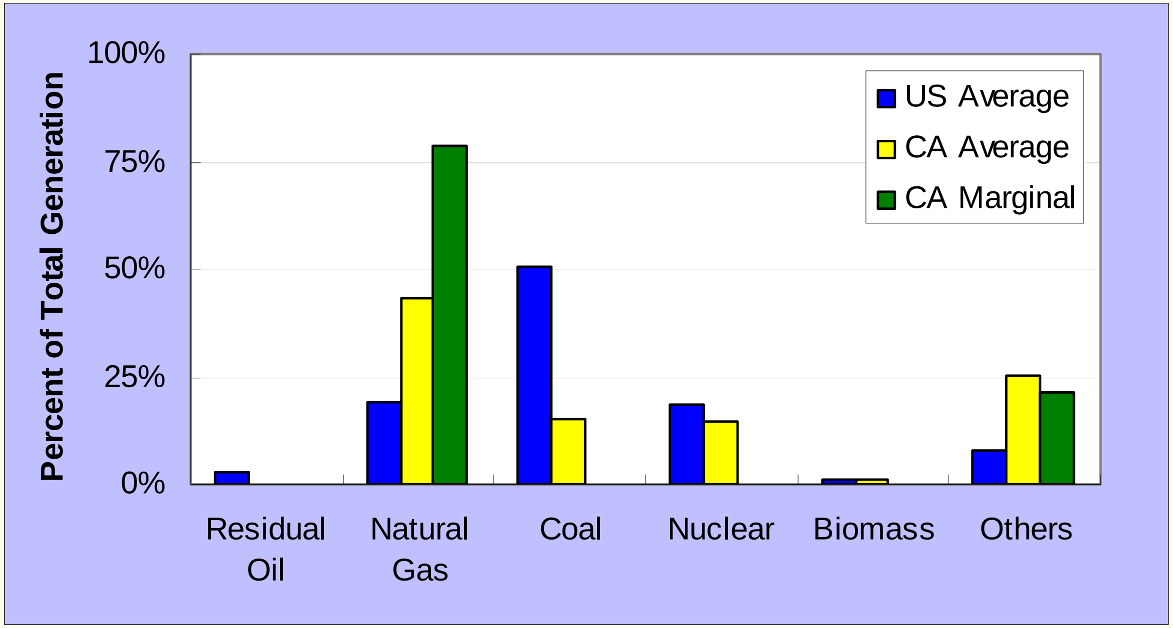
- The CA-GREET model modifies GREET 1.7 assumptions in order to make them California specific
- Modified assumptions include feedstock supplies (California crude supply is shown below), transport distances, vehicle emissions, etc.



How is CA-GREET Different From GREET 1.7?

– A California specific electricity generation mix has been added for average and marginal generation in California

– Electricity consumption outside of California is evaluated using the U.S. generation mix



How is CA-GREET Different From GREET 1.7?

- Natural gas pipeline leak rates corrected
  - Input from PG&E and SoCal Gas significantly reduced the loss of natural gas in pipelines
- The energy efficiency of the Thermally Enhanced Oil Recovery (TEOR) process has been updated
  - Reduction in process efficiency from 98-78% (which includes credit for natural gas cogeneration)
  - 20% of California crude is extracted using TEOR
  - Additional research necessary to determine what other sources of crude are extracted using TEOR

What are the steps still needed to improve CA-GREET?

– Land-use effects of biofuel production need to be updated
  - There are direct and indirect effects associated with the use of many biomass feedstocks that need to be incorporated
– Allocation of co-product credits needs to be improved
  - Many alternative fuel production processes yield multiple products
  - Emissions and energy-use need to be fairly allocated
– Uncertainty analysis is needed to better evaluate alternative fuels
  - Will illustrate which assumptions have a strong impact on the overall emissions and energy-use of an alternative fuel
  - Running the model with the expected variation of certain inputs will provide a range of emissions and energy-use for each alternative fuel pathway

What is Land-Use Change?

- Land-use change (LUC) refers to emissions associated with modifying the vegetation growing on a piece of land for the purpose of biofuel production

- Soils and plant biomass are the two largest biologically active stores of terrestrial carbon
- The conversion of native habitats to cropland will lead to significant CO2 emissions as a result of burning and microbial decomposition of organic matter
- The significant, one-time CO2 emissions needs to be amortized over some length of time in order to fairly compare various alternative fuels

- These effects should be considered when alterative fuels are evaluated, as they are part of the full-fuel cycle
- New research from multiple sources (including papers by Joseph Fargione, et al & Timothy Searchinger et al) suggests that land-use changes greatly effects the overall GHG emissions for many biofuels

What Types of Land-Use Change Should be Incorporated?

Direct Land-Use Change

- Conservation Reserve Program → Corn Production
- Tropical Rainforest → Palm Oil Production
- Brazilian Grassland → Sugarcane Production

Indirect Land-Use Change

- Corn for Food or Feed → Corn for Ethanol
  - → Fluctuation in Corn Market
  - → Conversion of Brazilian Grassland to Corn Production

It is likely that a global general equilibrium model of the agriculture industry is necessary to accurately quantify indirect land-use effects

What are Co-Product Credits?

- Production of some alternative fuels yields useful co-products
- In these cases, it is not appropriate to assign all of the production energy and emissions to the fuel
- A methodology is needed to fairly split the energy and emissions between the product fuel and the co-products
- Substitution or Displacement Method: In this method, the co-products are substituted for other substances. A credit is determined based on the energy/emissions associated with the other substances.
- Allocation by other factors:
  - Energy intensity
  - Market value
- GREET employs the substitution method for corn ethanol
- Dry Distillers Grains and Solubles (DDGS) is substituted for corn and soybean meal use for cattle feed.

Co-Product Credits Methodologies in GREET

- GREET employs the substitution/displacement method for corn ethanol
  - Dry Distillers Grains and Solubles (DDGS) is a co-product of dry mill ethanol production
  - DDGS can be used as cattle feed
  - DDGS is substituted for corn and soybean meal.
  - Dry Mill Corn EtOH is given energy and emission credits equal to the energy and emissions associated with corn and soybean meal production and transportation
  - EPA adopted this methodology in its Renewable Fuel Standard modeling, but adjusted the values
- GREET employs an allocation methodology based on energy intensity for soybean based biodiesel production

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Current Pathways in CA-GREET

Petroleum
- CA RFG, ULSD, LPG
- 9 Pathways

Natural Gas
- CNG, LNG, LPG
- 5 Pathways

Ethanol
- Ethanol
- 11 Pathways

Biodiesel
- Biodiesel (esterified)
- 3 Pathways

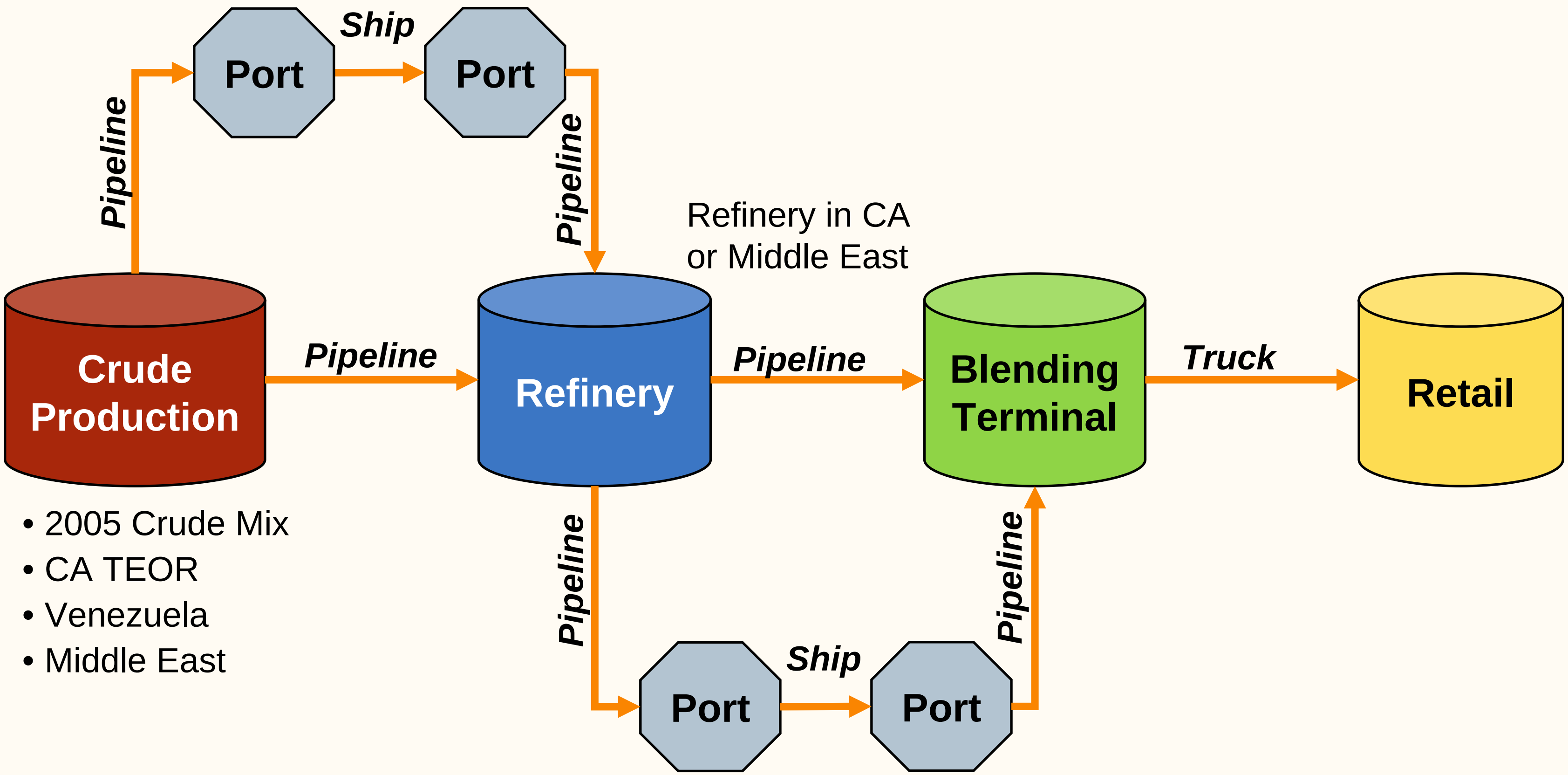
Syn Fuels
- MeOH, DME, XTL
- 13 Pathways

Electricity
- Electricity
- 11 Pathways

Hydrogen
- H2 (gas & liquid)
- 10 Pathways

7 Fuel Groups
14 Finished Fuels
62 Pathways

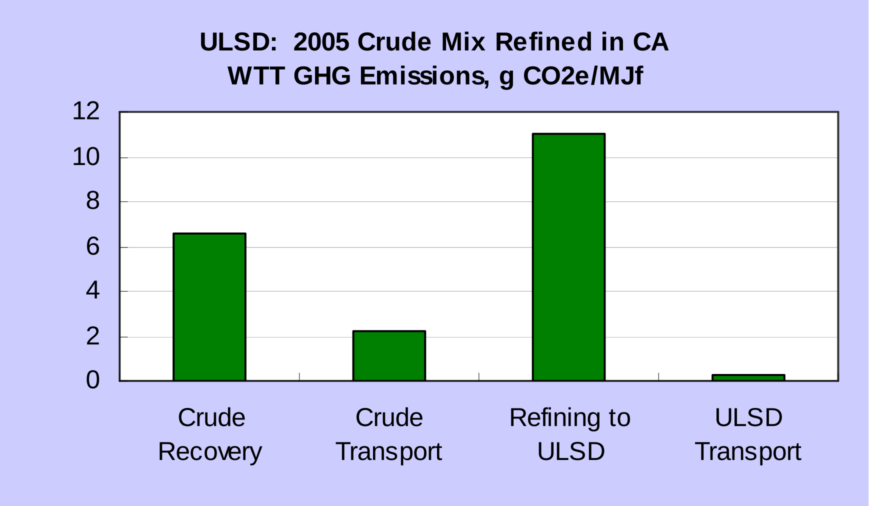
Petroleum Fuel Pathways in CA-GREET



- 2005 Crude Mix
- CA TEOR
- Venezuela
- Middle East

Petroleum Fuel Pathways – Key Inputs/Assumptions

- Process Efficiency
  - Crude Recovery Energy Consumption
  - Refining Energy Consumption
- Fuel and Equipment Mixes
  - Crude Recovery
  - Refining
- Losses (recovery, refining)
- Transport
  - Distances by mode
  - Tanker/Truck Inputs
    - Payload
    - Horsepower
    - Fuel economy
    - Speed
  - Pipeline Inputs
    - Energy intensity (Btu/ton-mile)
    - Compressor station fuel mix
    - Prime mover mix at compressor stations
  - Losses

