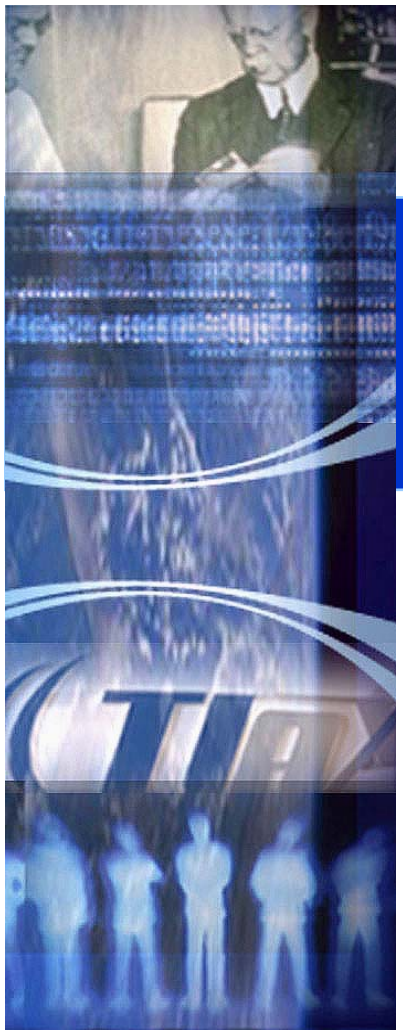

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FULL FUEL CYCLE ANALYSES FOR AB1007

-by-Fuel : Assumptions, Results, Sensitivities

Presented at

CEC-ARB Workshop on Developing a State Plan to Increase the Use of Alternative Transportation Fuels

March 2, 2007

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1. Introduction
2. FFCA Results
3. Conclusions

Factors affecting the full fuel cycle analysis

Sensitivities

- **Major uncertainties**
- **Unique assumptions**
- **Highlight one pathway**
- **Significant findings**
- **Surprises**

Assumptions

Production

- Process energy inputs
- Electricity inputs
- Emission factors

Transportation logistics

- Transportation distances and modes

Vehicles

- Vehicle energy consumption
- Vehicle evaporative and exhaust emissions

Multi Media Impacts

GREET model provides WTT analysis.

- Efficiency
- Resource Mix
- Distances
- Urban Shares

Scenario Control Variables and Input Assumptions

1. Selection of Key Options for Simulation

1.1) Target Year for Simulation: 2010

1.1) b Regional Mix 1 -- U.S., 2 -- N.E. 3 -- CA, 4 -- ROW (nNA): 4

10.2) Electricity Generation Mix

10.2.a) Selection of Marginal Electricity Generation Mix for Transportation Use

Marginal mix for transportation use	3	1 -- U.S.mix 2 -- NE U.S. mix
Average mix for stationary use	4	3 -- CA mix 4 -- User defined

- GREET WTT Results
  - E nergy
  - GHG
  - Total Critieria Pollutant
  - CA Urban

WTT Result	CA RFG	Diesel	CNG	LPG
Total Energy	278,203	217,903	257,309	159,178
WTP Efficiency	78.2%	82.1%	79.5%	86.3%
Fossil Fuels	272,586	216,494	254,571	156,026
Coal	16	11	17	11
Natural Gas	144,794	107,733	236,818	91,335
Petroleum	127,776	108,749	17,736	64,681
CO2	16,777	15,793	16,649	11,422
CH4	107.1	102.2	236.3	101.2
N2O	1.951	0.205	0.337	0.186
GHGs	19,818	18,205	22,184	13,805
VOC: Urban	5.136	3.706	0.100	96.261
CO: Urban	0.525	0.460	0.194	0.649
NOx: Urban	2.041	1.464	1.194	2.681
PM10: Urban	0.104	0.058	0.038	0.089

1 Introduction

2 FFCA Results

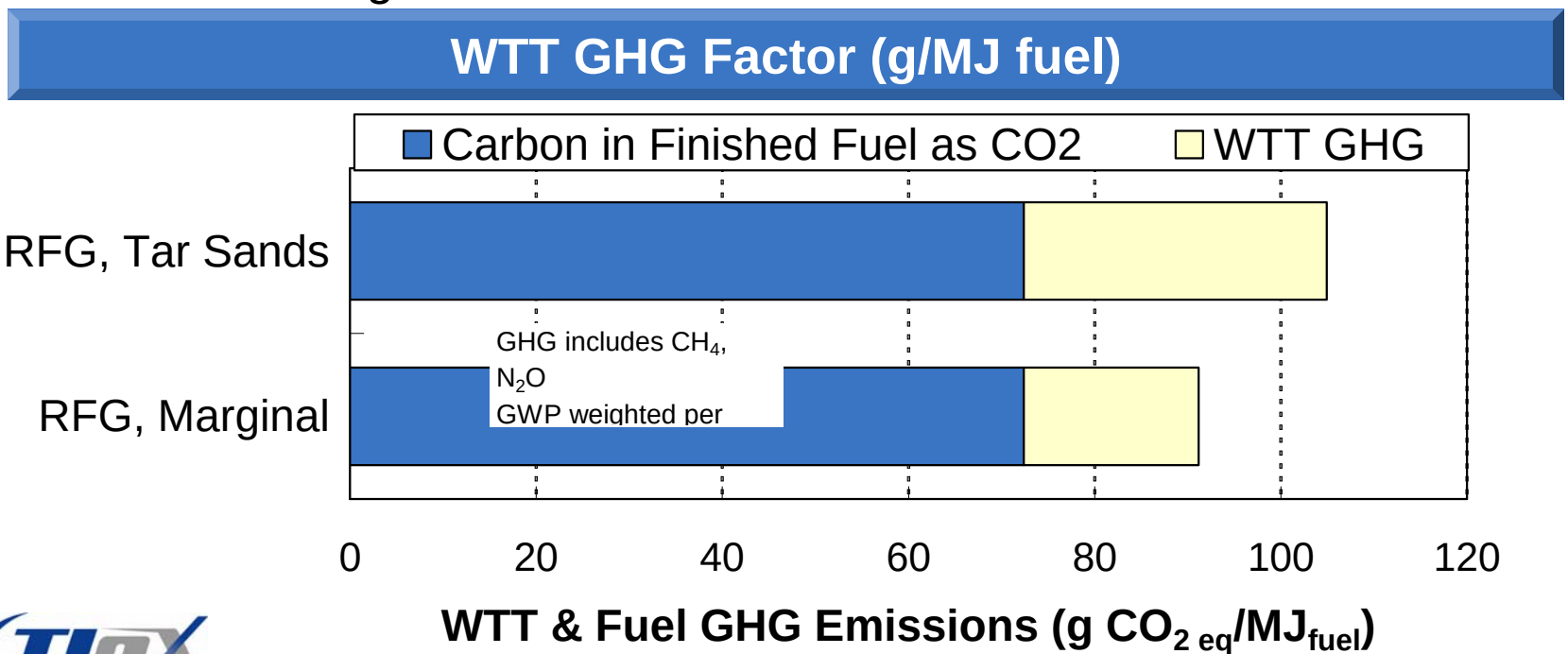
3 Conclusions

Gasoline production and delivery assumptions.

Descriptor	RFG, Marginal	Range
WTT Case ID	G1	
Feedstock	Crude Oil, SE Asia	Europe, etc.
Feedstock Recovery	98.0%	
Feedstock Transport (mi)	200	
Urban Miles	0	
Primary Mode	Pipeline	
Production Process	Refining	
Conversion Efficiency	84.5%	84% - 90%
Process Energy	300 scf/bbl	100 to 800 scf/bbl
Energy Input	Refinery Gas, NG, H2	
Other Fuels	E1 - 5.7%	Various ethanol
Product Transport Mode	Marine	
Product Tansport (mi)	9,800	
Urban miles	115	
Net Cargo (Tonne)	150,000	
Terminal Transport Mode	50	
Distance (mi)	Pipeline/ truck	
Local Delivery Mode	Truck	
Local Delivery (mi)/ losses	50	
Key parameters	Marginal import of products	

Energy inputs drive GHG emissions.

