

MOVES2004 Overview & Results

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Acknowledgements

- **Sujan Srivastava**

Outline

- **Overview**
 - “A Roadmap to MOVES2004”
- **Results**
 - Validation
 - Documented in “MOVES2004 Validation Results”
 - Projections
 - Example Well-To-Wheel Scenario

MOVES2004 Scope

- **Output:** Energy consumption (total, petroleum-based and fossil-based), N_2O , CH_4 , distance (e.g. VMT)
- **Sources:** all on-road sources, subdivided into 13 categories known as “source use types”.
- **Emission Processes:** running, start, extended idle, well-to-pump
- **Geography:** entire U.S. by nation, state and/or county
- **Time Spans:** calendar years 1999 through 2050 by year, month and/or hour

Advanced Technologies in MOVES

 = to be added later

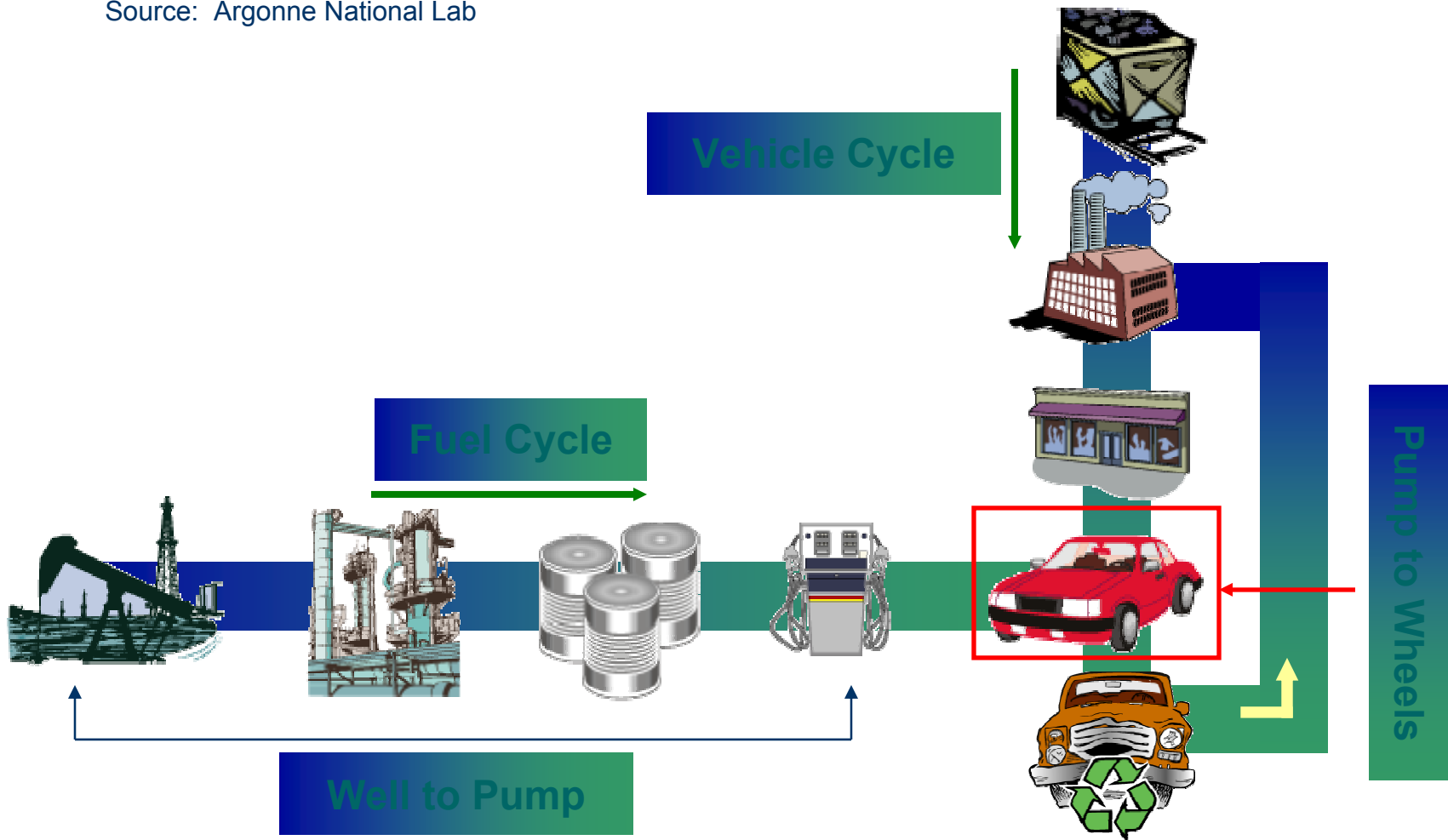
	Conventional Internal Comb	Advanced Internal Comb	Moderate Hybrid	Full Hybrid	Fuel Cell	Fuel Cell - Hybrid
Gas	X	X	X	X		
Diesel	X	X	X	X		
CNG	X					
E85	X					
M85	X					
LPG	X					
Electric						
Gas H ₂		X			X	X
Liquid H ₂					X	X

Key Changes from MOBILE

- **Inventory estimation**
 - MOBILE estimates emission factors (grams/mile)
- **Emission rates on modal basis**
 - MOBILE rates based on aggregate driving cycles
- **Software framework**
 - Relational database structure
 - Graphical User Interface (GUI)
 - Allows multiple-computer processing if desired
- **Well-to-Wheel (aka Life Cycle) analysis**