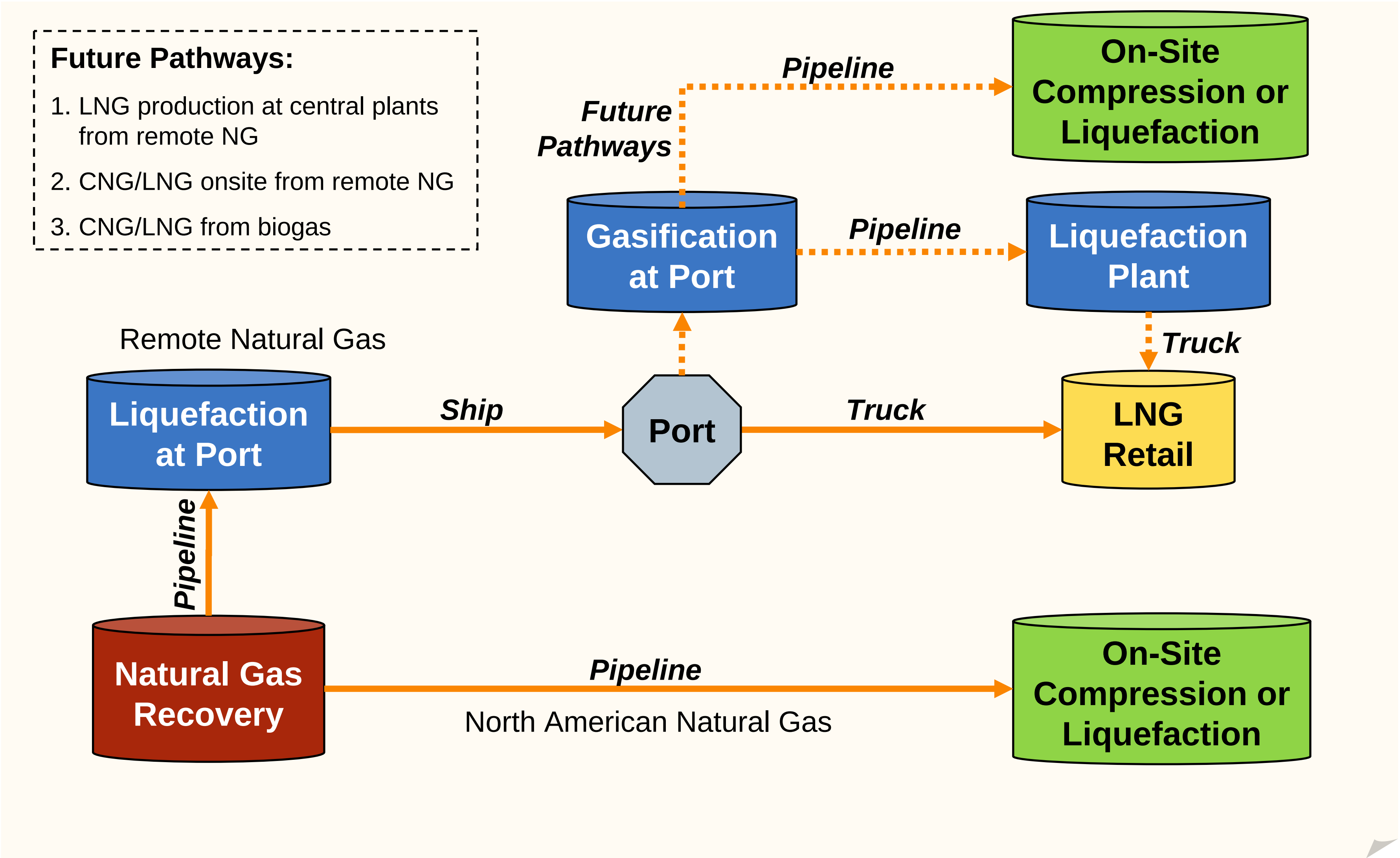


Petroleum Fuel Pathways in CA-GREET

Case #	G1b	G2	G13	G14	G11	D2	D3	P1
Fuel	CA RFG	CA RFG	CA RFG	CA RFG	CARBOB	ULSD	ULSD	LPG
Oxygen Content	2%	2%	0%	2%	0%	n/a	n/a	n/a
Oxygenate Type	Ethanol	Ethanol	n/a	Ethanol	n/a	n/a	n/a	n/a
Feedstock	Crude	Crude	Hvy Crude	Hvy Crude	Crude	Crude	Crude	Crude
Feedstock Origin	Foreign	CA Avg	Venezuela	CA TEOR	Foreign	Foreign	CA Avg	CA Avg
Refinery	Foreign	CA	Venezuela	CA	Foreign	Foreign	CA	CA

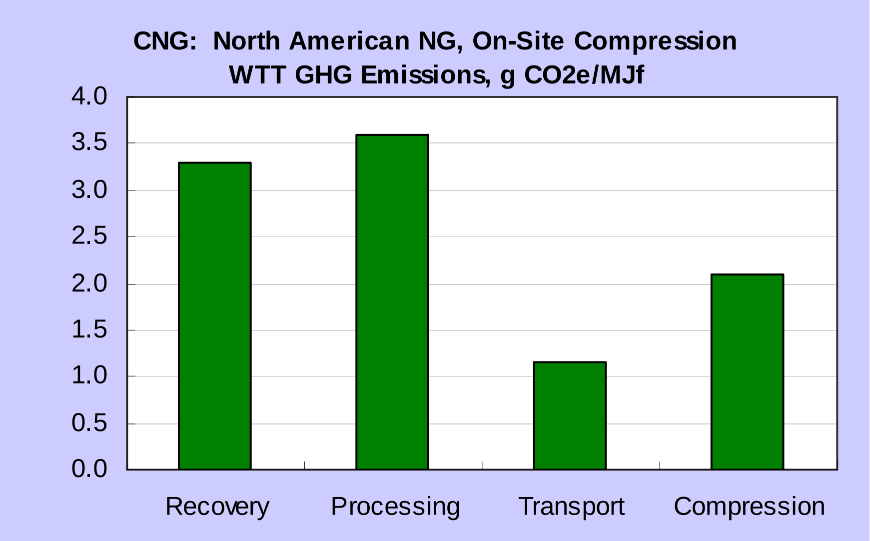
Would like to add a Tar Sands Case – currently GREET only has Tar Sands to Conventional Gasoline pathway.

Natural Gas Fuel Pathways



Natural Gas Fuel Pathways – Key Inputs/Assumptions

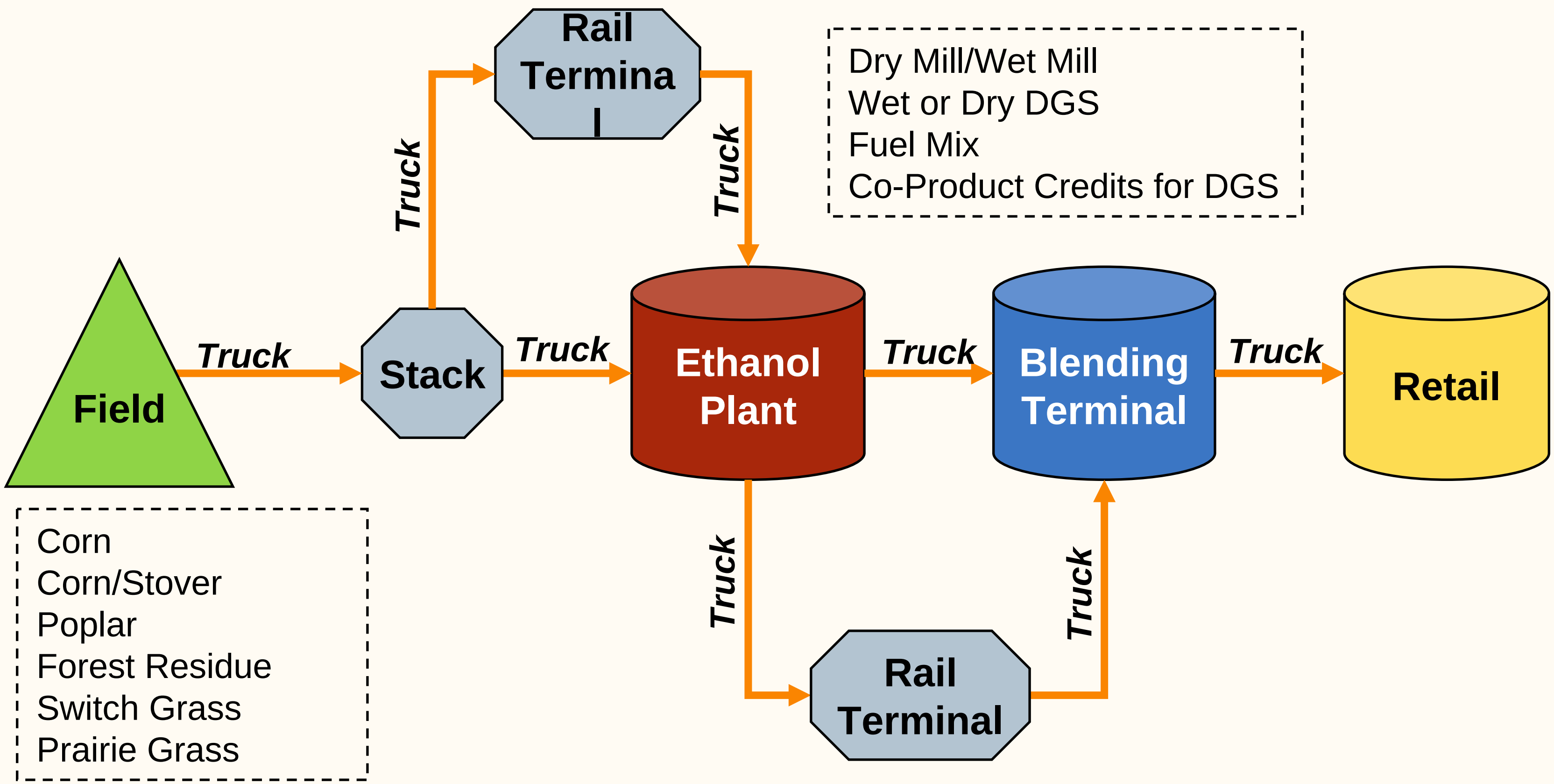
- Process Efficiency
  - Natural Gas Recovery Efficiency
  - Natural Gas Processing Efficiency
  - Compression Energy Consumption
- Fuel and Equipment Mixes
  - Recovery
  - Processing
  - Compression
- Losses (recovery, refining)
- Transport
  - Distances by mode
  - Tanker/Truck Inputs
    - Payload
    - Horsepower
    - Fuel economy
    - Speed
  - Pipeline Inputs
    - Energy intensity (Btu/ton-mile)
    - Compressor station fuel mix
    - Prime mover mix at compressor stations
  - Losses



Natural Gas Pathways

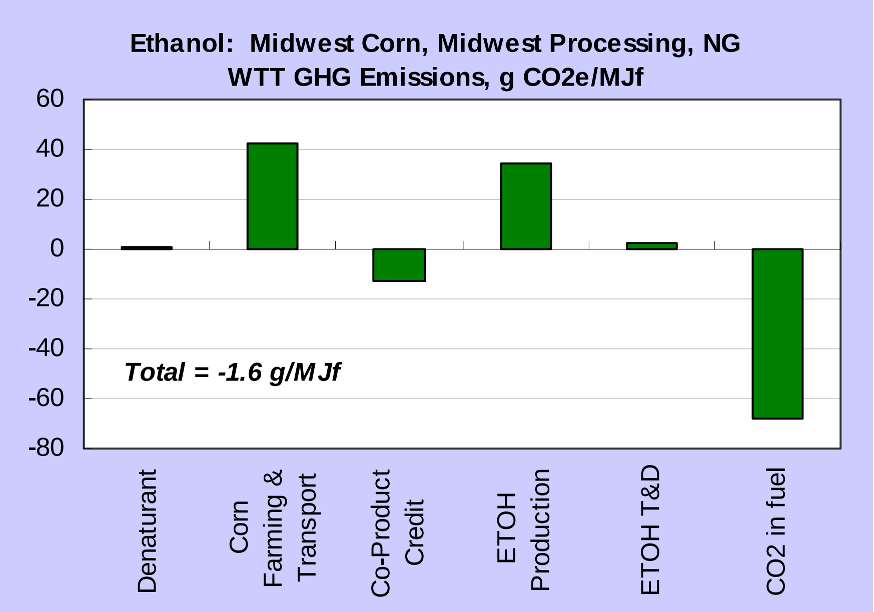
Case #	P2	C1	L3	L1
Finished Fuel	LPG	CNG	LNG	LNG
Feedstock	NA NG	NA NG	Remote NG	NA NG
Fuel Production Location	New Mexico	CA On-Site	Malaysia	CA On-Site
Transmission Leak Rates	0.08%	0.08%	0.35%	0.08%
Transport to CA by	Rail	n/a	Ship	n/a