- Marginal refinery efficiency
- Refinery creep subject to CEQA
- Hydrotreating to meet CA fuel requirements, heavier crude
- Transportation distance
- Ethanol blending



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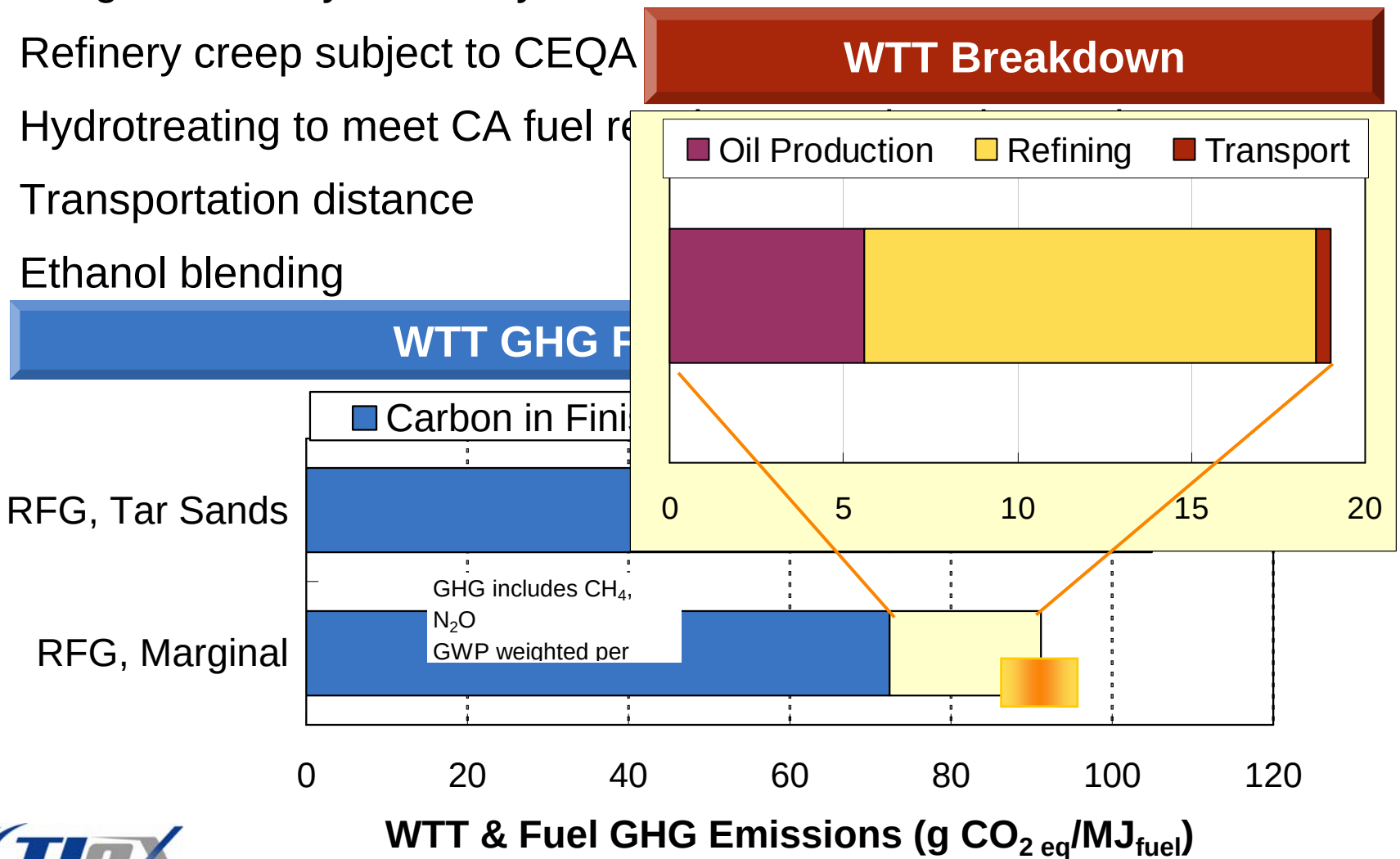
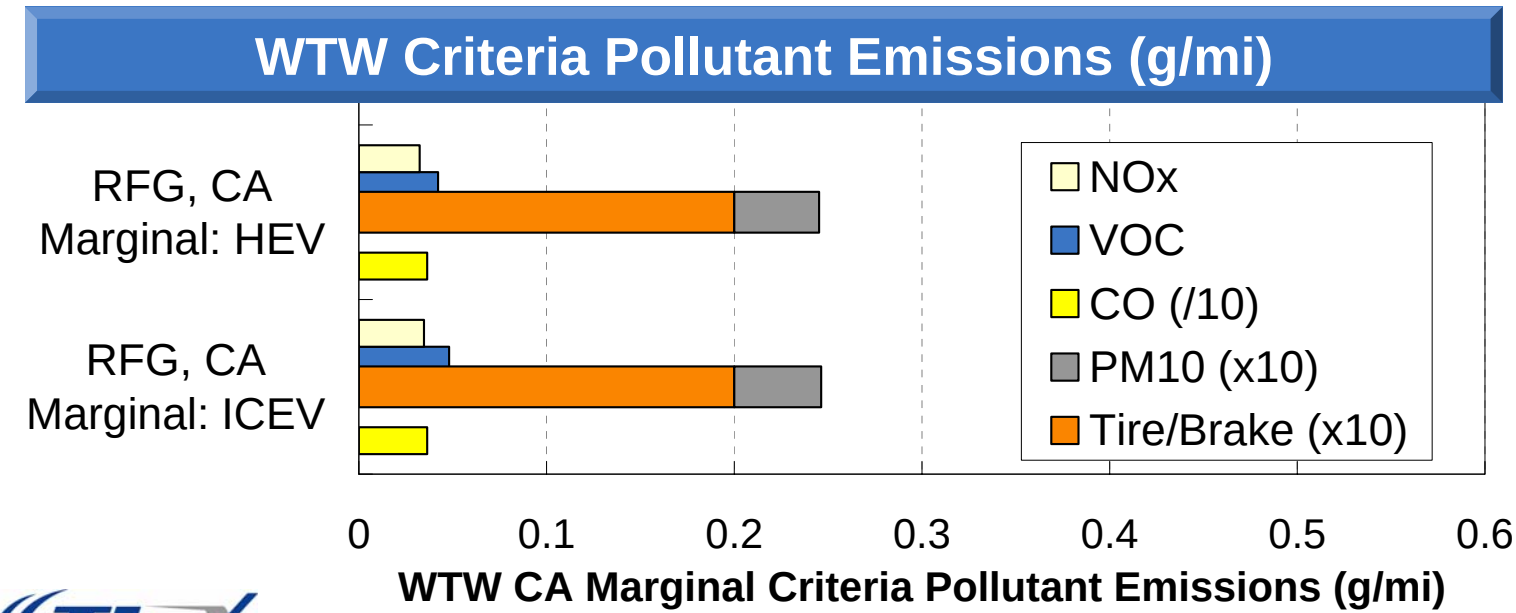


Marginal analysis and transportation logistics affect criteria pollutant comparison.

- Tanker ship distance
- Tank truck distance
- Import marginal product
- CA fueling station standards