Life Cycle – The Big Picture

Source: Argonne National Lab



Well-To-Wheel (WTW) is a subset of Life Cycle Analysis

Life Cycle Analysis In A Nutshell



Source: "Other Coast" by Adrian Raeside

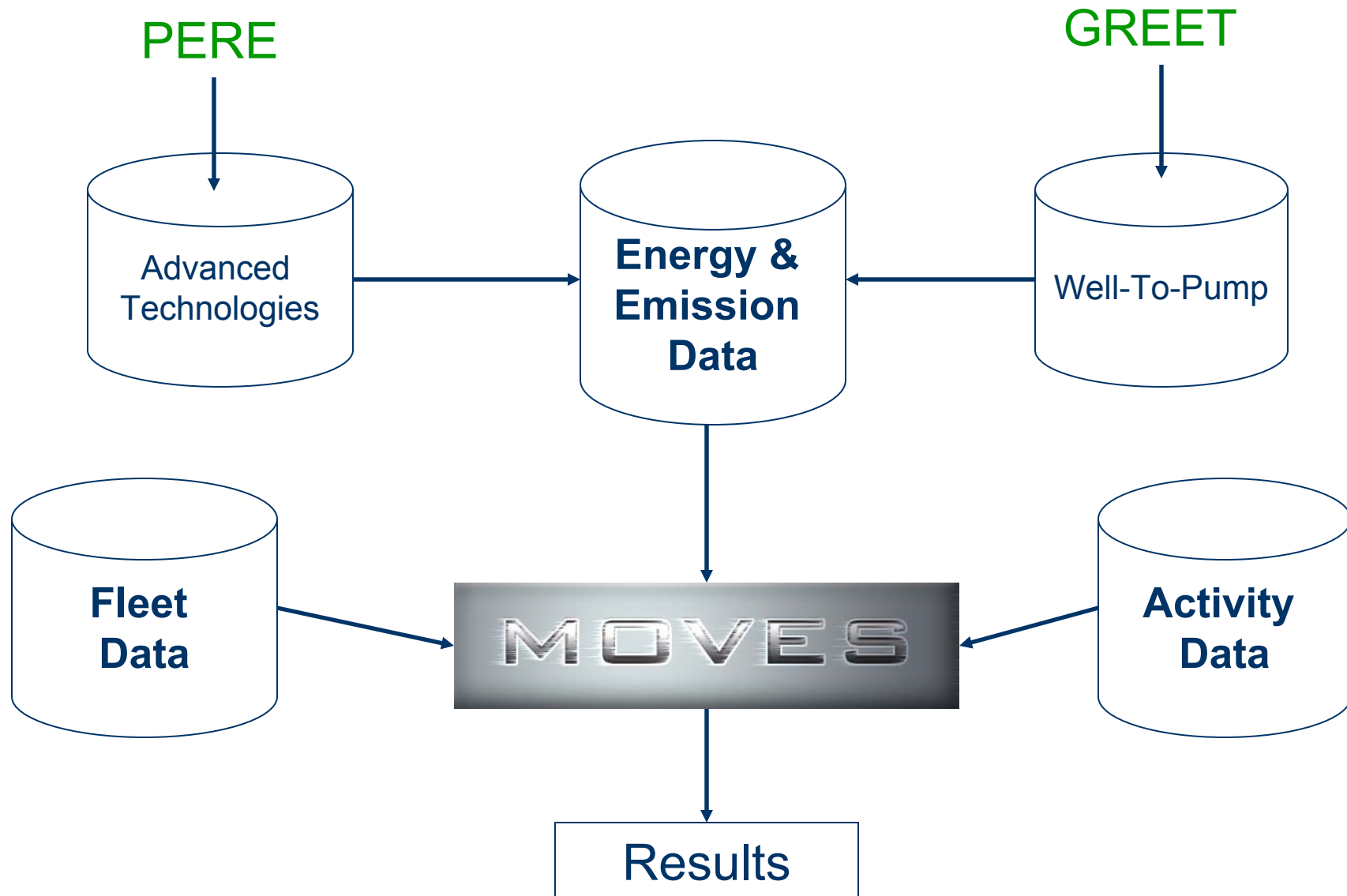
GREET

- **Well-To-Wheel model developed by Argonne National Lab**
- **Over 30 fuel pathways including Gas, Diesel, CNG, LPG, Ethanol, Methanol, Hydrogen, Electricity**
- **Models “per-vehicle” energy use (total, petroleum, fossil) CO₂, CH₄, N₂O, VOC, CO, NO_x, SO_x, and PM₁₀**
- **Version developed for MOVES2004 integration:**
 - Well-to-Pump only (MOVES provides Pump-to-Wheel)
 - No criteria pollutants
 - Adds: inputs by calendar year, ability to specify pathway mix

Physical Emission Rate Estimator (PERE)

- **Physically models fuel consumption**
 - Based on power demand and general engine characteristics
- **Designed for broader applicability than current state-of-the-practice vehicle models**
 - Does not require engine maps or other confidential data
- **Validated with fuel economy data**
- **Uses in MOVES**
 - Fill data “holes” for current fleet
 - Advanced technology vehicles

MOVES2004 Inputs



MOVES2004 Documentation

- **Installation Guide**
- **User Guide**
- **Software Design Manual**
- **Validation Results**
- **GREET Documentation**
- **PERE Documentation**
- **Fleet & Activity Inputs**
- **Energy & Emission Inputs**



Results

- **Fuel Consumption Validation**
- **Fuel Economy Comparison**
- **Projections**
- **Well-To-Wheel Analysis**

Fuel Consumption Validation

- **Primary reason for energy consumption in MOVES**
- **MOVES “bottom-up” vs. “top-down” fuel sales**
- **FHWA compiles state-level sales from tax records**
 - Gasoline and “special fuel” (mostly diesel)
 - Attempts to account for off-highway use, losses, spillage etc.
 - Doesn’t include military or (for diesel) other public vehicles
- **MOVES2004 total energy results converted to fuel consumption**
- **Comparison years: 1999 through 2002**
- **National and state level comparison**

