Emissions Reduction Performance Benefits of Fischer-Tropsch Fuel Combined with Advanced Aftertreatment

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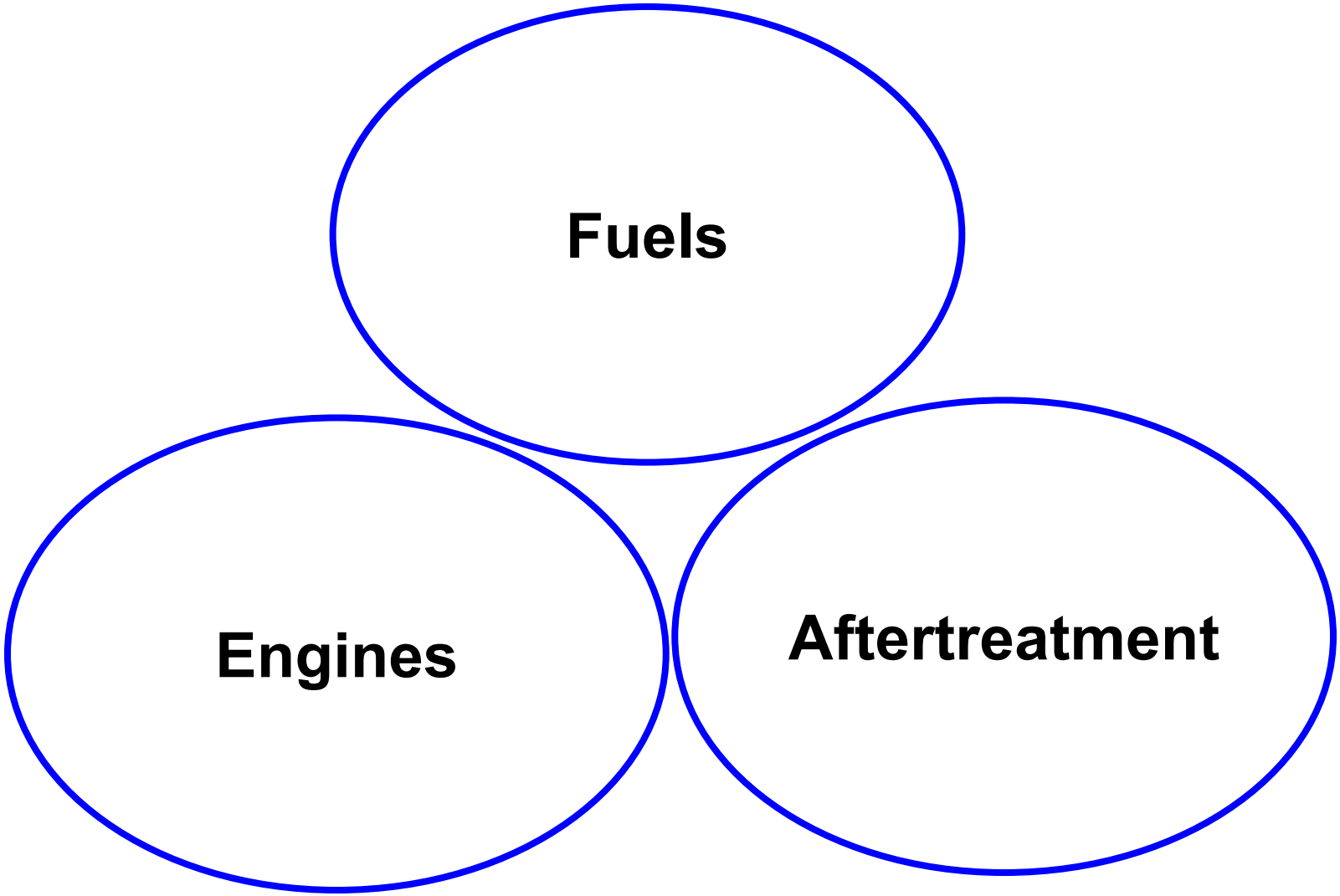
Agenda

- Overview
- Test Programs
  - CEC/Caltrans/CaTTS
  - SCAQMD/NREL Demonstration Program
- Summary

