



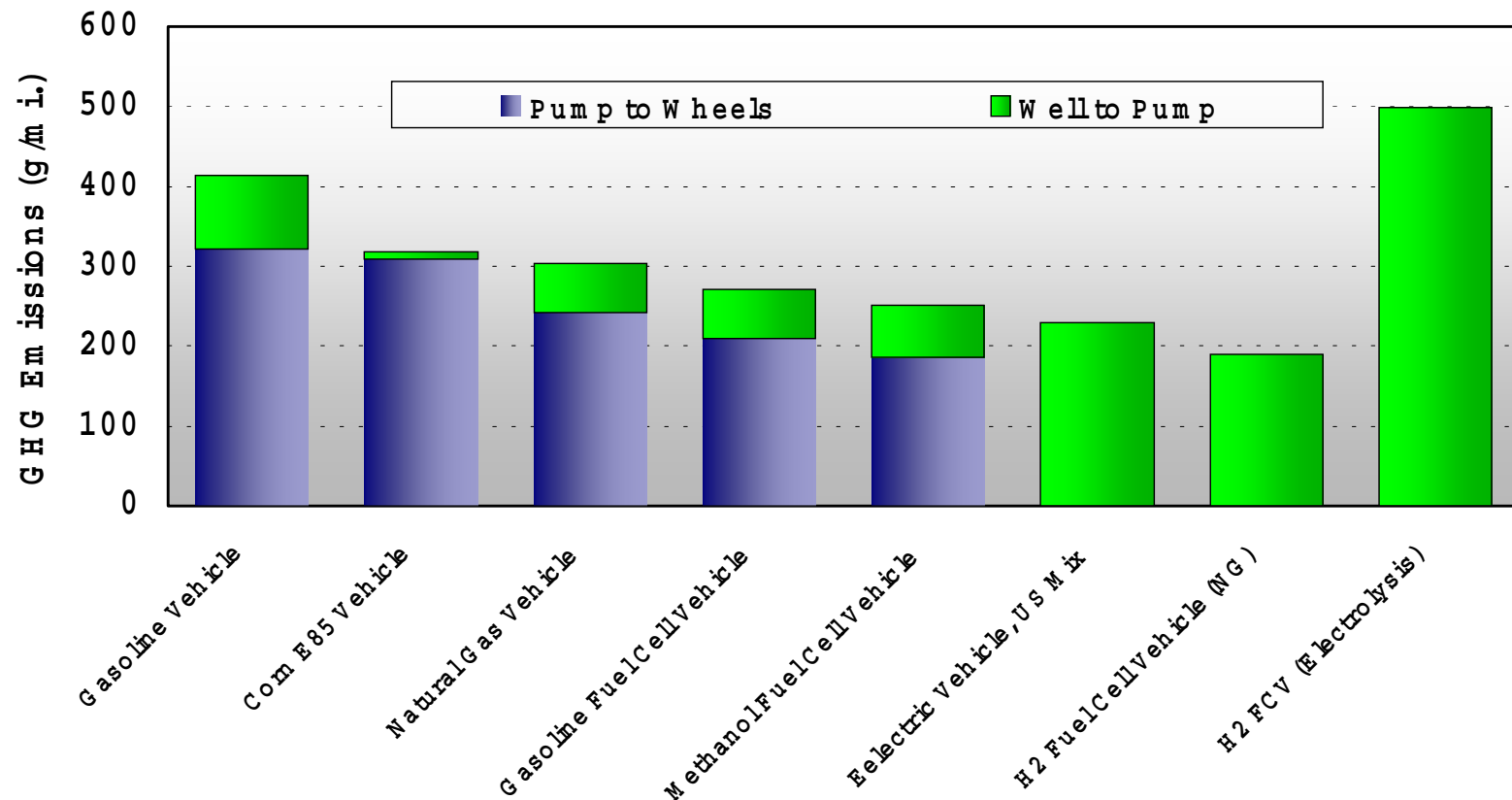
Integration of the GREET Model into MOVES

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Presentation at EPA MOVES Workshop
March 16, 2005

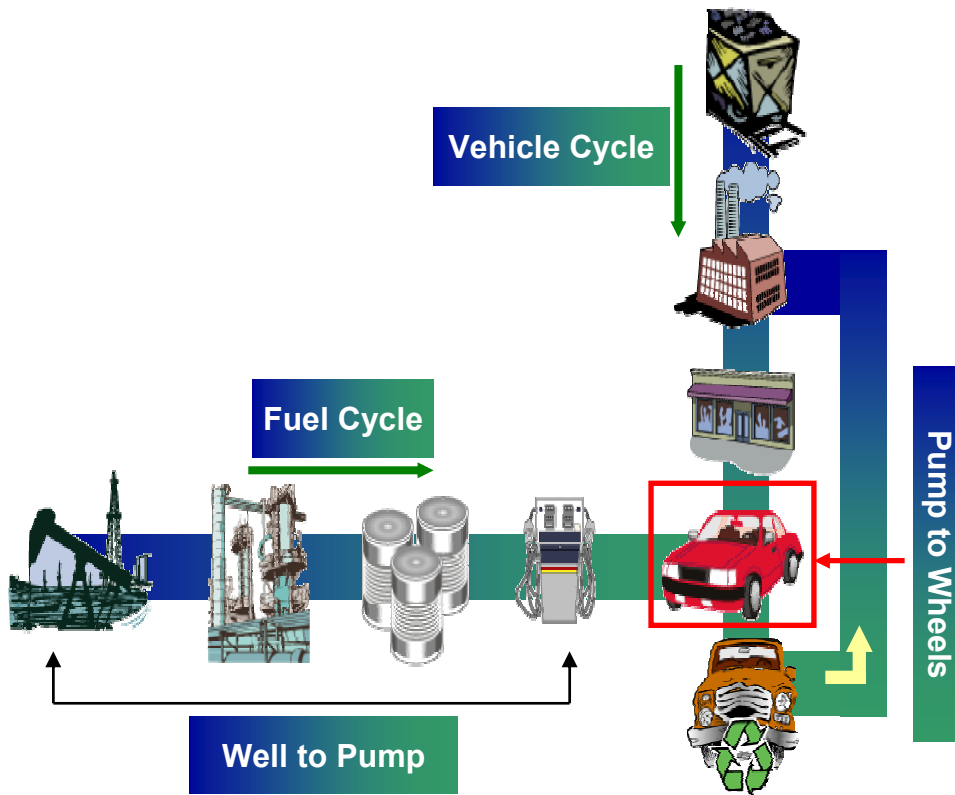
W T W Analysis Is a Complete Energy/Emissions Comparison

As an example, greenhouse gases are illustrated here





With DOE Support, Argonne Developed the GREET Model for Well-to-Wheels Analysis



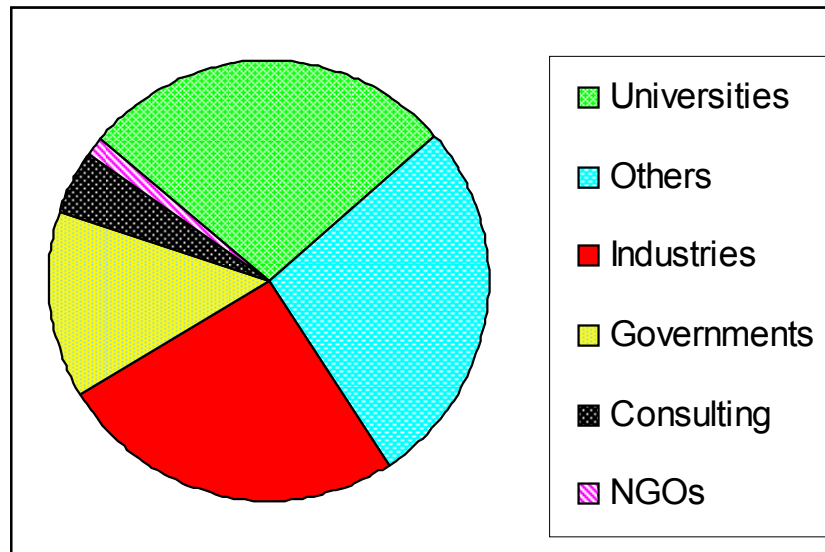
Key GREET features

- Emissions of greenhouse gases
 - ✓ CO_2 , CH_4 , and N_2O
- Energy use
 - ✓ All energy sources
 - ✓ Fossil fuels (petroleum, NG, coal)
 - ✓ Petroleum
- Emissions of five criteria pollutants
 - ✓ Total and urban separately
 - ✓ VOC, CO, NO_x , SO_x , and PM_{10}

GREET and its documents are available at
<http://www.transportation.anl.gov/software/GREET/index.html>