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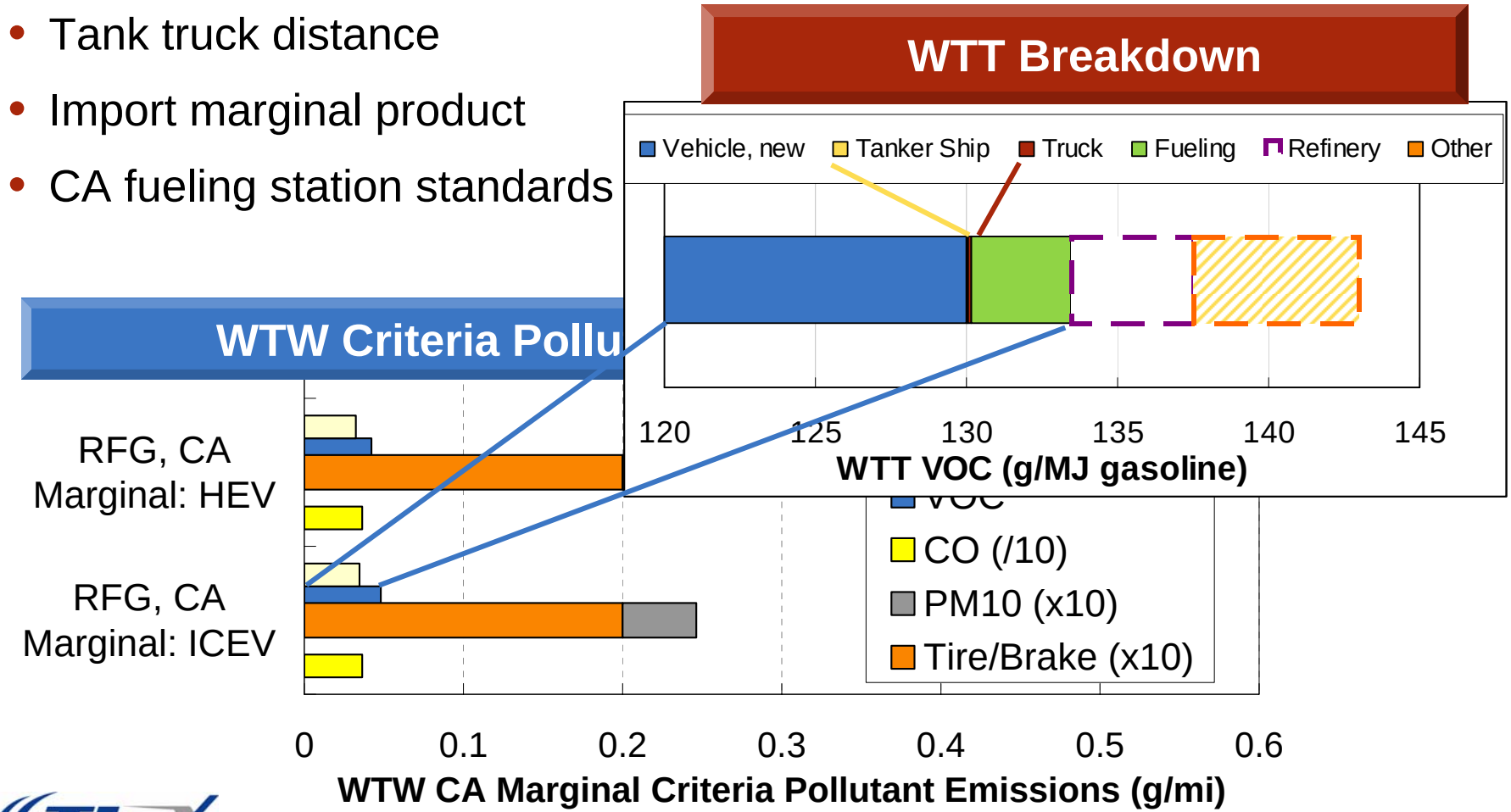
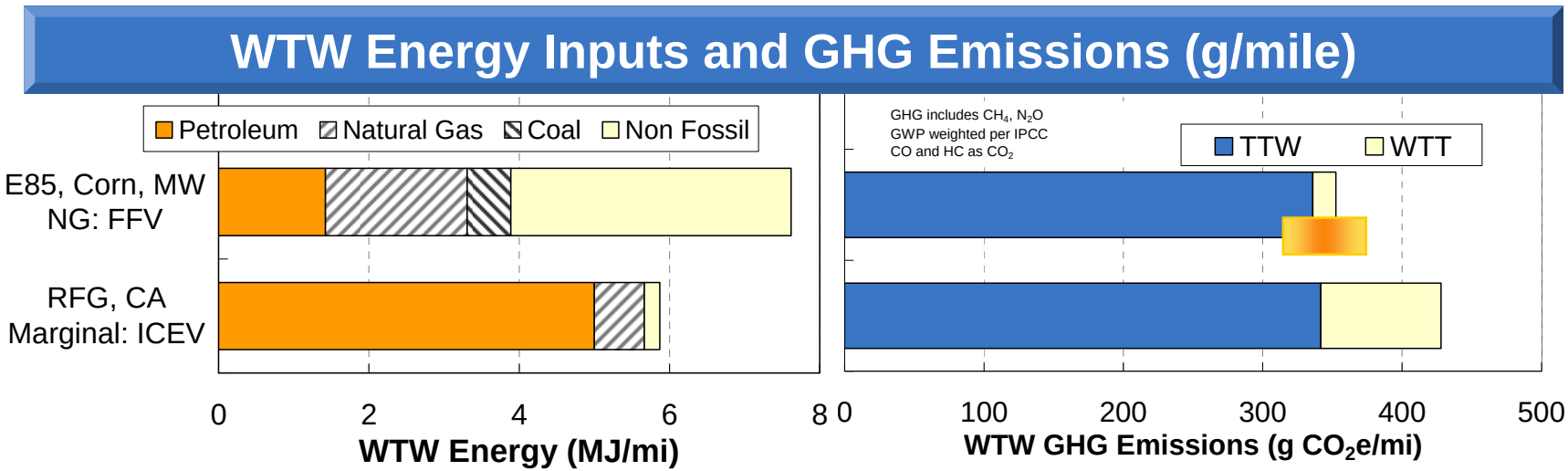


Ethanol production and delivery assumptions.

Descriptor	E85, Corn, MW NG
WTT Case ID	**E73**
Feedstock	MW Corn
Conversion Efficiency	2.7 gal/bu
Process Energy	36,000 Btu/gal
Energy Input	Natural Gas
Other Fuels	G13
Product Transport Mode	Rail
Product Tansport (mi)	1400
Urban miles	178
Net Cargo (Tonne)	9000
Terminal Transport Mode	Truck
Distance (mi)	50
Local Delivery Mode	Truck
Local Delivery (mi)/ losses	50

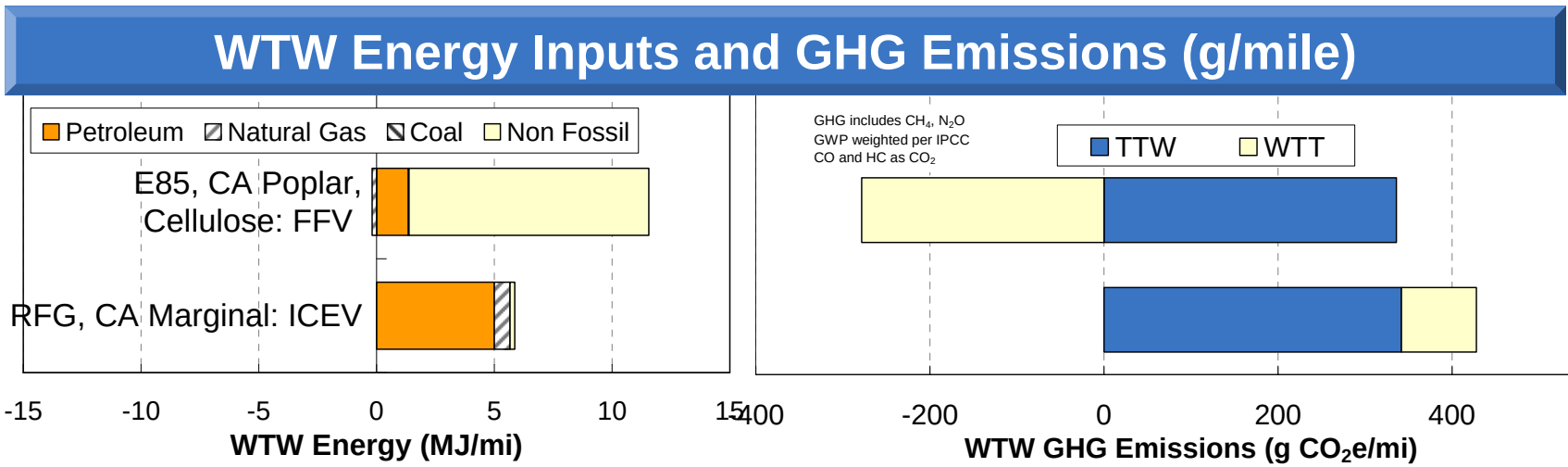
Processing energy and agricultural energy inputs.

- Corn plant energy input 31,000 to 33,000 Btu/gal, 0.75 to 1 kWh/gal
- Produce wet DGS, coal, corn stover, digester gas fuel (not shown here)
- Allocate 35% to byproducts
- Rising corn yield, no till agriculture, declining nitrogen inputs
- Use of existing agricultural land
- ANL assessment of displaced agricultural products (in U.S.)



Ethanol production and delivery assumptions.

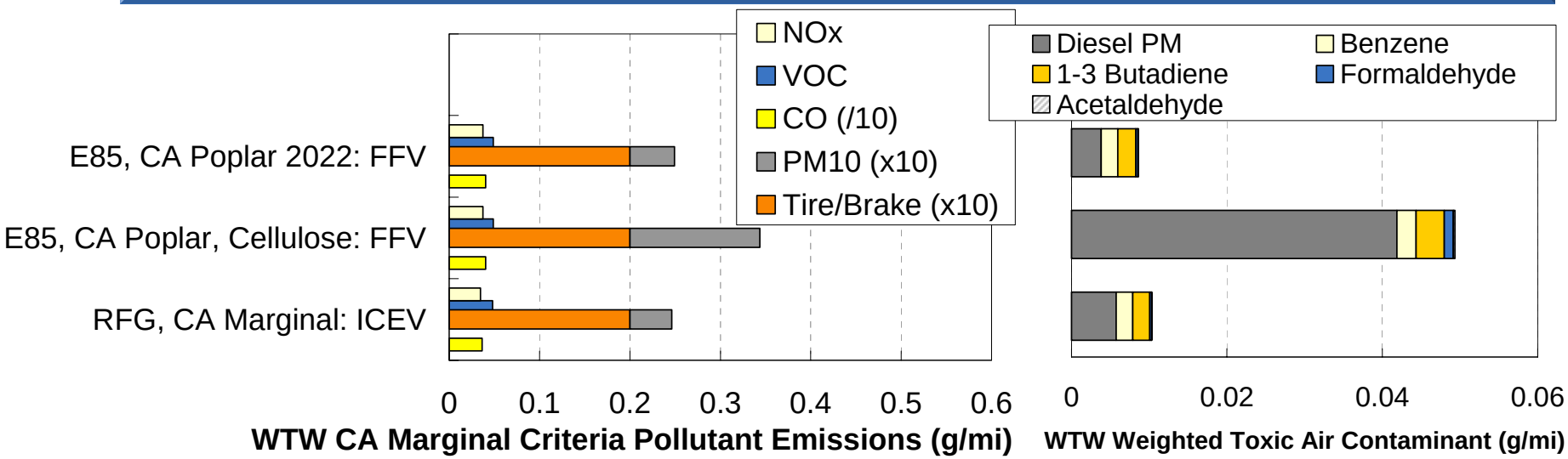
- Biomass farming energy inputs
- Credit for byproduct power (NG CCCT, other?)
- Ethanol plant energy (42,000 Btu/gal)
- Ethanol conversion yield (65-90 gal/BDT)



Agricultural equipment affects California PM emissions.