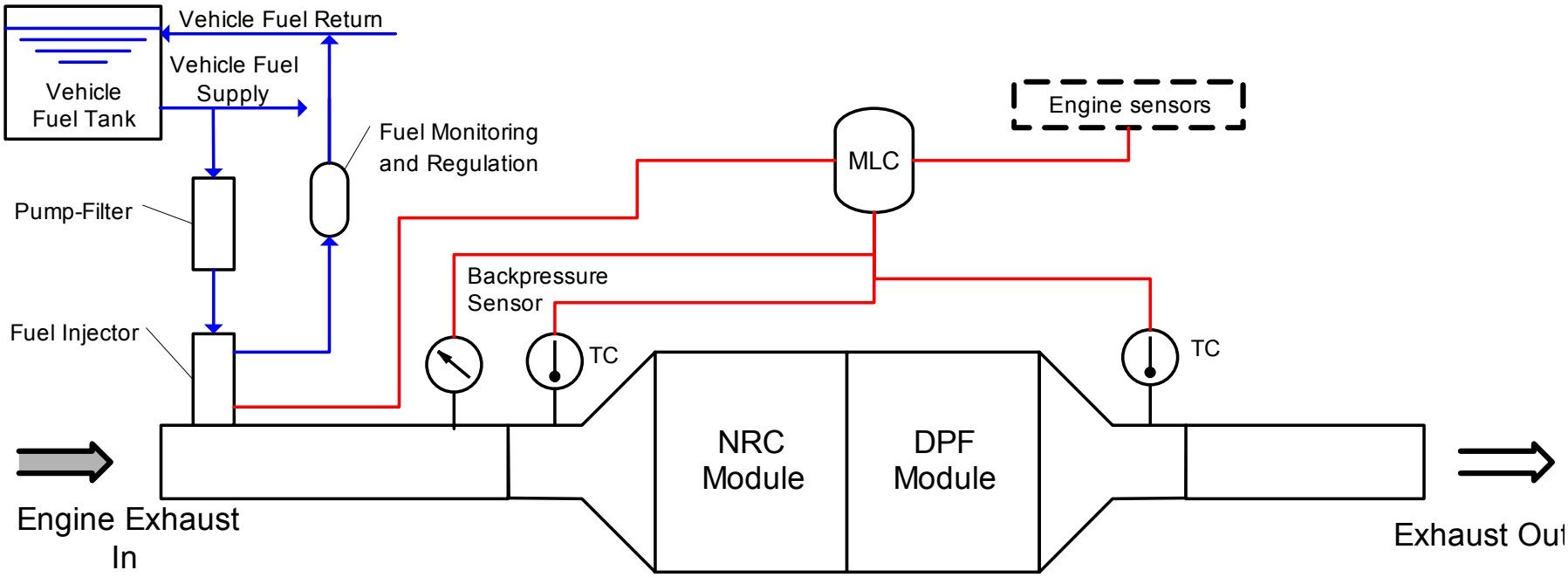
Low Emission Power Train Strategy



Fischer-Tropsch fuel

- **Good for the Engine**
  - High cetane number – lower NOx
  - Lower aromatics – lower PM
- **Good for the aftertreatment**
  - No sulfur
  - No aromatics
  - Straight chain hydrocarbons may be more selective for NOx reduction

Cleaire Longview™



Longview™

Cleaire Longview

- CARB verified as of April 11, 2003
- 25% NOx reduction
- >85% PM reduction
- Requires ULSD (or better) fuel

Test Program #1

- CEC/Caltrans/CaTTS

Test Program #1: CEC/Caltrans/CaTTS

Vehicle

Caltrans Truck with 1996 International DT466, 230 hp

Test Cycles

Transient (UDDS), Steady (Cruise-60)