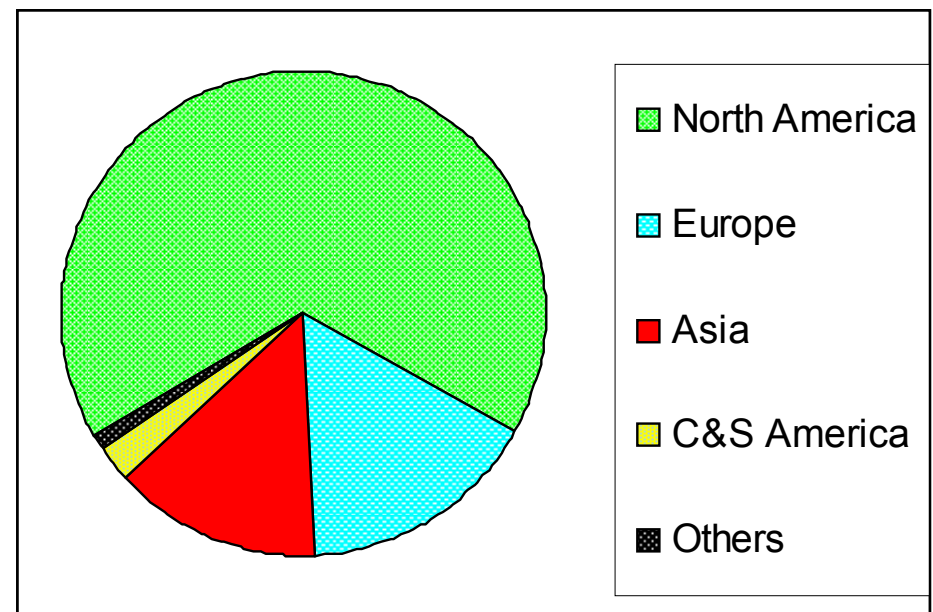


At Present, There Are More Than 1,700 GREET Registered Users Worldwide



GREET users are primarily in universities, industries, and governments

They are primarily in North America, Europe, and Asia





Integration of GREET into MOVES Has Been a Joint Effort Between EPA and DOE

- ❑ EPA focus: GREET/MOVES integration
 - GREET well-to-pump + MOVES pump-to-wheels
 - Seamless programming integration of two models
- ❑ DOE focus: add new fuel production pathways
 - Coal Gasification to H₂
 - Nuclear energy to H₂
 - Biomass gasification to H₂
 - Gasoline and diesel from Canadian oil sands
- ❑ The integration effort completed so far was for energy use and GHG emission modeling



Time Series Based Simulations Were Added To GREET Through This Effort

- ❑ Previous GREET versions were based on two snap-shot simulations
 - Near term
 - Long term
- ❑ New GREET version can simulate a target year
 - Between 1990 and 2020
 - Technology advancement over time is established with time-series look-up tables in GREET
- ❑ Users can conduct simulations over time by using values for key parameters
 - GREET default values in look-up tables
 - User-specified values over time
 - GREET interpolation and extrapolation of partial inputs from users



For a Given Fuel, the New GREET Version Combines Production Options with Market Shares

- ❑ Previous GREET versions conducted simulations for a fuel's production options exclusive to each other
- ❑ The new version combines different production options with their potential market shares
- ❑ As an example, users can generate one set of results for the following H2 production options combined with their potential market shares

NG central SMR

NG distributed SMR

Nuclear H2

Biomass H2

Coal H2

Electrolysis H2

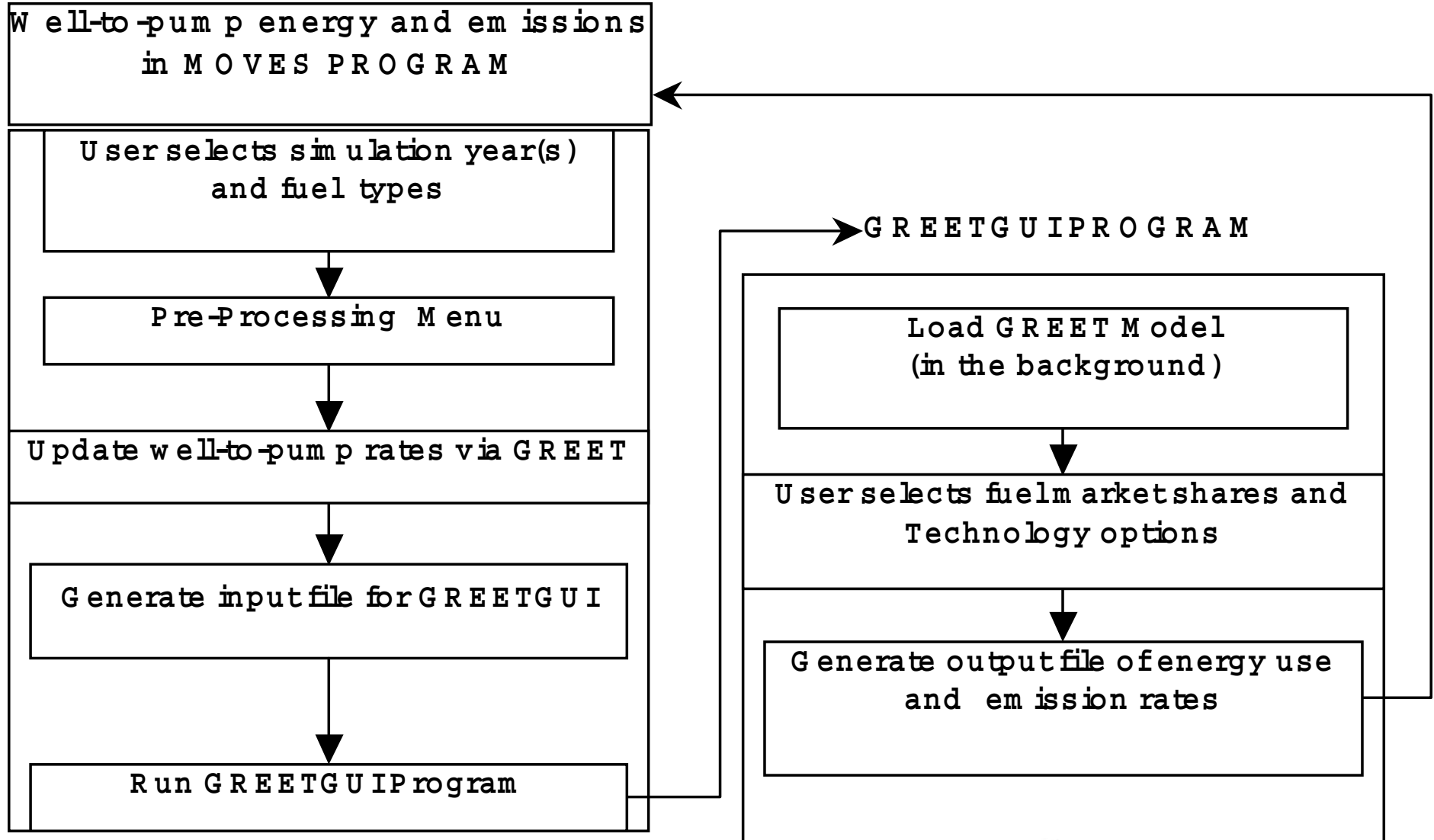
Solar PV H2

MeOH/EtOH to H2 at refueling stations

- ❑ But users can still simulate a single production option by assigning 100% market share to it



Simulation Steps of Integrated GREET/MOVES



GREET GUI Designs for GREET/MOVES Integration

From MOVES



Scenario and Fuel Pathway Selections

List of Years to be Simulated:

1990	1995	2000	2005	2010	2015	2020
1991	1996	2001	2006	2011	2016	
1992	1997	2002	2007	2012	2017	
1993	1998	2003	2008	2013	2018	
1994	1999	2004	2009	2014	2019	

Vehicle Type:

☒ Passenger Cars

☐ Light Duty Trucks 1

☐ Light Duty Trucks 2

Fuel Pathway Groups:

☐ Petroleum >>

☐ Natural Gas/Biomass >>

☐ Bio-Ethanol >>

☐ Hydrogen >>

☐ Biodiesel

☐ Electricity

☐ Select / Deselect All Items

Crystal Ball Options (Single Year Simulation Only):

☒ No, I do not want to run probability-based Crystal Ball Simulations

☐ Yes, I want to run probability-based Crystal Ball Simulations

Continue >>

User Options

GREET Simulation Options

	GREET Default Estimates for Market Shares	Linear Interpolation between Start Year and End Year Estimates	User Select Market Shares
Reformulated/Conventional Gasoline Market Shares	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Low Sulfur/Conventional Diesel Market Shares	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Gas H2 Production: Central/Refueling Station Shares	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Liquid H2 Production: Central/Refueling Station Shares	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
LPG Production: NG/Crude Feedstock Shares	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ethanol Production: Corn/Biomass Feedstock Shares	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>

☐ Default All ☐ Interpolate All ☐ User Select All

Continue >>

Gasoline and Diesel Fuel Types and Shares

Gasoline Fuel Types and Shares

GREET Default

Year	RFG %	CG %
1990	0.0	100.0
1991	3.0	97.0
1992	6.0	94.0
1993	9.0	91.0
1994	12.0	88.0
1995	15.0	85.0
1996	18.0	82.0
1997	21.0	79.0
1998	24.0	76.0
1999	27.0	73.0
2000	30.0	70.0
2001	31.0	69.0
2002	32.0	68.0
2003	33.0	67.0
2004	34.0	66.0
2005	35.0	65.0
2006	36.0	64.0

Diesel Fuel Types and Shares

GREET Default

Year	LSD %	CD %
1990	0.0	100.0
1991	0.0	100.0
1992	0.0	100.0
1993	0.0	100.0
1994	0.0	100.0
1995	0.0	100.0
1996	0.0	100.0
1997	0.0	100.0
1998	0.0	100.0
1999	0.0	100.0
2000	0.0	100.0
2001	0.0	100.0
2002	0.0	100.0
2003	0.0	100.0
2004	0.0	100.0
2005	0.0	100.0
2006	0.0	80.0

