A Life Cycle Assessment Comparing Select Gas-to-Liquid Fuels with Conventional Fuels in the Transportation Sector

Robert E. Abbott, Ph.D. ConocoPhillips
Paul Worhach, Ph.D. Nexant Corporation

Diesel Engines Emission Reduction Conference
Loews Coronado Bay Resort
Coronado, CA

August 29 – September 2, 2004

Study Purpose

- Evaluate GTL energy use and emissions in comparison to alternative fuel production processes and end-uses
- Education and communication with peers and stakeholders
- Assess and improve environmental programs
- DOE's interest in cleaner fuels for the future led to sponsorship under the DOE Ultra Clean Fuels Initiative

Unique Aspects of this Study

- Used COP process efficiencies
  - Thermal efficiency 67% (2006); 70% (2015)
  - Carbon efficiency 85%
- Followed ISO 14040 and convened Critical Review Panel to verify standards were met
- Developed Co-Product Function Expansion (CFE) methodology to account for co-product contributions to emissions
- Inventory results modeled in LCIA

Life Cycle Analysis

- COP elected to conduct study following procedures established under ISO 14040 standards on Life Cycle Analyses
- Independent Review Panel convened to ensure ISO standards were followed
- Two main phases of LCA’s
  - Life Cycle Inventory (LCI)
  - Life Cycle Impact Analysis (LCIA)

Study Scope

- This paper focuses on how FTD and naphtha fuels produced using COP's GTL technology compare with both conventional and ultra-low sulfur diesel, and FRFG motor fuels.
- The UCF LCA develops a set of near-term (2006) and long-term (2015) scenarios to assess impacts associated with likely commercial scenarios for these time frames.

Near-Term UCF Fuel Scenarios

Scenario Name	Fuel	Vehicle
PADD III FTD20 CIDI	Blend of 20% remotely produced GTL diesel and 80% PADD III LSD	Light duty (LD) passenger vehicle with a compression ignition, direct injection (CIDI) engine
PADD III conventional diesel CIDI	PADD III conventional diesel	LD vehicle with CIDI engine
PADD III ULSD CIDI	PADD III ULSD, with CFE	LD vehicle with CIDI engine
PADD III FRFG	PADD III federal reformulated gasoline with CFE	Light duty passenger vehicle with spark ignition direct injection (SIDI) engine

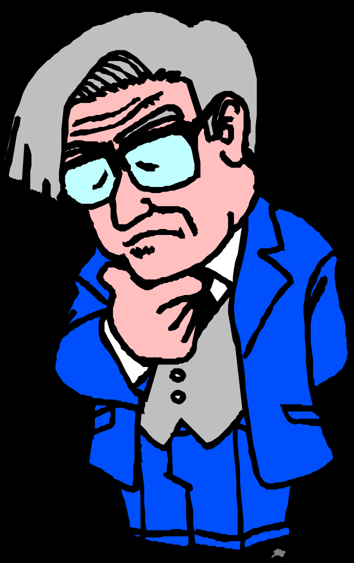
Long-Term UCF Fuel Scenarios

Scenario Name	Fuel	Vehicle
FTD100 CIDI	100% remotely produced GTL diesel	Light duty passenger, CIDI engine
PADD III ULSD CIDI	PADD III ULSD with CFE	Light duty passenger, CIDI engine
PADD III FRFG	PADD III FRFG with CFE	Light duty passenger, SIDI engine
PADD III FRFG FCV	PADD III federal reformulated gasoline with CFE	FCV, with gasoline reformer
FT naphtha FCV	100% remotely produced FT naphtha	FCV with FT naphtha reformer

Tools Used in the Analysis

- DOE's **Greenhouse Gases Regulated Emissions and Energy in Transportation (GREET)** Model - fuel cycle model that inventories energy usage, greenhouse gas and criteria pollutants (NOx, SOx, PM10, VOC's, CO) for many fuel pathways.
- **Process Industries Modeling System (PIMS) Model** - simulates the operation of petroleum refineries, considering crude slates, desired product slates, and refinery configuration.
- **Aspen Plus** - a process simulator extensively used to model heat and material balances, thermodynamic equilibriums, and optimization of process design and the operation.
- U.S. EPA's **Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI model)** assesses impacts by taking the emissions data from the LCI.

