Assessment of Full Fuel Cycle Emissions

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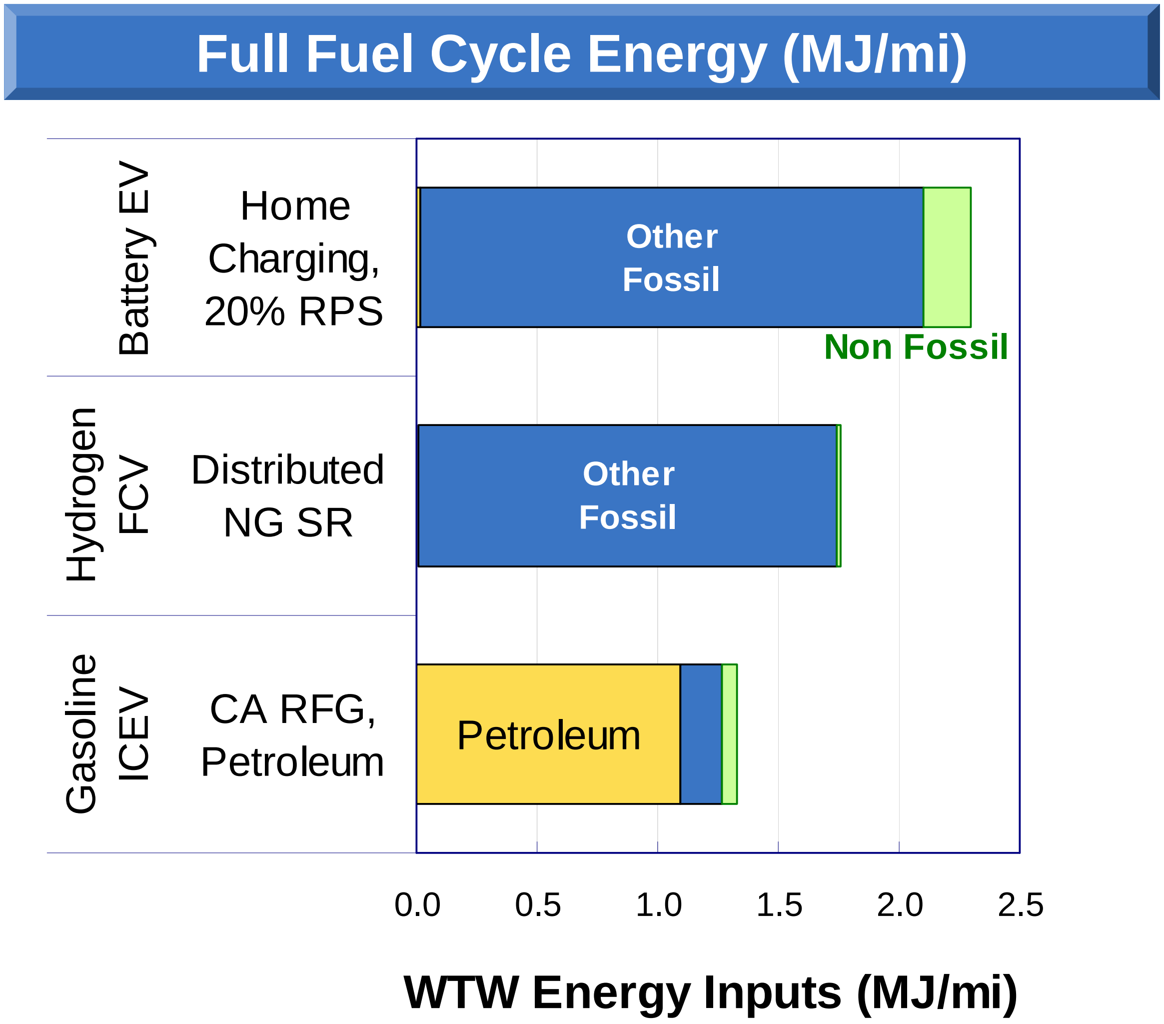
Stefan Unnasch
TIAX LLC

TIAX LLC
Cupertino, California

Reference: E3100

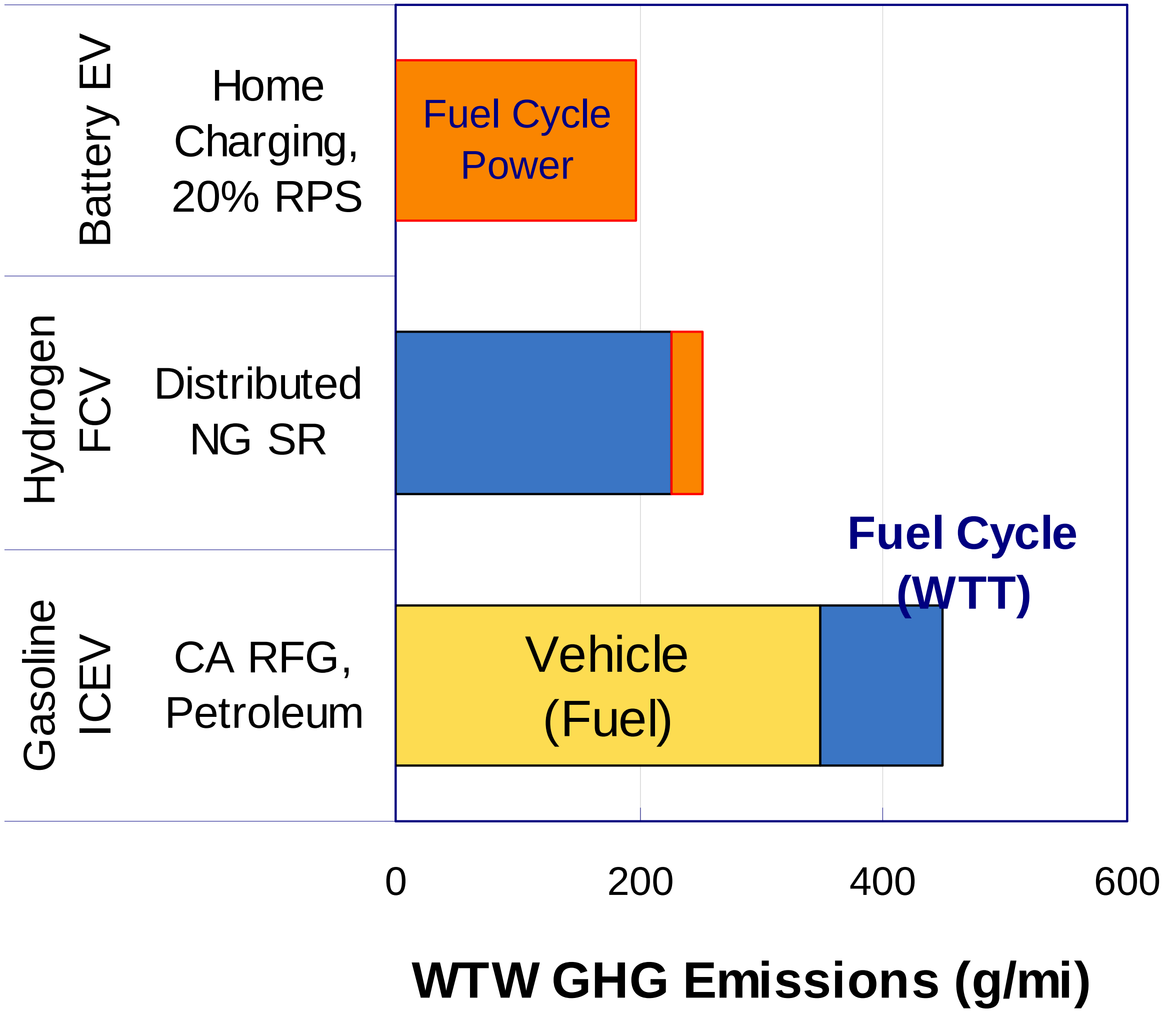
Outline

- **WTW Results**
- **Analysis Scope**
- **Approach**
- **Assumptions**
- **WTW Results and Conclusions**



All results are based on well to tank values in Unnasch, S., "California Hydrogen Highway Network Blueprint Plan, Societal Benefits Topic Team Report," March 2005.

Full Fuel Cycle GHG Emissions (g/mi)



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A full fuel cycle analysis provides a basis for comparing the energy inputs and emissions from various fuel production and end use options.

Objectives

- Provide basis for including impacts of fuel production associated with vehicle operation
- Applications: ARB ZEV, DOE H_2, H_2 Highway, AB1493, AB2076, AB1007

Fuel Pathways

- Petroleum, natural gas, coal, biofuels, renewable power, etc.

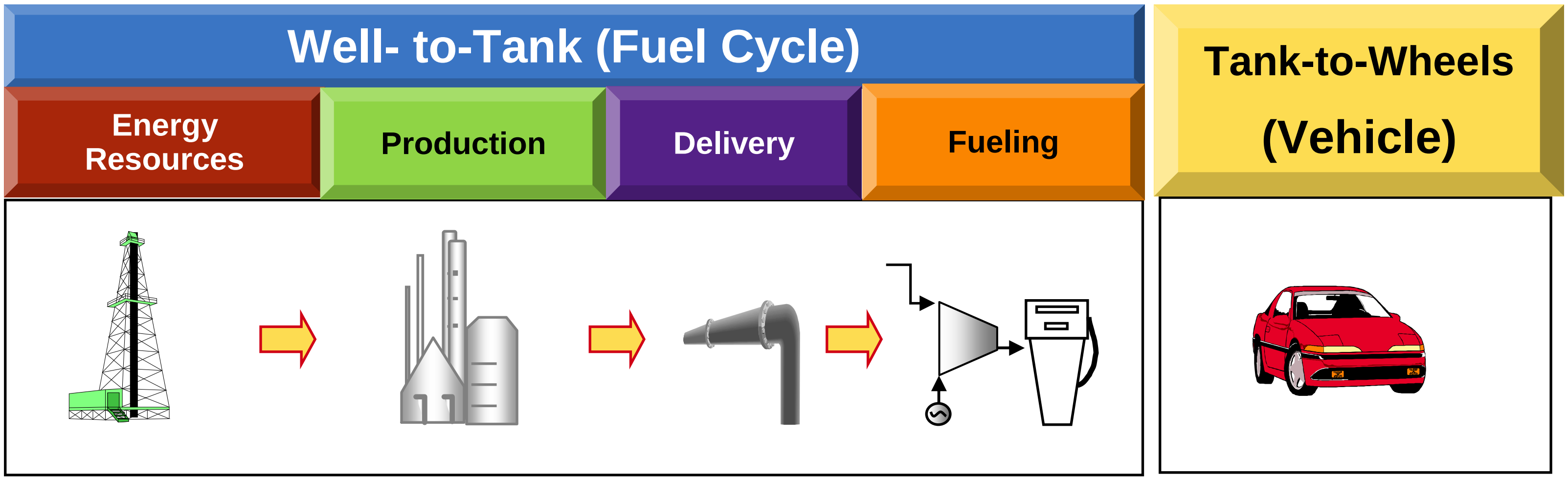
Vehicles

- Blended fuel comparisons (biodiesel, FTD, E10)
- New vehicle strategies (Hydrogen, EV, PHEV, CNG)
- Light-duty vehicles, heavy-duty vehicles, etc.