- All emissions for CA agricultural equipment are counted in California non attainment areas
- ARB's standards for HD trucks and off-road equipment reduce emission impact
- Ethanol plants will need to manage emissions from biomass combustion

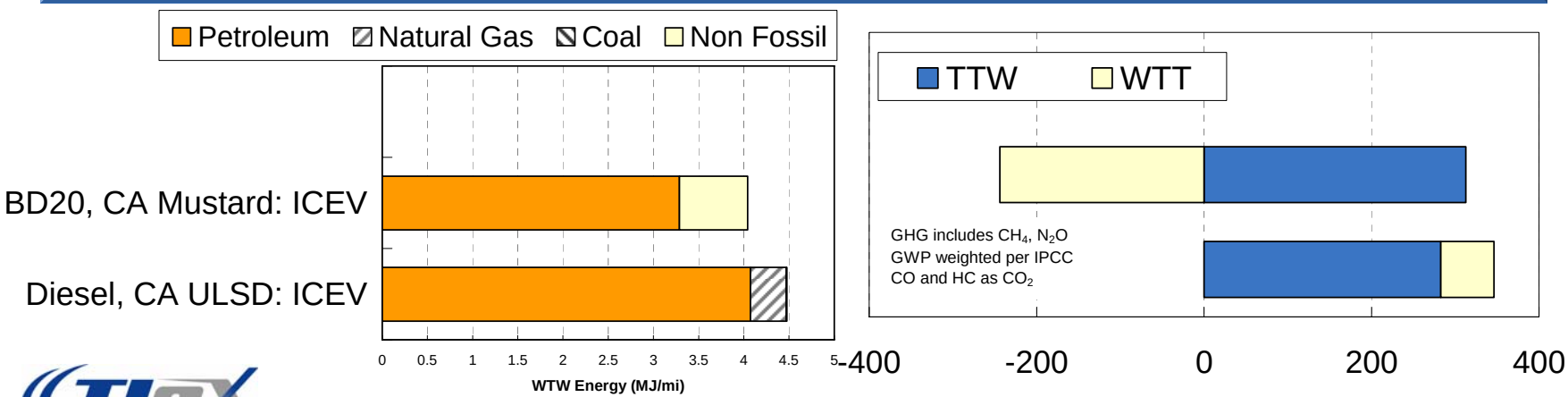
WTW Energy Inputs and GHG Emissions (g/mile)



Biodiesel from California Mustard Seed.

- Low agricultural inputs
- Cover crop, no pesticides and herbicides needed
- Nitrogen fixing

WTW Energy Inputs and GHG Emissions (g/mile)



Low carbon content of fuel combined with energy inputs affect GHG emissions. Methane losses can have a significant impact.

- 100 psi inlet pressure for NGV compressors – 0.6 kWh/gge
- Low methanol losses from U.S. (7% of UAF)
- NG/RPS mix for compression energy

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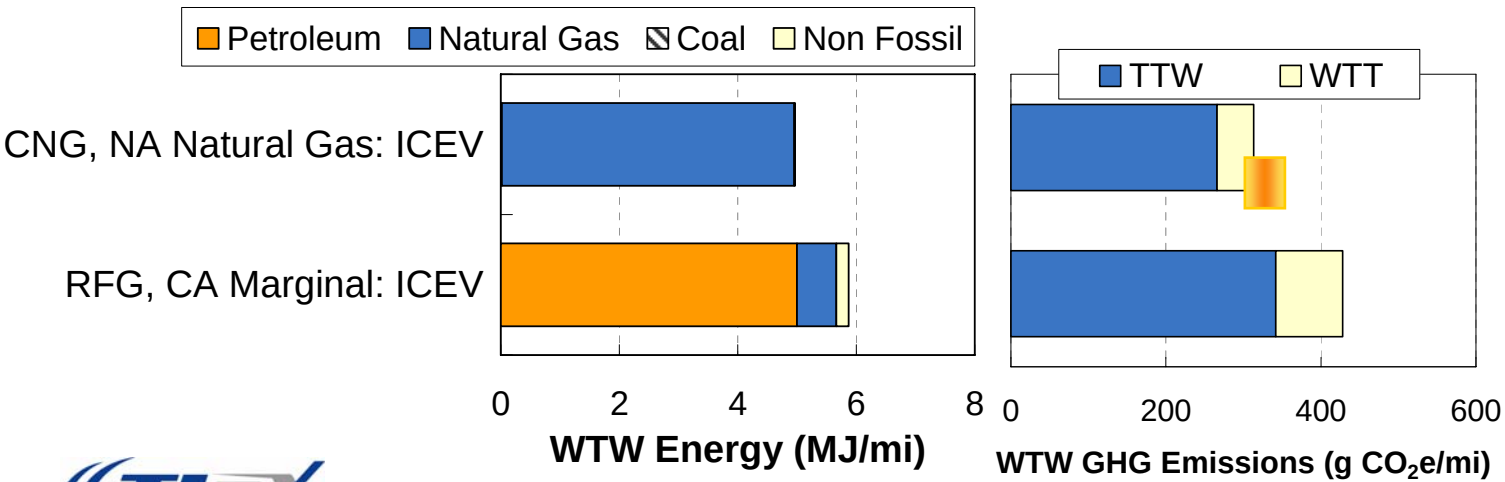