Ethanol Pathways



Ethanol Fuel Pathways – Key Inputs/Assumptions

- Feedstock Assumptions
  - Material (corn, farmed trees, herbaceous, corn stover, forest residue)
  - Farming/collection energy use
    - Split by fuel type
    - Split by combustion device
    - Fertilizer/pesticide/herbicide
    - Amounts by type
    - Production energy consumption
    - Transport modes and distances
    - % of N in fertilizer emitted as N2O
  - Crop yields
  - Feedstock transport modes and distances



- Ethanol Production
  - Process efficiency (energy use)
    - Split by fuel type
    - Split by combustion device
  - Process yield (gal/bu)
  - Co-product credits (DGS substituted for feed corn & soybean meal)
  - Transport modes and distance

Ethanol Pathways

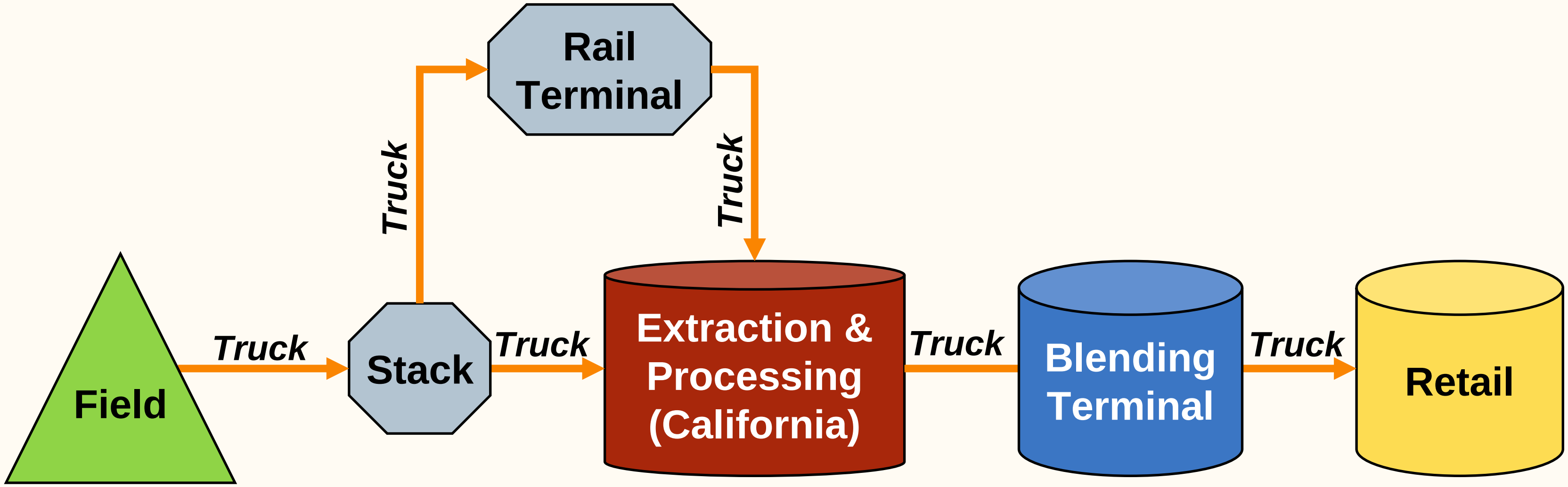
Case #	Et1	Et2	Et3	Et4	Et5	Et6	Et74	Et21	Et22	Et23	Et24
Feedstock	Corn	Corn	Corn	Corn	40/60 Corn/ Stover	20/80 Corn/ Stover	Corn	Poplar (farm)	Forest Res	Switch Grass	Prairie Grass
Feed Origin	MW	MW	MW	MW	MW	MW	MW	CA	CA	CA	CA
Ethanol Production Location	MW	MW	MW	MW	MW	MW	CA	CA	CA	CA	CA
Dry Mill %	80%	100%	100%	100%	100%	100%	100%	n/a	n/a	n/a	n/a
% Coal*	10%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Transport to CA	EtOH	EtOH	EtOH	EtOH	EtOH	EtOH	Corn				
Mode:	Rail	Rail	Rail	Rail	Rail	Rail	Rail				

* = % coal used as process fuel – balance natural gas

MW = Midwest

T/R = Transport to terminal and then to retail

Biodiesel Pathways

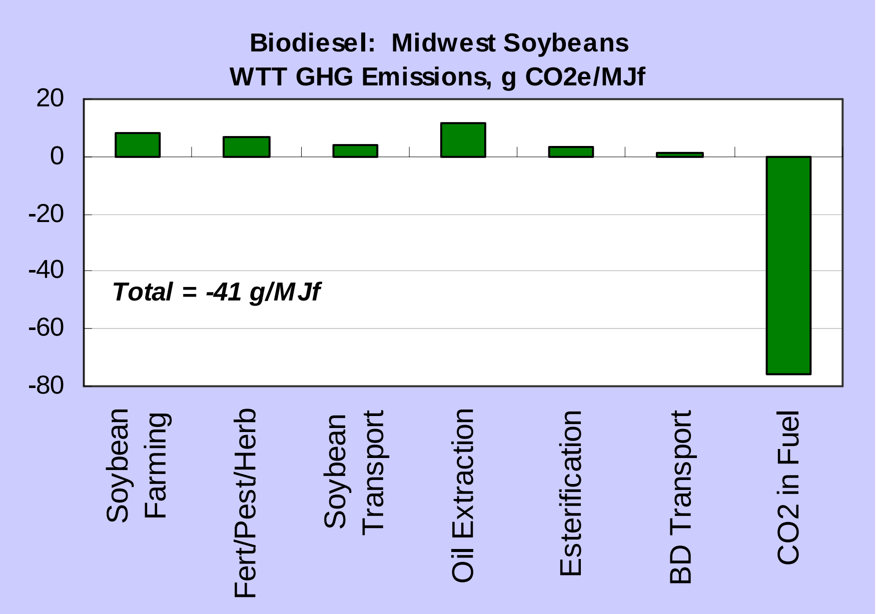


Soybeans (Midwest)
Canola (California)
Mustard Seed (California)

Fuel Mix
Co-Product Credits for soybean meal and glycerin

Biodiesel Pathways – Key Inputs/Assumptions

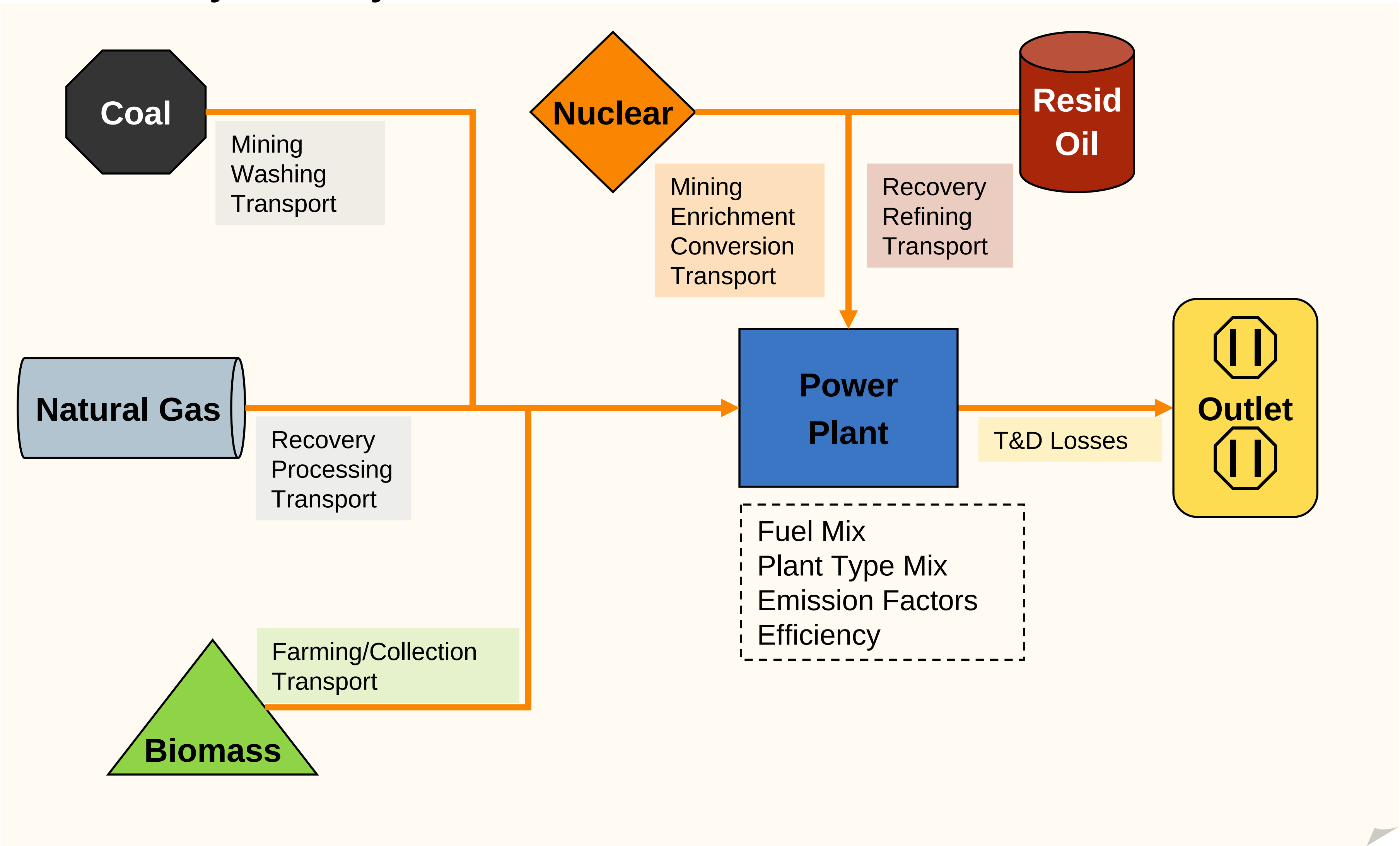
- Feedstock Assumptions
  - Material (soybeans, canola, mustard)
  - Farming/collection energy use
    - Split by fuel type
    - Split by combustion device
    - Fertilizer/pesticide/herbicide
    - Amounts by type
    - Production energy consumption
    - Transport modes and distances
    - % of N in fertilizer emitted as N2O
  - Crop yields
  - Feedstock transport modes and distances
- Biodiesel Production
  - Process efficiency (energy use)
    - Split by fuel type
    - Split by combustion device
  - Process yield (gal/bu)
  - Co-product credits
  - Transport modes and distance



Biodiesel Pathways

Case #	BD3	BD1	BD4
Feedstock	Soybeans	Canola	Mustard
Feedstock Origin	Midwest	California	California
Production Location	California	California	California
Farming Energy Adjustment Factor	100%	37.5%	78%
Fertilizer Use Adjustment Factor	100%	50%	0%
Farming/Extraction Allocation to Biodiesel	62.1%	62.1%	100%
Refining Allocation to Biodiesel	79.6%	79.6%	79.6%
Transport Biodiesel to California by	Rail	n/a	n/a

Electricity Pathways



Electricity Pathways – Key Inputs/Assumptions

- Feedstock Assumptions
  - Fuel Mix (NG, coal, biomass, nuclear, oil, other*)
  - Recovery, processing, transportation energy and emissions
- Electricity Production
  - Mix of generation equipment
  - Efficiency
  - Emission Factors
  - Transport & Distribution Losses