Emission Sources and Boundaries

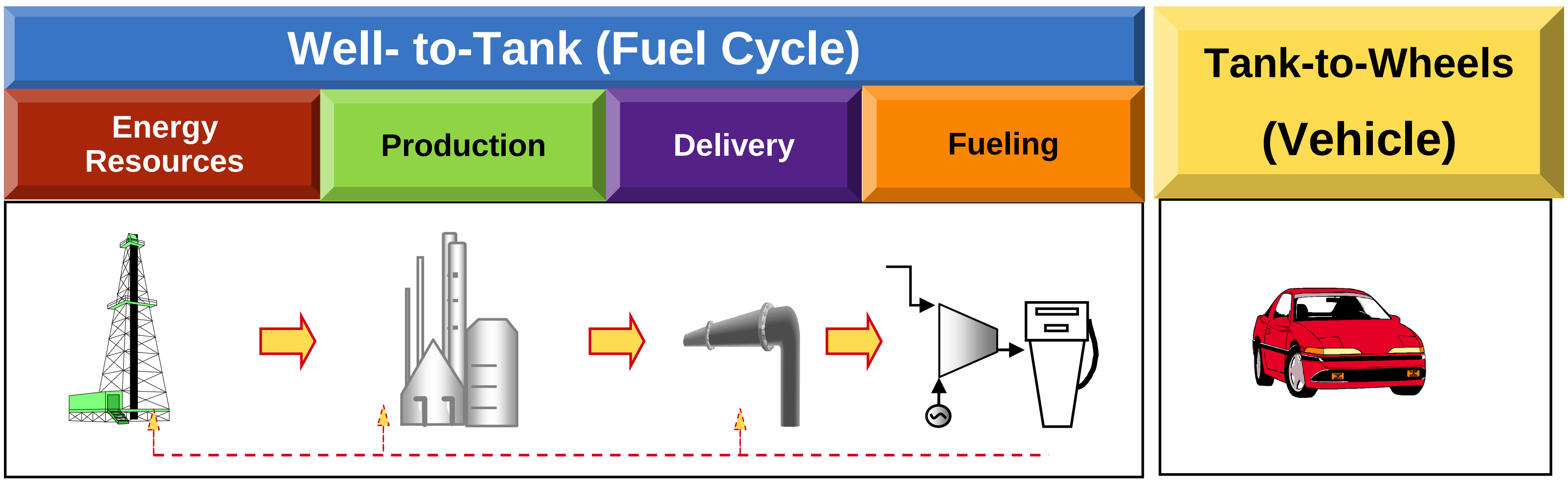
- Geographic location of fuel production
- Local emission constraints
- Marginal production

Well-to-Wheels/ Fuel Cycle Emission Steps



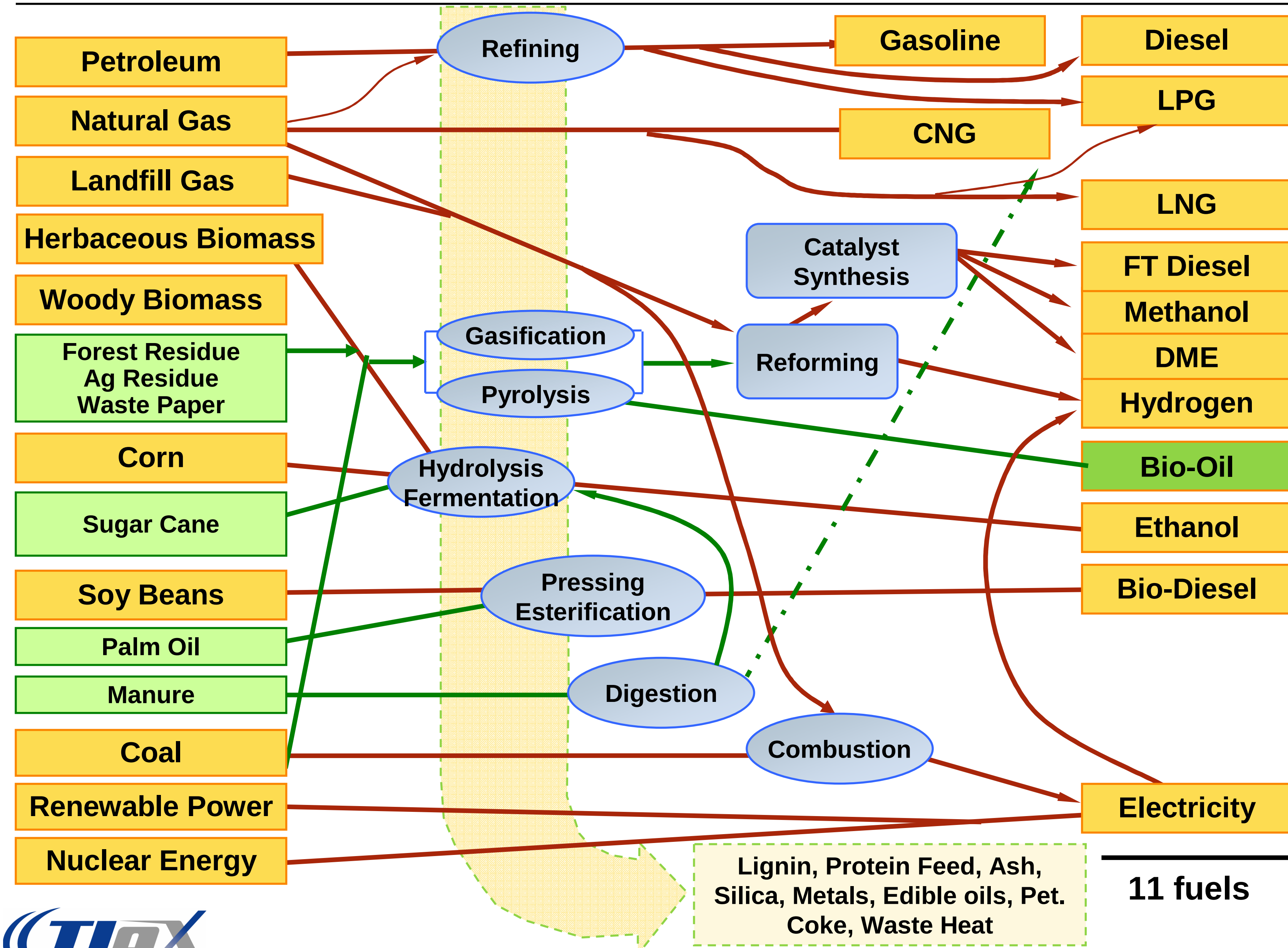
- Full fuel cycle emissions correspond to combustion, fugitive, and spillage emissions from resource extraction, fuel production, delivery, and vehicle exhaust, running/evaporative

Well-to-Wheels/ Fuel Cycle Emission Steps

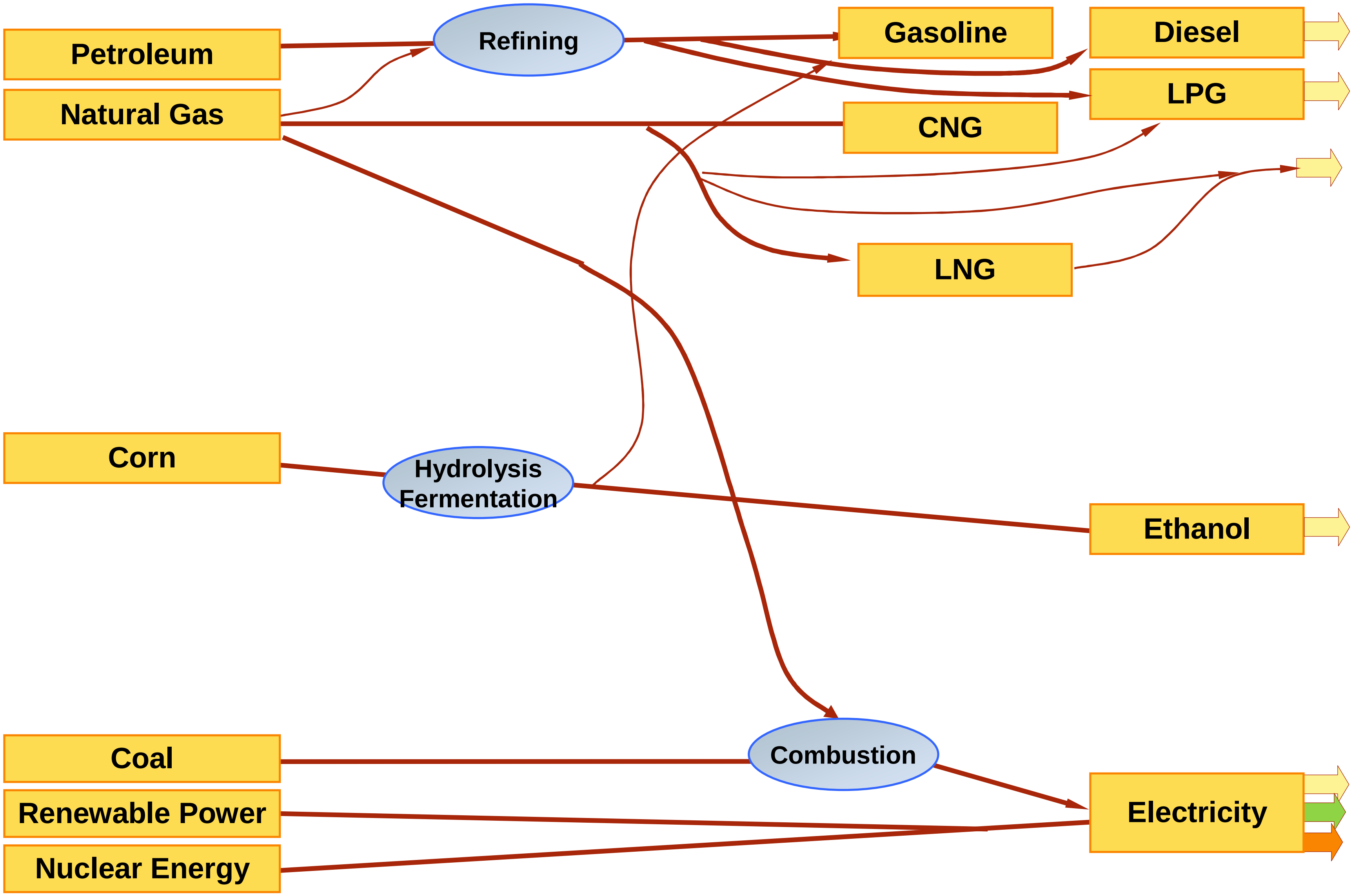


- Full fuel cycle emissions correspond to combustion, fugitive, and spillage emissions from resource extraction, fuel production, delivery, and vehicle exhaust, running/evaporative
- Fuel cycle fuel and losses are included
- Emissions from facility and vehicle manufacturing are not included (LCA)
- Feedstock supply, regulations, fuel prices, etc. also affect emissions