Continue

File Edit Format Help

Year	RFG %	CG %
1990	0.0	100.0
1991	3.0	97.0
1992	6.0	94.0
1993	9.0	91.0
1994	12.0	88.0
1995	15.0	85.0
1996	18.0	82.0
1997	21.0	79.0
1998	24.0	76.0
1999	27.0	73.0
2000	30.0	70.0
2001	31.0	69.0
2002	32.0	68.0
2003	33.0	67.0
2004	34.0	66.0
2005	35.0	65.0
2006	36.0	64.0

Fuel Production Assumptions - Year: 2010

Items	Assumptions
Crude Recovery Efficiency (%)	97.7%
CG Refining Efficiency (%)	86.0%
FRFG Refining Efficiency (%)	85.5%
CARFG Refining Efficiency (%)	85.5%
CD Refining Efficiency (%)	89.0%
LPG Refining Efficiency (%)	93.5%

Pathways Options for Base Year: 2010

LH2: 10.0% Central GH2: 90.0% Station LH2: 90.0% Station

Petroleum Natural Gas LPG Ethanol Electricity Biodiesel GH2: 10.0% Central

DIESEL: 100.0% Low Sulfur DIESEL: 0.0% Conventional

GASOLINE: Reformulated GASOLINE: Conventional California Reformulated Gasoline

O2 Content (by Weight): 2.3 % Sulfur Level: 26 ppm

Oxygenate:

☒ MTBE

☐ EtOH

☐ ETBE

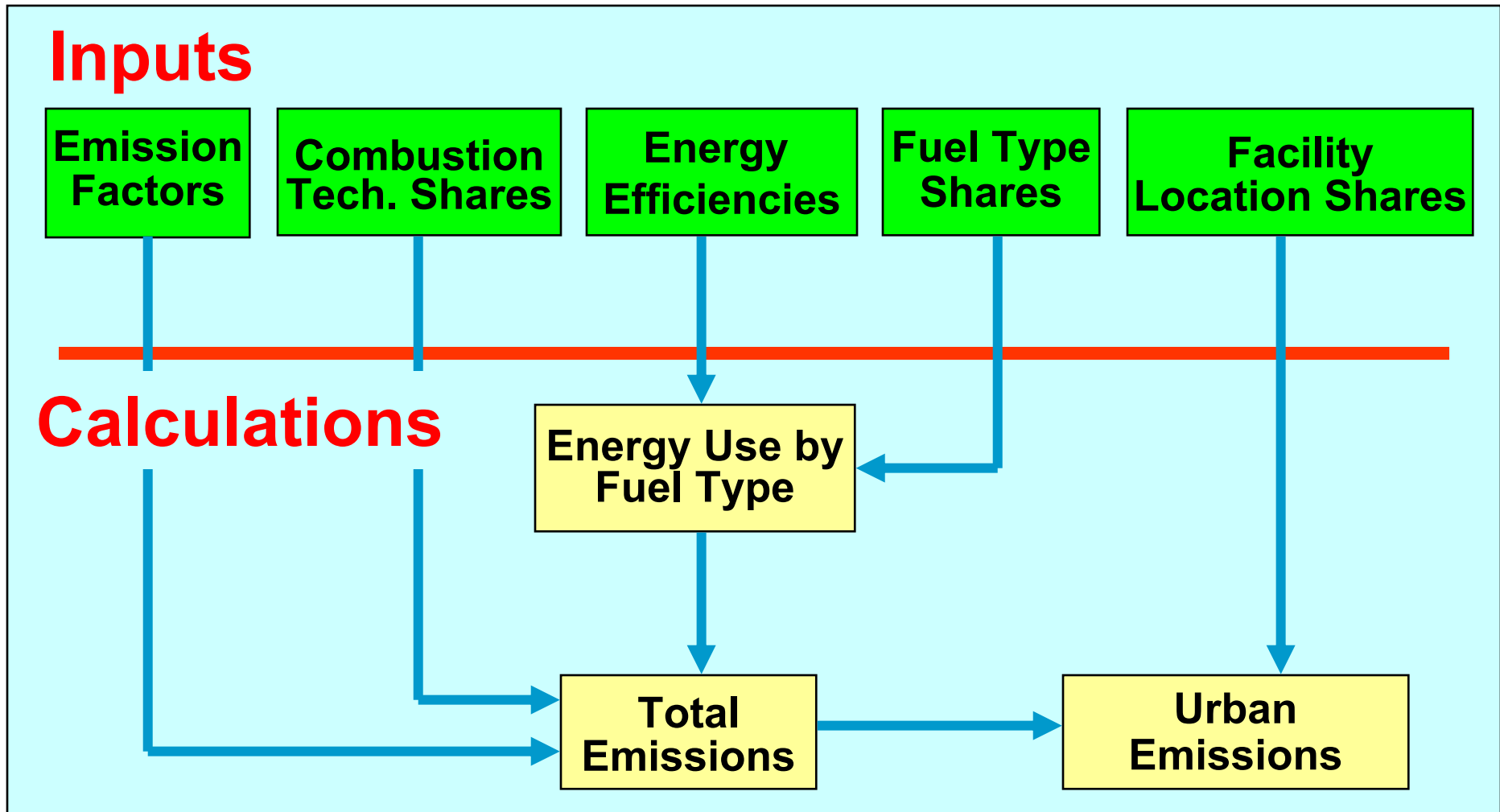
☐ TAME

☐ No Oxygenate

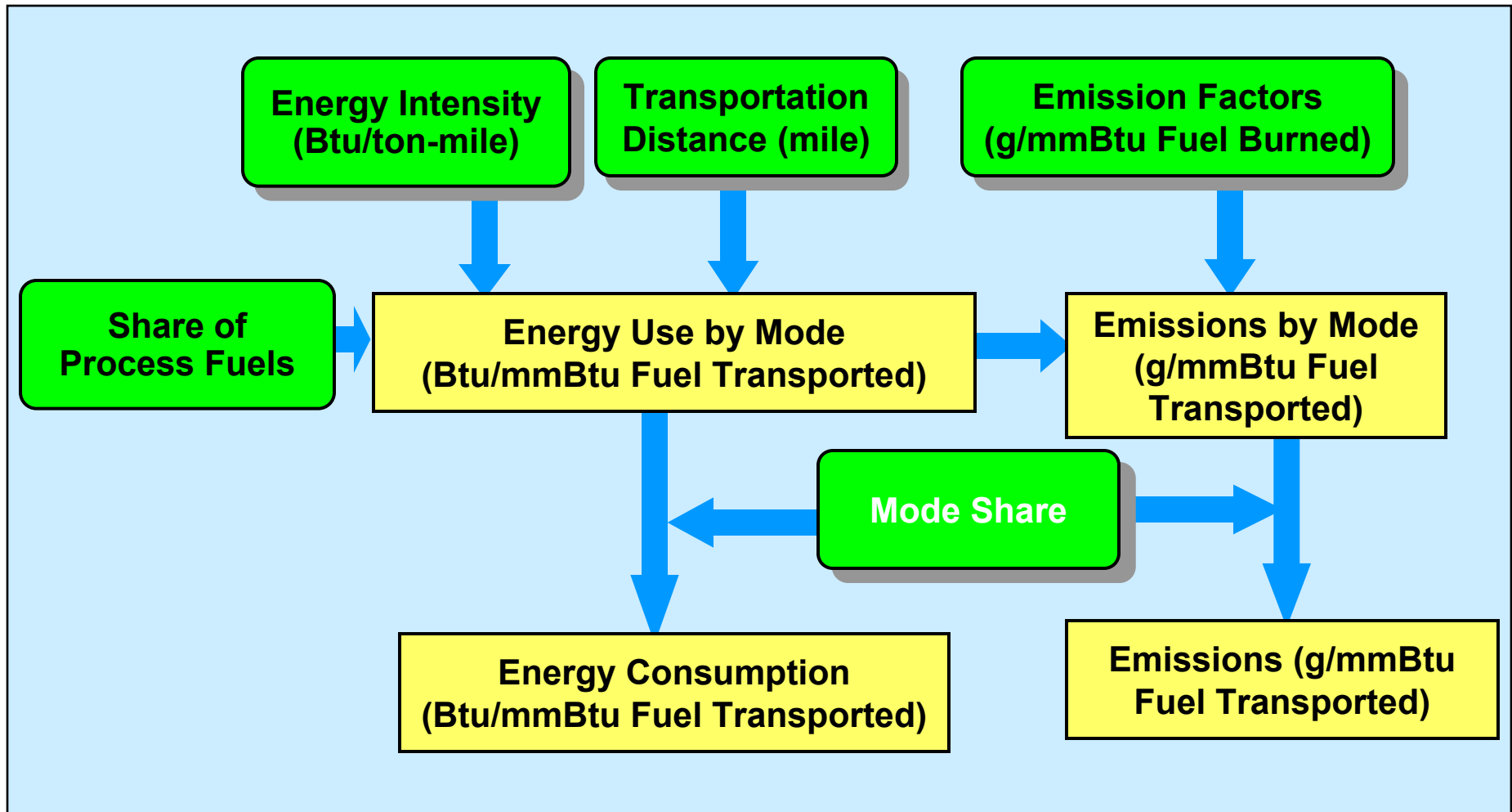
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Back to MOVES