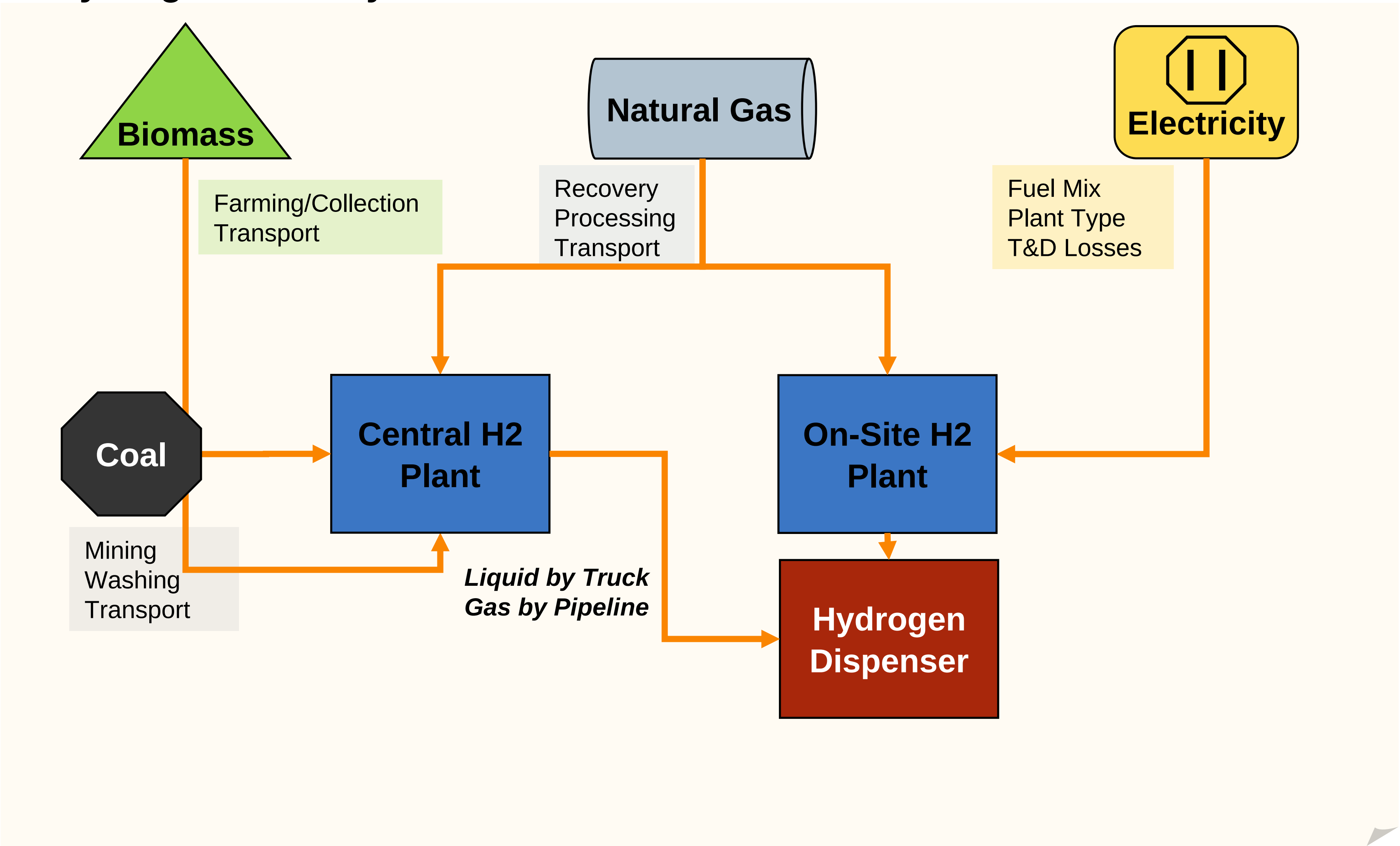
* Other = noncombustible renewables like hydro, geothermal, solar

Electricity Pathways

Case #	Feedstock/Prime-movers
e92	Nuclear Power
e53	Renewable Power (non-combustion sources only)
e54	Forest Residue utilized in utility boiler
e11	California Average (Based on 2005 electricity resource mix)
e12	US Average (default GREET)
e1	NG CCCT+RPS: RPS is non-combustion renewable, balance is natural gas CCCT
e30	NG CCCT: 100% of electricity is from natural gas fired CCCTs (base loaded units)
e31	NG SCCT: 100% of electricity is from natural gas fired SCCTs (peakers)
e36	Coal IGCC: 100% from coal fired IGCC plants
e37	Coal IGCC + CCS – assumes 85% of CO2 from coal IGCC is captured and sequestered
e38	Coal Supercritical – assumes all electricity comes from new supercritical PC unit

RPS = Renewable Portfolio Standard
CCCT = Combined Cycle Combustion Turbine
SCCT = Simple Cycle Combustion Turbine
IGCC = Integrated gasification combined cycle
CCS = Carbon Capture and sequestration
PC = pulverized coal

Hydrogen Pathways



Hydrogen Pathways – Key Inputs/Assumptions

- Feedstock Assumptions
  - Feedstock type: (NG, coal, biomass, H2O electrolysis)
  - Recovery, processing, transportation energy and emissions associated with feedstock

- Hydrogen Production
  - On-Site or central station
  - Final form (liquid or gas)
  - Process efficiency
  - Portion of feedstock used as process fuel
  - Process fuel mix and equipment type
  - Compression/Liquefaction efficiency
  - Transport modes and distances

Hydrogen Pathways

Case #	H2	H3	H4	H4c	H5	H7	H11	H13	H22	H23
Final Form	Liquid	Liquid	Gas	Gas	Gas	Gas	Gas	Gas	Gas	Gas
Station	Central	Central	Central	Central	Central	Central	On-Site	On-Site	On-Site	On-Site
Location	CA	CA	CA	CA	CA	CA	CA	CA	CA	CA
Feedstock	NG	NG	Coal	Coal*	NG	Biomass	NG	NG	Electric	Electric
Renewable Electricity	RPS	100%	RPS	RPS	RPS	RPS	0%	100%	RPS	70%
Transport Mode	Truck	Truck	Pipeline	Pipeline	Pipeline	Pipeline				

RPS = Renewable Portfolio Standard
* With carbon capture & sequestration

8:30-9:00	Introduction
9:00-11:00	Full Fuel Cycle Overview
11:00-12:00	CA GREET Pathways
12:00-1:00	**Lunch**
1:00-1:30	CA GREET Structure
1:30-2:00	Running the CA-GREET Model
2:00-4:00	Detailed Look at CA RFG and EtOH Pathways
4:00-4:30	Updates to CA-GREET Model

8:30-9:00	Introduction
9:00-11:00	Full Fuel Cycle Overview
11:00-12:00	CA GREET Pathways
12:00-1:00	Lunch
1:00-1:30	**CA GREET Structure**
1:30-2:00	Running the CA-GREET Model
2:00-4:00	Detailed Look at CA RFG and EtOH Pathways
4:00-4:30	Updates to CA-GREET Model

CA GREET Model Overall Structure

Control Panel

Global Worksheets:
- Inputs
- Fuel_Prod_TS
- EF_TS and EF
- Fuel_Specs
- Ag_Inputs
- Coal
- Uranium
- T&D
- Urban_Shares
- Results

Fuel Worksheets:
- Petroleum
- EtOH
- BD
- NG
- Hydrogen
- Electric

Unused (so far):
- LF-Gas (MeOH)
- E-D Additives
- LDT1_TS
- LDT2_TS
- Vehicles
- Dist_Specs
- Forecast_Specs
- Forecast_Deleted

WTT Global Worksheets

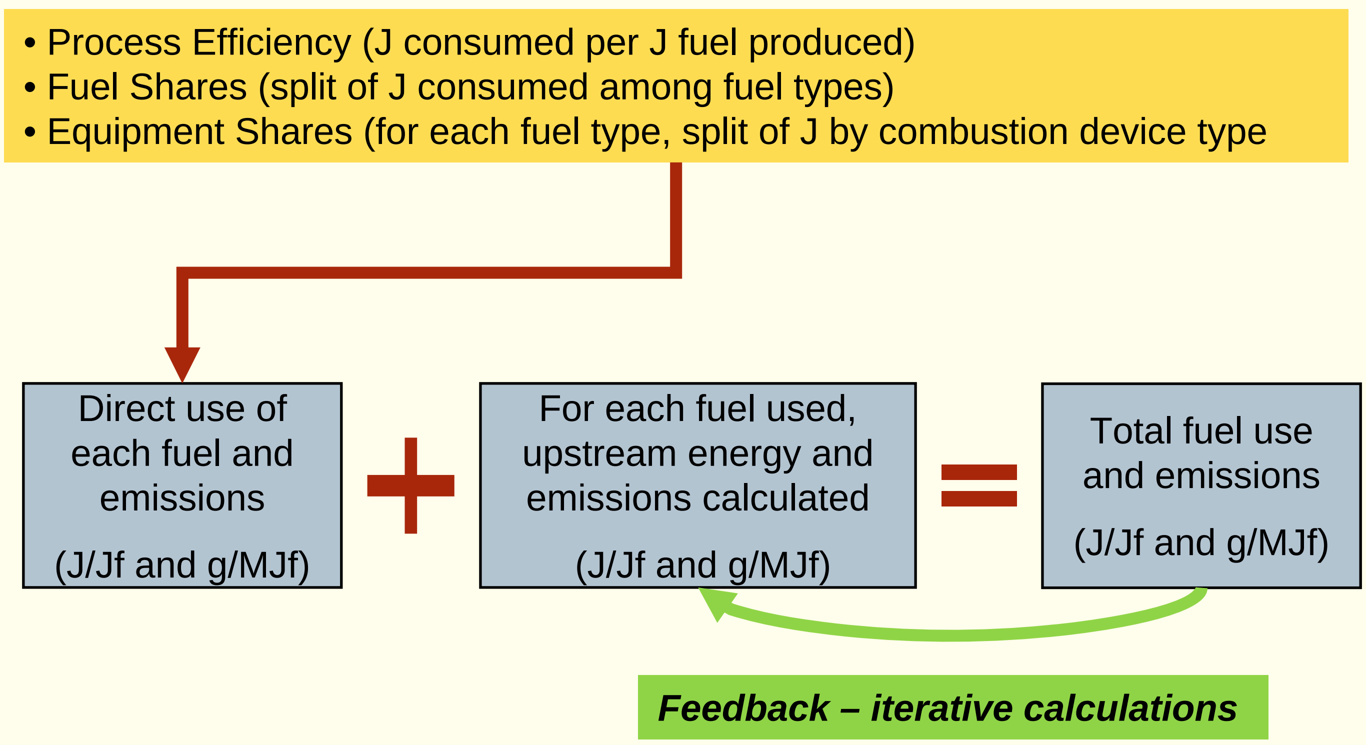
- Control Panel
  - Added by TIAX
  - Select analysis year and case from pull down menus
  - Stores and documents pathway specific inputs
  - Allows inputs for each case to be saved and re-used
- Fuel_Prod_TS
  - Contains efficiency, market shares process data inputs by analysis year
  - Do not change yellow/green values on top left of each table – macros
  - Ok to modify values in center column of each table
  - TIAX inserted some logic related to control panel to run different cases
- EF_TS
  - Contains emission factors by year for each equipment/fuel type
  - Note TIAX Modifications
- Input Sheet
  - Some cells are inputs
  - Some pull from other sheets (control panel, fuel_prod_ts, etc)
  - Form of documentation, but not all inputs are here…

WTT Global Worksheets (Concluded)

- Fuel_Specs
  - TIAX modified a number of the fuel properties
  - Yellow and green cells may be modified
- Ag_Inputs
  - Quantifies energy use and emissions from fertilizer and pesticide production and use
  - TIAX used all GREET default values
- T&D
  - Calculates emissions associated with transporting and final distribution of feedstocks and finished fuels
    - Define distances on inputs sheet
    - Cargo capacities input here
    - Transport “mode share” input here
  - TIAX plans to clean up some of the logic on T&D inputs (drive from control panel sheet)

General Structure of Fuel Worksheets

- Calculations are split into:
  - Feedstock: extraction/collection/recovery and transport
  - Fuel: production and transport
- The feedstock extraction and fuel production calculations proceed as follows:



General Structure of Fuel Worksheets (continued)

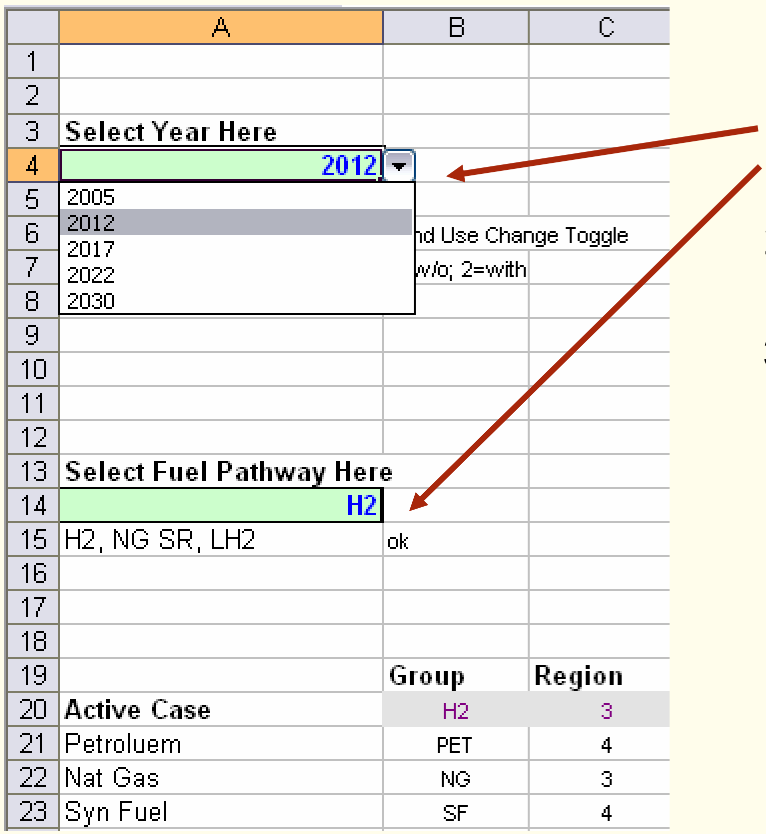
- Transport & distribution of feedstocks and fuels
  - Energy and emissions calculated on the T&D Worksheet
  - Pulled to the fuel sheet where they are added to the feedstock extraction and fuel production values
- First order Inputs are transport mode & miles
- Other T&D inputs include:
  - Cargo Ship
    - Payload
    - Horsepower
    - Speed
    - Load Factor
  - Tanker Trucks
    - Payload
    - Fuel Economy
  - Rail
    - Energy Intensity, Btu/ton-mile
  - Pipeline
    - Compressor station engine type split
    - Energy Intensity, Btu/ton-mile

8:30-9:00	Introduction
9:00-11:00	Full Fuel Cycle Overview
11:00-12:00	CA GREET Pathways
12:00-1:00	Lunch
1:00-1:30	CA GREET Structure
1:30-2:00	**Running the CA-GREET Model**
2:00-4:00	Detailed Look at CA RFG and EtOH Pathways
4:00-4:30	Updates to CA-GREET Model

GET STARTED!