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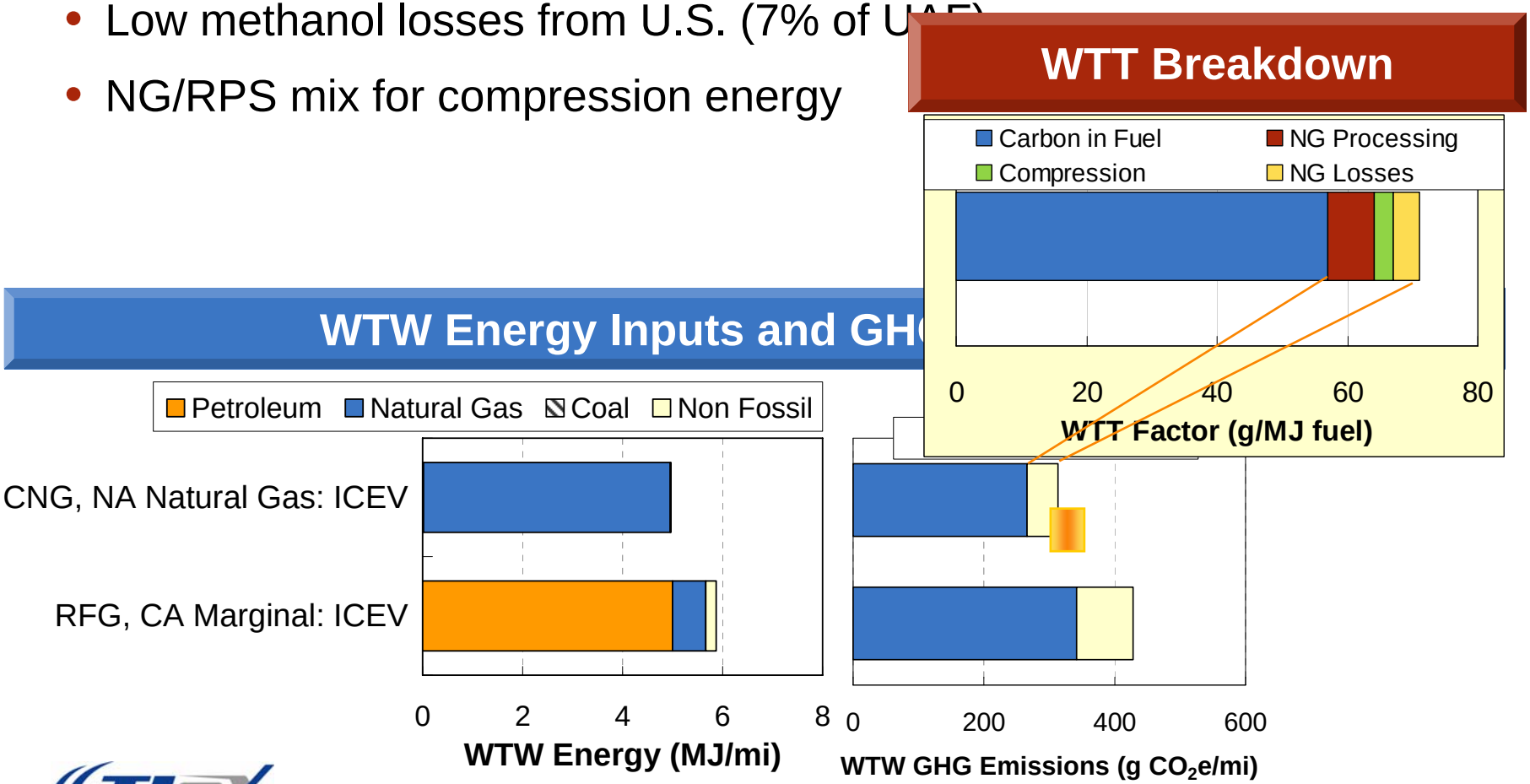
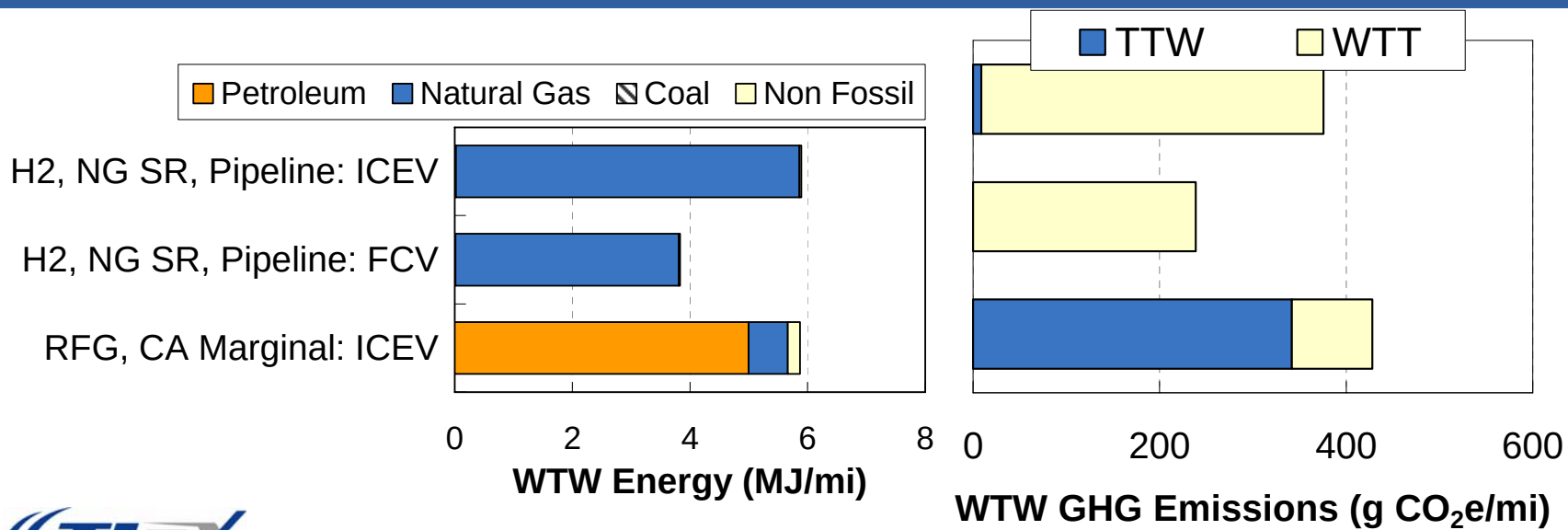


Hydrogen from natural gas.

- Reformer efficiency
- Vehicle efficiency
- Generation mix
- PM emission factor

WTW: 2012: LDA/MY Start 2010/MJ1

WTW Particulate Emissions



Energy efficiency translates to carbon conversion efficiency

Production

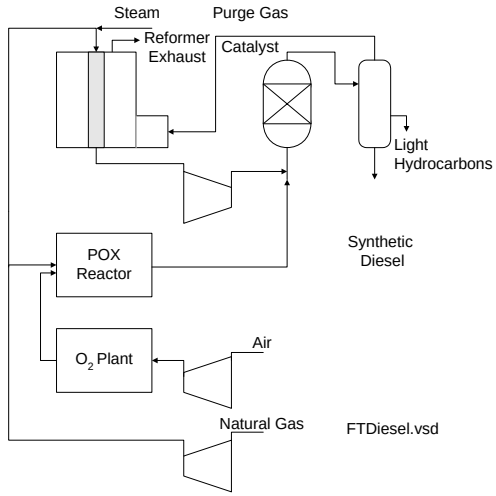
- Process energy inputs
- Waste heat utilization
- Emission factors