Fuels

CARB #2 Diesel

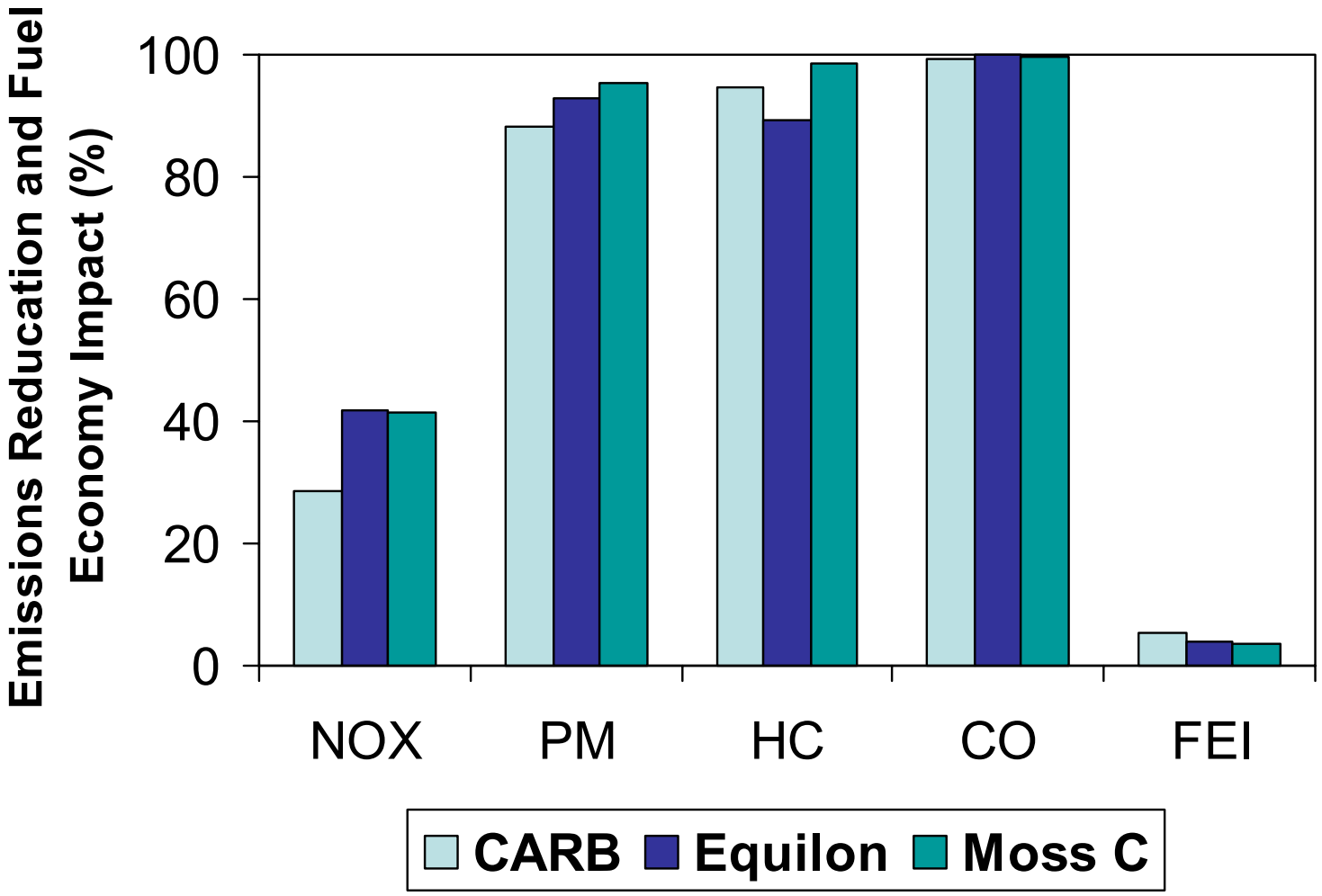
Fischer-Tropsch

Shell (Equilon), Petro AS (Moss C)