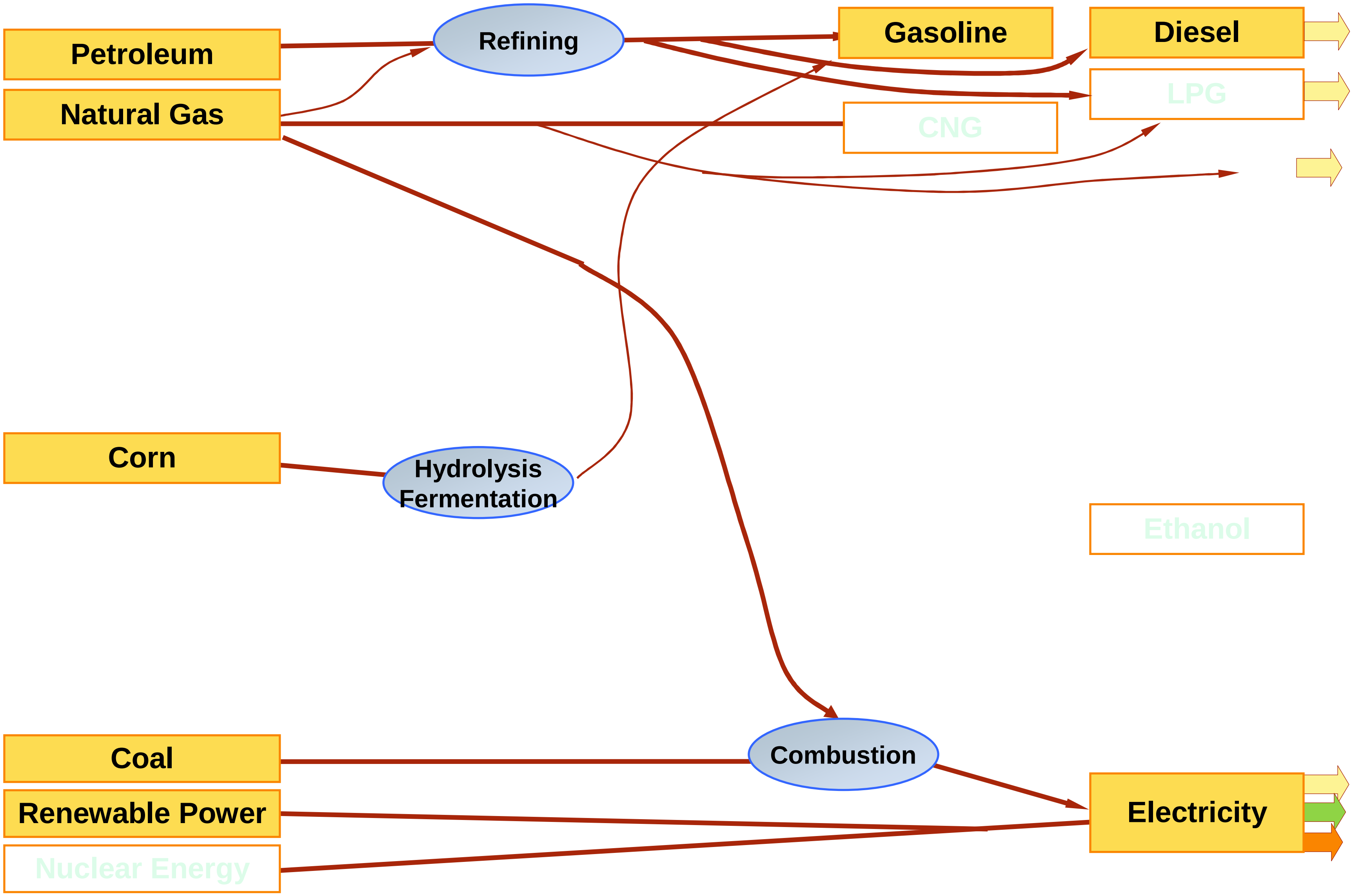
Analysis Scope Pathways *Multiple Pathways*



Analysis Scope Pathways *Primary Fuels*



Analysis Scope Pathways *This Presentation*



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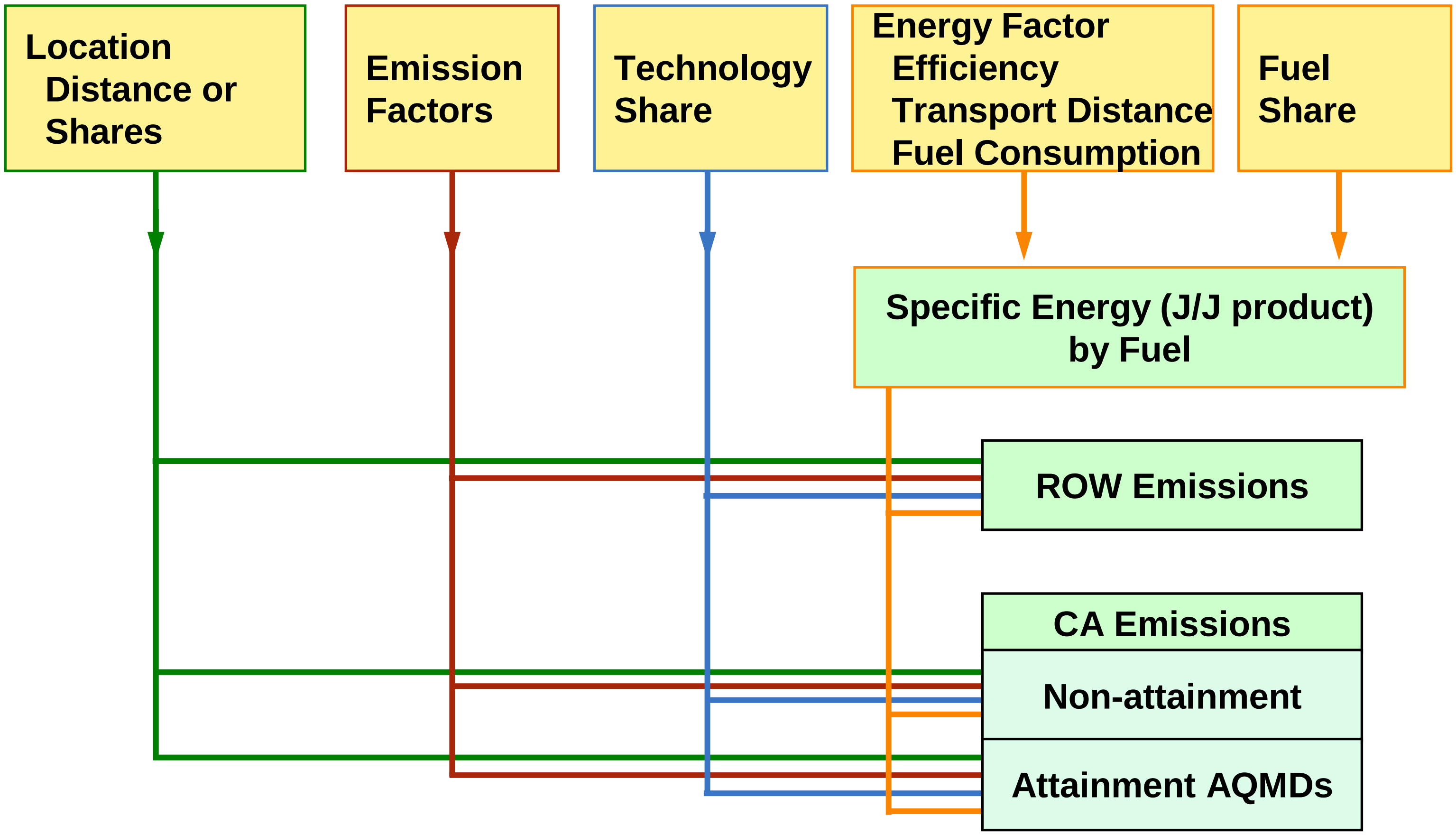
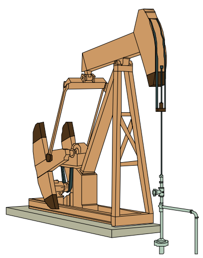
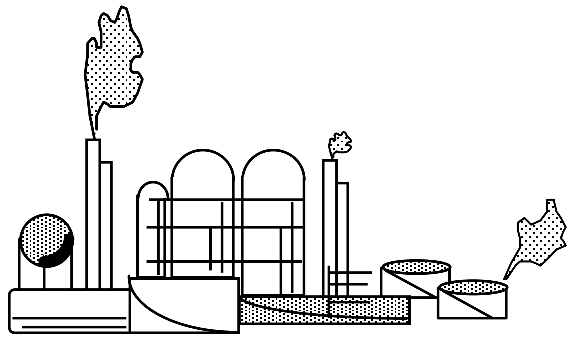
Fuel cycle model inputs need to capture California boundaries.



Boundary definitions affect how emissions are determined.