Calculation Logic for a Given W T P Production Activity in GREET



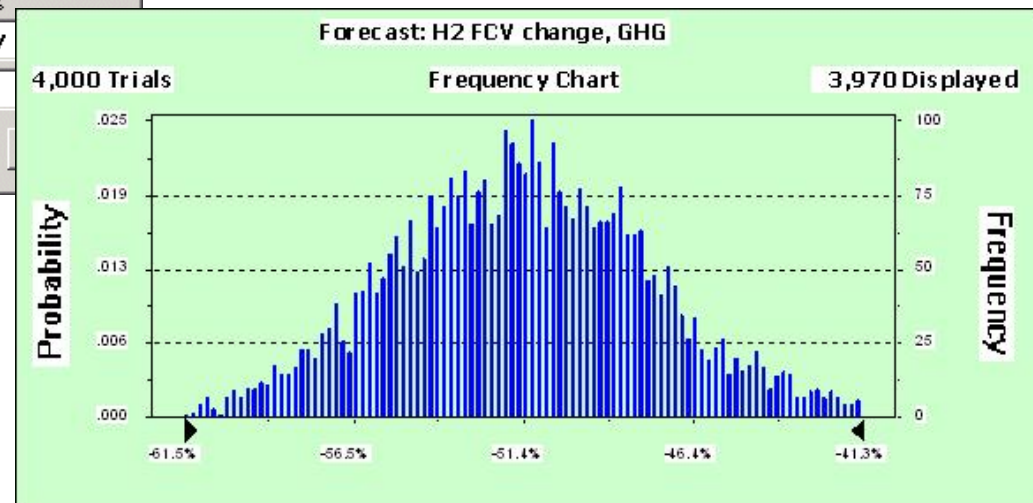
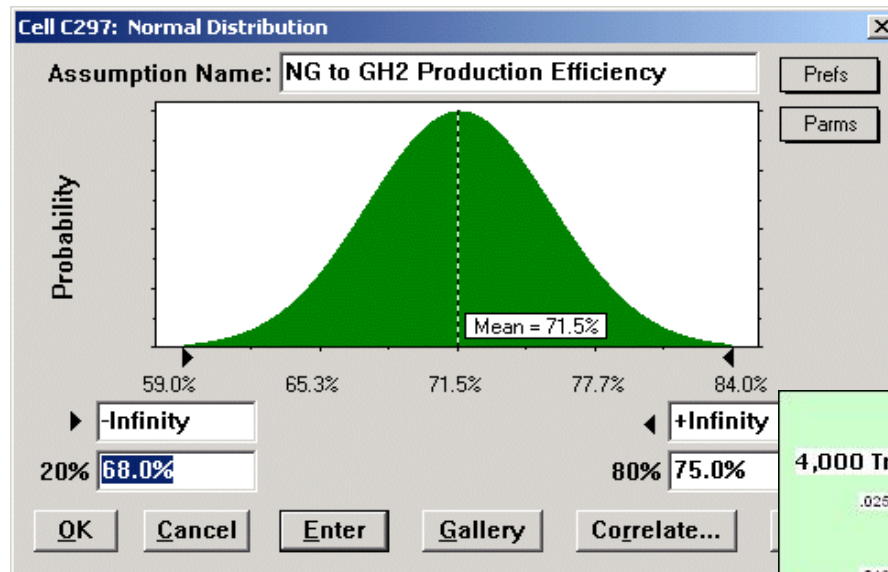
Calculation Logic for a Given W T P Transportation Activity in GREET





GREET Is Designed to Conduct Stochastic Simulations

Distribution-Based Inputs Generate Distribution-Based Outputs



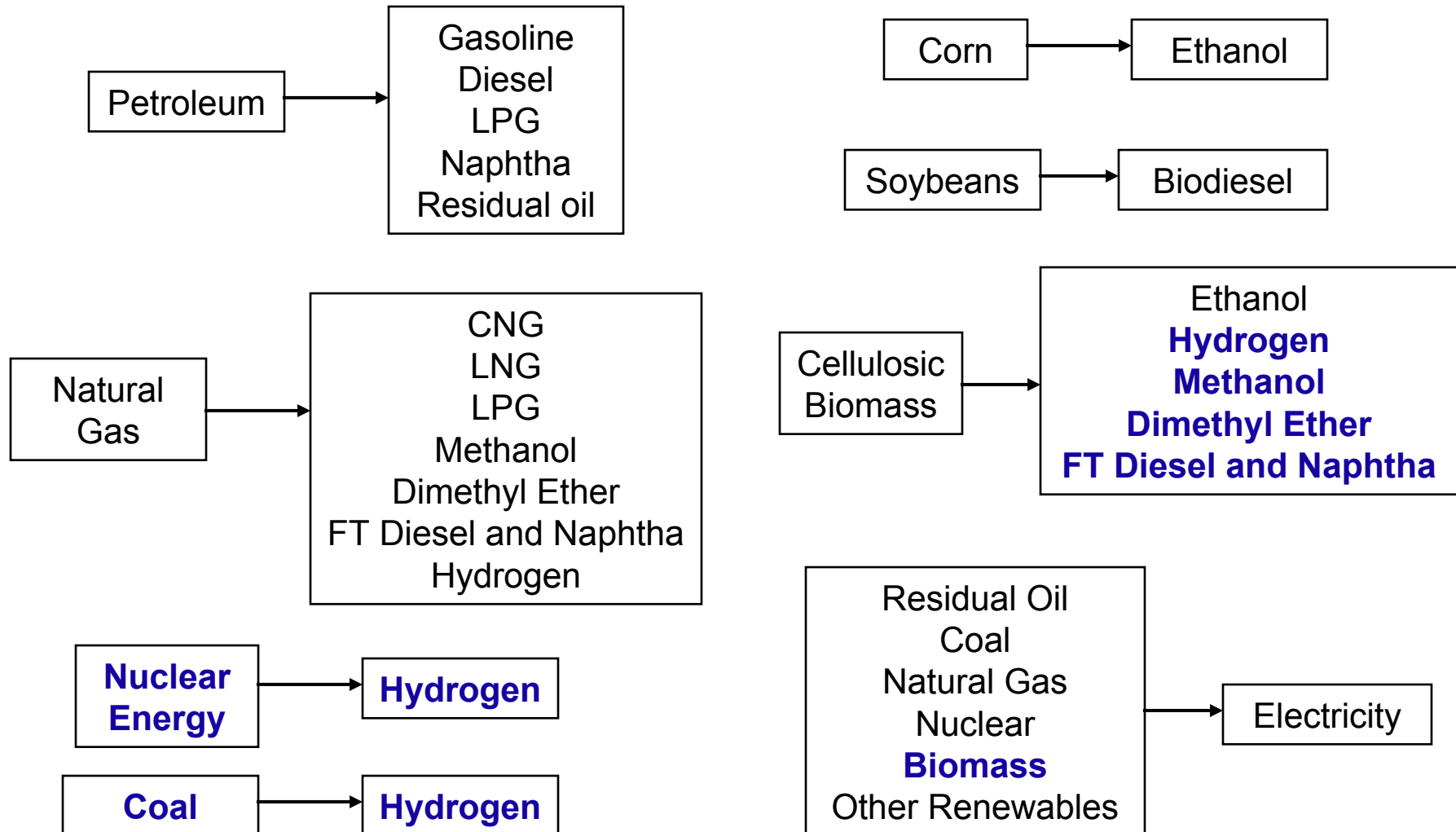


W T P Criteria Pollutant Issues Were Addressed Through A Project with GM

- ☐ Data for relevant facilities were extracted from EPA's 1999 National Emissions Inventory database
- ☐ Total emissions for a given facility were divided by its throughput to develop emissions factors
- ☐ Distribution curves were fitted to current EPA emission data
- ☐ The curves were further adjusted to account for improvements by future technologies and emission controls



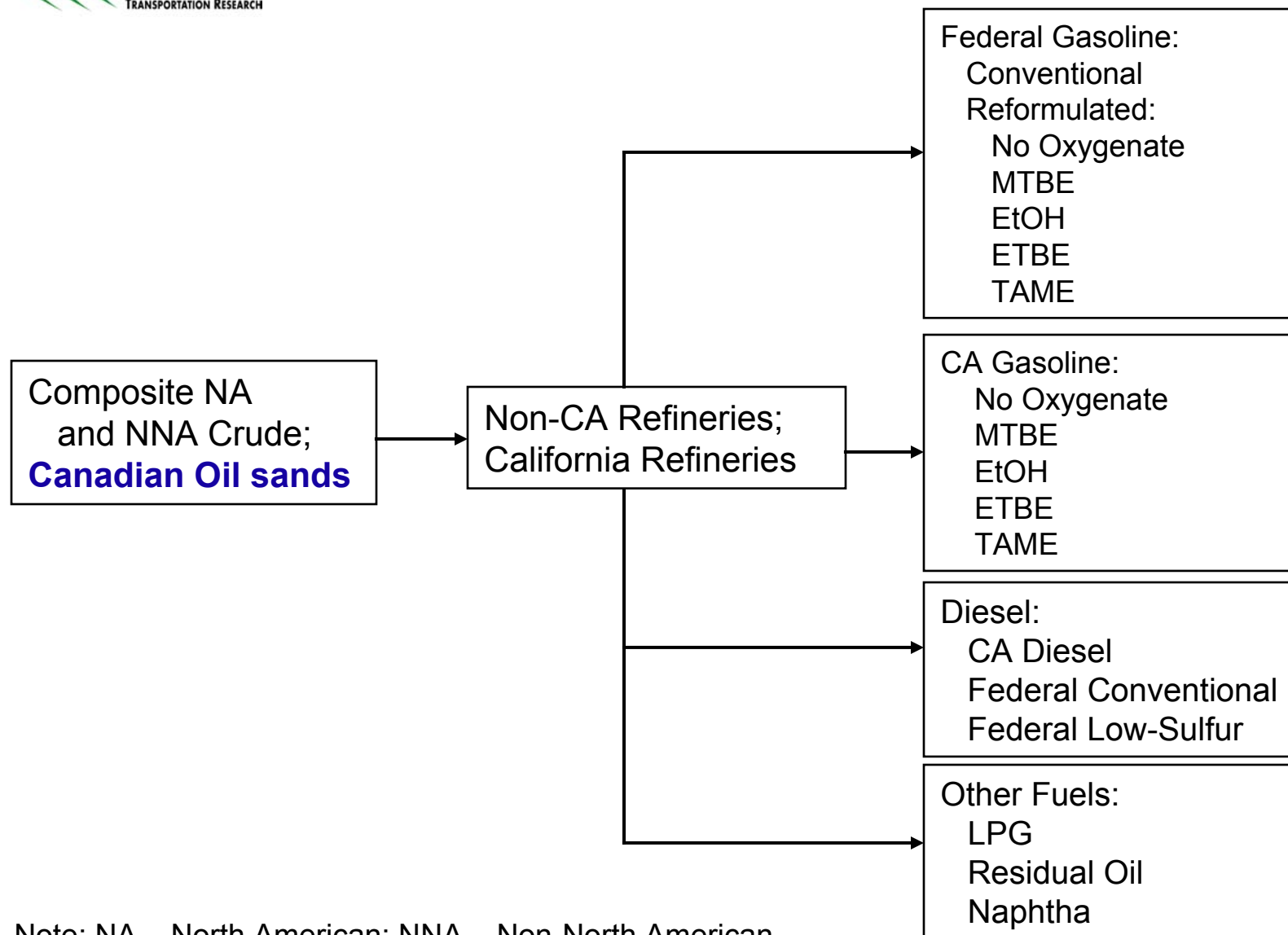
GREET Includes Transportation Fuels from Various Energy Feedstocks