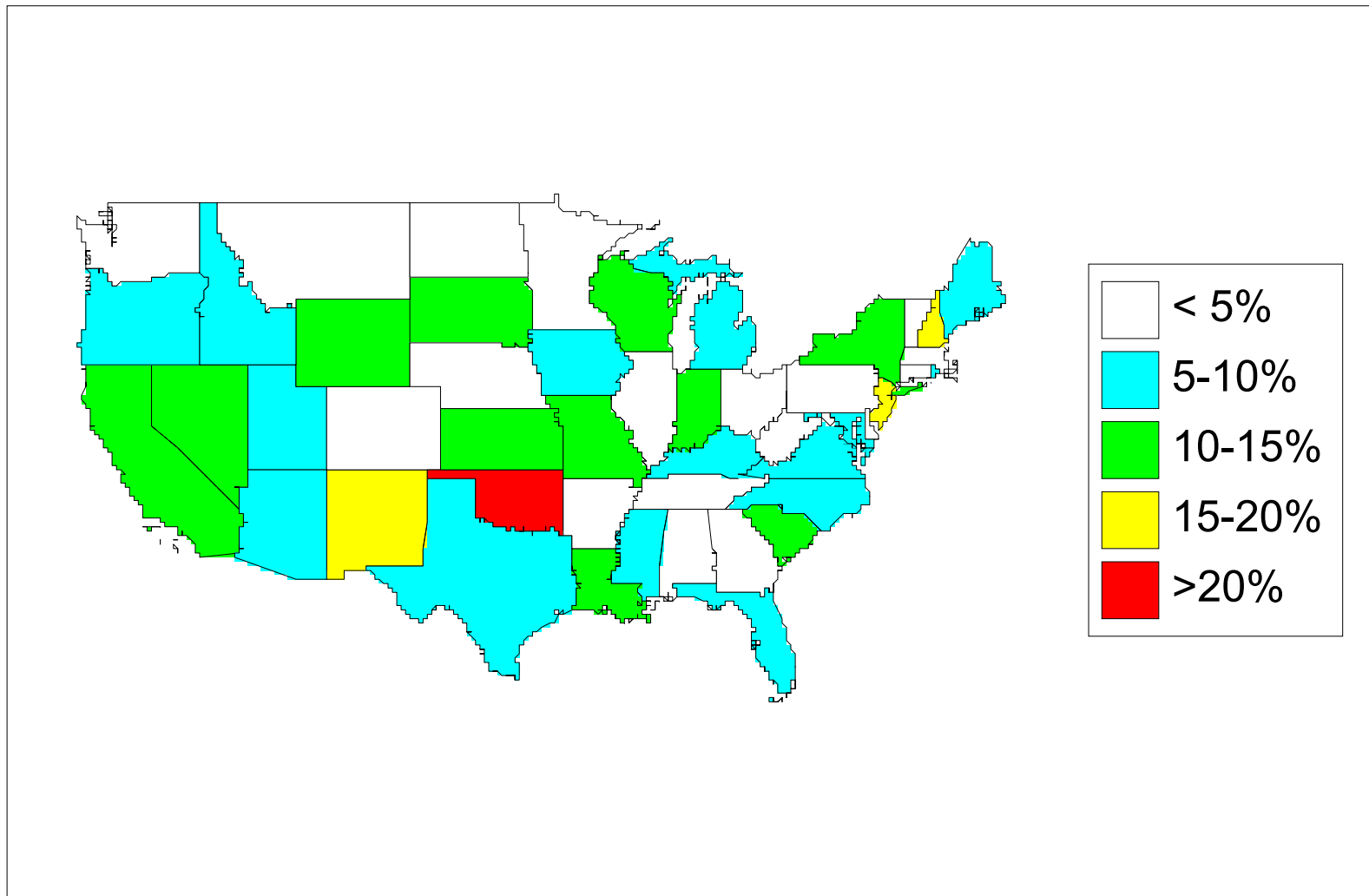
National Results

U.S. Annual Highway Fuel Consumption Estimates
from FHWA and MOVES2004 (billion gallons)

Year	Gasoline			Special Fuel		
	FHWA	MOVES	% Diff	FHWA	MOVES	% Diff
1999	128.7	126.6	-2%	31.9	30.8	-3%
2000	128.9	127.9	-1%	33.4	32.0	-4%
2001	129.7	129.0	-1%	33.4	32.7	-2%
2002	133.0	131.5	-1%	34.8	33.8	-3%