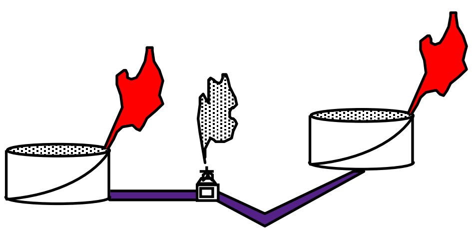
PRODUCTION



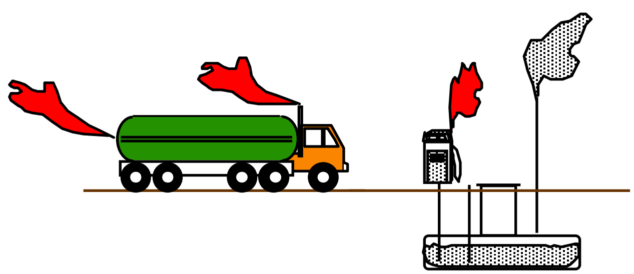
PROCESSING

PRODUCT STORAGE

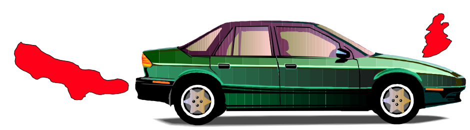
BULK FUEL TRANSPORTATION



BULK STORAGE

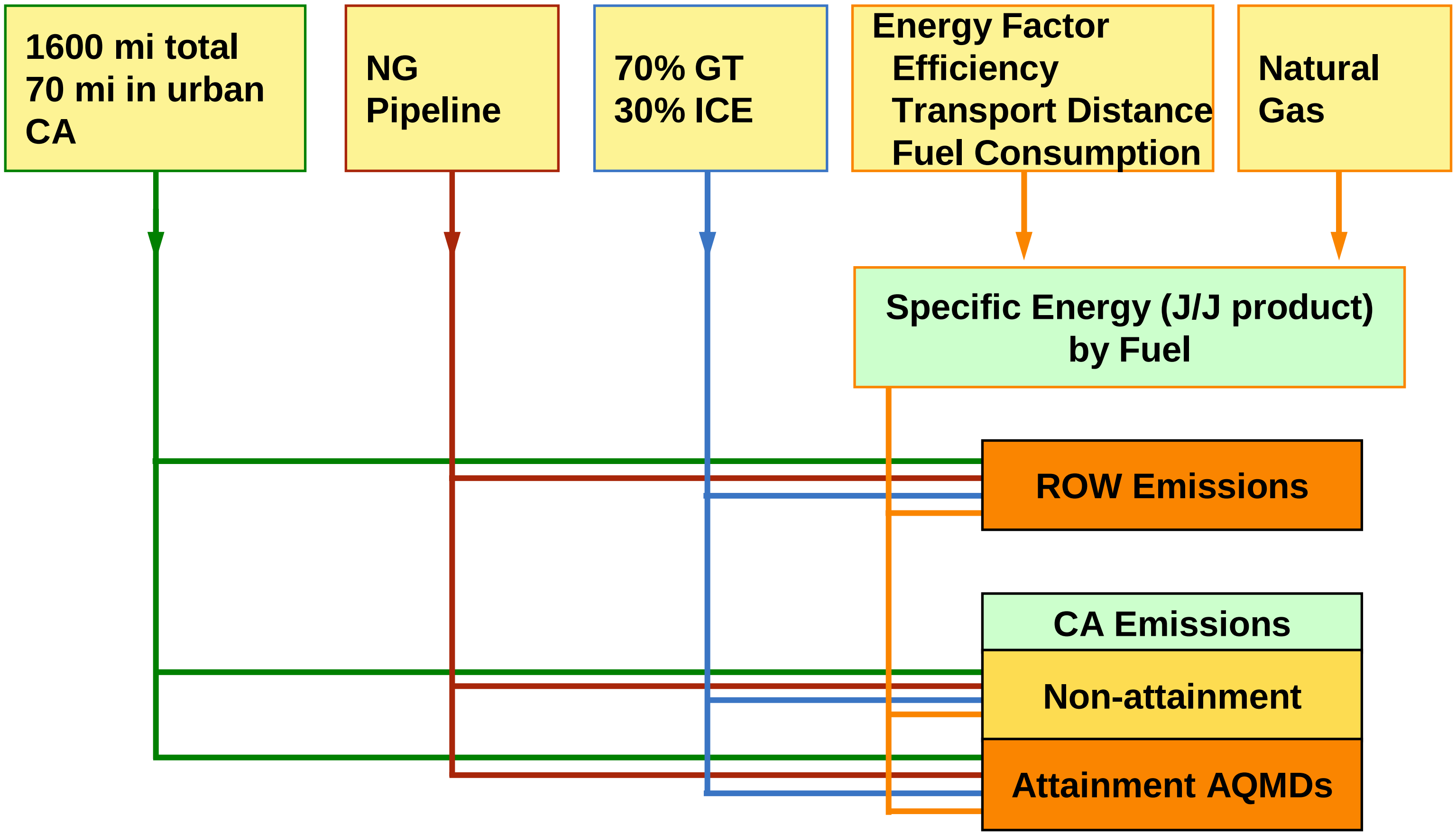


TRANSPORTATION AND DISTRIBUTION



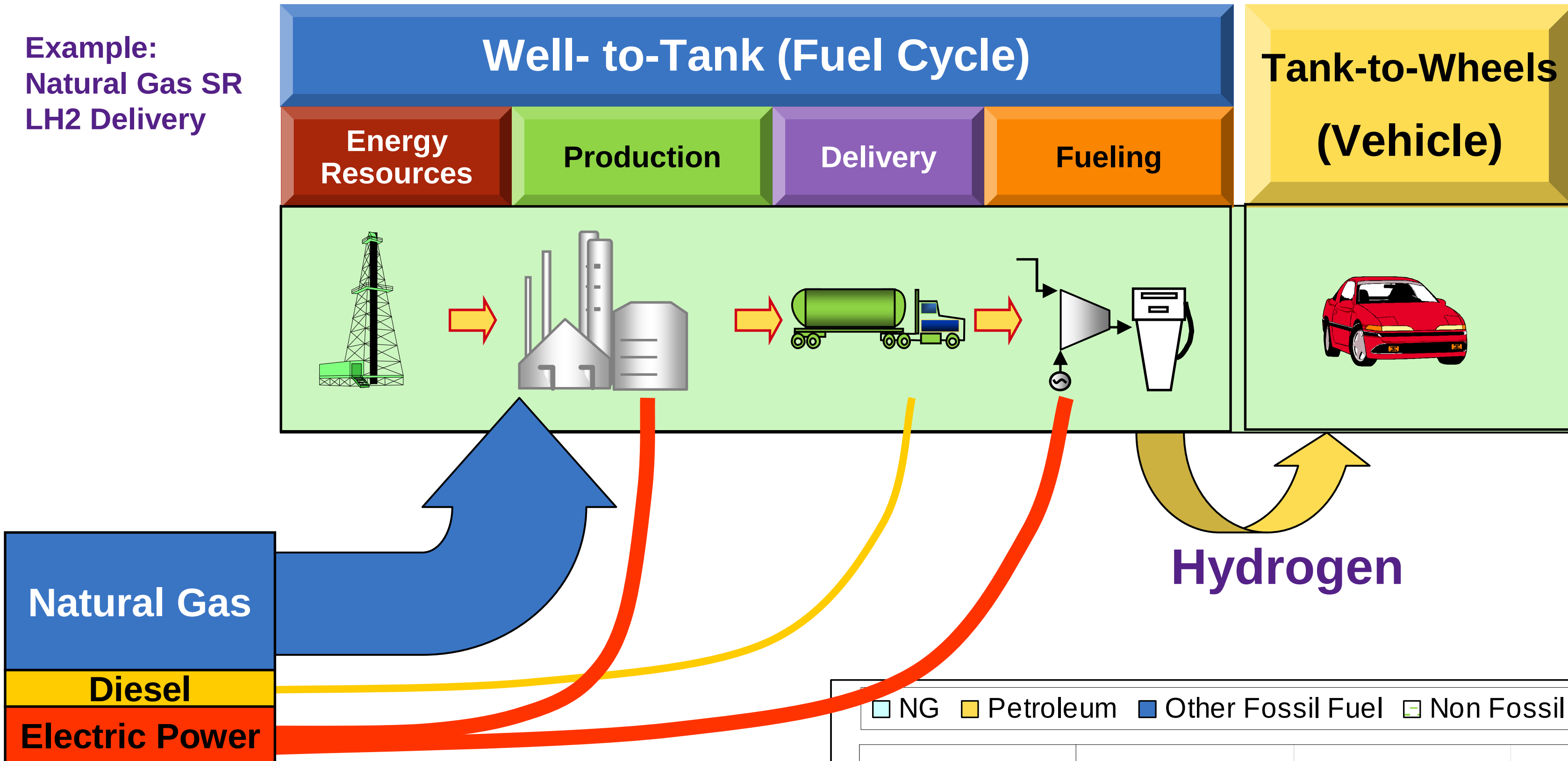
VEHICLE EMISSIONS

Example for delivering natural gas to California.



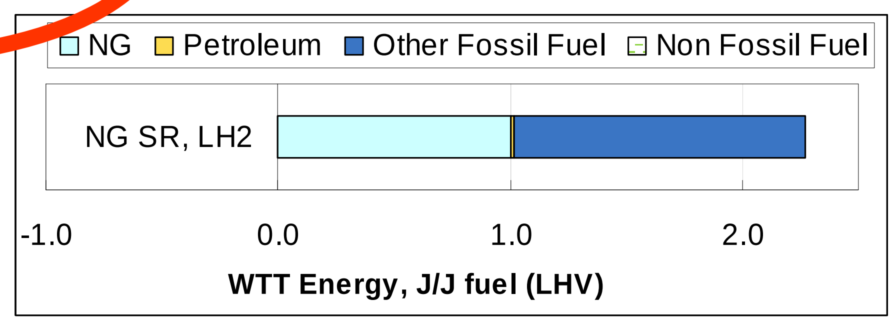
Most fuel pathways can be represented as a combination of primary fuels plus a feedstock. WTW = (WTT+carbon in fuel)/FE = gGHG/MJ x MJ/mi