- Load Files
  - Make a CA GREET Folder on your hard drive
  - Copy “GREET1.7_ROW_US_CA_v98.xls” into this folder
- Start it Up
  - Double click on file
  - Click “enable macros”
  - Click “Yes” to continue
- General Advice
  - Make sure you are in **Manual Calculation Mode**
    - Go to “Tools-Options-Calculation” and select “Manual”
    - Must be in manual mode b/c it is designed with circular references to allow secondary energy and emission effects.
  - Make sure the **Formula Auditing Toolbar** is displayed (tools, formula auditing)
  - If changing values/logic, **Save Frequently**

How to Run Existing Pathways



1. In Control Panel tab,
   – Select an analysis year
   – Select a fuel pathway (case)
2. Hit F9 **and** go to the "results" worksheet to initiate calculations
3. **Important**: You must go to the results tab to set off a macro that starts the iterative calculations.

Return to Control Panel to View Results in Appropriate Column

	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1															
2			RESULTS: Paste these into the WTT post-processor												Gaseous
3			Fed RFG	CA RFG	ULSD	NG, CNG	LNG	LPG	Methanol	DME	Ethanol	FTD	BD	Electricity	Hydrogen
4	Total Energy	J/J	0.22	0.26	0.21	0.07	0.18	0.12	0.62	0.55	0.71	0.71	0.69	1.01	0.50
5	WTP eta	%	81.8%	79.1%	82.8%	93.2%	85.0%	89.2%	61.8%	64.4%	58.6%	58.5%	59.1%	49.8%	66.5%
6	Fossil Fuels	J/J	0.22	0.26	0.21	0.07	0.18	0.12	0.62	0.55	0.70	0.71	0.68	0.99	0.50
7	Coal	J/J	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	Natural Gas	J/J	0.09	0.14	0.10	0.07	0.17	0.09	0.58	0.52	0.61	0.69	0.44	0.98	0.50
9	Petroleum	J/J	0.10	0.12	0.11	0.00	0.00	0.03	0.04	0.03	0.08	0.02	0.25	0.01	0.01
10	CO2	g/MJ	16.24	14.78	13.98	4.99	10.74	7.93	22.98	21.42	-26.69	27.86	-36.84	99.61	84.31
11	CH4	g/MJ	0.10	0.10	0.10	0.13	0.20	0.10	0.23	0.22	0.09	0.24	0.07	0.23	0.18
12	N2O	g/MJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.01	0.00	0.00
13	**GHGs**	**g/MJ**	18.55	17.68	16.26	8.05	15.29	10.34	28.26	26.48	-11.65	33.43	-32.41	105.52	88.61
14	VOC: Total	g/GJf	11.18	13.71	10.90	6.63	6.72	79.18	16.50	66.91	43.85	13.18	208.96	10.96	9.27
15	CO: Total	g/GJf	14.46	19.37	13.44	8.51	9.75	10.34	19.17	19.39	148.19	14.77	566.60	27.40	13.84
16	NOx: Total	g/GJf	16.48	38.70	36.20	5.98	4.00	8.76	67.70	49.19	66.60	34.57	129.09	9.89	8.61
17	PM10: Total	g/GJf	5.19	4.56	3.87	0.31	0.39	0.70	6.31	3.94	15.43	2.76	10.48	1.85	1.22
18	PM2.5 Total	g/GJf	2.30	3.48	3.12	0.57	0.66	0.81	5.44	3.43	6.95	2.58	9.46	2.28	1.59
19	SOx: Total	g/GJf	7.87	17.21	15.63	10.25	11.33	14.70	32.30	26.56	32.41	24.04	87.90	16.96	14.35
20	VOC: Urban	g/GJf	4.28	4.87	3.52	0.14	0.03	70.46	5.38	56.74	6.27	2.58	7.78	0.23	0.19
21	CO: Urban	g/GJf	0.18	0.66	0.60	0.26	0.10	0.76	1.16	1.01	0.80	0.61	19.54	13.76	0.39
22	NOx: Urban	g/GJf	0.07	1.84	1.43	0.59	0.13	2.40	4.24	3.56	0.31	2.11	60.49	0.98	0.59
23	PM10: Urban	g/GJf	0.02	0.11	0.07	0.01	0.01	0.10	0.21	0.17	0.07	0.10	2.42	1.35	0.02
24	PM2.5 Urban	g/GJf	0.02	0.10	0.07	0.01	0.01	0.09	0.18	0.15	0.08	0.09	2.23	1.36	0.02
25	SOx: Urban	g/GJf	0.00	0.17	0.03	0.00	0.00	0.03	0.37	0.28	-0.01	0.17	1.67	0.00	0.00
26			Fed RFG	CARFG	ULSD	CNG	LNG	LPG	Methanol	DME	Ethanol	FTD	BD	Electricity	Hydrogen
27			Only Use This												
28			Column for												
29			Tar Sands												
30															

Overview / Mods / **Control Panel** / Results / Inputs / Fuel_Specs / EF_TS / EF / Fuel_Prod_TS / T&D / Ag_Inputs / Petroleum / EtOH / BD / Hydroger

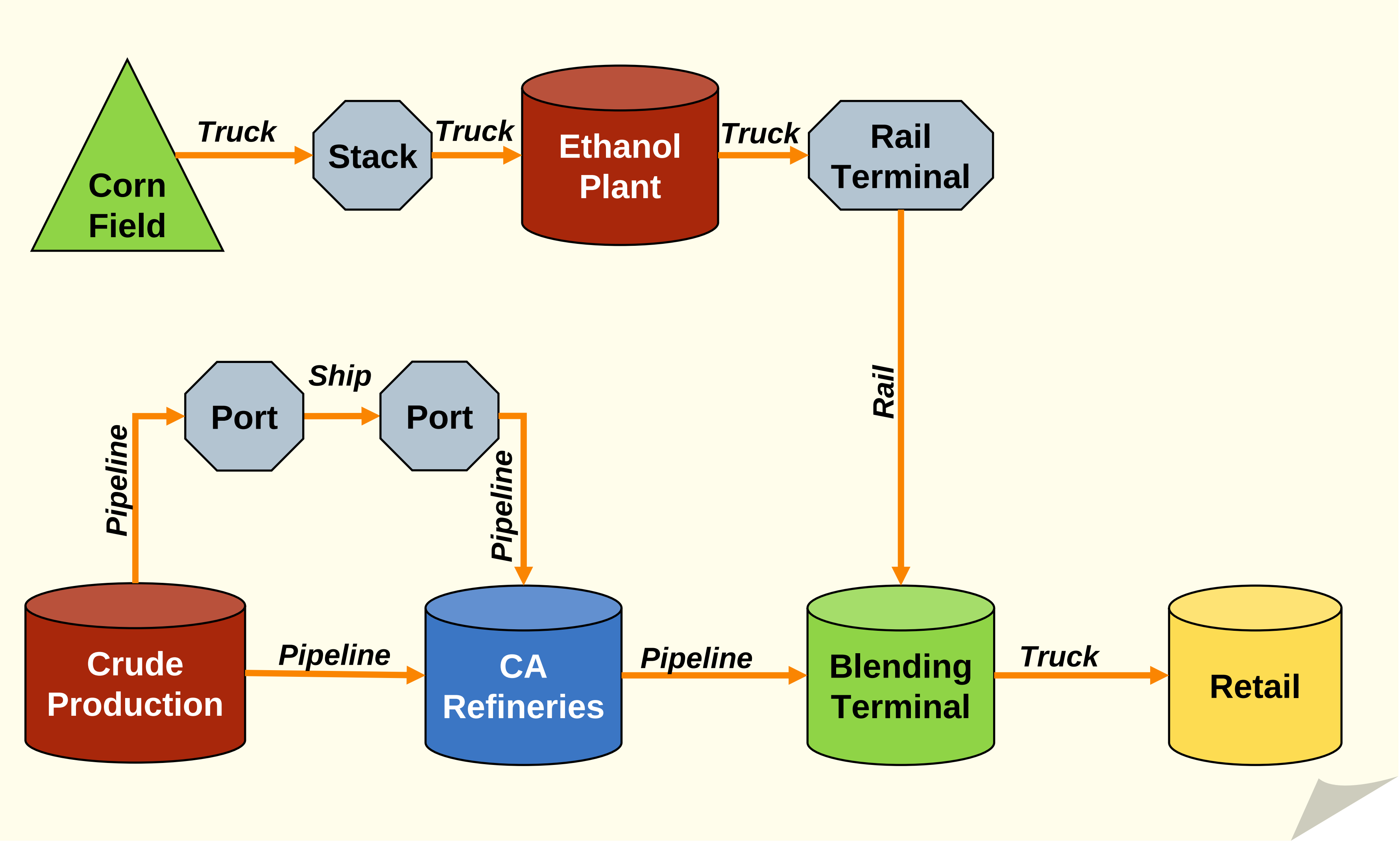
View Key Assumptions for Each Pathway in the Control Panel

	A	B	C	D	E	F	G	H	I	J	K	L
38			PET									
39		Active	RFG, Marginal	RFG, CA Average Crude Mix	RFG0, Heavy Crude	RFG, CA TEOR	RFG, Tar Sands	CARBOB	RFG, 0 Oxygen	E10, Corn, MW EtOH	Diesel, Marginal CA ULSD	Diesel, Average CA ULSD
40		G1b	G1b	G2	G13	G14	G15	G11	G0	E10	D2	D3
41	Region	4	4	2	1	2	1	4	4	4	4	2
42	Oil Sands Shares	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
43	CARFG Oxygen	2.0%	2.0%	2.0%	0.0%	2.0%	2.0%	0.0%	0.0%	3.5%	0.0%	0.0%
44	LPG Natural Gas Frac	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%
45	Fed RFG Refinery η	85.5%	85.5%	85.5%	83.1%	83.4%	85.5%	85.5%	85.5%	85.5%	85.5%	85.5%
46	CA RFG Refinery η	84.5%	84.5%	84.5%	82.1%	83.5%	84.5%	84.5%	84.5%	84.5%	84.5%	84.5%
47	LSD Refinery η	87.0%	87.0%	87.0%	87.0%	87.0%	87.0%	87.0%	87.0%	87.0%	86.7%	86.7%
48	Conv Crude Oil Extraction η	98.0%	98.0%	93.9%	77.8%	77.8%	98.0%	98.0%	98.0%	98.0%	98.0%	93.9%
49	Crude Transport ship, miles	0	0	3,550	0	0	800	0	0	0	0	3,550
50	Crude Transport pipeline, miles	50	50	266	200	50	715	50	50	50	50	266
51	CA RFG Transport ship, miles	7,700	7,700	0	3,710	0	0	7,700	7,700	7,700	0	0
52	CA RFG Transport pipeline miles	50	50	50	50	50	50	50	50	50	50	50
53	CA RFG Transport Truck miles	50	50	50	50	50	50	50	50	50	50	50
54	ULSD Transport ship, miles	7,700	7,700	0	0	0	0	0	0	0	7,700	0
55	ULSD Transport pipeline miles	50	50	50	50	50	50	50	50	50	50	50
56	ULSD Transport Truck miles	50	50	50	50	50	50	50	50	50	50	50
57	NG to LPG Plant Pipeline miles	50	50	50	50	50	50	50	50	50	50	50
58	LPG Transport Ship miles	0	0	0	0	0	0	0	0	0	0	0
59	LPG Transport rail miles	50	50	50	50	50	50	50	50	50	50	50
60	LPG Transport truck miles	50	50	50	50	50	50	50	50	50	50	50
61												
62												