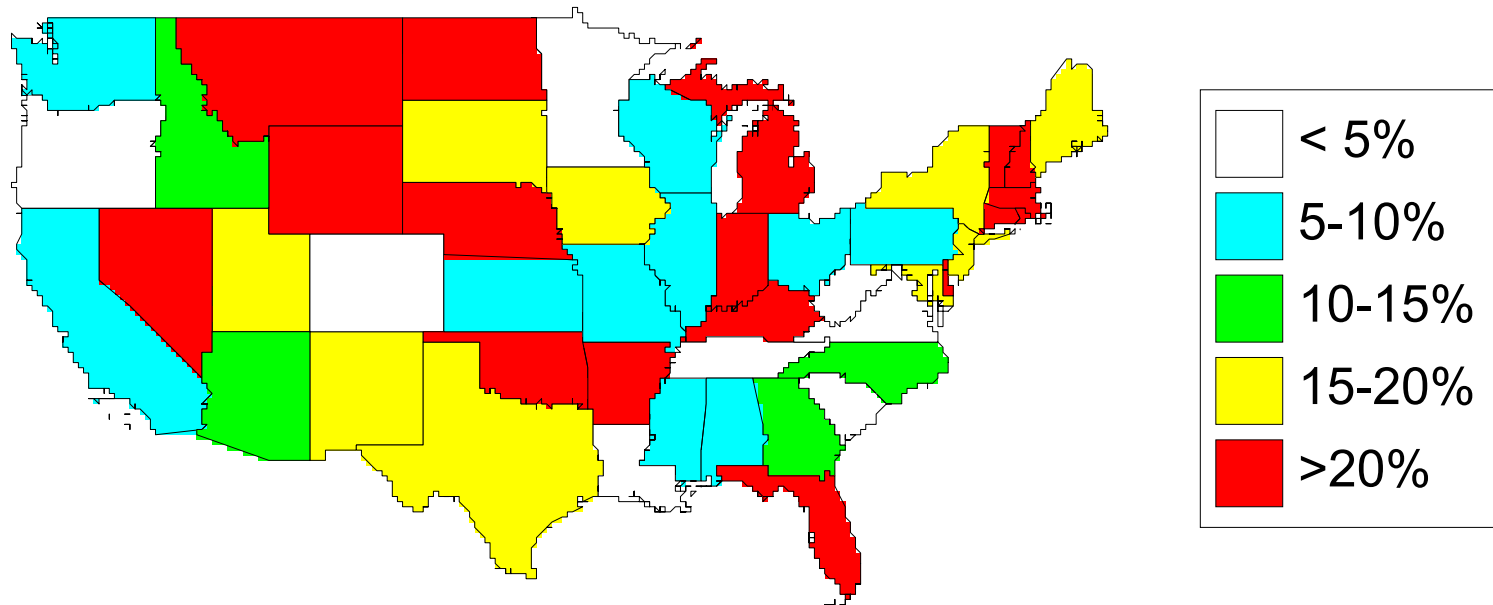
State-By-State Gasoline Results

Absolute difference MOVES2004 vs. FHWA



State-By-State Diesel Results

Absolute difference MOVES2004 vs. FHWA

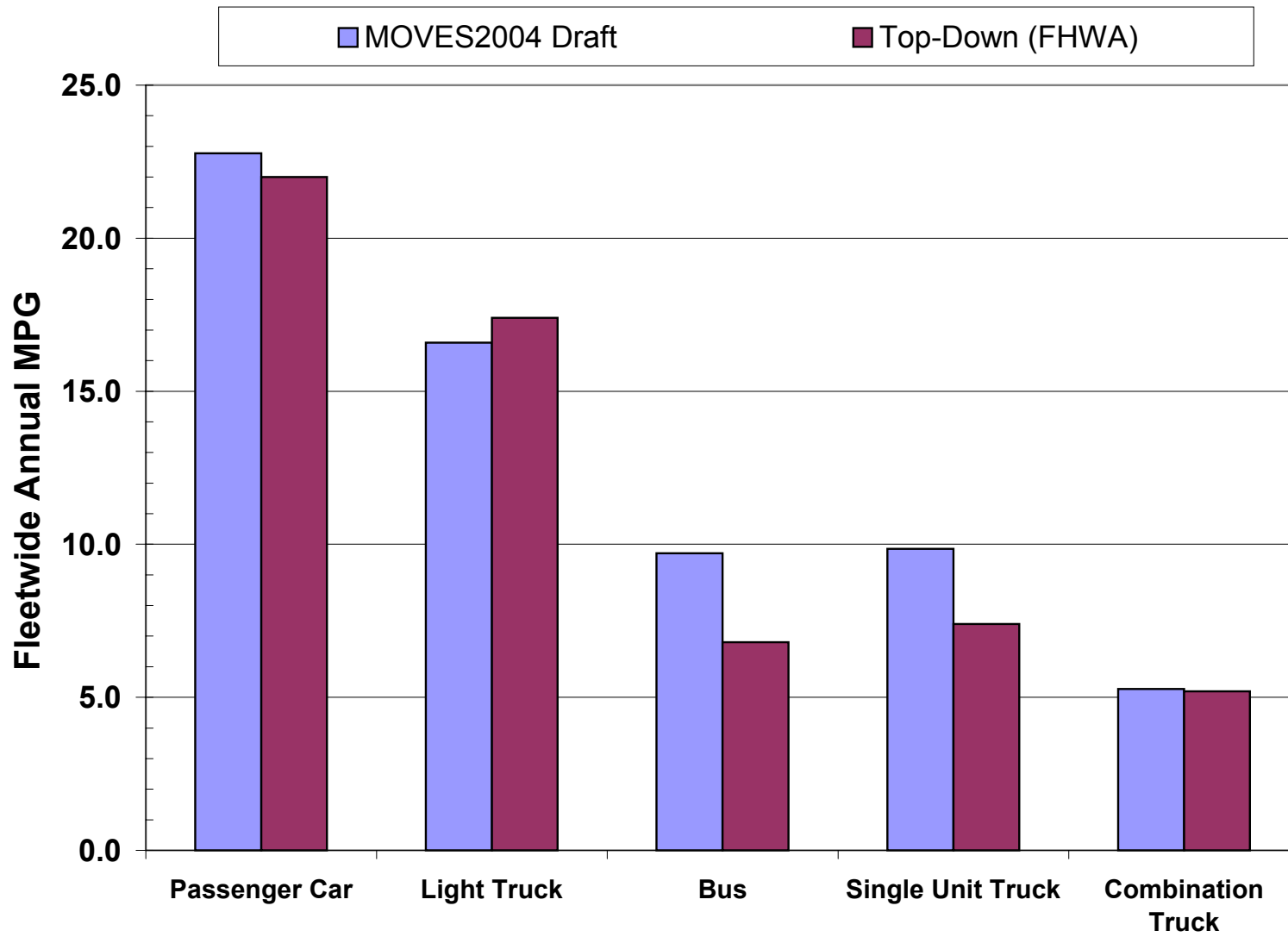


Fuel Economy Comparisons

- **Fleet average (2002)**
 - vs. FHWA Highway Statistics
- **By model year (1975 – 2004)**
 - vs. EPA Fuel Economy Trends Report
- **Advanced technology**
 - Selected technologies