Transportation logistics

- Overseas gas resources

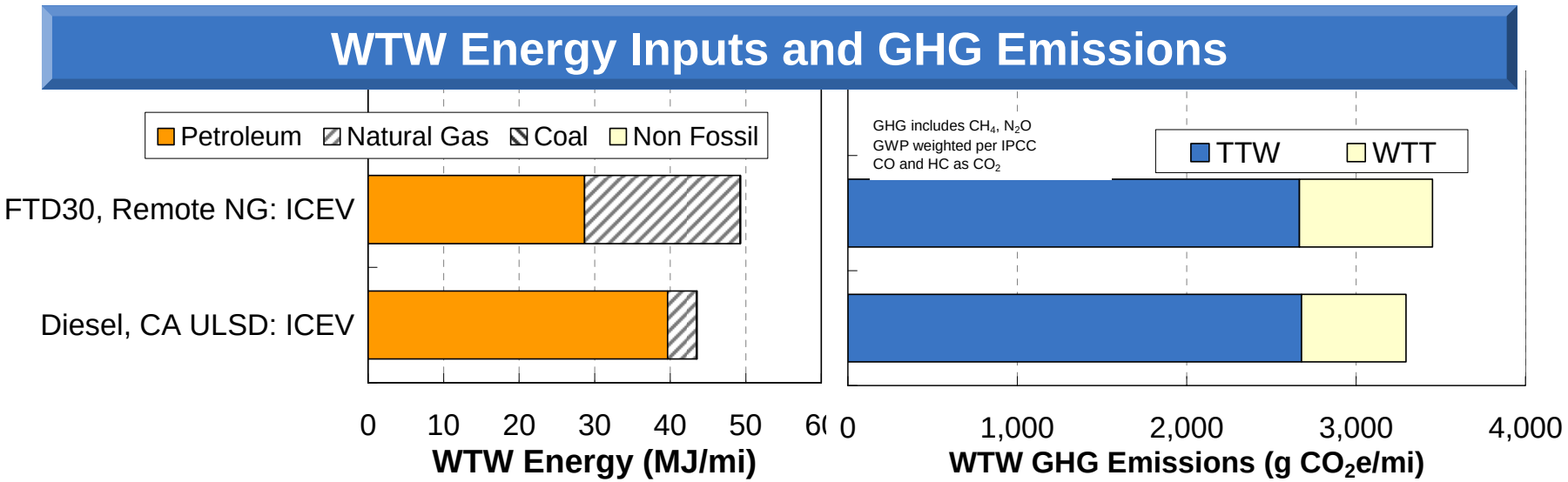
Vehicles

- Vehicle energy consumption
- Potential for GTL 100 fuel

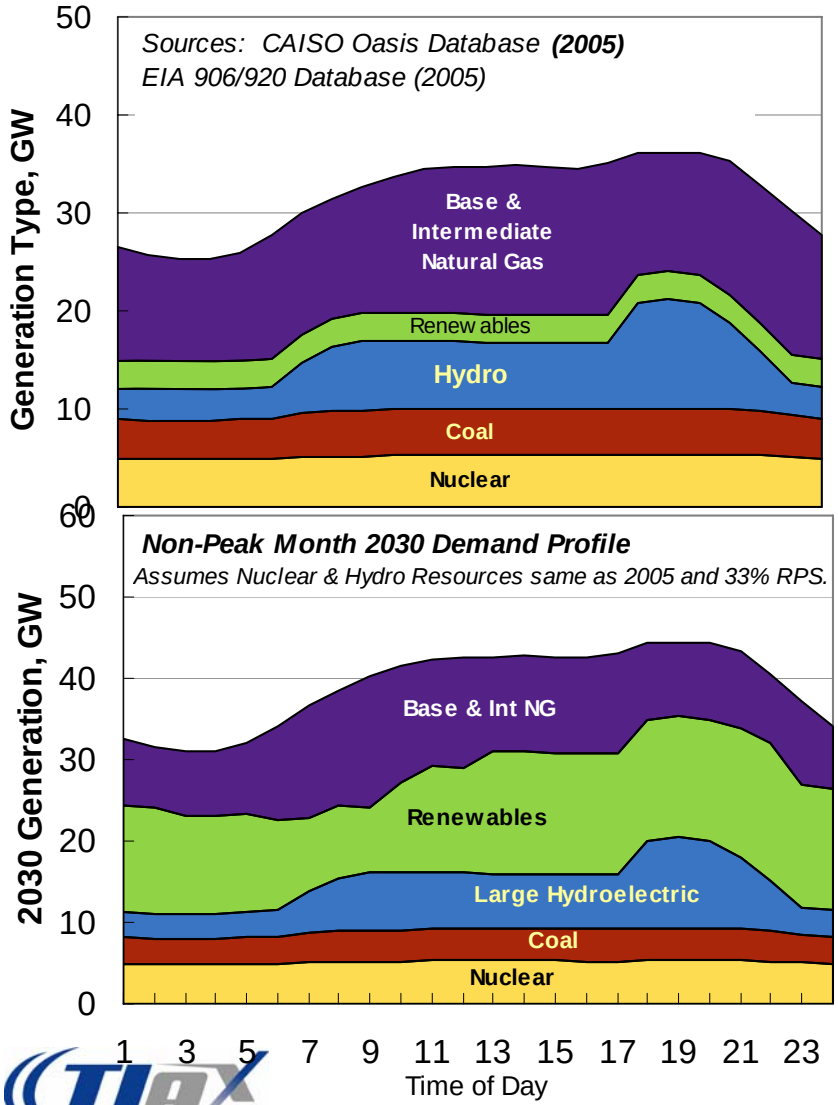


Energy efficiency translates to carbon conversion efficiency

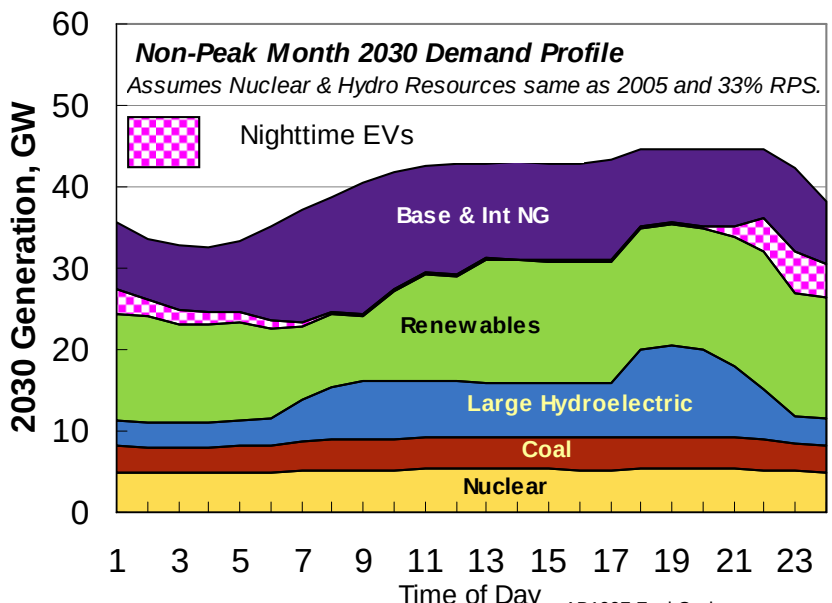
- 63% conversion efficiency in 2012
- 69% in 2022
- Carbon conversion = η x 0.78
- Produced in Malaysia (7200 mi)



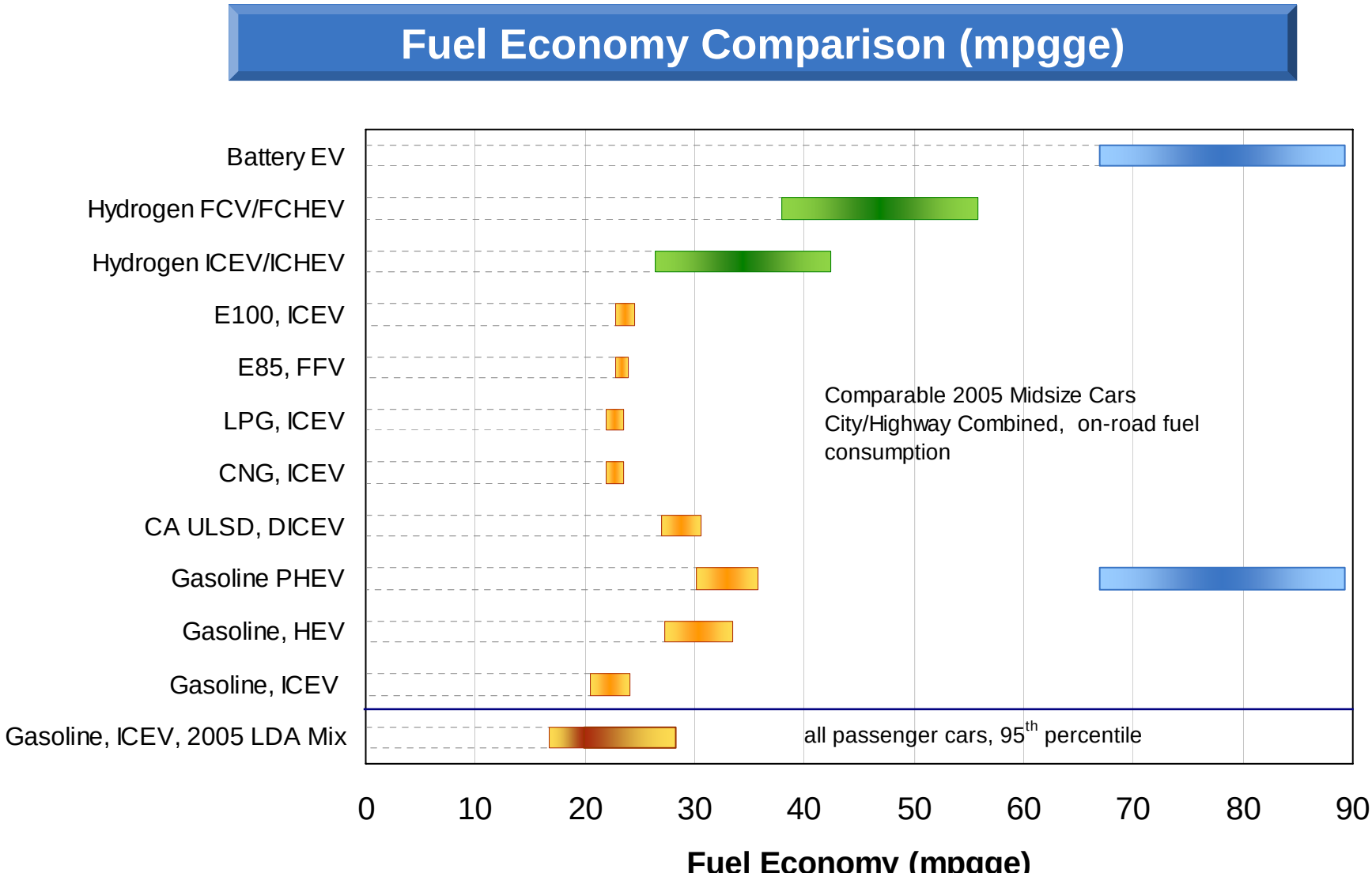
Generation mix changes as CA approaches RPS requirement.