Note: options in blue are new.

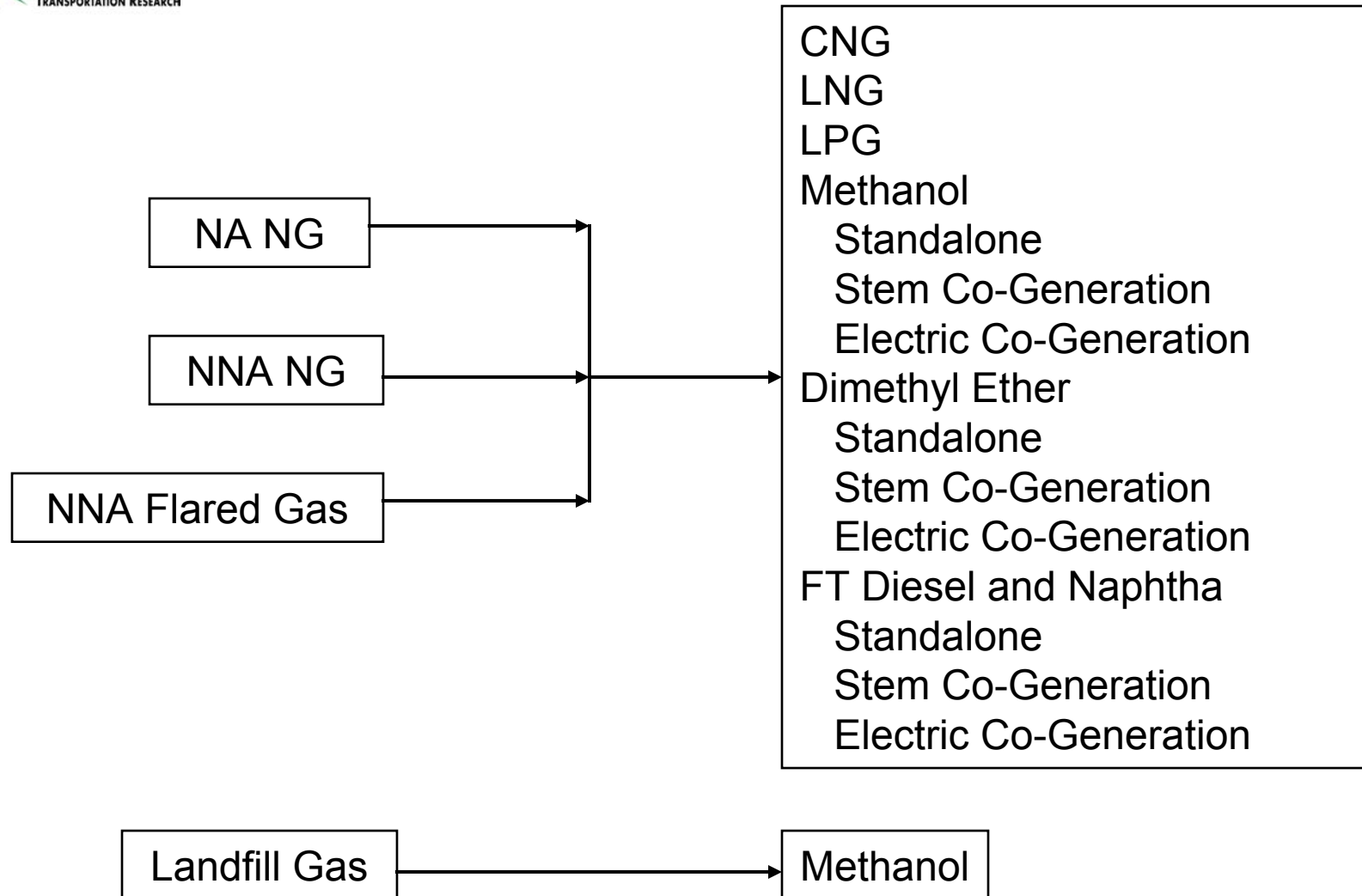


GREET Petroleum Fuel Pathways



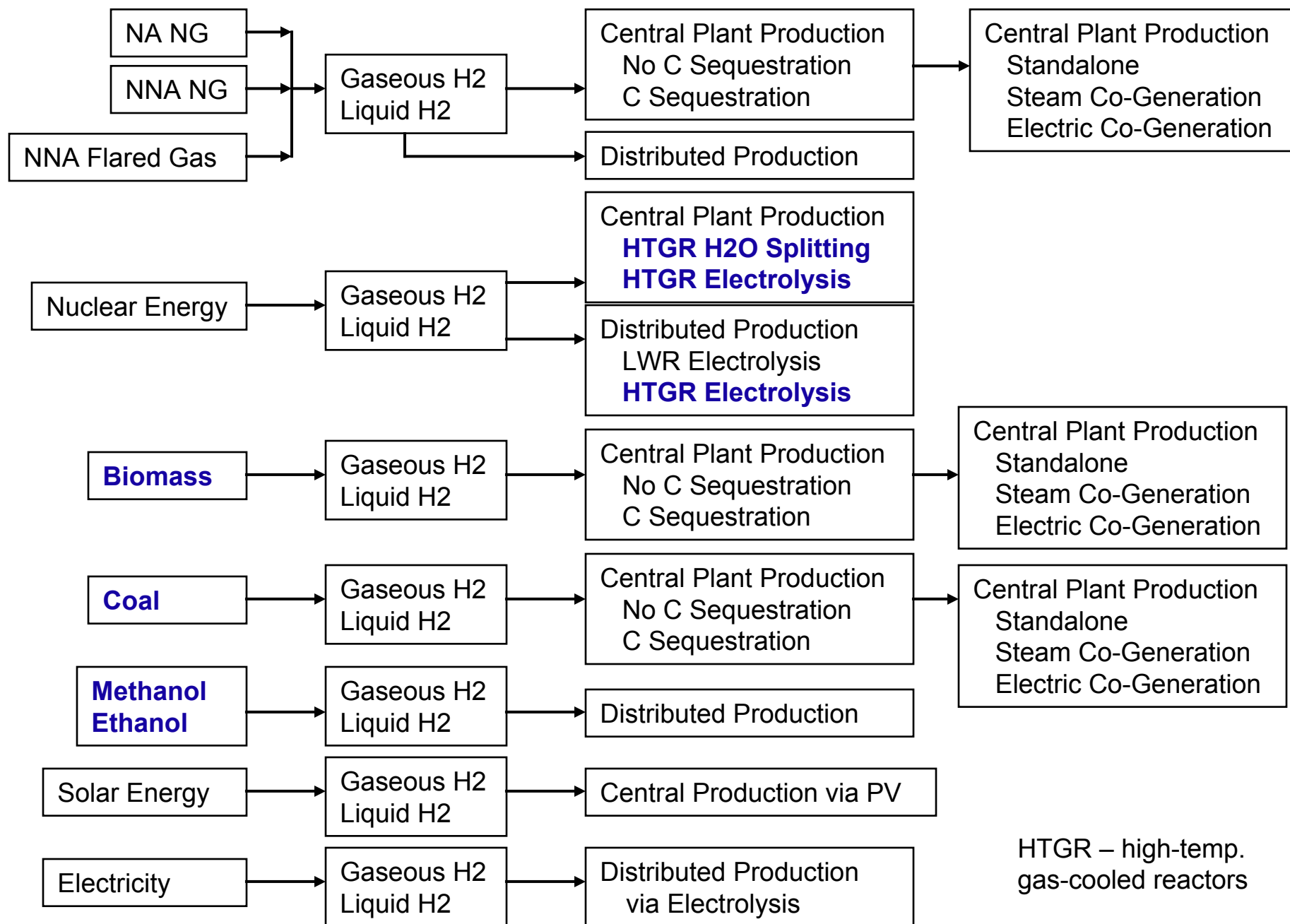
Note: NA – North American; NNA – Non-North American