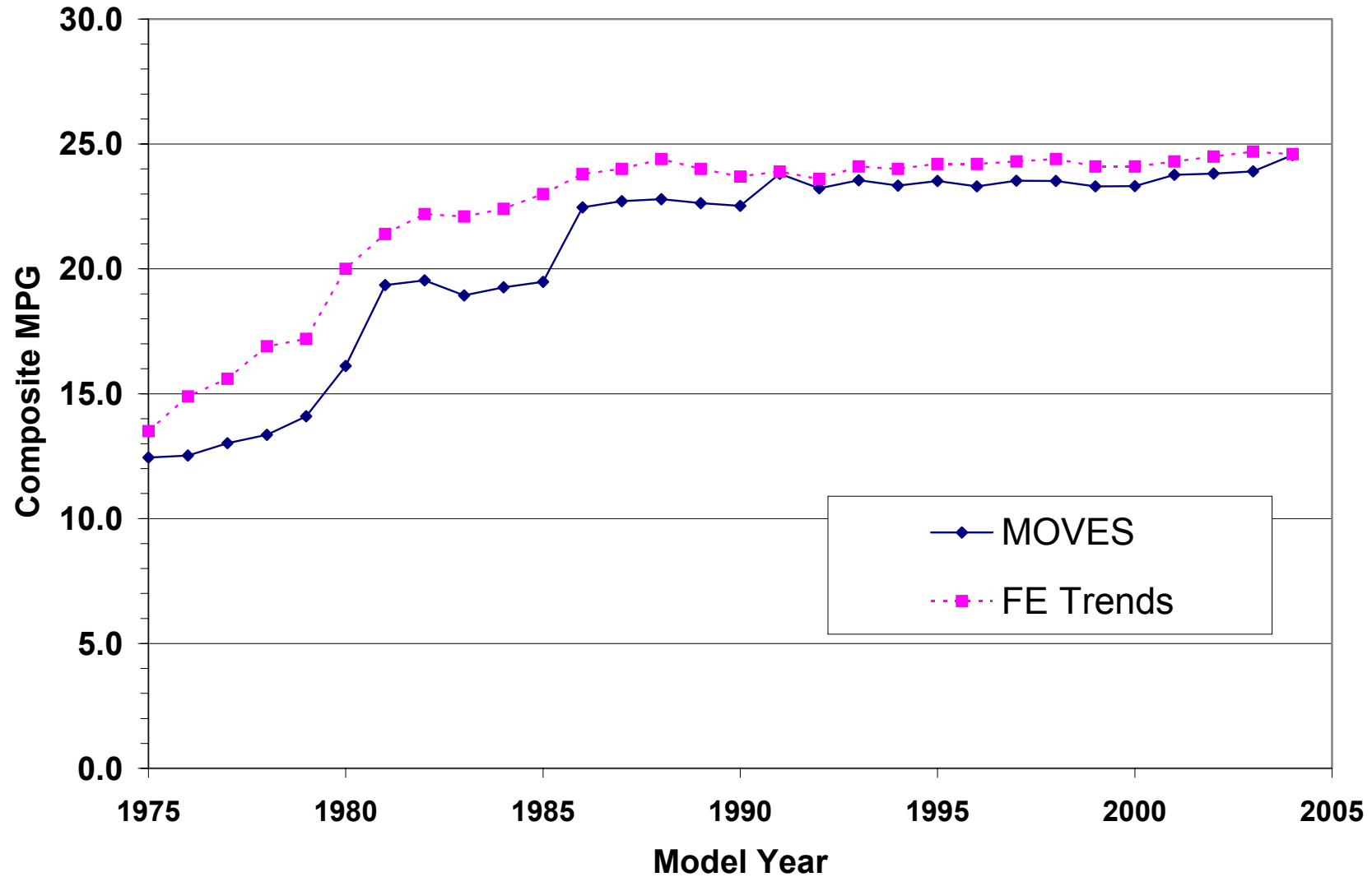
2002 Fleetwide Fuel Economy

MOVES2004 vs. FHWA



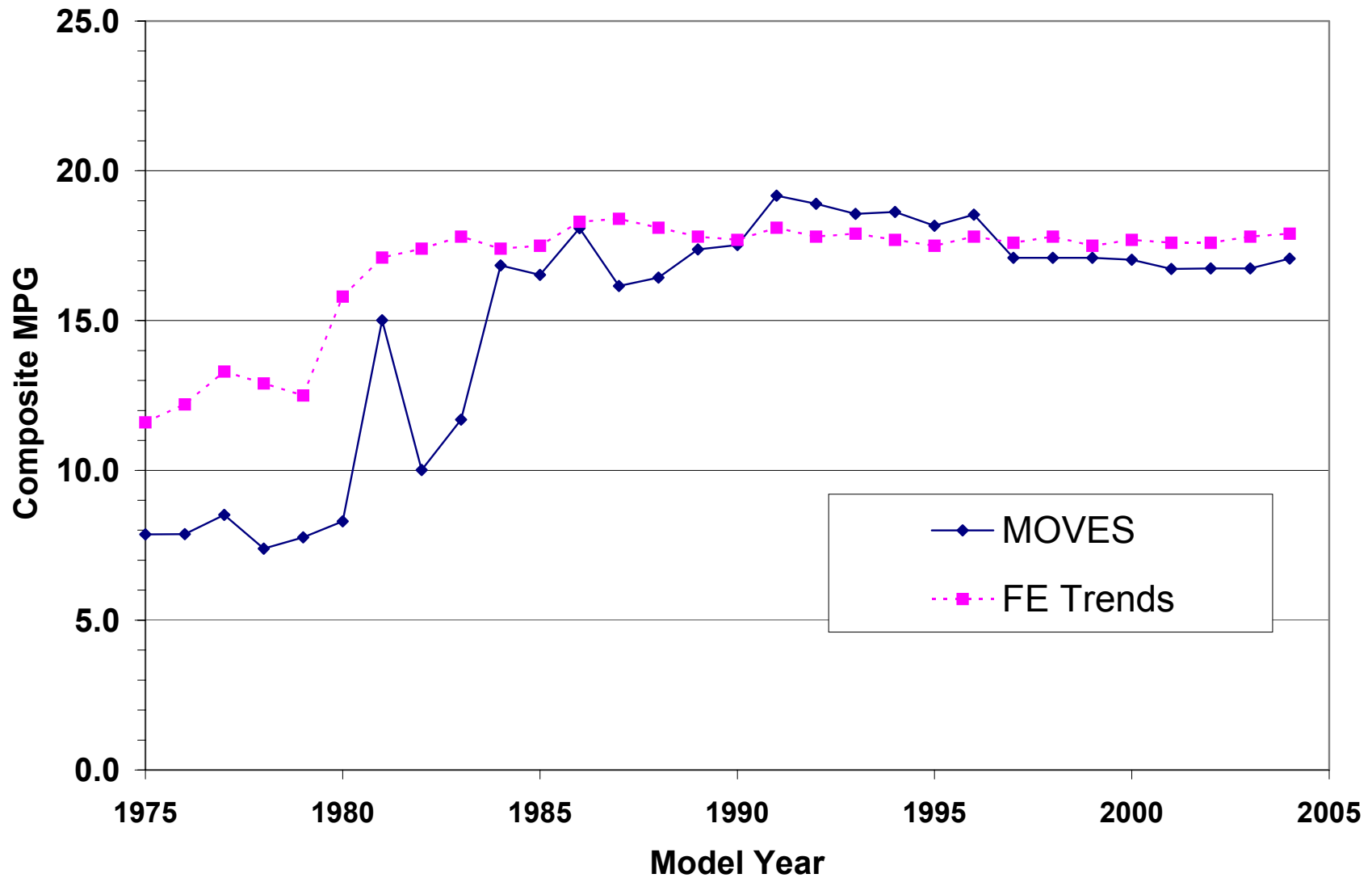
Car Fuel Economy

MOVES2004 vs. Trends Report



Light Truck Economy