- Hydropower and nuclear capacity
  - No new capacity due to load growth
  - These resources are not on the margin
- Assumed NG CCCT/RPS mix

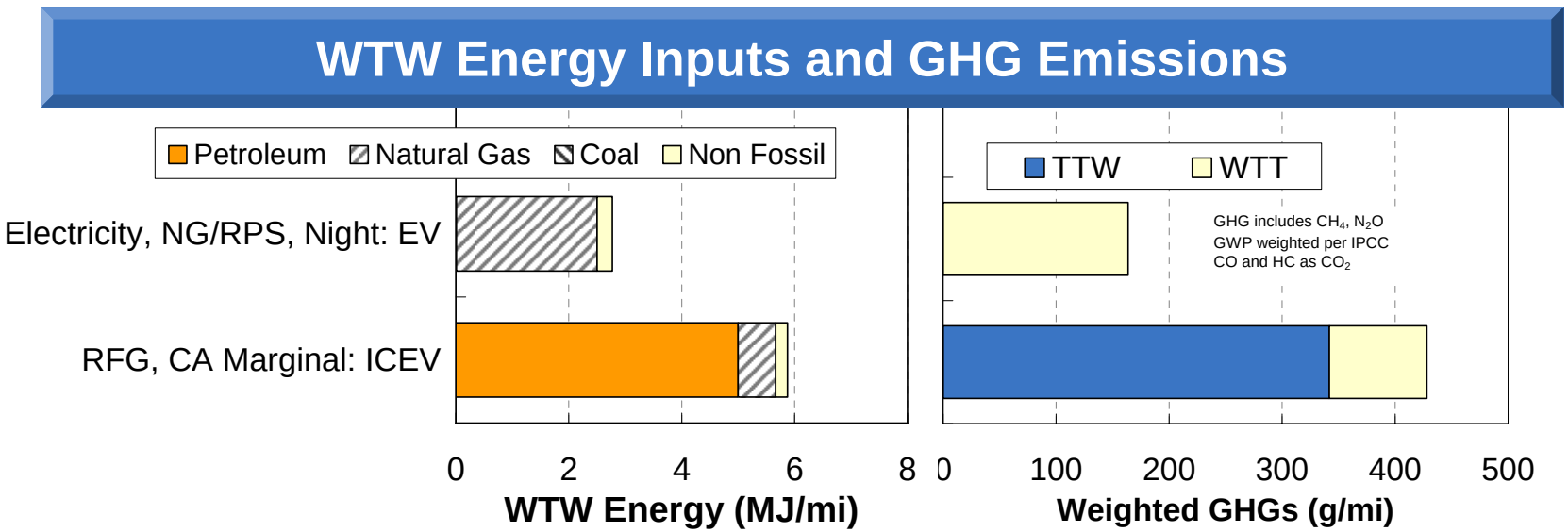


Electric transportation energy consumption reflects on road data and modeling studies, adjusted for "comparable" midsize cars.



Electric energy inputs depend on generation mix.

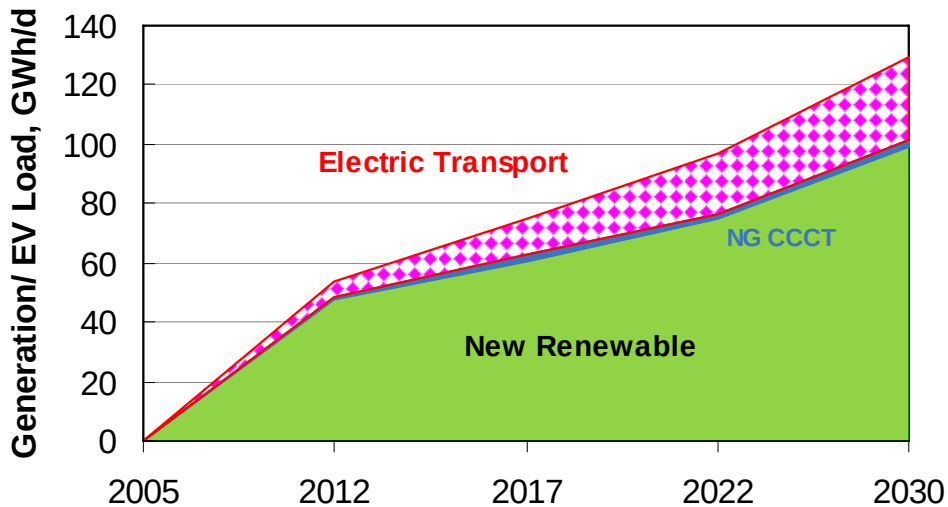
- NG CCCT/RPS
- 7300 to 7000 Btu/kWh, HHV for new natural gas plants
- Non combustion renewables



What is the marginal generation requirement?

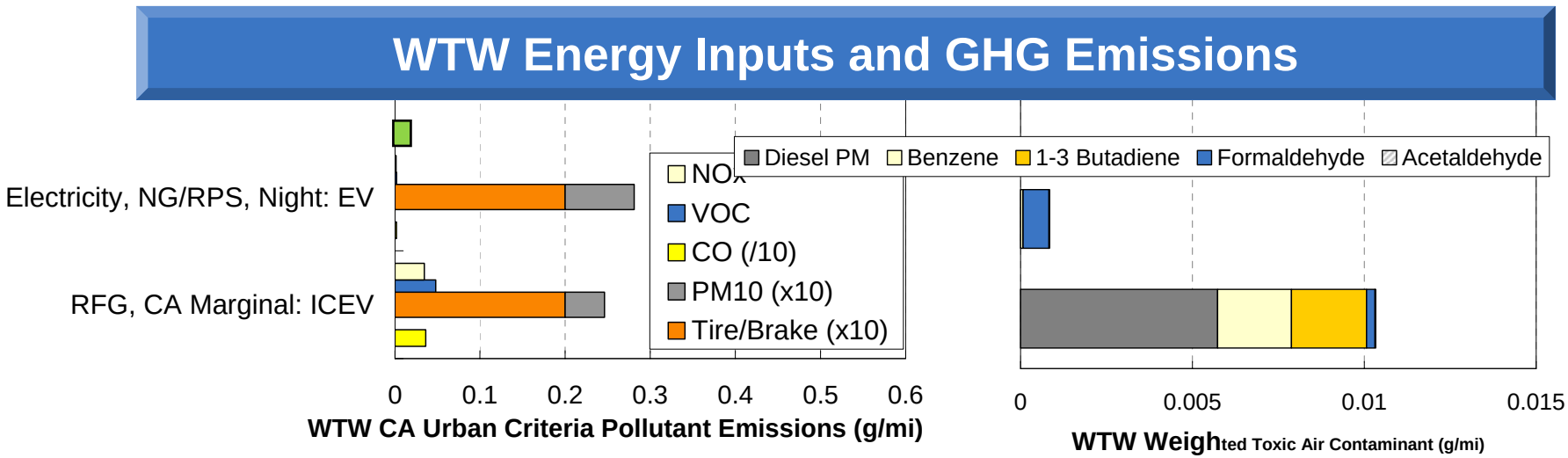
- Most new generation capacity must be renewable to meet RPS
  - RPS targets for 2010, 2010
  - Electric transport is new load growth
- Marginal power is from fossil fuel generation
  - Assume production from natural gas combined cycle
  - Apply applicable RPS requireme to mix (33% in 2030)
  - EV/PHEV charging profiles
- Options for renewable power
  - Solar PV homes own REC
  - Option to buy RECs

Does electric transportation force and acceleration of the RPS schedule?



Emission assumptions from power plants.

- NG CCCT EPA AP-42 emission factor (3 g/MMBtu)
- Offset NOx and VOC emissions from new plants
- BACT requirements for natural gas prime mover engines



1. Introduction
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Rationale for scenario selection.

Assumptions

- California specific production and delivery options
- Statutory requirement for emission control

Zero fossil fuel scenarios

- GHG results are predictable
- Quantification is relevant for LCFS comparison
- Question on displaced resource

Vehicle Emissions

- Effect of alternative fuels on future engines is uncertain
- ARB has ongoing programs to test and assess future engines
- Emission factors, PM, H2, CA offsets

Vehicle Applications

- Comparable GHG results for different vehicle classes
- WTW processor generates > 2000 vehicle/fuel/year combinations

Energy Inputs

- Efficiency (process energy input)
- Power generation mix
- Feedstock

GHG Emissions

- Methane losses
- Land use impacts for biofuels

Criteria Pollutants

- CA fuel production facilities
- Emission factors, PM, H2, CA offsets
- Roll in of CA vehicle and off-road standards

Water Impacts

- Fuel options are primary non petroleum
- Existing LUST, tanker ship, engine oil
- CA regulations on facilities and ag