Dealing with Uncertainty

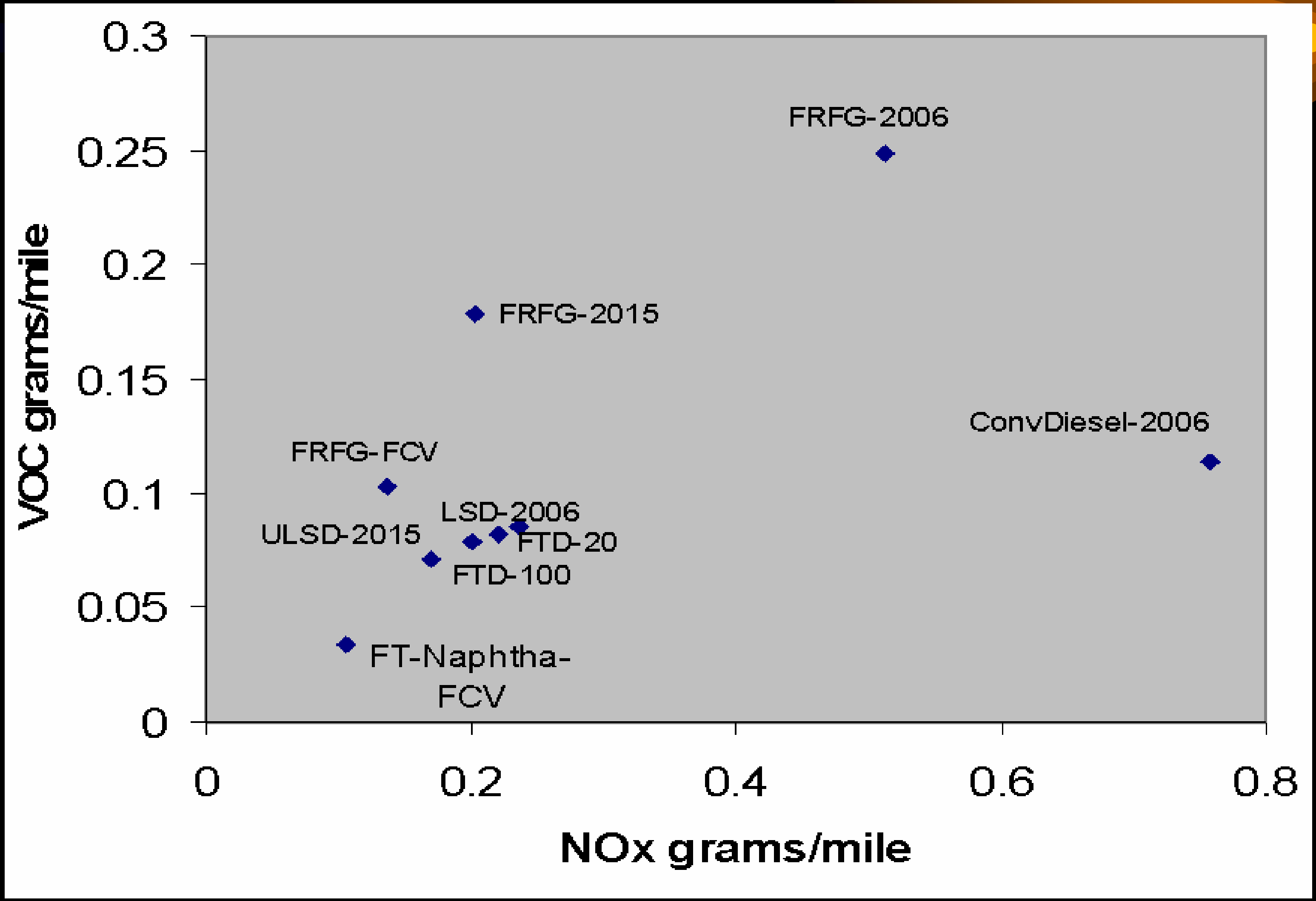


- Significant uncertainty is inherent in most LCA’s
- LCI – 10% difference chosen for GHG and energy
- LCI – 15% difference chosen for criteria emissions
- LCIA – 100% difference chosen for environmental impact categories