MOVES2004 vs. Trends Report

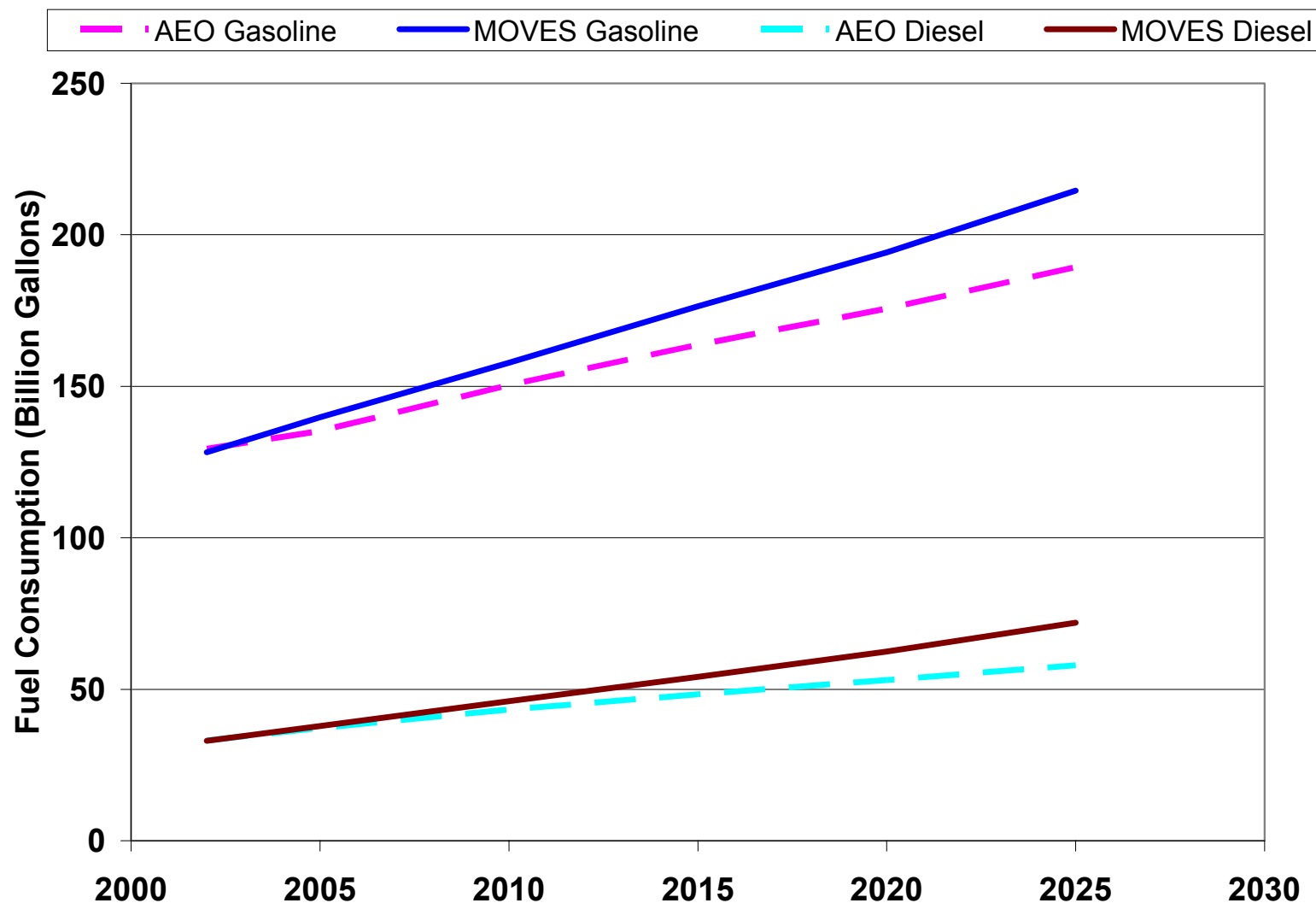


Projections

- **Fuel Consumption**
 - vs. Annual Energy Outlook (2005)
- **CH₄ and N₂O**
 - vs. U.S. Greenhouse Gas Emissions & Sinks Report (2004)