GREET Natural Gas Fuel Pathways



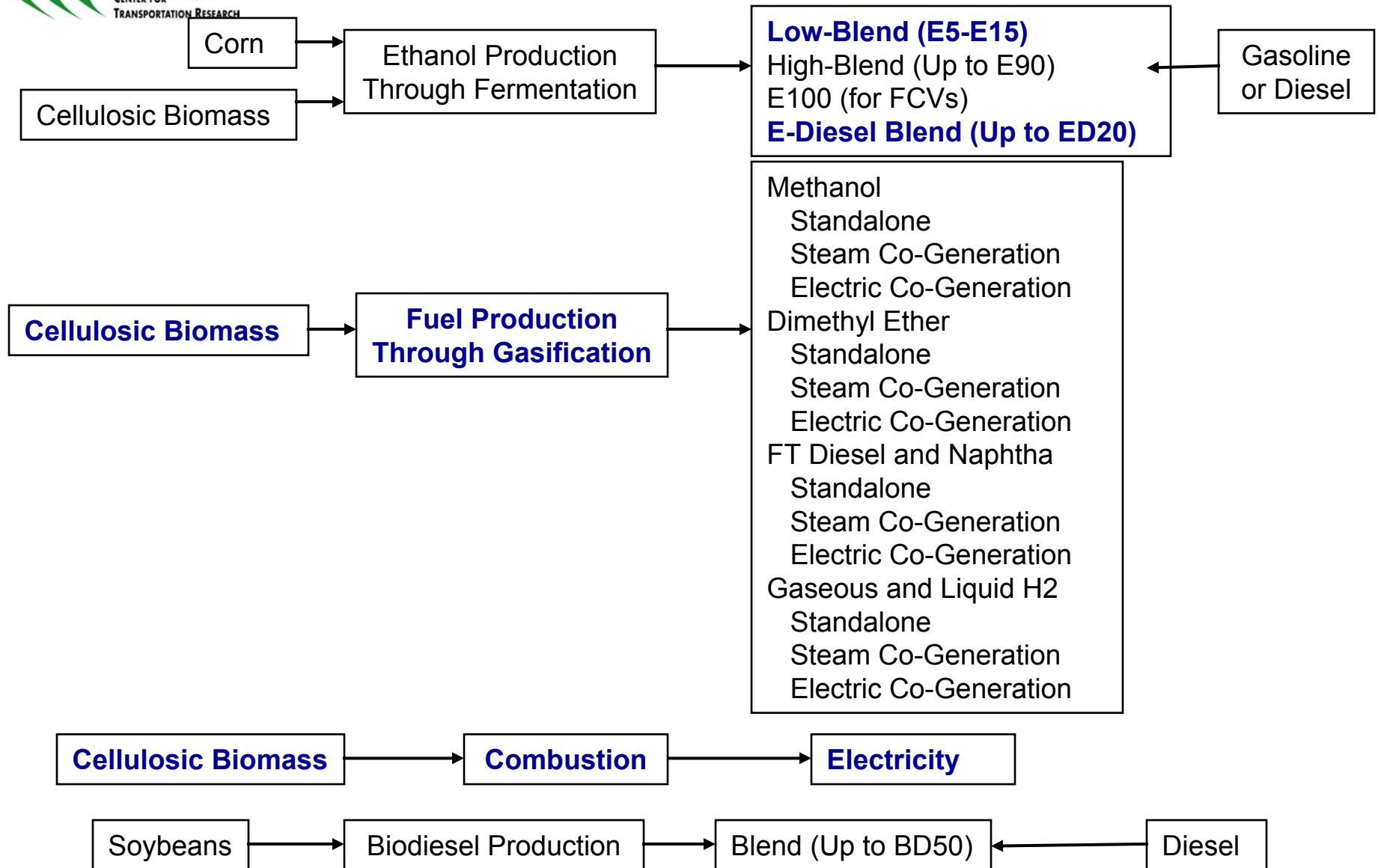
Note: hydrogen from NG options are not presented here.