We are in the process of pulling all key variables to the control panel to enhance transparency and improve accuracy

8:30-9:00	Introduction
9:00-11:00	Full Fuel Cycle Overview
11:00-12:00	CA GREET Pathways
12:00-1:00	Lunch
1:00-1:30	CA GREET Structure
1:30-2:00	Running the CA-GREET Model
2:00-4:00	**Detailed Look at CA RFG and EtOH Pathways**
4:00-4:30	Updates to CA-GREET Model

Schematic of Average CA RFG Pathway (G2)



Example Pathway G2: Control Panel Worksheet

	A	B	C	D	E	F	G	H	I	J	K
38			PET								
39		Active	RFG, Marginal	RFG, CA Average Crude Mix	RFG0, Heavy Crude	RFG, CA TEOR	RFG, Tar Sands	CARBOB	RFG, 0 Oxygen	E10, Corn, MW EtOH	Dies Margi CA UL
40		G2	G1b	G2	G13	G14	G15	G11	G0	E10	D2
41	Region	2	4	2	1	2	1	4	4	4	4
42	Oil Sands Shares	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.
43	CARFG Oxygen	2.0%	2.0%	2.0%	0.0%	2.0%	2.0%	0.0%	0.0%	3.5%	0.
44	LPG Natural Gas Frac	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%	60.
45	Fed RFG Refinery η	85.5%	85.5%	85.5%	83.1%	83.4%	85.5%	85.5%	85.5%	85.5%	85.
46	CA RFG Refinery η	84.5%	84.5%	84.5%	82.1%	83.5%	84.5%	84.5%	84.5%	84.5%	84.
47	LSD Refinery η	87.0%	87.0%	87.0%	87.0%	87.0%	87.0%	87.0%	87.0%	87.0%	86.
	Conv Crude Oil Extraction η	93.9%	98.0%	93.9%	77.8%	77.8%	98.0%	98.0%	98.0%	98.0%	98.
	Crude Transport ship, miles	3,550	0	3,550	0	0	800	0	0	0	
	Crude Transport pipeline, miles	266	50	266	200	50	715	50	50	50	
	CA RFG Transport ship, miles	0	7,700	0	3,710	0	0	7,700	7,700	7,700	
	CA RFG Transport pipeline miles	50	50	50	50	50	50	50	50	50	
	CA RFG Transport Truck miles	50	50	50	50	50	50	50	50	50	
54	ULSD Transport ship, miles	0	7,700	0	0	0	0	0	0	0	7,7

- Crude Recovery Efficiency
- Refining Efficiency
- Crude Transport miles
- CA RFG Transport miles

Example Pathway G2: Inputs Worksheet

	A	B	C	D	E	F	G	
40	3.2) Gasoline Fuel Options							
41	3.2.a) Share of Reformulated Gasoline in Total Gasoline Use, by volume							
42		100%						
43								
44	3.2.b) Gasoline Specifications and Refining Efficiencies for Gasoline							
45			O2 content by wt.	Oxygenate type	Sulfur level, ppm	Refining Efficiency		Note: Oxygenate Type
46		Conventional Gasoline	0.0%	5	26	86.0%	1 -- MTBE	4 -- Ethanol
47		RFG: Gasoline Blendstock	0.0%	5	15	85.5%	2 -- ETBE	5 -- No oxygenate
48		CARFG: Gasoline Blendstock	2.0%	4	11	84.5%	3 -- TAME	
49								
50	3.2.c) Ethanol Production Options for Gasoline if ETBE or Ethanol Is Selected as the Oxygenate							
51			Corn	Woody Biomass	Herbaceous Biomass			
52		Share of Ethanol Feedstock	100.0%	0.0%	0.0%			

- Inputs Sheet
  - Cell B42 – all gasoline is reformulated
  - Cell C48 blendstock oxygen content (from control panel) = 2
  - Cell D48 oxygenate type is "4" = ethanol.
  - Cell C52 100% corn is feedstock for ethanol

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Example Pathway G2: Fuel_Prod_TS Worksheet

Conventional Oil Recovery and Fuel Refining from Conventional Oil

	98.0%	85.5%
Fixed (original for 2010)	98.0%	85.5%
Interpolated Default or user input	93.9%	84.5%

5-year period	Crude Recovery Efficiency	E (to
1990	98.0%	
1995	98.0%	
2000	98.0%	
2005	98.0%	
2010	**93.9%**	
2015	**93.9%**	
2020	**93.9%**	

5-year period	CARFG Refining Efficiency	Rela Effici (to yr 2
1990	86.0%	1
1995	86.0%	1
2000	85.5%	1
2005	85.5%	1
2010	**84.5%**	**10**
2015	**84.5%**	1
2020	**84.5%**	1

Do not change green or yellow cells – these are filled by macros

- Cell D15: Crude recovery efficiency 93.9%
  - 20% of crude refined is CA TEOR with a recovery efficiency of 78%
  - Balance of crude assumed to have a recovery efficiency of 98% (GREET default)
- Cell P15: CA RFG Refining efficiency 84.5%
  - GREET default for federal RFG is 85.5%
  - CA RFG assumes increased H2 use in refining to remove sulfur

Example Pathway G2: T&D Worksheet Crude

	A	G	H	I	J	K
82	**Feedstock/Fuel**	**Crude Oil for Use in California Refineries**				
83	**Transportation Mode**	**Ocean Tanker**	**Barge**	**Pipeline**	**Rail**	**Truck**
84	Urban Emission Share	0.0%	0.0%	0.0%	0.0%	33.3%
85	Distance (Miles, one-way)	3,550	0	266	0	0
86	Share of Fuel Type Used:					
87	Diesel	0%	0%	0%	100%	100%
88	Residual Oil	100%	100%	0%		
89	Natural Gas			0%		
90	LPG					
91	DME					
92	FTD					
93	Methanol					
94	Ethanol					
95	Biodiesel					
96	Hydrogen					
97	Electricity			100%	0%	

		C	D	E
		Crude Oil for Use in CA Refineries	**Oil Sands Products for Use in U.S. Refineries**	**Cc**
		rude Transportation	**Crude Transportation**	
128	Percentage of Fuel Transported by a Given Mode			
129	Ocean tanker	100.0%	100.0%	
130	Barge	0.0%	0.0%	
131	Pipeline	100.0%	100.0%	
132	Rail	0.0%	0.0%	
133	Truck	100.0%	0.0%	
134	Energy Consumption: Btu/mmBtu of fuel transporte			
135	Total energy	10,014	16,035	

Crude Transport

- Cells G85-K85 have crude transport distances for each mode
- Cells C129-C133 have crude transport mode shares
- Whether crude is refined in CA or not, this is the label for crude made into CA RFG

Example Pathway G2: T&D Worksheet CA RFG

	A	AA	AB	AC	AD	AE
82	**Feedstock/Fuel**	**CA Reformulated Gasoline for CA Use**				
83	**Transportation Mode**	**Ocean Tanker**	**Barge**	**Pipeline**	**Rail**	**Truck**
84	Urban Emission Share	0.0%	0.0%	100.0%	44.5%	100.0%
85	Distance (Miles, one-way)	0	0	50	0	50
86	Share of Fuel Type Used:					
87	Diesel	0%	0%	0%	100%	100%
88	Residual Oil	100%	100%	0%		
89	Natural Gas			0%		
90	LPG					
91	DME					
92	FTD					
93	Methanol					
94	Ethanol					
95	Biodiesel					
96	Hydrogen					
97	Electricity			100%	0%	

	A	I	J
		CA RFG	
		Gasoline Transportation	**Gasoline Distribution**
128	Percentage of Fuel Transported by a Given Mode		
129	Ocean tanker	**100.0%**	
130	Barge	0.0%	
131	Pipeline	80.0%	
132	Rail	0.0%	
133	Truck		99.4%
134	Energy Consumption: Btu/mmBtu of fuel transpor		
135	Total energy	645	3,551

CA RFG Transport & Distribution

- Cells AA85-AE85 have CA RFG transport distances for each mode
- Cells I129-J133 have CA RFG transport mode shares
- Distances and modes are cross multiplied before calculating energy and emissions

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Example Pathway G2: Petroleum Worksheet Crude

	A	B	C	D	E
32		Crude Oil			
33		Recovery	Transportation to U.S. Refineries	Transportation to CA Refineries	Storage
34	**Energy efficiency**	93.9%			
35	**Urban emission share**	0.0%	0.0%	0.0%	0.0%
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	62.0%			
43	Coal	0.0%			
44	Electricity	19.0%			
45	Refinery still gas	0.0%			
46	Feed loss	0.0%			
47	**Energy use: Btu/mmBtu of fuel throughput**				
48	Crude oil	648			
49	Residual oil	648			
50	Diesel fuel	9,726			
51	Gasoline	1,297			
52	Natural gas	40,201			
53	Coal				
54	Electricity	12,320			
55	Feed loss	28	62	62	0
56	Refinery still gas				
57	Natural gas flared	16,800			
58	Total energy	86,477	6,505	10,076	0

Crude Recovery & Transport

- Recovery efficiency from control panel
- Fuel splits are GREET defaults
- Energy use in rows 48-57 are DIRECT energy use.
- Total energy in row 58 sums 48-57 and includes WTT energy
  - e.g. the energy to recover the crude to make resid oil to recover the crude…
- CA RFG uses the transport energy in column D – row 58 comes from the T&D sheet (C135) + feedloss (D55)

Example Pathway G2: Petroleum Worksheet RFG

	A	X	Y	Z	AA	AB
32		Reformulated Gasoline				
33		CARFG Gasoline Blendstock Refining	CARFG Gasoline Blendstock Refining: Non-RFG	Transportation and Distribution	RFG Storage	CA RFG Transportation and Distribution
34	**Energy efficiency**	84.5%				
35	**Urban emission share**	0.0%		100.0%	100.0%	100.0%
36	**Loss factor**	1.000		1.000	1.000	1.000
37	**Shares of process fuels**					
38	Crude oil	0.0%				
39	Residual oil	6.0%				
40	Diesel fuel	0.0%				
41	Gasoline	0.0%				
42	Natural gas	40.0%				
43	Coal	0.0%				
44	Electricity	4.0%				
45	Refinery still gas	50.0%				
46	Feed loss	0.0%				
47	**Energy use: Btu/mmBtu of f**					
48	Crude oil	0				
49	Residual oil	11,006				
50	Diesel fuel	0				
51	Gasoline	0				
52	Natural gas	73,373				
53	Coal	0				
54	Electricity	7,337				
55	Feed loss	0		184	0	201
56	Refinery still gas	91,716				
57	Natural gas flared					
58	Total energy	208,621		6,484	0	4,397

Refining & Transport Energy

- Refining efficiency (X34) from control panel
- Fuel splits are GREET defaults
- Energy use in rows 48-57 are DIRECT energy use.
- Total energy in row 58 sums 48-57 and includes WTT portion also.
  - e.g. the energy to recover the crude and refine to resid oil to refine the crude to CARFG…
- T&D energy in AB58 comes from the T&D sheet (I135+J135) plus AB55

Example Pathway G2: Petroleum Worksheet Oxygenates

	A	B	C	E	G	H	J	K
84	4) Calculations of Energy Use and Emissions of Oxygenate Production							
85	4.1) The Amount of Oxygenates Required for Meeting Gasoline Oxygen Requirements							
86		O2 Content (by weight)	Weight Content for CG	Weight Content for CARFG	Volumetric Content for RFG	Volumetric Content for CARFG	Energy Content for RFG	Energy Content for CARFG
87	MTBE	18.2%	0.0%	11.0%	0.0%	11.0%	0.0%	9.1%
88	ETBE	15.7%	0.0%	12.7%	0.0%	12.8%	0.0%	10.9%
89	TAME	15.7%	0.0%	12.7%	0.0%	12.4%	0.0%	10.9%
90	Ethanol	34.8%	0.0%	5.7%	0.0%	5.4%	0.0%	3.6%
91								

- Case G2 utilizes corn ethanol for oxygenate
- Ethanol weight, volume & energy contents in gasoline based on 2% oxygen content specified in Control Panel
- The CA RFG energy and emission values are an energy weighted average of the CA RFG Blendstock and Corn Ethanol results (EtOH worksheet)