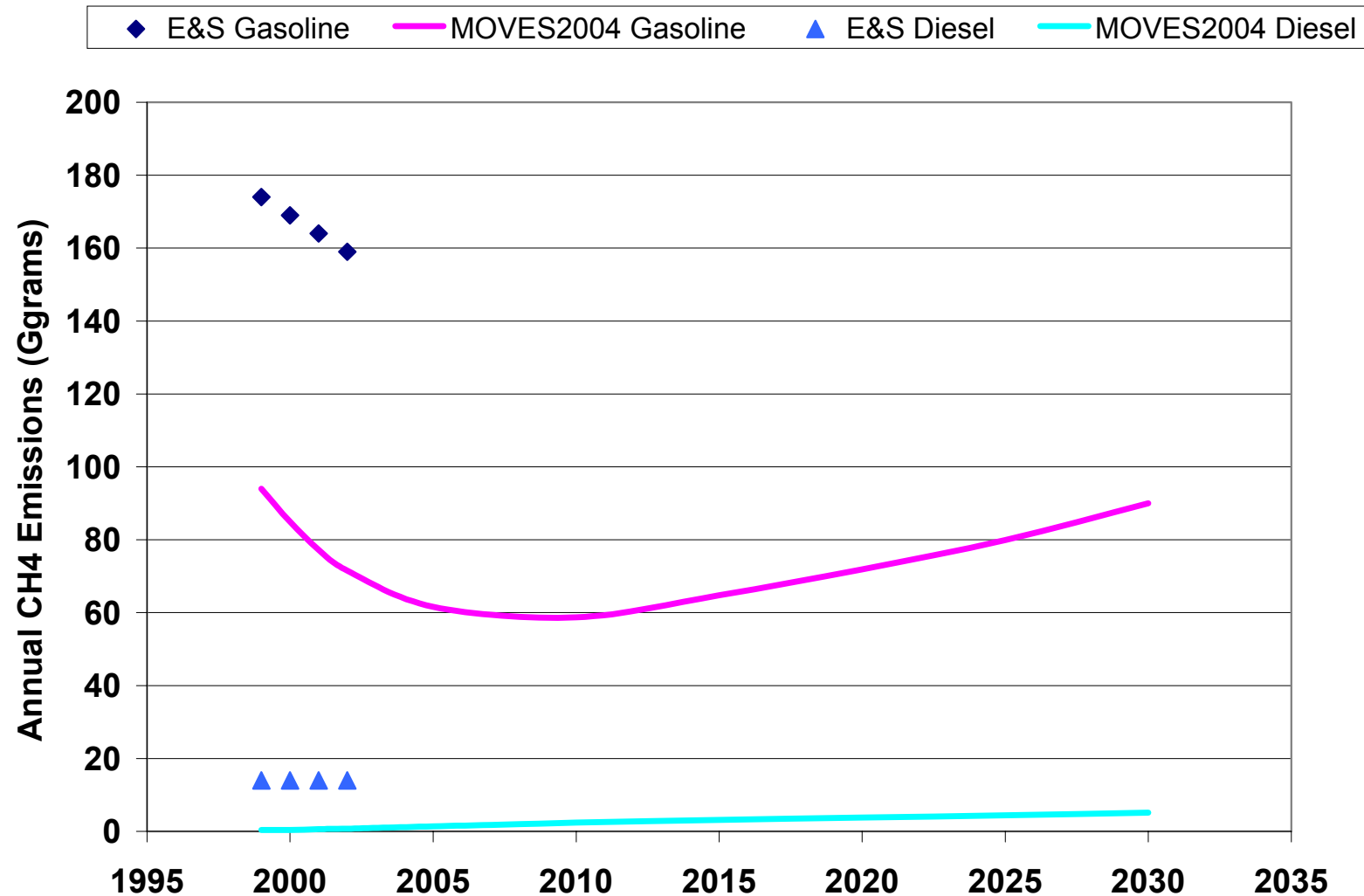
U.S. On-Road Fuel Consumption

MOVES2004 vs. Annual Energy Outlook 2005



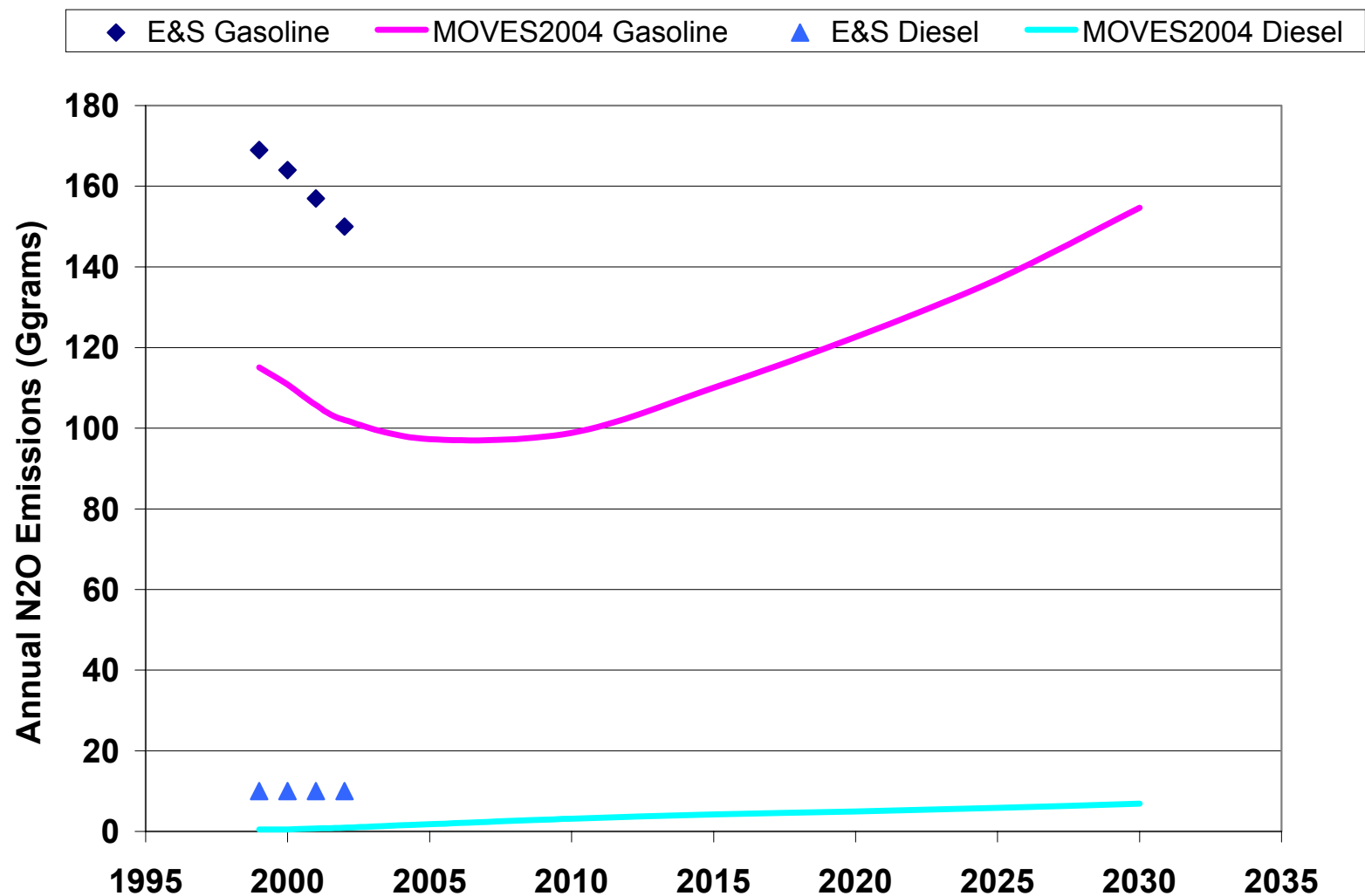
U.S. On-Road CH₄ Emissions