Example:
Natural Gas SR
LH2 Delivery

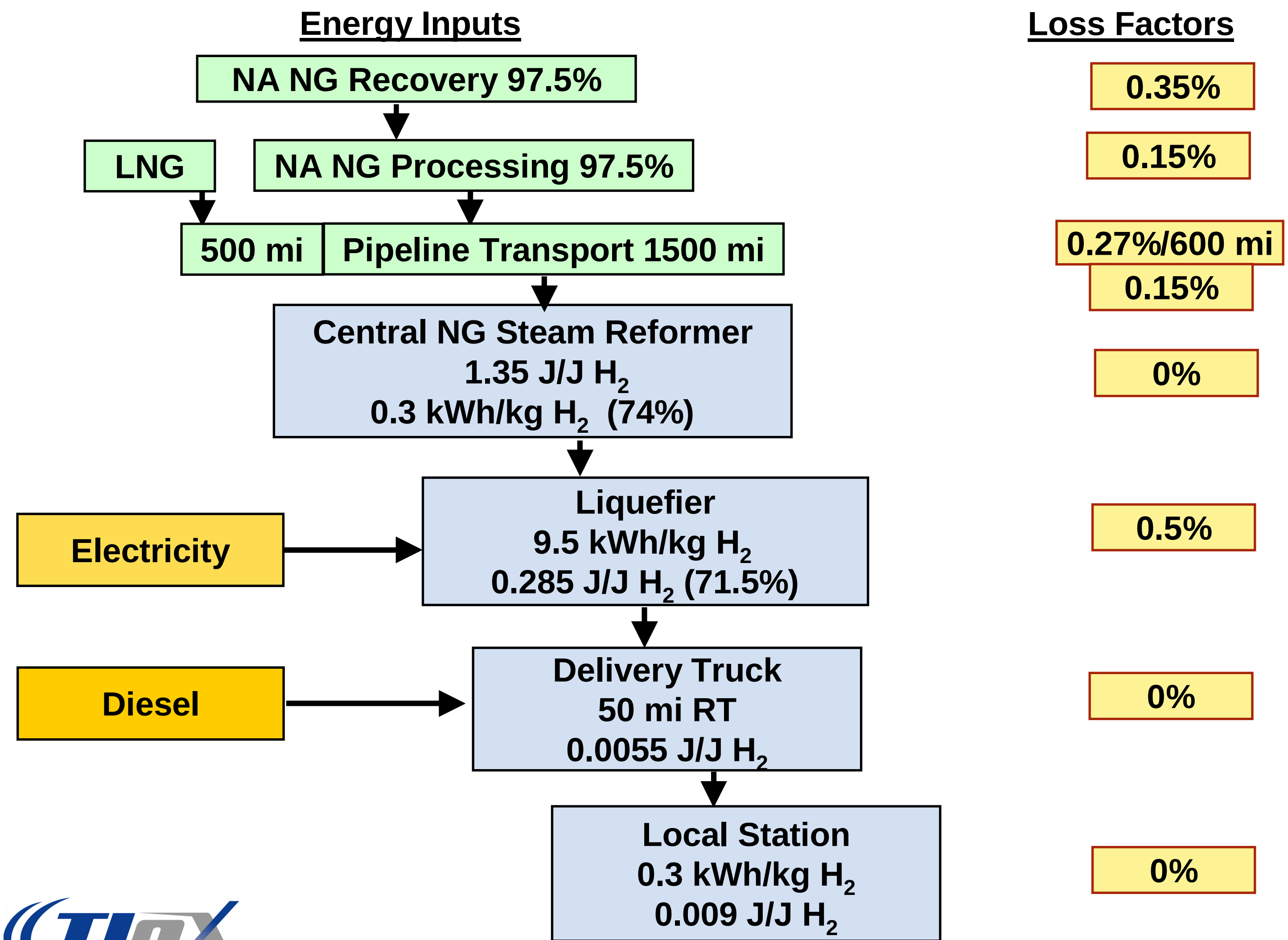


WTT (+ Fuel) Energy = 2.27 J/J H_2

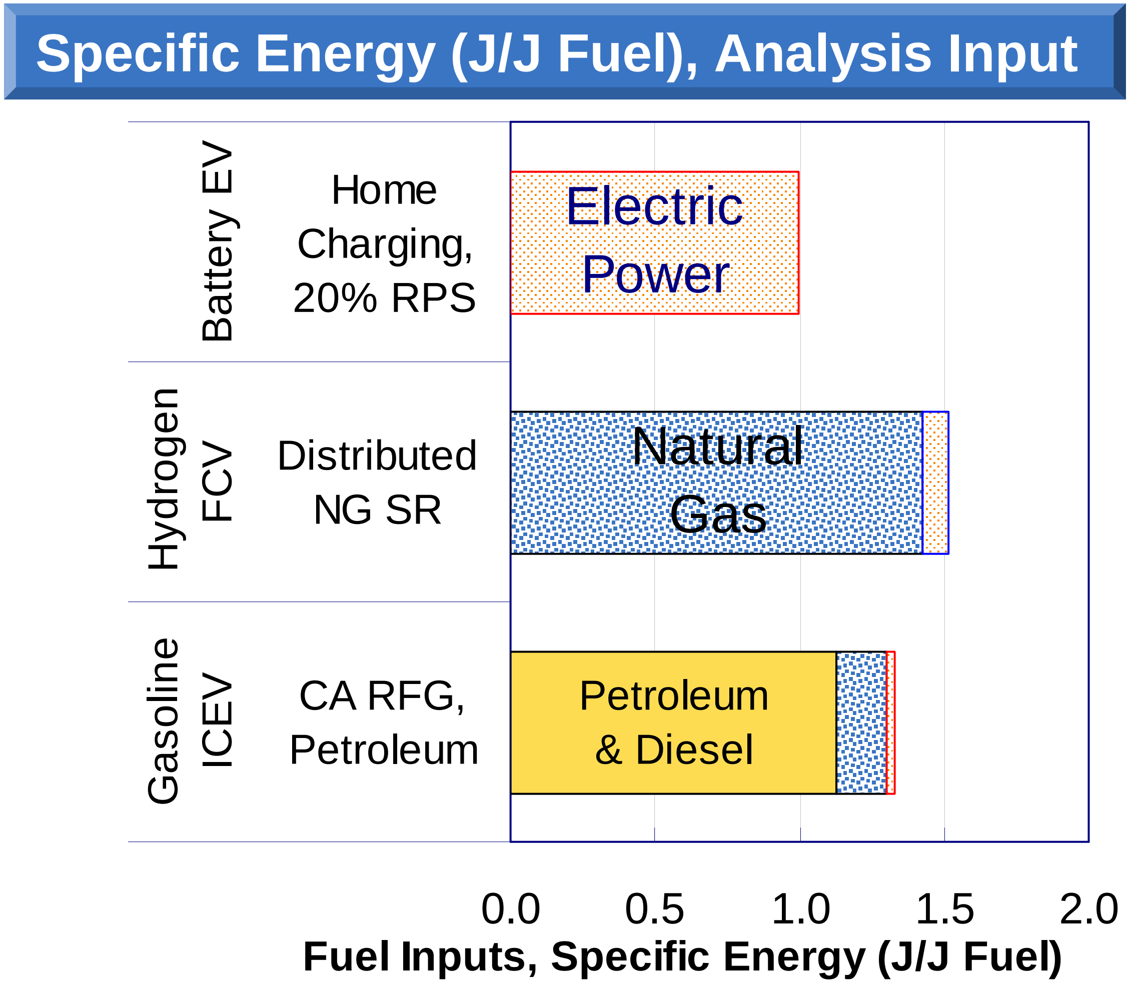
WTT_f η = 44%



Assumptions are identified for all of the fuel cycle steps. While inputs can be expressed as % η, simple chain multiplications don't work.



Specific energy inputs values are used to build up WTT results.



Primary Fuels

- Determine results from GREET or other fuel cycle model
- Apply emission constraints by location

Fuel Production

- Identify fuel production process energy (1/η)
- Weight primary fuel WTT coefficients
- Specific energy values provide a quick explanation of assumptions. These are not on a WTT or WTW basis.

A post processor enables the calculation of numerous complex fuel chains based on the WTT results for primary fuels from the GREET model.

Case BE85_3: E85 — Ethanol from Ag Residue

Process		Production	Delivery	Fueling Station
Step Description		Cellulose, Dilute Acid	Tank Truck	U.G. Tank, Dispenser
% losses in step		0.003%	0.0008%	0.001%
Energy Input (Feedstock or Utility) Selection:		Specific Energy (MJ Input/MJ Fuel)		
Biomass, Ag Residue		=2.8 x 0.79	0	0
Electricity — CA RPS Mix	▼	=0.06 x 0.79	0	0.0001
Natural gas — North American		0	0	0
Gasoline		0.21	0	0
Low-sulfur CA diesel		0	0.0046	0

Model inputs in blue. For blends, fraction of ethanol and gasoline, energy weighted are multiplied by the process energy input. The multiplication is indicated.

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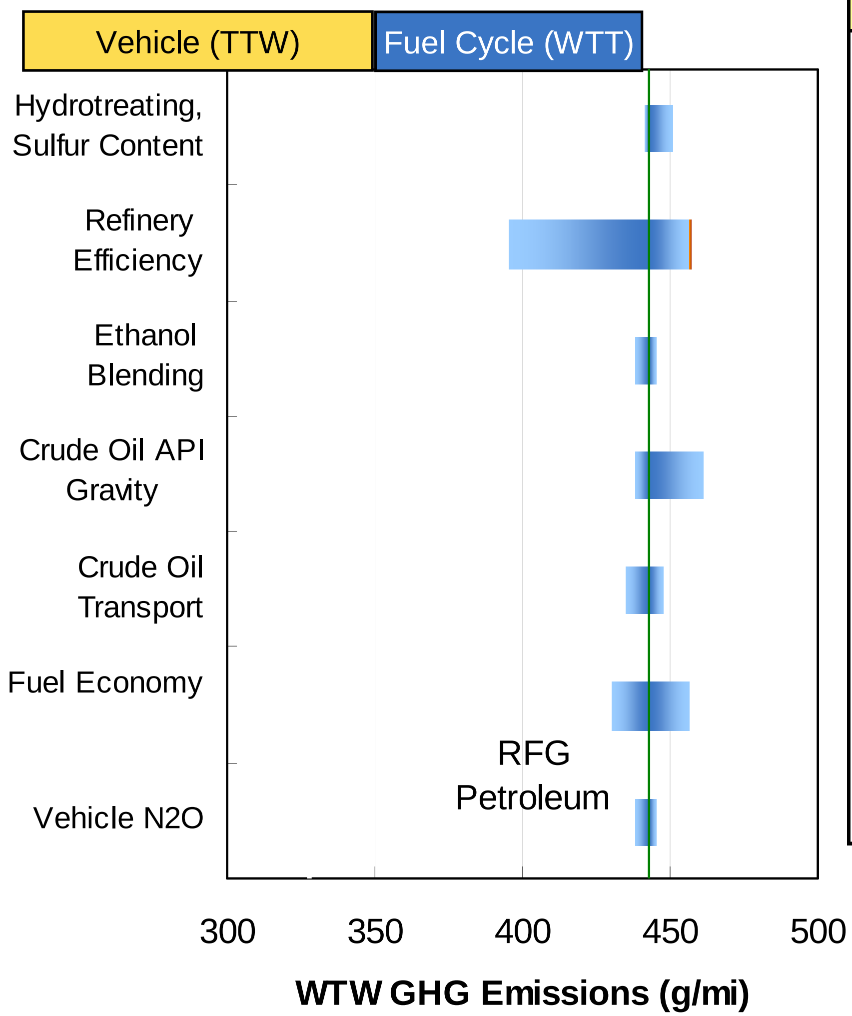
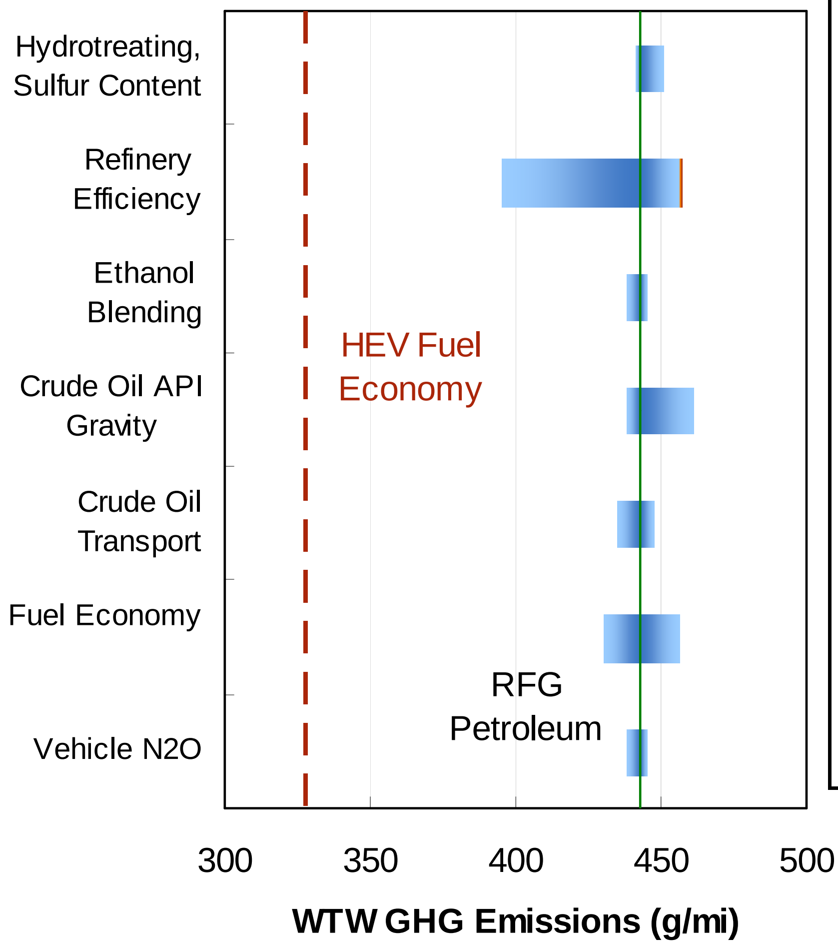
Fuel cycle GHG emissions are about 20 percent of the WTW total.