Example Pathway G2: Petroleum Worksheet Results

	A	B	C	D	E	F	G	H	I
173	5) Summary of Energy Consumption and Emissions: Btu or Grams per mmBtu of Fuel Throughput at Each St								
174		Energy Use and Total Emissions							
175		Feedstocks		Fuels					
176		Crude for Use in U.S. Refineries	Crude for Use in CA Refineries	Conv. Gasoline	RFG Gasoline Blendstock	CARFG Gasoline Blendstock	RFG	CARFG	LPG
177	Loss factor			1.000			1.000	1.000	1.007
178	Total energy	92,986	96,558	189,960	197,660	213,060	197,660	232,992	112,975
179	Fossil fuels	86,739	89,562	186,102	193,645	208,601	193,645	227,739	102,595
180	Coal	6,462	7,233	25,148	26,194	4,597	26,194	8,421	10,689
181	Natural gas	62,462	63,184	67,341	70,112	95,312	70,112	111,944	40,648
182	Petroleum	17,815	19,146	93,613	97,338	108,692	97,338	107,374	51,258
183	VOC	6.680	6.933	7.949	8.000	8.398	8.000	9.551	98.916
184	CO	30.005	30.133	8.526	8.802	7.248	8.802	12.963	5.088
185	NOx	38.237	46.180	17.684	18.174	14.335	18.174	18.410	10.110
186	PM10	2.078	3.173	5.625	5.840	2.200	5.840	3.695	2.692
187	PM2.5	1.164	1.914	2.093	2.168	1.325	2.168	1.836	1.083
188	SOx	1.911	4.730	7.059	7.165	7.794	7.165	9.302	5.494
189	CH4	90.671	90.795	12.221	12.709	13.682	12.709	16.572	7.125
190	N2O	0.118	0.122	0.123	0.128	0.135	0.128	1.899	0.084
191	CO2	6,963	7,234	13,884	14,442	13,784	14,481	15,328	7,332
192									

Total Energy and Emissions

- Crude recovery & transport summed in column C (recovery energy*loss factor + T&D)
- CA RFG Blendstock refining & transport is summed in column E (refining energy*loss factor + T&D)
- CA RFG Fuel is in Column H (energy content wtd avg of column F and values from ethanol sheet)
- Columns C and H are summed in the “Results” worksheet (column C).

Example Pathway G2 (Avg CA RFG): Results, Control Panel Worksheet

Column C of the Results Worksheet is pulled to the Control Panel and converted to g/MJf.

	D	E	F	G	H	I	J	K	L	M	N	O
3			Fed RFG	CA RFG	ULSD	NG, CNG	LNG	LPG	Methanol	DME	Ethanol	FTD
4	Total Energy	J/J	0.29	0.33	0.27	0.07	0.18	0.15	0.62	0.56	0.75	0.71
5	WTP eta	%	77.5%	75.2%	78.7%	93.1%	84.9%	87.0%	61.7%	64.3%	57.2%	58.4%
6	Fossil Fuels	J/J	0.28	0.32	0.26	0.07	0.18	0.14	0.62	0.55	0.72	0.71
7	Coal	J/J	0.03	0.02	0.01	0.00	0.00	0.01	0.00	0.00	0.11	0.00
8	Natural Gas	J/J	0.13	0.18	0.14	0.07	0.17	0.10	0.58	0.52	0.54	0.69
9	Petroleum	J/J	0.12	0.13	0.11	0.00	0.00	0.03	0.04	0.03	0.08	0.02
10	CO2	g/MJ	20.33	18.78	17.58	5.07	10.89	9.85	23.25	21.65	-17.28	28.02
11	CH4	g/MJ	0.10	0.10	0.10	0.13	0.20	0.10	0.23	0.22	0.09	0.24
12	N2O	g/MJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
13	**GHGs**	**g/MJ**	22.65	21.69	19.87	8.12	15.44	12.27	28.53	26.70	-2.11	33.59
14	VOC: Total	g/GJf	13.92	15.63	13.01	6.23	6.40	80.06	16.39	66.43	37.31	12.62
15	CO: Total	g/GJf	36.79	40.85	34.42	11.39	13.71	21.19	25.85	24.34	151.95	19.41
16	NOx: Total	g/GJf	53.48	61.23	55.30	22.60	31.88	33.67	94.24	72.37	119.46	59.79
17	PM10: Total	g/GJf	7.51	6.51	4.77	0.55	0.98	2.29	6.70	4.36	39.82	3.12
18	PM2.5 Total	g/GJf	3.16	3.56	2.87	0.42	0.74	1.22	5.19	3.25	14.22	2.35
19	SOx: Total	g/GJf	8.60	13.30	11.18	10.25	11.33	14.99	32.32	26.58	45.27	24.05
20	VOC: Urban	g/GJf	4.31	4.88	3.56	0.14	0.03	70.48	5.38	56.74	6.07	2.58
21	CO: Urban	g/GJf	0.27	0.70	0.71	0.29	0.10	0.78	1.17	1.02	0.03	0.62
22	NOx: Urban	g/GJf	0.72	2.05	2.11	0.89	0.28	2.87	4.46	3.77	-0.29	2.30
23	PM10: Urban	g/GJf	0.03	0.08	0.09	0.01	0.01	0.10	0.22	0.18	-0.01	0.10
24	PM2.5 Urban	g/GJf	0.03	0.08	0.08	0.01	0.01	0.10	0.18	0.15	0.00	0.09
25	SOx: Urban	g/GJf	0.00	0.03	0.03	0.00	0.00	0.03	0.37	0.28	-0.06	0.17
26			Fed RFG	CARFG	ULSD	CNG	LNG	LPG	Methanol	DME	Ethanol	FTD

Example Et3 (Midwest corn ethanol): Control Panel

	A	B	C	D	E	F	G	H	I	J	K
99	**Ethanol Parameters**			ETOH							
100		**Active**	**E-Diesel, Ave. MW EtOH**	**Ethanol, Corn, MW Ave**	**Ethanol, Corn, MW Coal**	**E85, Corn, MW NG**	**E85, Corn, MW NG, WDGS**	**Ethanol, Corn, MW Stover**	**Ethanol, Corn, MW Stover Max**	**Ethanol, CA Corn, WDGS**	**Ethanol, Corn, CA WDGS, Digester gas**
101		Et3	D6	Et1	Et2	Et3	Et4	Et5	Et6	Et74	Et75
102	Other..	0.0%	0.18	20.0%	0	0	0	0	0	0	0
103	Dry Mill %	100.0%	100.0%	80.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%
104	Other..	0.0%	0.0%	10.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
105	Corn	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	60.0%	20.0%	100.0%	100.0%
106	Farmed Trees	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
107	Sw Grass	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
108	Stover	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	40.0%	80.0%	0.0%	
109	Low input Herbaceous	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
110	Region	1	1	1	1	1	1	1	1	3	3
111	Corn to EtOH Yield	2.80	2.80	2.72	2.80	2.80	2.80	2.80	2.80	2.80	2.80
112	Heat Rate, dry mill Btu/gal	32,330	32,330	32,588	40,250	32,330	21,830	32,330	32,330	21,830	21,830
113	Power Use, dry mill, kWh/gal	0.75	0.75	1.00	0.87	0.75	0.75	0.75	0.75	0.75	
114	Coal	0.0%	0.0%	10.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

- Run Case Et3 (select Et3 in pull down menu, go to results worksheet and come back to control panel)
- Key Inputs
  - Dry mill %, heatrate and electricity usage
  - Corn/Stover ratio (100% corn)
  - Corn/Etoh yields – for marginal cases, modern plants, slightly better than Et1 case (avg)
  - Amount of coal used as process fuel

Example Pathway Et3: Inputs Worksheet

	A	B	C	D	E	F	G
192	8. Key Input Parameters for Fuel Ethanol Pathway Simulations						
193	8.1) Selection of Ethanol Production Feedstocks: Combination of Corn, Woody Biomass, and Herbaceous Biomass						
194			Corn	Farmed Trees	Herbaceous Biomass	Corn Stover	Forest Residu
195		Share of Each Feedstock	100.0%	0.0%	0.0%	0.0%	0.0'
196							
197	8.2) Selection of Corn Ethanol Plant Types						
198		Dry Milling Plant	100.0%				
199		Wet Milling Plant	0.0%				
200							
201	8.3) Selection of Method for Estimating Credits of Co-Products of Corn Ethanol						
202		1	1 -- displacement method				
203			Other values -- market value-based method				
204							

- "Corn Share" and "% dry milling" from Control Panel to Fuel_Prod_TS to Inputs sheet
- Displacement method as opposed to market value method
- These values go to the EtOH Worksheet

Example Pathway Et3: Inputs, Continued

Inputs Worksheet

8.5a) N2O Emissions: N in N2O as % of N in N fertilizer

Corn Farming	Biomass Farming	Corn Stover
2.0%	1.5%	2.0%

8.5b) N2O Credit from Corn Stover Removal

N in N2O Avoided per Unit of Corn Stover Removed	N Content of Corn Stover	N in N2O Avoided per Unit of N in Stover Removed
-0.00563%	0.45%	-1.25%

8.6) Farming Energy Use and Fertilizer use

	Corn (per bushel)	Farmed Trees (per d.ton)	H. Biomass (per d.ton)	Corn Stover (per d.ton)	Forest Residue (per d.ton)
Farming Energy Use: Btu	22,500	234,770	217,230	235,244	612,700
Fertilizer Use					
Grams of Nitrogen	420.0	709.0	10,635	3,175	
Grams of P2O5	149.0	189.0	142.0	1,633	
Grams of K2O	174.0	331.0	226.0	8,346	
Grams of $CaCO_3$	1202.0	0.0	0.0		
Pesticide Use					
Grams of Herbicide	8.10	24.00	28.00	0.00	
Grams of Insecticide	0.68	2.00	0.00	0.00	

- Factors for N2O emissions from fertilizer application – 1.7 defaults used. GREET 1.8 has lower values (1.3% vs 2%).
- Assumptions for farming energy use, ethanol yields, crop yields etc listed on above are GREET 1.7 defaults pulled from Fuel_Prod_TS Worksheet

Example Pathway Et3: Inputs, Continued

	A	B	C	D	E
235	**8.8) Key Assumptions for Simulating Corn-Based Ethanol Production**				
236	**8.8.a) Ethanol Yield: gallons/bushel**				
237		Dry Milling Plant	2.80		
238		Wet Milling Plant	2.62		
239					
240	**8.8.b) Energy Use for Ethanol Production: Btu/gallon**				
241		Dry Milling Plant	32,330		
242		Wet Milling Plant	45,950		
243					
244	**8.8.c) Share of Process Fuels in Corn-Based Ethanol Plants**				
245			Coal	NG	
246		Dry Milling Plant	0%	100%	
247		Wet Milling Plant	40%	60%	
248					

- Final 3 Inputs for Corn Ethanol
  - Ethanol yield (GREET 1.7 defaults)
  - Plant energy consumption (GREET 1.7 defaults)
  - Process fuels (either coal or natural gas)

Example Pathway Et3: T&D Worksheet Corn

	A	FH	FI	FJ	FK
82	**Feedstock/Fuel**		**Corn**		
83	**Transportation Mode**	**Truck**	**Barge**	**Rail**	**Truck**
84	Urban Emission Share	5.0%	0.0%	0.0%	5.0%
85	Distance (Miles, one-way)	10	200	200	40
86	Share of Fuel Type Used:				
87	Diesel	100%	0%	100%	100%
88	Residual Oil		100%		
89	Natural Gas				
90	LPG				

		BZ	CA
		Corn	
127	**Stage**	**Farm to Collection Stack**	**Stack to Ethanol Plant**
128	Percentage of Fuel Transported by a Given Mode		
129	Ocean tanker		
130	Barge		0.0%
131	Pipeline		
132	Rail		0.0%
133	Truck	100.0%	100.0%
134	Energy Consumption: Btu/mmBtu of fuel transporte	Btu per ton	
135	Total energy	51,943	161,786

- FH85 through FK85 have corn transport distances by mode
- BZ126 through CA133 have mode share inputs
- These are cross multiplied to get total miles by mode for each feedstock – for this case all by truck

Example Pathway Et3: T&D Worksheet Ethanol

	A	GA	GB	GC	GD	GE	GF
82	**Feedstock/Fuel**			**Ethanol**			
83	**Transportation Mode**	**Ocean Tanker**	**Barge**	**Pipeline**	**Rail**	**Truck**	**Truck**
84	Urban Emission Share		0.0%	0.0%	12.7%	0.0%	100.0%
85	Distance (Miles, one-way)	0	0	0	1,400	40	50
86	Share of Fuel Type Used:						
87	Diesel	0%	0%	20%	100%	100%	100%
88	Residual Oil	100%	100%	50%			
89	Natural Gas			24%			
90	LPG						
91	DME						