GREET Hydrogen Production Pathways



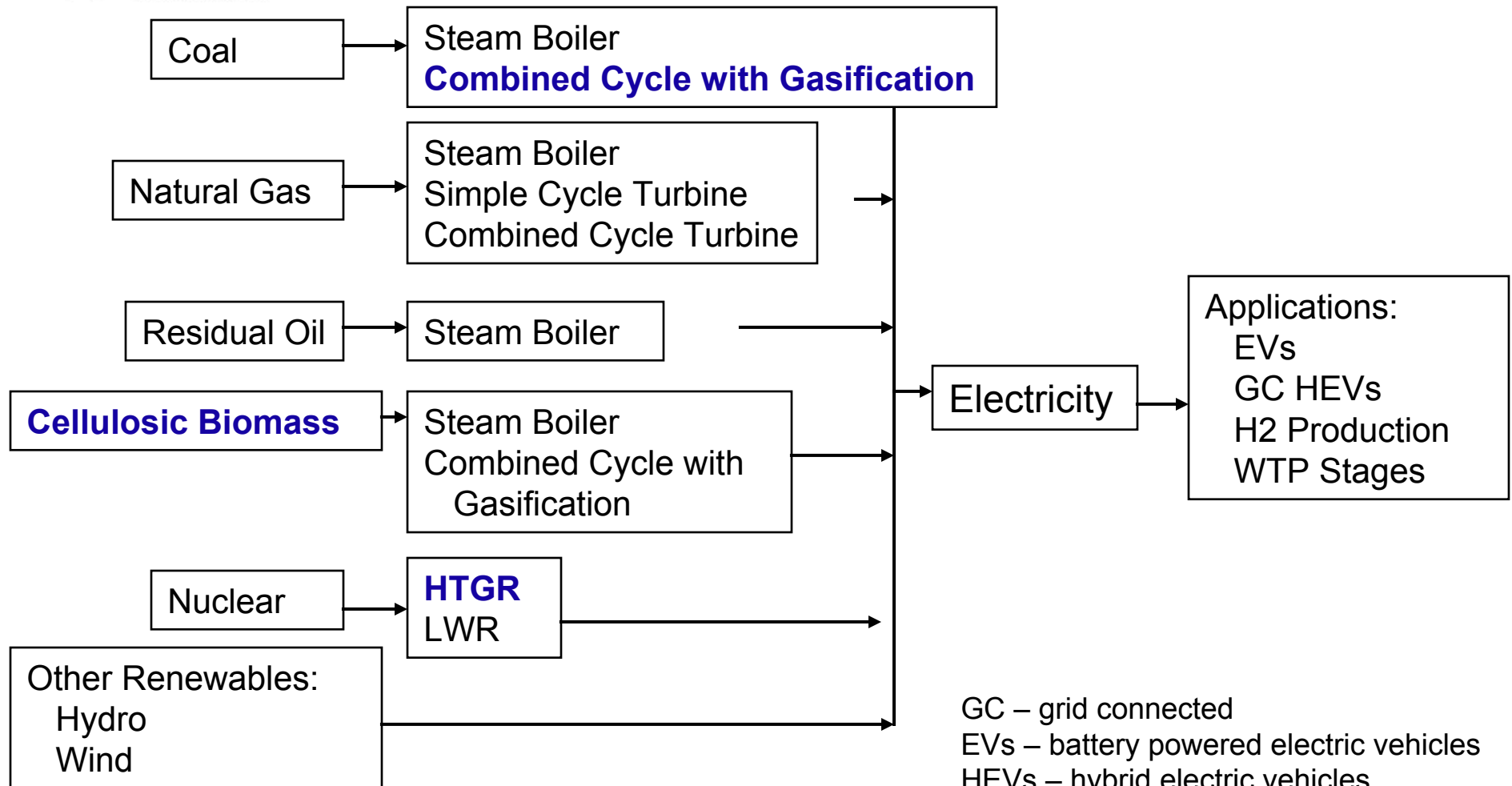


GREEN Includes a Variety of Biofuel Pathways





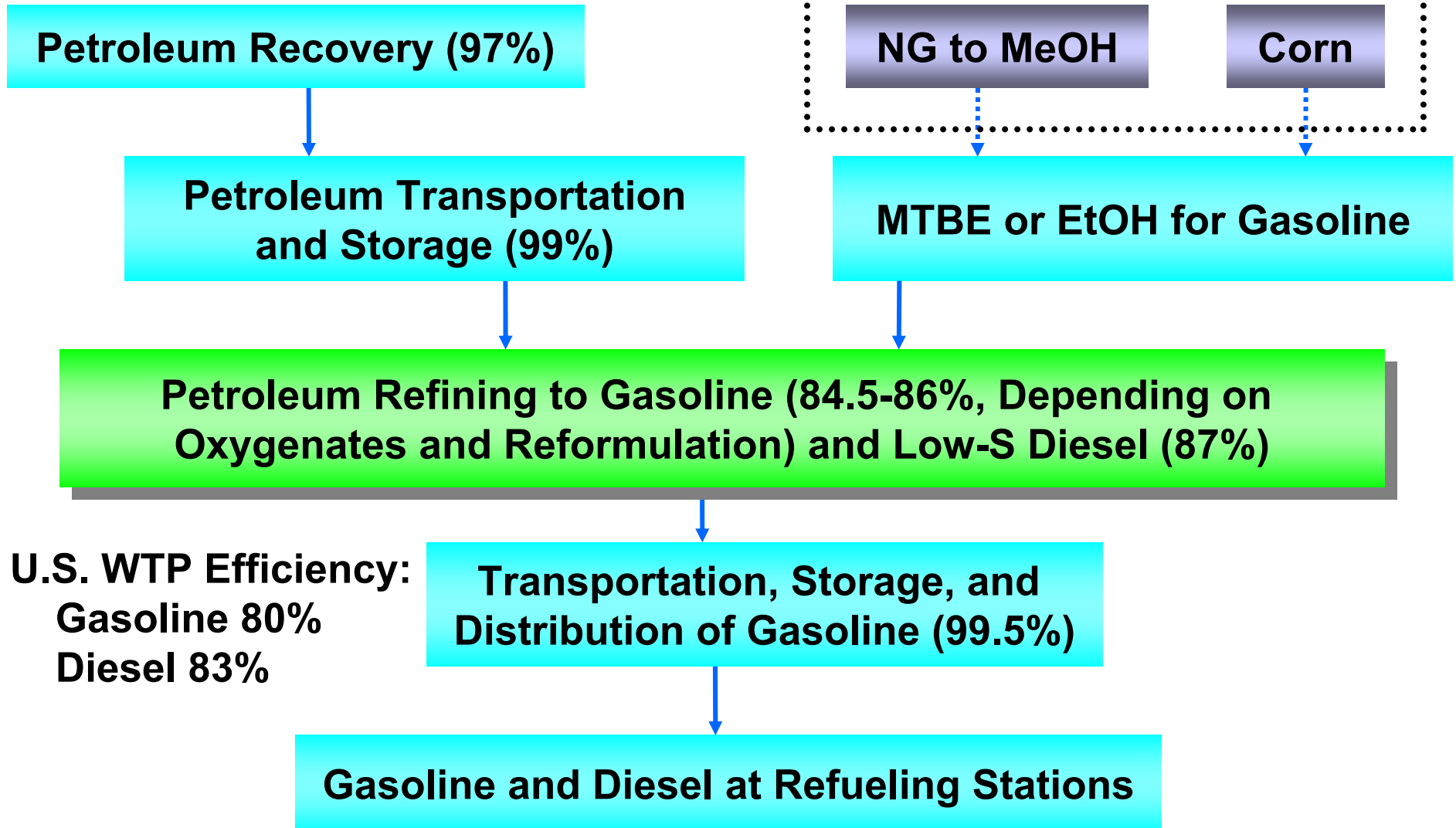
GREET Electricity Generation Pathways



GC – grid connected
EVs – battery powered electric vehicles
HEVs – hybrid electric vehicles
WTP – well to pump
HTGR – high-temp. gas-cooled reactors
LWR – light water reactors