Units	Min	Base	Max
scf/bbl	100	150	250
% to RFG	83.5	84.5	92
Corn Process	Wet Feed	U.S. Mix	Coal
°API	33	30	26
mi	2500	4500	5500
mpg	26.3	25.5	24.8
g/MJ	1.5	2	2.5

Vehicle technology affects WTW GHG emissions.



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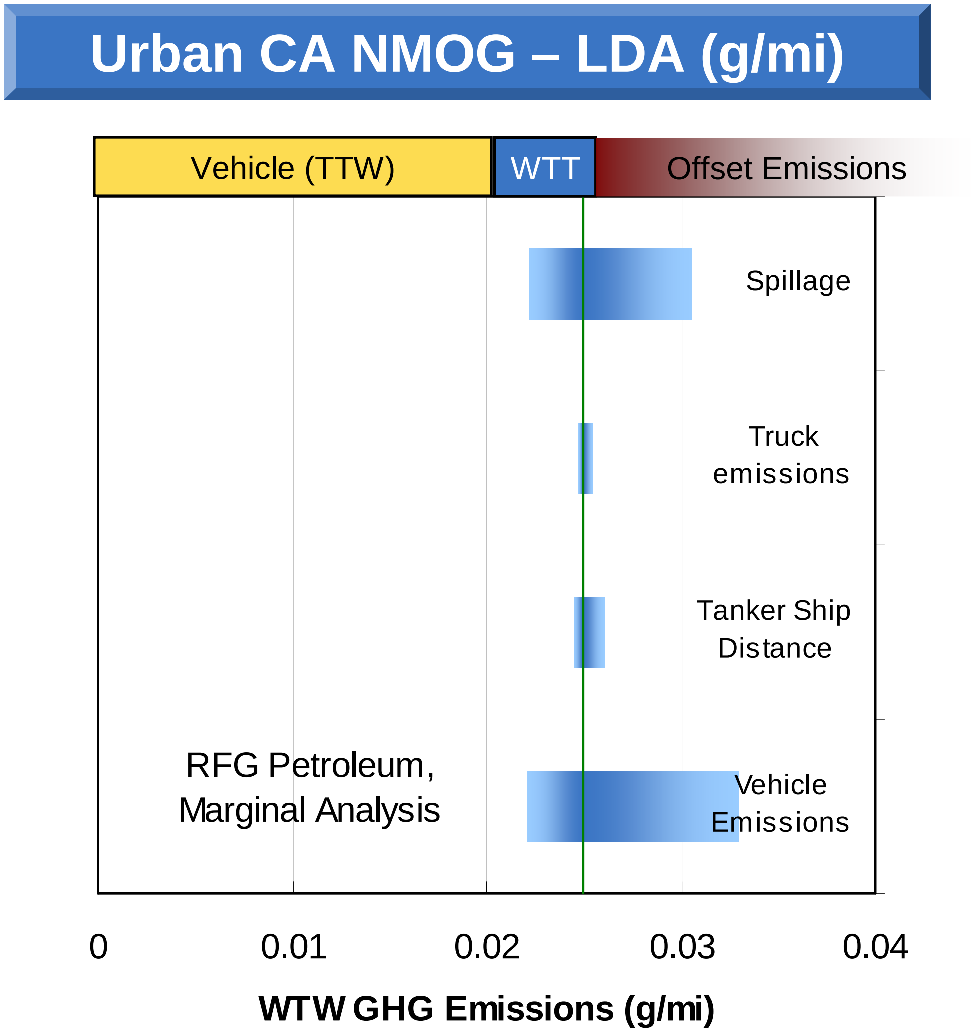
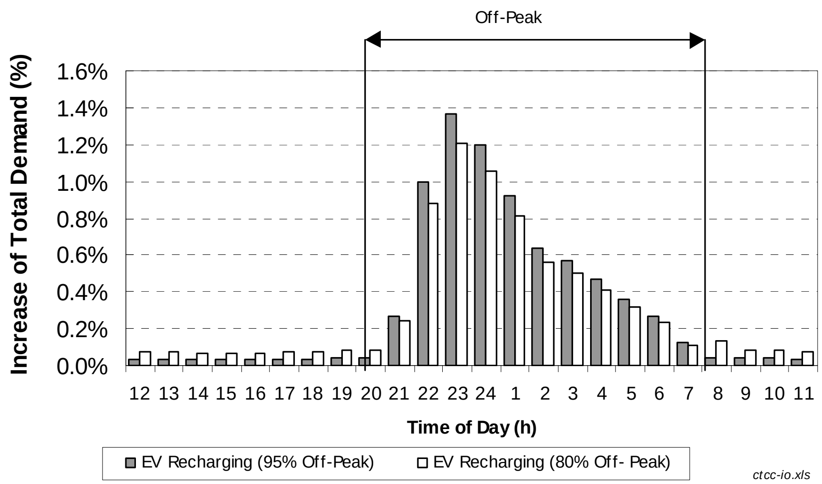
g/MJ	1.5	2	2.5

Local NMOG in the fuel cycle are primarily due to fuel and vapor losses.



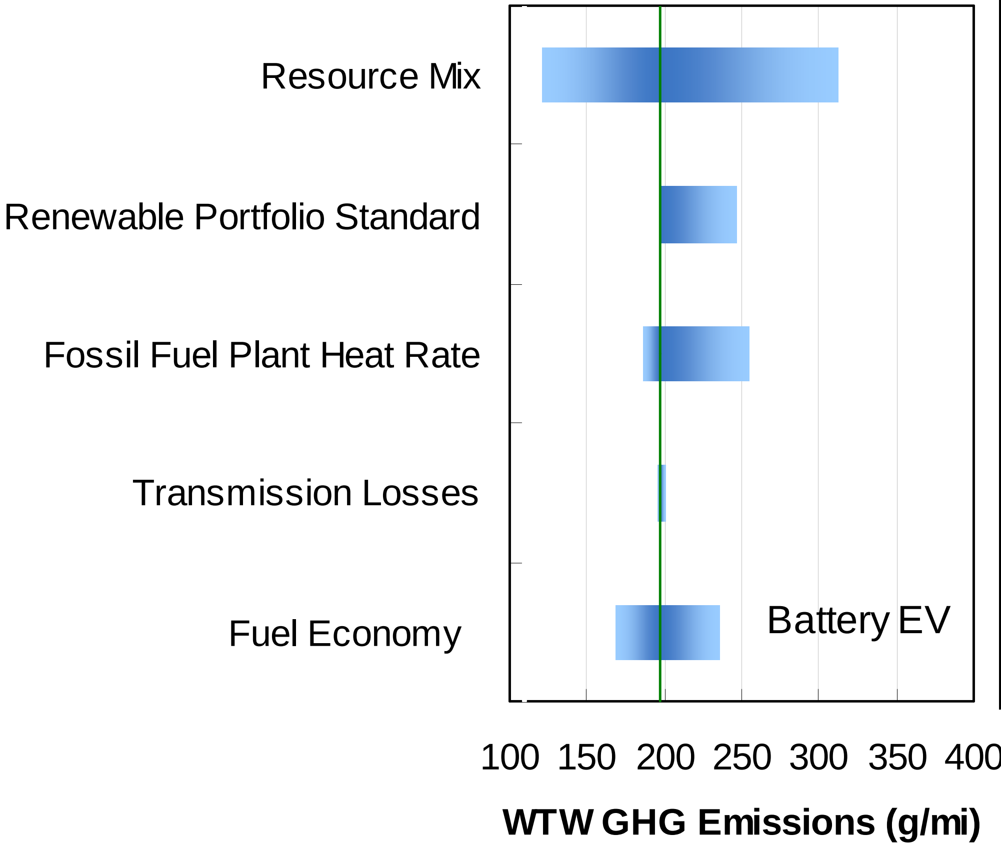
Dispatch models have been used to determine marginal generation emissions.