Aftertreatment

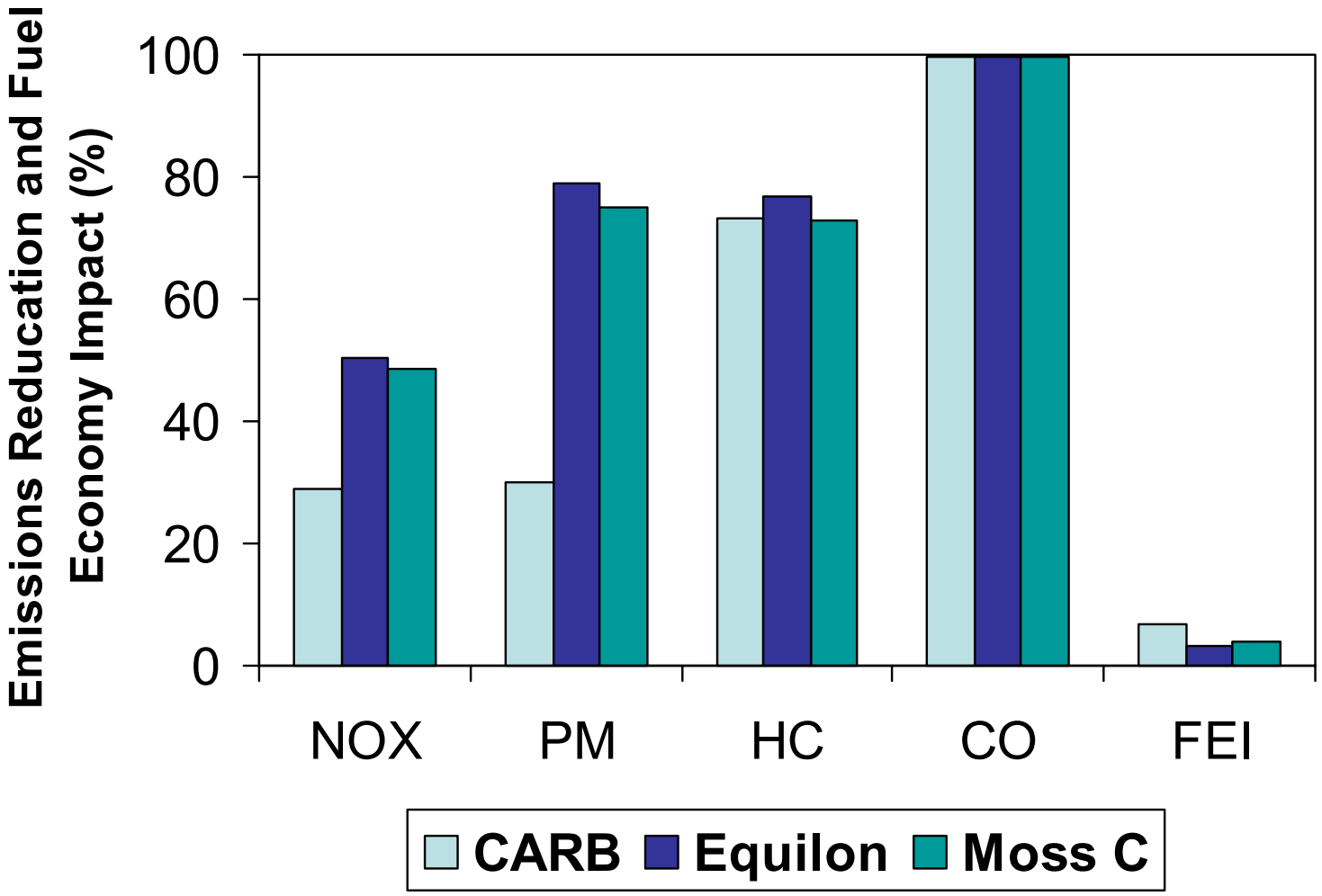
Cleaire Longview

CARB vs. F-T Fuel over UDDS Cycle



Engine: 1996 International DT-466

CARB vs. F-T Fuel over Cruise-60 Cycle



Engine: 1996 International DT-466

Test Program #2

- SCAQMD/NREL Fischer-Tropsch Demonstration

Test Program #2: Use of FT Fuel on an Engine with Emission Controls

- Development and Demonstration of Fischer-Tropsch Fueled Heavy-Duty Vehicles with Control Technologies for Reduced Diesel Exhaust Emissions
  - SCAQMD RFP #P2002-18
  - Co-funded by National Renewable Energy Laboratory
- Team includes Automotive Testing Labs, Ricardo, Shell, and Cleaire
- Program includes work in test cell and in field

Engine and Emission Targets

- Engine
  - 2002 Cummins ISM, 370 hp
  - Pistons modified by Ricardo
  - Increased EGR rate

- Emission targets on composite FTP (g/bhp-hr)
  - NOx 1.2
  - NO_2 0.4
  - PM 0.01
  - HC 1.3
  - CO 15.5

Method to Reach 1.2 g/bhp-hr NOx

• Baseline, standard diesel	2.3 g/bhp-hr
• Baseline, FT	2.0 g/bhp-hr
• Higher EGR rate, new combustion bowl, F-T	1.5 g/bhp-hr
• Higher EGR rate, new combustion bowl, F-T, DPF, Lean NOx catalyst	1.2 g/bhp-hr

Targets are achieved

Composite FTP results (g/bhp-hr)

	Target	Result
NOx	1.2	1.17
PM	0.01	0.005
HC	1.3	0.04
CO	15	0.06
NO2	0.3	0.4

Emissions performance is achieved within engine operating limits. Good transient performance is expected

Summary

- F-T Fuel in combination with advanced aftertreatment lowers engine emissions with no engine modification
  - NOx: 40-50%
  - PM: >85%
- F-T Fuel in combination with advanced aftertreatment and engine modification lowers engine out emissions
  - NOx: <1.2 g/bhp-hr
  - PM: 0.005 g/bhp-hr
  - Very low CO and HC (including some air toxics)

Summary

- F-T Fuels lowers engine emissions
- F-T Fuels enables aftertreatment to work better
- Benefits appear to be synergistic but not interdependent, which is attractive from a deployment point of view