Fuel Economy

- H2, EV comparison, what car did the customer buy

1. Introduction
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4. **Response to Questions**

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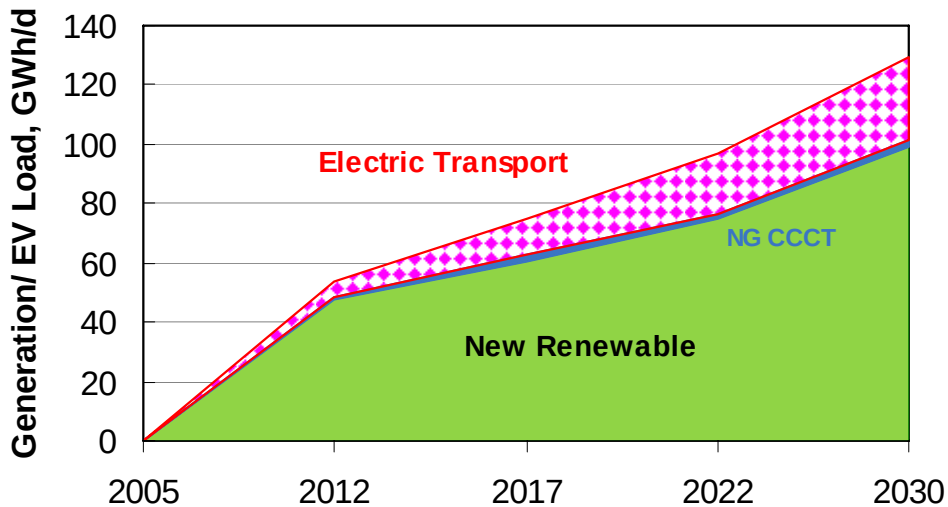
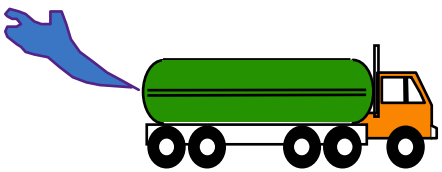


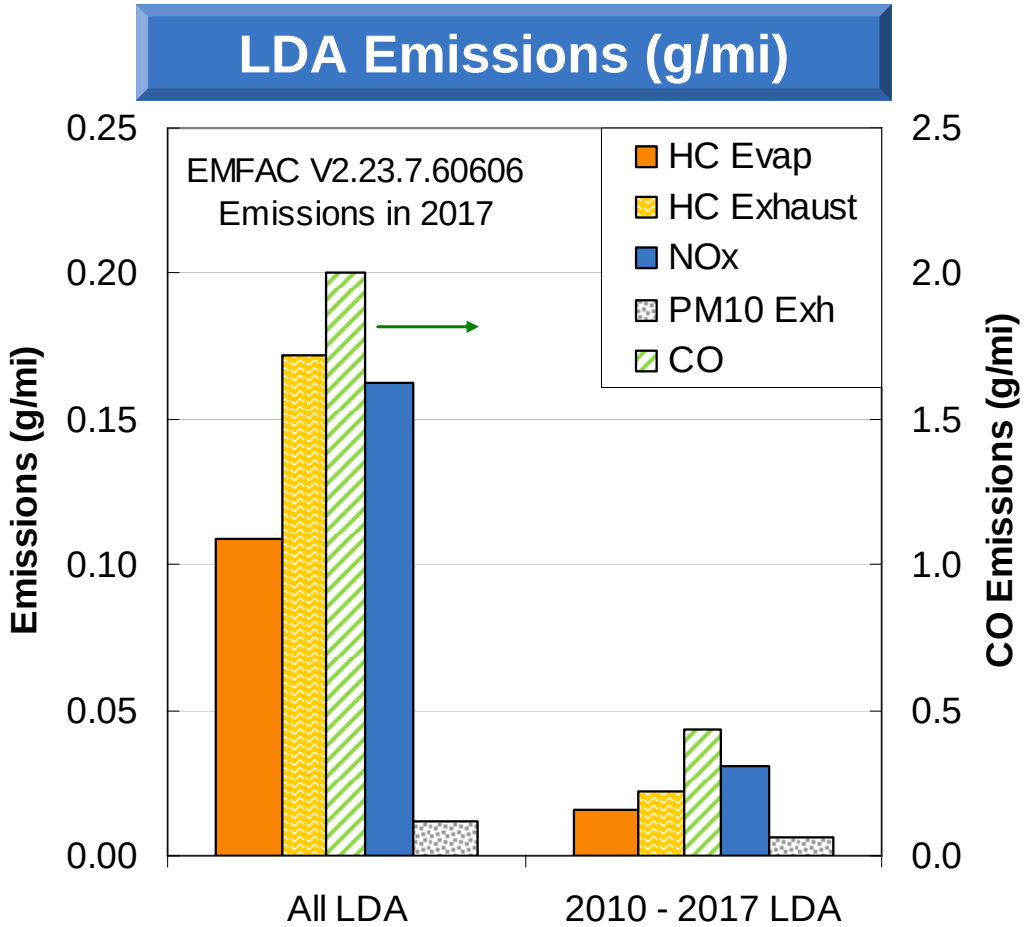
WTW processor allows for the selection of year, fuel, vehicle class, vehicle/fuel type, and stock mix.

		FYEAR	2012	
WTW Scenarios		**VYEAR**	E12	
		VCLASS	LDA	
	FOPT	G1 Marginal	C1 CNG	e1 NGRPS
	VTYPE	G new	CNG	EV
TTW Input	**Start year**	s10	s10	s10

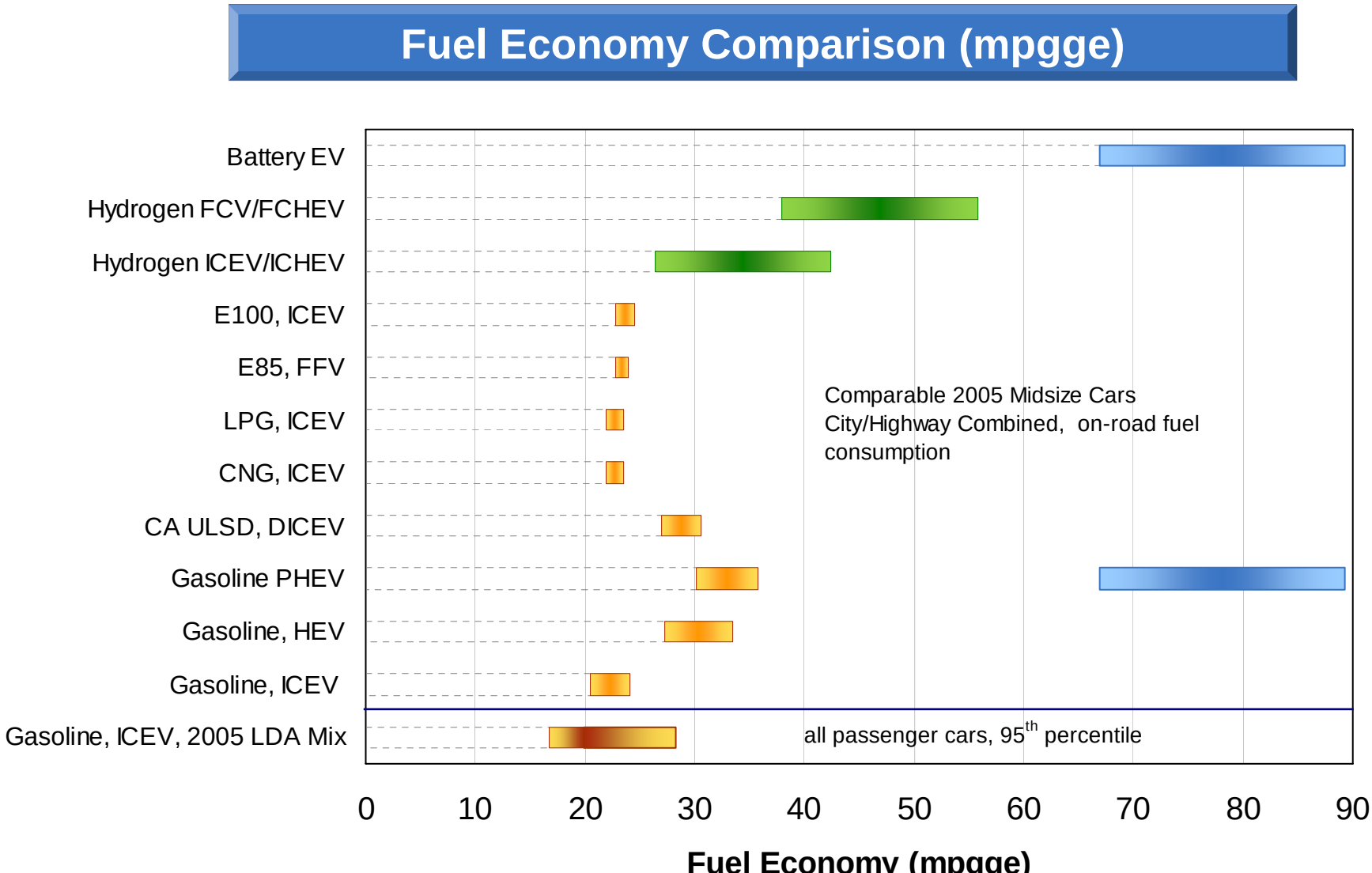
Why discuss

- Introduction scenario affects displaced gasoline or diesel vehicle
- New vehicle strategies and blend fuel strategies require separate treatment





Don’t some vehicles achieve higher energy consumption?



WTW emissions include the vehicle plus the fuel cycle. Fuel cycle emissions are grouped by region.