- Scenarios
  - Fuel production process power
  - EV/PHEV charging at night
- Scope
  - Analysis day
  - Typical incremental load
- Issues
  - Out of state resource mix and heat rate



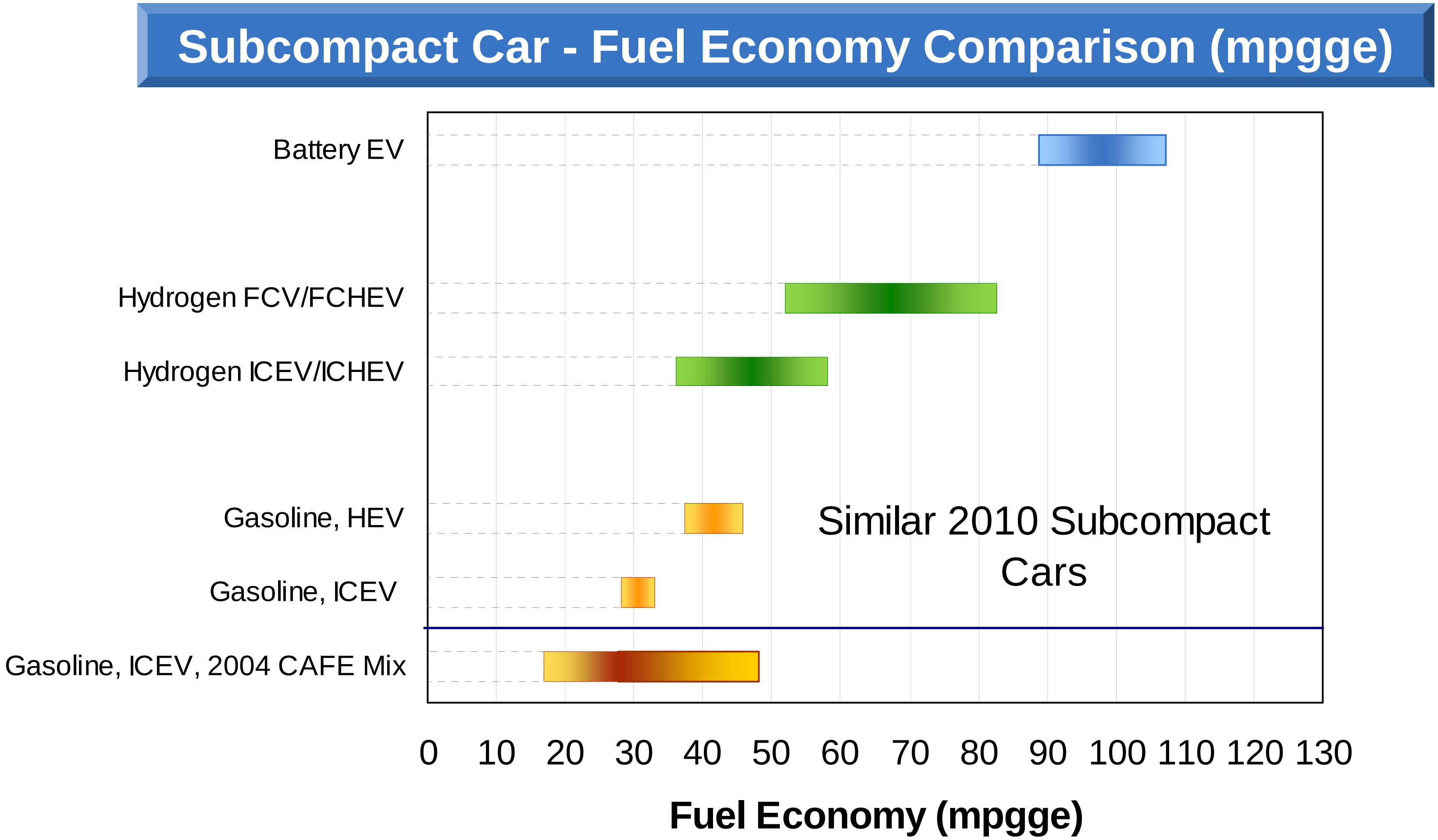
Scenario	Profile	Time	GWh/y	Application
1	24-hr Marginal - N Cal	15-Oct-10	400	Fuel production
2	24-hr Marginal - S Cal	15-Oct-10	400	Fuel production
3	Night-time 95/5	15-Oct-10	63	Battery Charging
4	Night-time 80/20	15-Oct-10	63	Battery Charging
5	CA Average Mix	15-Oct-10	240000	For Reference

Power generation efficiency and resource mix affect the WTW emissions from electric transportation.



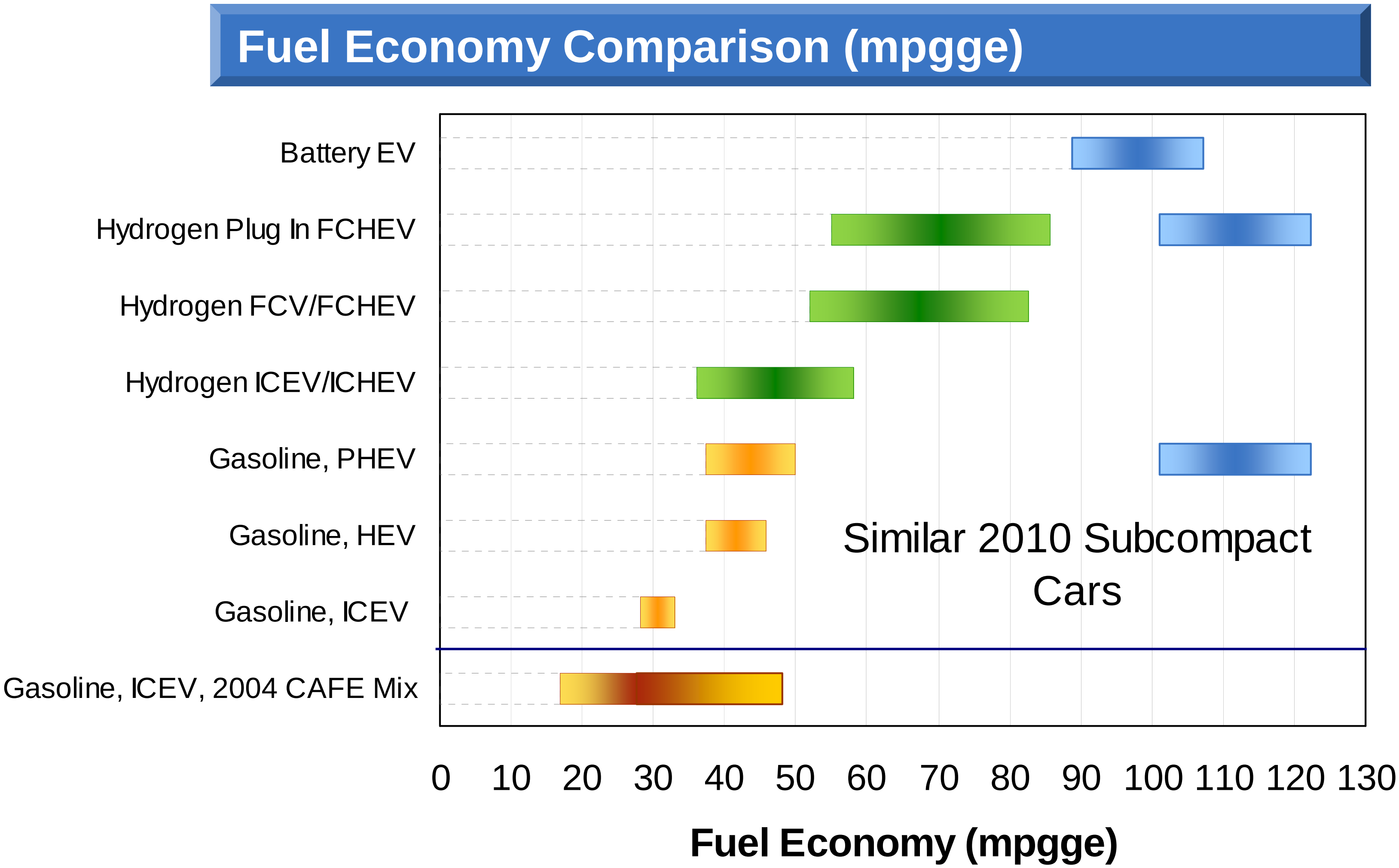
Units	Min	Base	Max
	CA Avg, Nix	NG 20% RPS	Coal
% RPS	20	20	0
Btu/kWh, HHV	8,000	8,500	10,000
% Loss	5	6	8
EER	3.5	3	2.5

Many studies of vehicle fuel economy provide the basis for WTW comparisons.

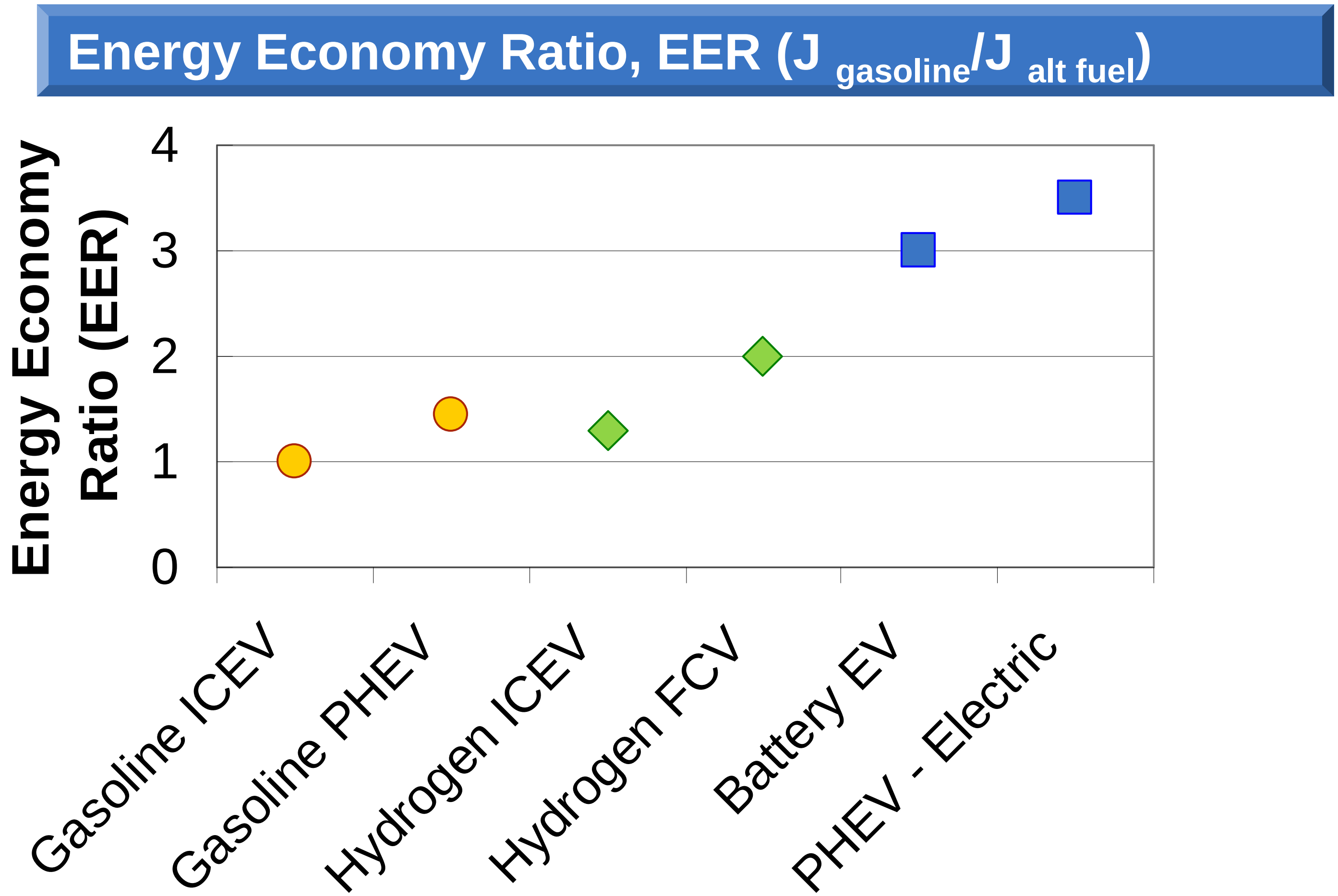


Source: Unnasch, S., "Fuel Cycle Energy and Emission Analysis," ARB ZEV Review 2001. Unnasch, S., "California Hydrogen Highway Network Blueprint Plan, Societal Benefits Topic Team Report," March 2005.