		CJ	CK
		Ethanol Transportation	**Ethanol Distribution**
128	Percentage of Fuel Transported by a Given Mode		
129	Ocean tanker	0.0%	
130	Barge	0.0%	
131	Pipeline	0.0%	
132	Rail	100.0%	
133	Truck	70.0%	100.0%
134	Energy Consumption: Btu/mmBtu of fuel transported		
135	Total energy	29,299	5,231

- GA85 through GF85 have ethanol transport distances by mode
- CJ126 through CK133 have mode share inputs
- These are cross multiplied to get total miles by mode for each feedstock

Example Pathway Et3: EtOH Worksheet CoProduct Credits

	A	B
51	**Calculations of Co-Product Credits for Corn Ethanol**	
52	**Displacement-based method:**	
53	Co-product yield: bone-dry lb. per gallon of ethanol	
54	Dry milling	
55	DGS	4.87
56		
57		
58	Displacement ratios: lb/lb co-product	
59		Dry Mill By-Product
60	Product Displaced:	DGS
61	Feed Corn	1.077
62	Soybean Meal (SBM)	0.823
63	N-Urea	
64	Co-products used for new cattle production:	
65	Convert Displacement Ratios to lb/gal ethanol	
66		Dry milling
67	Product Displaced:	Data
68	Feed Corn	-4.450
69	Soybean Meal (SBM)	-3.400

- Assumes that Digester Grains and Solubles (DGS) substitutes for Feed Corn and Soybean Meal
- Amount displaced is slightly different than recent EPA values in RFS RIA – will update
- These values are used to credit energy and emissions associated with ethanol production

Example Pathway Et3: EtOH Worksheet, Corn Farming

	A	B	C	D	E	F	G	H	I	J
92		Corn Farming								
93		Corn Farming	Corn Farming Fertilizer Use by Nutrient (grams/bushel)				Corn Farming Pesticide Use (grams/bushel)		Corn Transpo	Total: Corn Farming and Transportati on
94		Btu/bushel	Nitrogen	P2O5	K2O	CaCO3	Herbicide	Insecticide	Per bushel	Per bushel
95	**Production inputs**	22,500	420.0	149.0	174.0	1202.0	8.10	0.68		
96	**Urban emission share**	0.0%								
97	**Loss factor**									
98	**Shares of process fuels**									
99	Residual oil	0.0%								
100	Diesel fuel	38.3%								
101	Gasoline	12.3%								
102	Natural gas	21.5%								
103	Coal	0.0%								
104	Liquefied petroleum gas	18.8%								
105	Electricity	9.0%								
106	Feed loss	0.0%								
107	**Energy Use: Btu/mmBtu of fuel throughput, except as noted**									
108	Residual oil	0								
109	Diesel fuel	8,618								
110	Gasoline	2,768								
111	Natural gas	4,838								
112	Coal	0								
113	Liquefied petroleum gas	4,230								
114	Biomass: tons									
115	Electricity	2,025								
116	Total energy	28,918	19,330	1,991	1,472	9,311	2,153	214	5,984	69,374

- Energy use and split GREET defaults
- Energy use in rows 108-115 is DIRECT energy use.
- Total energy in row 116 sums 108-115 and includes WTT energy
  - e.g. the energy to recover the crude and refine to diesel to use in the tractors…

Example Pathway Et3: EtOH Worksheet, Ethanol Production

	A	K	L	M	N
92		**Corn Ethanol Production**			
93		**Dry Mill Ethanol Production**	**Dry Mill Ethanol Production: Non-Combustion Emissions**	**Wet Mill Ethanol Production**	**Wet Mill Ethanol Production: Non-Combustion Emissions**
94		Btu/gallon	Per gallon	Btu/gallon	Per gallon
95	**Production inputs**	34,889		45,950	
96	**Urban emission share**	0.0%		0.0%	
97	**Loss factor**				
98	**Shares of process fuels**				
99	Residual oil				
100	Diesel fuel				
101	Gasoline				
102	Natural gas	92.7%		60.0%	
103	Coal	0.0%		40.0%	
104	Liquefied petroleum gas				
105	Electricity	7.3%	from ctrl panl	0.0%	
106	Feed loss				
107	**Energy Use: Btu/mmBtu of fuel throughput, except as noted**	**Per gallon**			
108	Residual oil	0		0	
109	Diesel fuel	0		0	
110	Gasoline	0		0	
111	Natural gas	32,330		27,570	
112	Coal	0		18,380	
113	Liquefied petroleum gas	0		0	
114	Biomass: tons				
115	Electricity	2,559		0	
116	Total energy	41,507		48,302	

- Energy use and split from process fuel and electricity inputs on control panel
- Energy use in rows 108-115 is DIRECT energy use.
- Total energy in row 116 sums 108-115 and includes WTT energy
  - e.g. the energy to recover the natural gas to produce the ethanol

Example Pathway Et3: EtOH Worksheet, Energy Credits from Coproducts

	A	S	T
92		Co-Product Credits of (	
93		Drg Mill: Displaced Corn	Drg Mill: Displaced Soybean Meal
106	Feed loss		
107	**Energy Use: Btu/mmBtu of fuel throughput, except as noted**		
108	Residual oil		
109	Diesel fuel		
110	Gasoline		
111	Natural gas		
112	Coal		
113	Liquefied petroleum gas		
114	Biomass: tons		
115	Electricity		
116	Total energy	-6,431	-2,312
117	[illegible]	[illegible]	[illegible]

- Credit for displaced corn based on corn farming and transport energy and emissions (column J)
- Credit for displaced soybean meal from soybean farming and transport energy and emissions (BD worksheet)

Example Pathway Et3: EtOH Worksheet, Summary

	A	B	C
144	Energy in Btu/MMBtu Emissions g/MMBtu	**Dry Milling Corn Ethanol**	
145		**Corn**	**Ethanol**
146	Loss factor		
147	Total energy	210,058	578,392
148	Fossil fuels	203,771	566,853
149	Coal	30,870	56,364
150	Natural gas	96,288	473,158
151	Petroleum	76,613	37,331
152	VOC	8.602	41.031
153	CO	159.240	27.644
154	NOx	93.026	71.657
155	PM10	9.278	23.991
156	PM2.5	4.807	7.106
157	SOx	29.905	5.497
158	CH4	24.062	71.872
159	N2O	47.808	0.294
160	CO2	17,115	38,825
161			

- Corn values are converted to Btu and g per MMBtu basis
- Ethanol production values include co-product credits
- Columns B and C are summed and pulled to Results Worksheet columns
  - The ethanol in results tab is denatured with a bit of conventional gasoline so final result is combination of both, weighted by energy fractions.

TIAX

Example Pathway Et3: Control Panel, Results

Column N of the Results Worksheet is pulled to the Control Panel and converted to g/MJf.

	D	E	F	G	H	I	J	K	L	M	N
2			RESULTS: Paste these into the WTT post-processor								
3			Fed RFG	CA RFG	ULSD	NG, CNG	LNG	LPG	Methanol	DME	Ethanol
4	Total Energy	J/J	0.23	0.27	0.22	0.07	0.18	0.13	0.62	0.56	0.77
5	WTP eta	%	81.3%	78.5%	82.3%	93.1%	84.8%	88.6%	61.7%	64.3%	56.6%
6	Fossil Fuels	J/J	0.23	0.27	0.21	0.07	0.18	0.12	0.62	0.55	0.75
7	Coal	J/J	0.04	0.02	0.02	0.00	0.01	0.02	0.01	0.01	0.09
8	Natural Gas	J/J	0.08	0.12	0.09	0.07	0.17	0.08	0.57	0.52	0.55
9	Petroleum	J/J	0.11	0.13	0.11	0.00	0.00	0.03	0.04	0.03	0.11
10	CO2	g/MJ	18.02	17.05	15.69	5.25	11.27	9.72	23.51	21.91	-16.67
11	CH4	g/MJ	0.10	0.10	0.10	0.13	0.20	0.10	0.23	0.22	0.09
12	N2O	g/MJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
13	**GHGs**	**g/MJ**	20.33	19.96	17.98	8.31	15.82	12.14	28.80	26.96	-1.57
14	VOC: Total	g/GJf	11.21	13.85	10.92	6.23	6.41	78.99	16.31	66.37	45.73
15	CO: Total	g/GJf	19.05	25.21	17.96	11.48	13.95	14.63	25.47	23.70	171.37
16	NOx: Total	g/GJf	32.94	59.50	52.45	22.67	32.10	25.92	93.76	72.05	151.59
17	PM10: Total	g/GJf	8.46	8.62	7.02	0.87	1.63	4.01	7.32	4.93	30.69
18	PM2.5 Total	g/GJf	3.05	4.44	3.83	0.50	0.91	1.52	5.33	3.39	10.99
19	SOx: Total	g/GJf	7.87	17.22	15.63	10.25	11.33	14.70	32.29	26.56	32.62
20	VOC: Urban	g/GJf	4.28	4.89	3.52	0.13	0.03	70.45	5.37	56.73	6.62
21	CO: Urban	g/GJf	0.03	0.51	0.45	0.27	0.06	0.60	1.12	0.98	1.25
22	NOx: Urban	g/GJf	0.08	2.11	1.44	0.84	0.18	2.36	4.35	3.67	6.95
23	PM10: Urban	g/GJf	0.00	0.10	0.06	0.01	0.00	0.08	0.21	0.17	0.18
24	PM2.5 Urban	g/GJf	0.00	0.09	0.05	0.01	0.00	0.07	0.18	0.14	0.16
25	SOx: Urban	g/GJf	0.00	0.17	0.03	0.00	0.00	0.03	0.37	0.28	0.05

8:30-9:00	Introduction
9:00-11:00	Full Fuel Cycle Overview
11:00-12:00	CA GREET Pathways
12:00-1:00	Lunch
1:00-1:30	CA GREET Structure
1:30-2:00	Running the CA-GREET Model
2:00-4:00	Detailed Look at CA RFG and EtOH Pathways
4:00-4:30	**Updates to CA-GREET Model**

Updates to CA WTT Model

- CA TEOR Recovery Efficiency
  - Default value for crude recovery is 98%
  - Based on 2006 data, amount of steam injected and amount of TEOR was determined[1].
    - 0.29 Btu steam per Btu crude recovered is used
    - Assumed a cogeneration credit for a net penalty of 20.2%
  - Resulting TEOR efficiency is 98% - 20.2% = 77.8%
  - This impacts CA Avg case since 20% of crude refined in CA is steam injected
- CA RFG
  - Refining efficiency (corrected from 84.2 to 84.5)
    - Was coded incorrectly (GM-Argonne 2005 Value)
  - Deleted efficiency penalty for removing pentanes (0.05%)
- CA ULSD
  - Refining efficiency: GM/Argonne 2005 value was coded incorrectly (corrected from 87.5 to 86.6)
- CA NG transmission leak fraction was not coded in correctly for:
  - Central Gaseous H2 plant (column T, NG Sheet)
  - NG Electric Power Plant (column W, NG Sheet)
  - NG to LPG plant (column Q, NG Sheet)

1. "2006 Annual Report of the State Oil and Gas Supervisor", California Department of Conservation, Division of Oil and Gas & Geothermal Resources.

Updates to CA WTT Model Since AB 1007 Analysis (Concluded)

- Corrected error in Hydrogen from electrolysis assuming 70% renewables case
  - 70% was used for renewables (correct) and for % station share (incorrect)
  - Effect was 70% station electrolysis and 30% methanol (1-sum of all others).
- Transportation distances and mode shares for petroleum fuels corrected, inputs brought to control panel.

We have more work to do

- Need to pull more of the buried inputs to the Control Panel
  - Enhances transparency
  - Quality assurance
  - Improve documentation of variables in the control panel
- Need to add better descriptions of the existing default pathways
- Add new pathways
  - Brazil sugarcane
  - California sugarcane
  - CNG/LNG from Biogas
  - Biodiesel from yellow grease
- Add breakdown of composite results to a minimum of
  - Feedstock recovery
  - Feedstock transport
  - Fuel processing
  - Fuel transport

We have more work to do (concluded)

- Need to review GREET 1.8 and make updates to CA-GREET (based on 1.7)
  - Added Sugarcane from Brazil
  - For LNG and Hydrogen, changed storage and transit days
  - For LNG, changed recovery rates for boil-off gas in transport to bulk terminal and bulk terminal storage
  - Added N2O emissions from N content of above and below ground biomass (corn farming only)
  - Reduced N in N2O as percent of N in fertilizer (N2O emissions from fertilizer)
  - Increased ethanol yield from cellulosic fermentation
  - Reduced soybean farming energy and fertilizer use
- Focus on 2005 as LCFS baseline year – AB1007 analysis was for 2012, 2017, 2022, 2030
- Add LCFS Pathways as needed