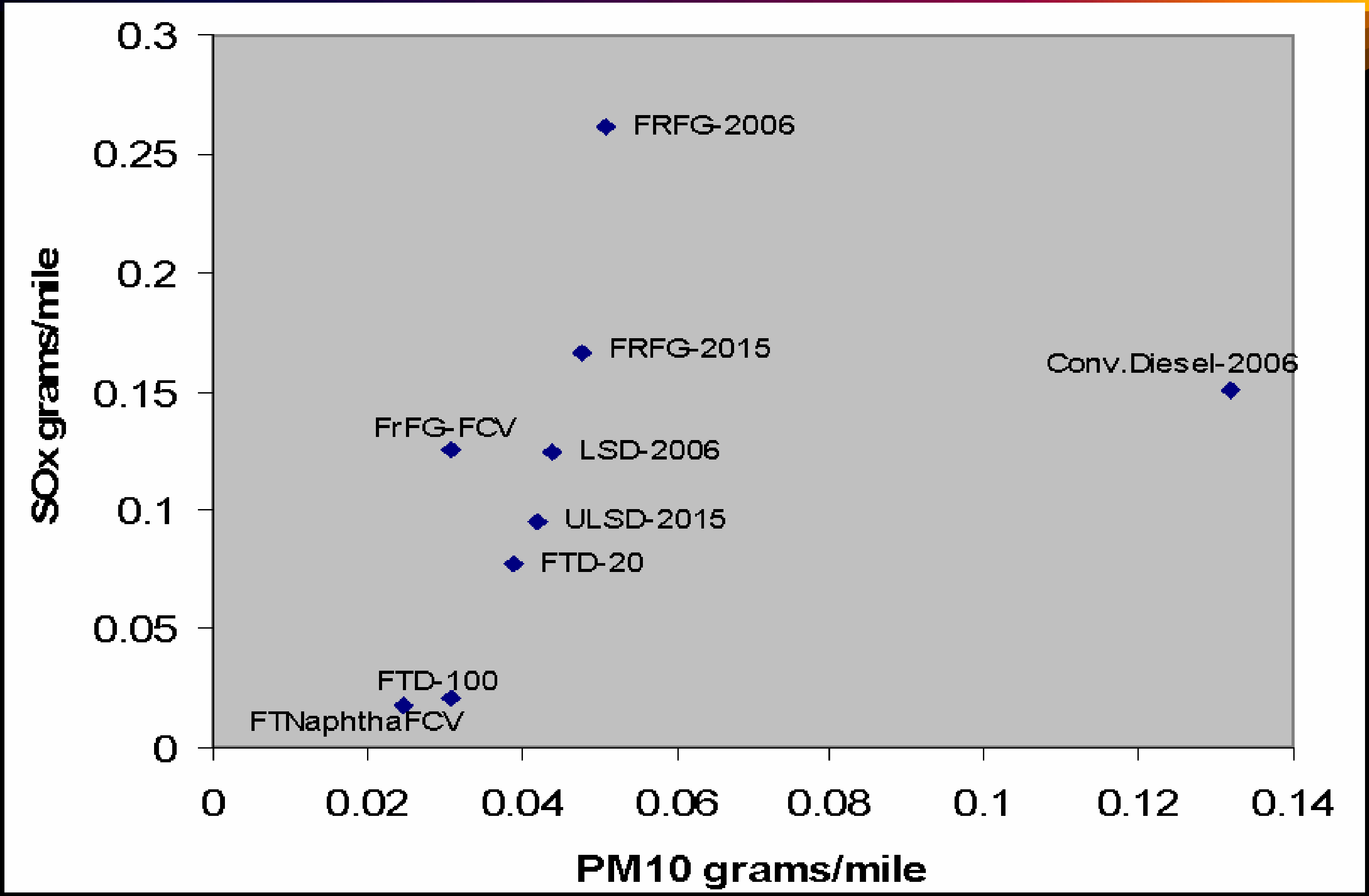
Comparisons of FTD100 with ULSD and FRFG and FT Naphtha with FRFG in 2015