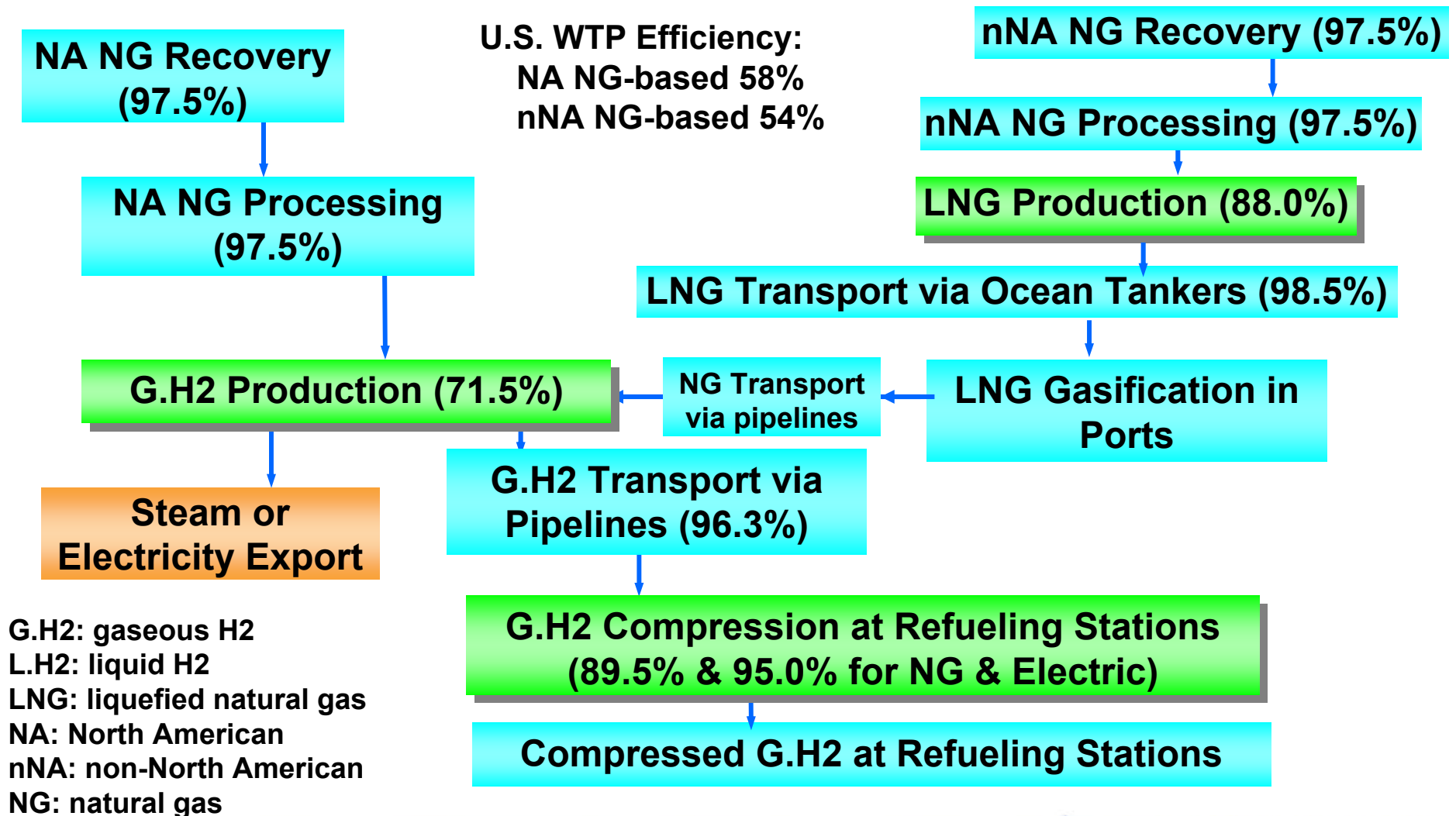


Petroleum Refining Is the Key Energy Conversion Step for Gasoline and Diesel



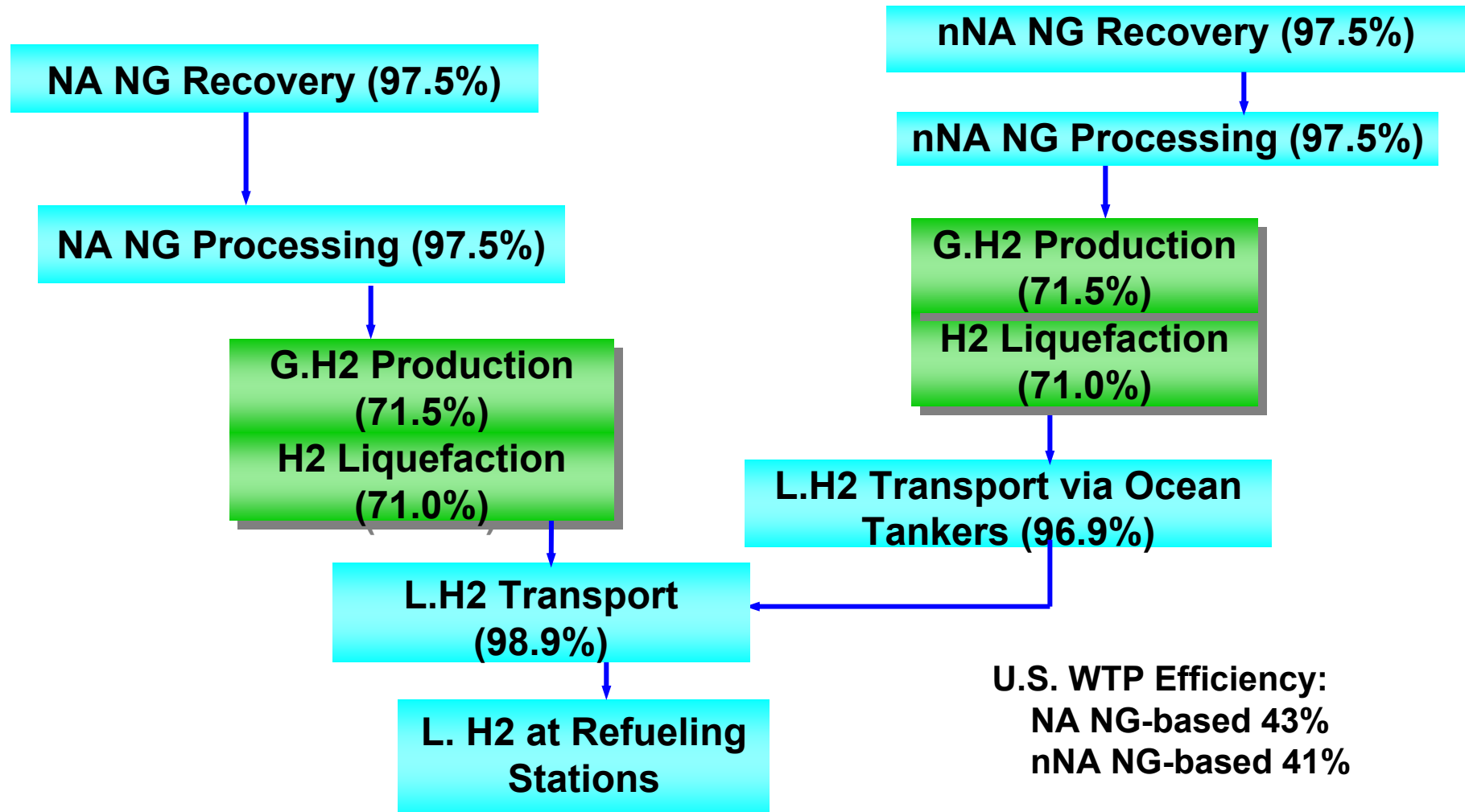


Production and Compression Are Key Steps for G.H₂ Production



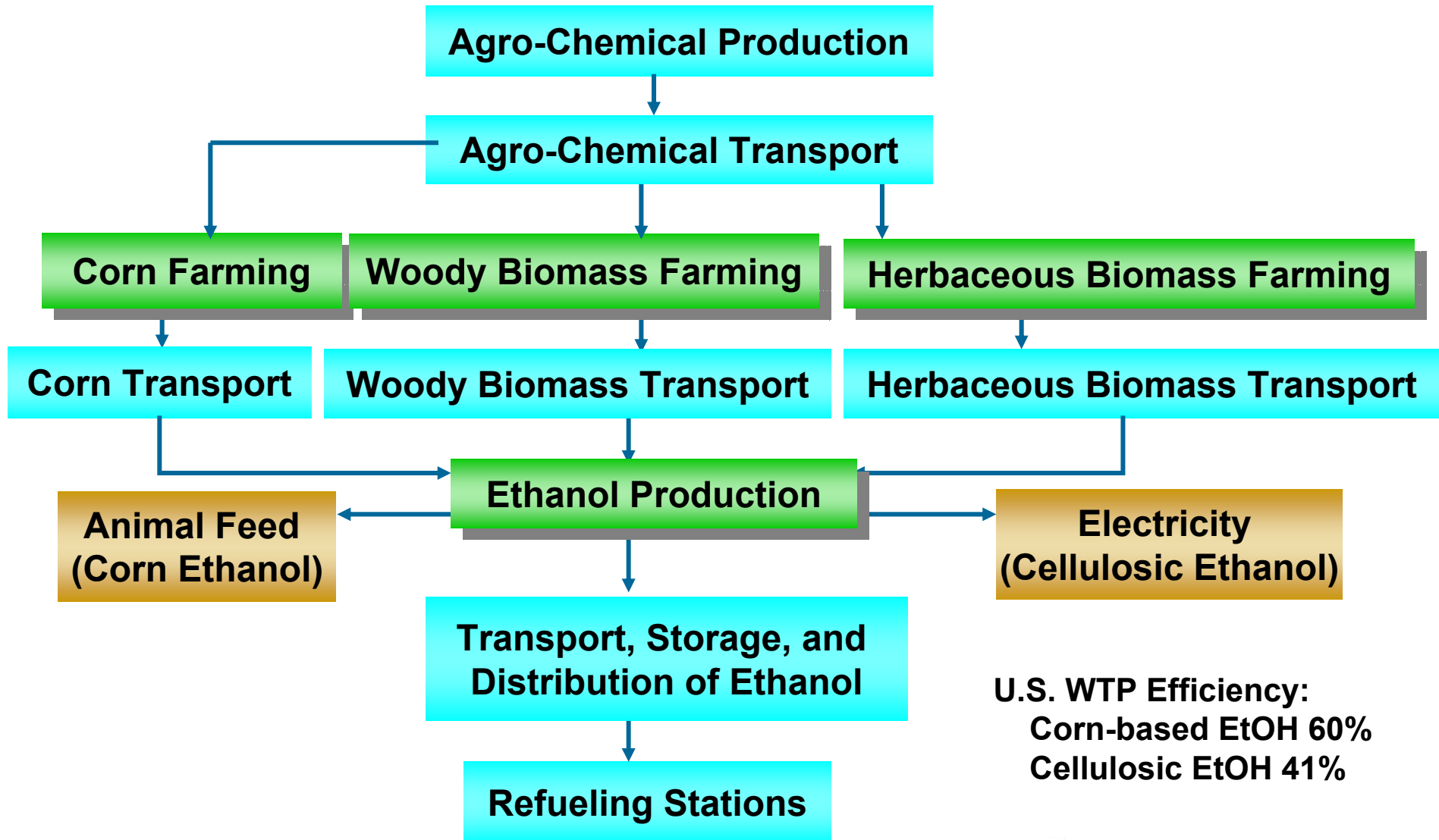


H₂ Liquefaction Has Higher Energy Losses Than H₂ Compression





Ethanol W T P Pathways Include Activities from Fertilizer to Ethanol at Stations



U.S. WTP Efficiency:
Corn-based EtOH 60%
Cellulosic EtOH 41%

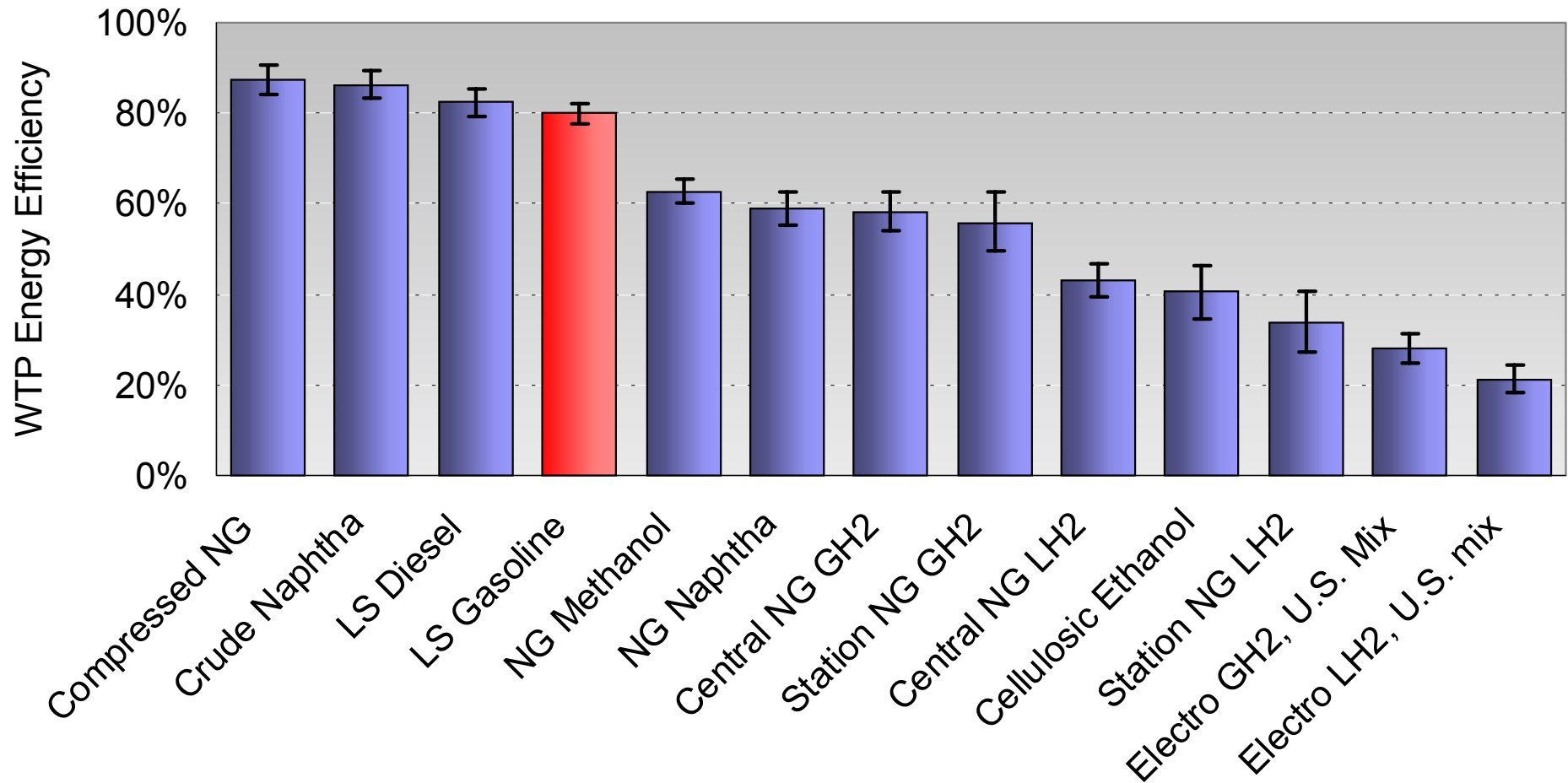


Users of GREET/M O V E S Need to Pay Close Attention to Key Input Parameters

- ❑ GREET WTP default assumptions are U.S. averages
- ❑ Scope and assumptions for individual states/regions could differ significantly
 - Transportation fuel types for simulations
 - Fuel production options for a given fuel (such as electricity generation and reformulated gasoline production)
 - Market shares of production options for a given fuel



Integrated GREET/ MOVES Generates Results to Put Different Fuels into Perspective





Thank You!