PHEVs have been modeled with plug in all electric range.



Fuel economy values used in this analysis.



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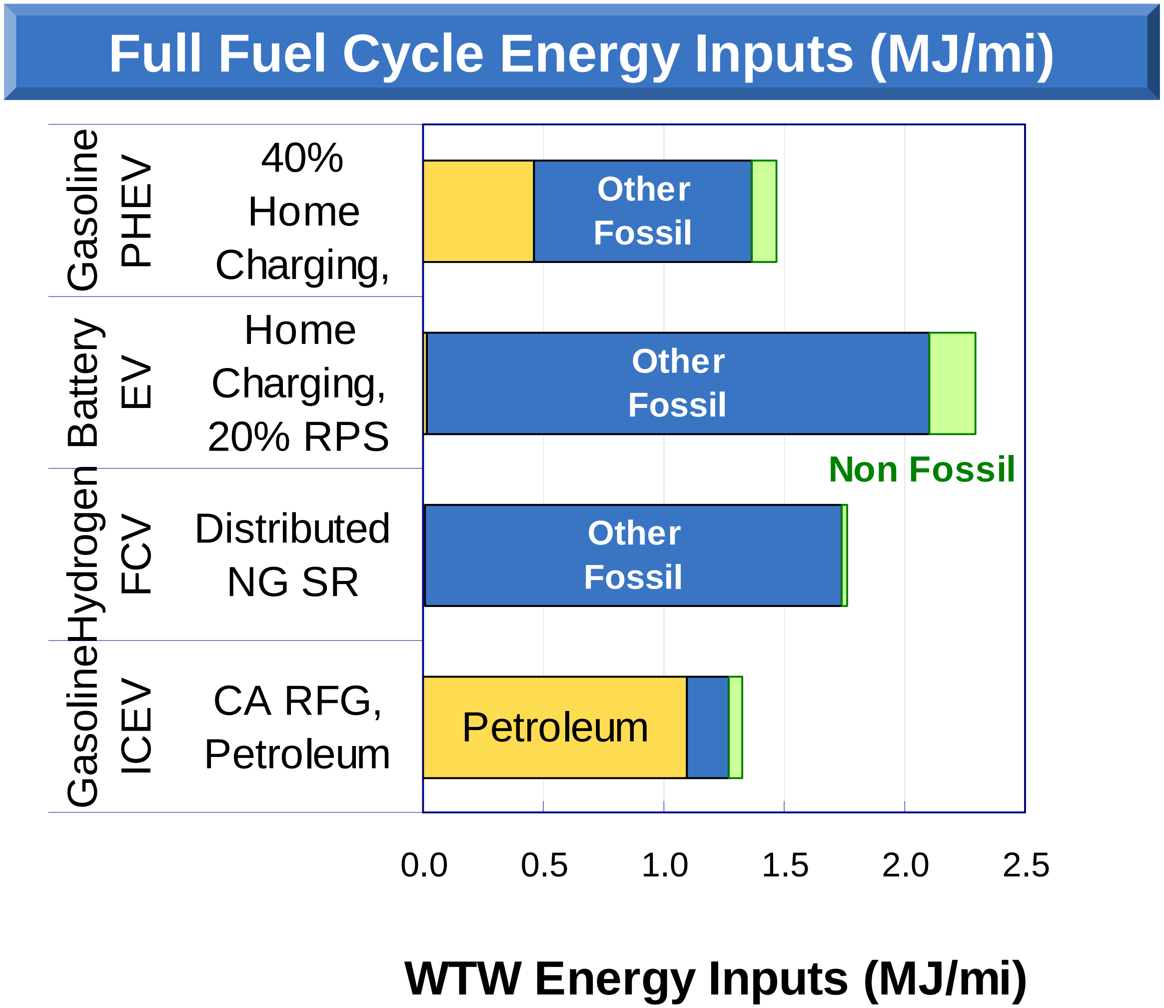
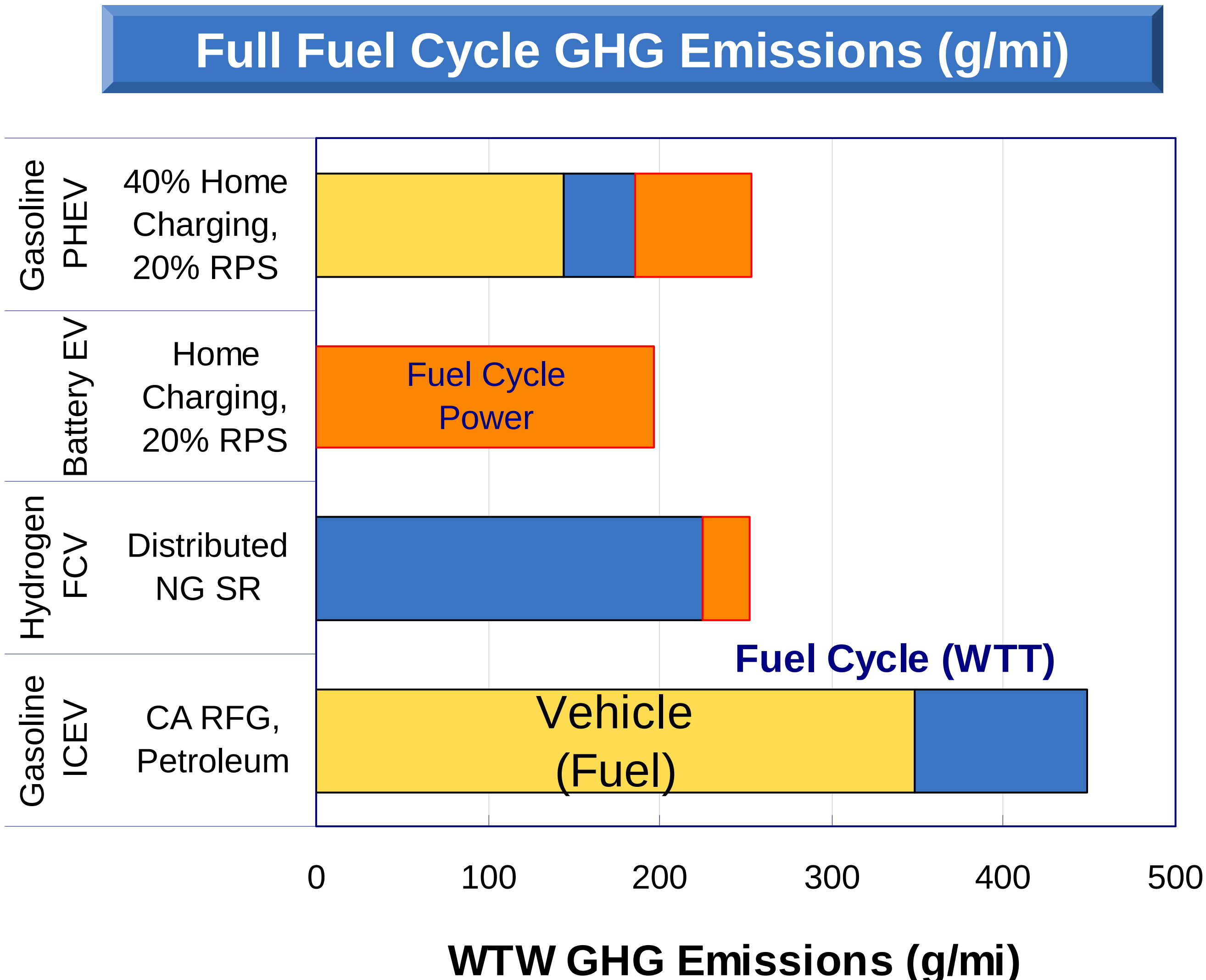

Full Fuel Cycle Energy Inputs (MJ/mi)
Gasoline PHEV
40% Home Charging,
Battery EV
Home Charging, 20% RPS
Hydrogen FCV
Distributed NG SR
Gasoline ICEV
CA RFG, Petroleum
Other Fossil
Other Fossil
Non Fossil
Other Fossil
Petroleum
0.0
0.5
1.0
1.5
2.0
2.5
WTW Energy Inputs (MJ/mi)


Full Fuel Cycle GHG Emissions (g/mi)
Gasoline PHEV
40% Home Charging, 20% RPS
Battery EV
Home Charging, 20% RPS
Hydrogen FCV
Distributed NG SR
Gasoline ICEV
CA RFG, Petroleum
Fuel Cycle Power
Fuel Cycle (WTT)
Vehicle (Fuel)
0
100
200
300
400
500
WTW GHG Emissions (g/mi)

ZEV technology can result in reduced emissions on a full fuel cycle basis, but the results depend on many parameters.

Fuel Economy

- Agreeing on a fuel economy assumptions for advanced vehicle technologies is challenging
- Analysis can proceed with benchmark values
- Implementation of programs can be based on actual vehicle performance

GHG Emissions

- GHG emissions for conventional fuels are well characterized
- Conversion efficiency has the most significant impact on fuel cycle emissions
- Agricultural and land use impacts are important for biofuels

Criteria Pollutants

- Boundaries for emissions analysis are as important as emission performance when considering local criteria pollutants
- Future stationary and vehicle emission regulations will affect the full fuel cycle comparison.