		Comparison with FTD100 CIDI (FTD100 CIDI % Difference)			Comparison with FT Naptha FCV (FT Naptha FCV % Difference)
Outputs	FTD100	ULSD CIDI	FRFG SIDI	FT Naphtha FCV	FRFG FCV
Total energy	5,188(btu/mi)	25%	15%	4,420	26%
CO_2	327 (g/mi)	-3%	-7%	261	-4%
CH_4	0.369	0%	-31%	0.318	-16%
N_2O	0.016	-4%	-44%	0.006	-11%
GHG emissions	340	-3%	-8%	270	-4%
VOC	0.071	-11%	-61%	0.034	-68%
CO	1.198	7%	-58%	0.661	10%
NO_X	0.171	-15%	-16%	0.105	-24%
PM10	0.031	-26%	-34%	0.024	-23%
SO_X	0.021	-78%	-87%	0.018	-86%
VOC: urban	0.051	-11%	-63%	0.018	-75%
CO: urban	1.071	-1%	-61%	0.552	-2%
NO_X: urban	0.056	-35%	-8%	0.009	-65%
PM10: urban	0.028	-21%	-30%	0.021	-15%
SO_X: urban	0.000	-99%	-99%	0.000	-98%

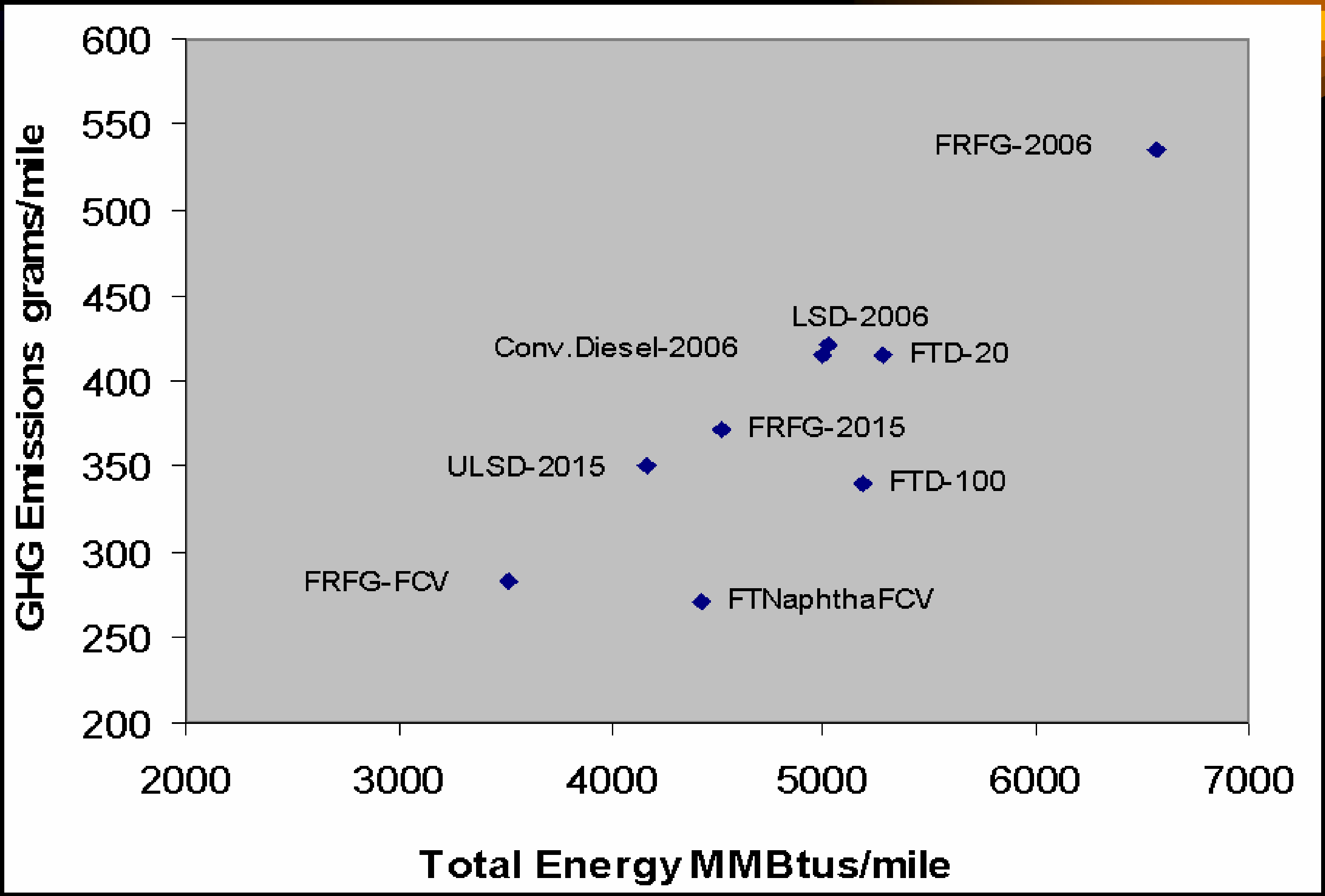
NOx/VOC Comparison



PM10/SOx Comparison



GHG/Total Energy Comparison



Sensitivity Analyses

- Four Operational Sensitivities Examined:
- Heavy and Light Crude Slates – differences minimal
- From 10 to 3 ppm Ultra-Low Sulfur Diesel- differences minimal
- 100% Middle East Crude Supplies – NOx inventory increased by tanker transportation
- Assuming 10% Flared Gas in GTL Production – GHG and energy consumption improved

Life Cycle Inventory Conclusions

Energy Utilization

- On full life cycle basis based on light duty vehicle miles driven, COP-produced GTL uses ~ 25% more energy than ULSD (GREET model base case showed 44% difference)

Greenhouse Gas Emissions

- GHG emissions (Global Warming Potential) are equivalent between GTL and ULSD

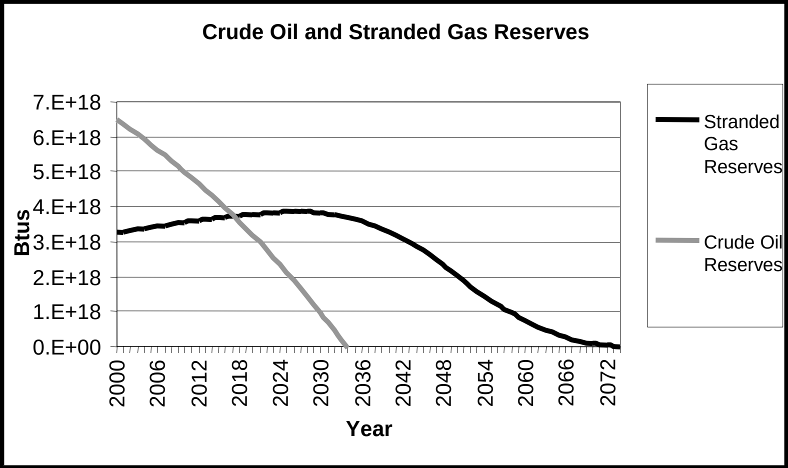
Criteria Pollutant Emissions

- SOx, NOx, VOC, CO and PM10 inventories lower for GTL fuels in both total and urban venues

Environmental Impact Categories with Respective Category Indicators

- Global Warming Potential - gram CO_2 equivalents
- Acidification – mole equivalents of H+
- Photochemical Smog – grams NOx equivalents
- Eutrophication – kilograms Nitrogen equivalents
- Ecotoxicity – pounds of dichlorophenoxyacetic acid equivalent
- Human Health Criteria – Disability adjusted life-years (DALY's)
- Human Health-NonCancer– Human Toxicity Potential (HTP) based on benzene equivalent factor
- Human Health-Cancer – same as HH-NonCancer

Natural Resource Depletion



- Stranded gas utilization extends hydrocarbon reserves significantly
- GTL utilizes very small percentage of stranded gas at current projections
- Crude curve based upon:
  - Crude oil reserves 2000=1.212E+12
  - Undiscovered reserves =6.93E+11
  - Consumption (BOPD)=6.70E+07

Life Cycle Impact Analysis - Conclusions

- Impact categories (acidification, smog, eutrophication, human health, etc.) trend toward favoring GTL fuels compared to ULSD and FRFG
- definitive conclusions unwarranted by data