MOVES2004 vs. Emissions & Sinks 2004

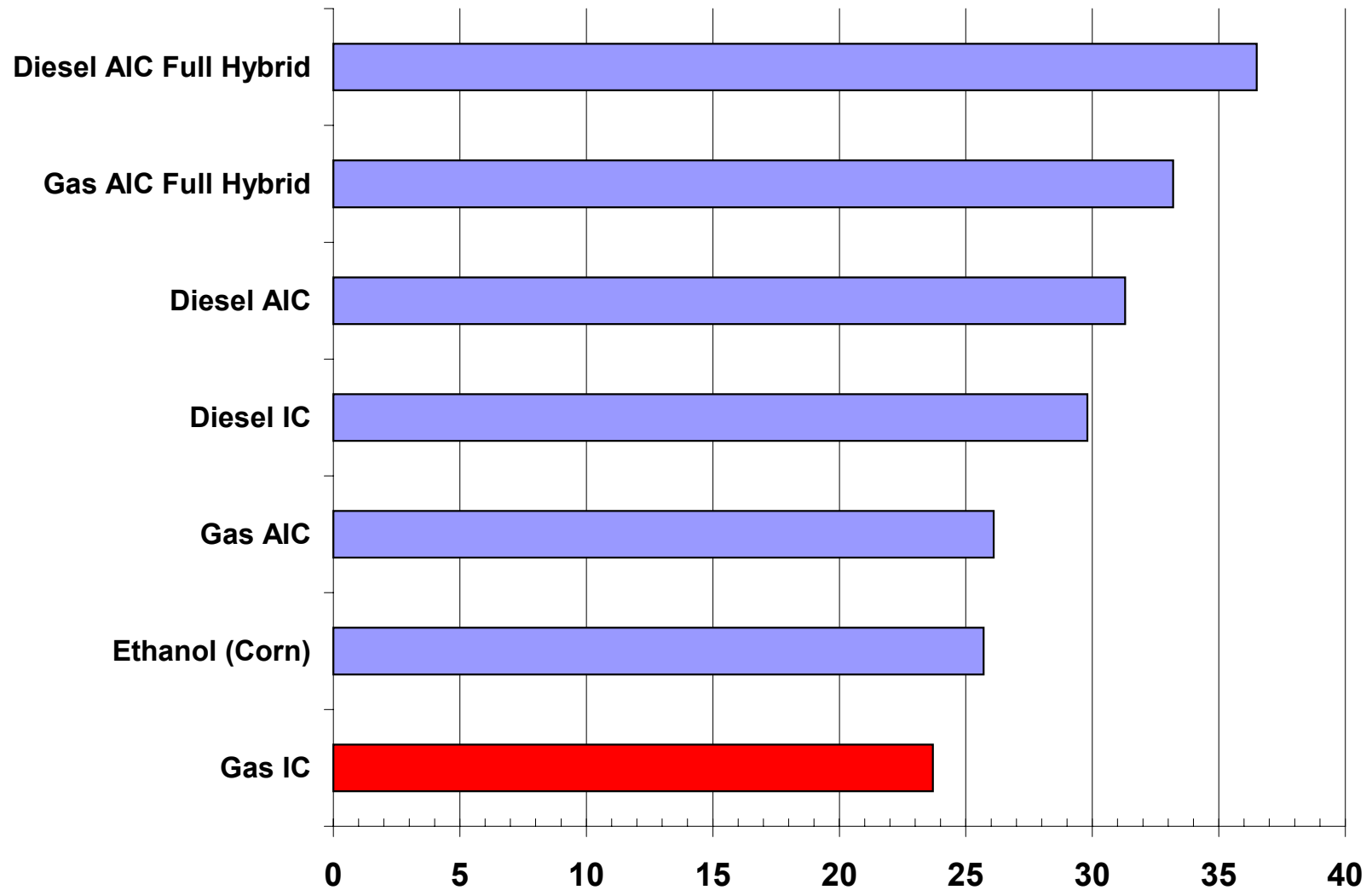


U.S. On-Road N₂O Emissions

MOVES2004 vs. Emissions & Sinks 2004



Passenger Car MPG Results – Selected Technologies

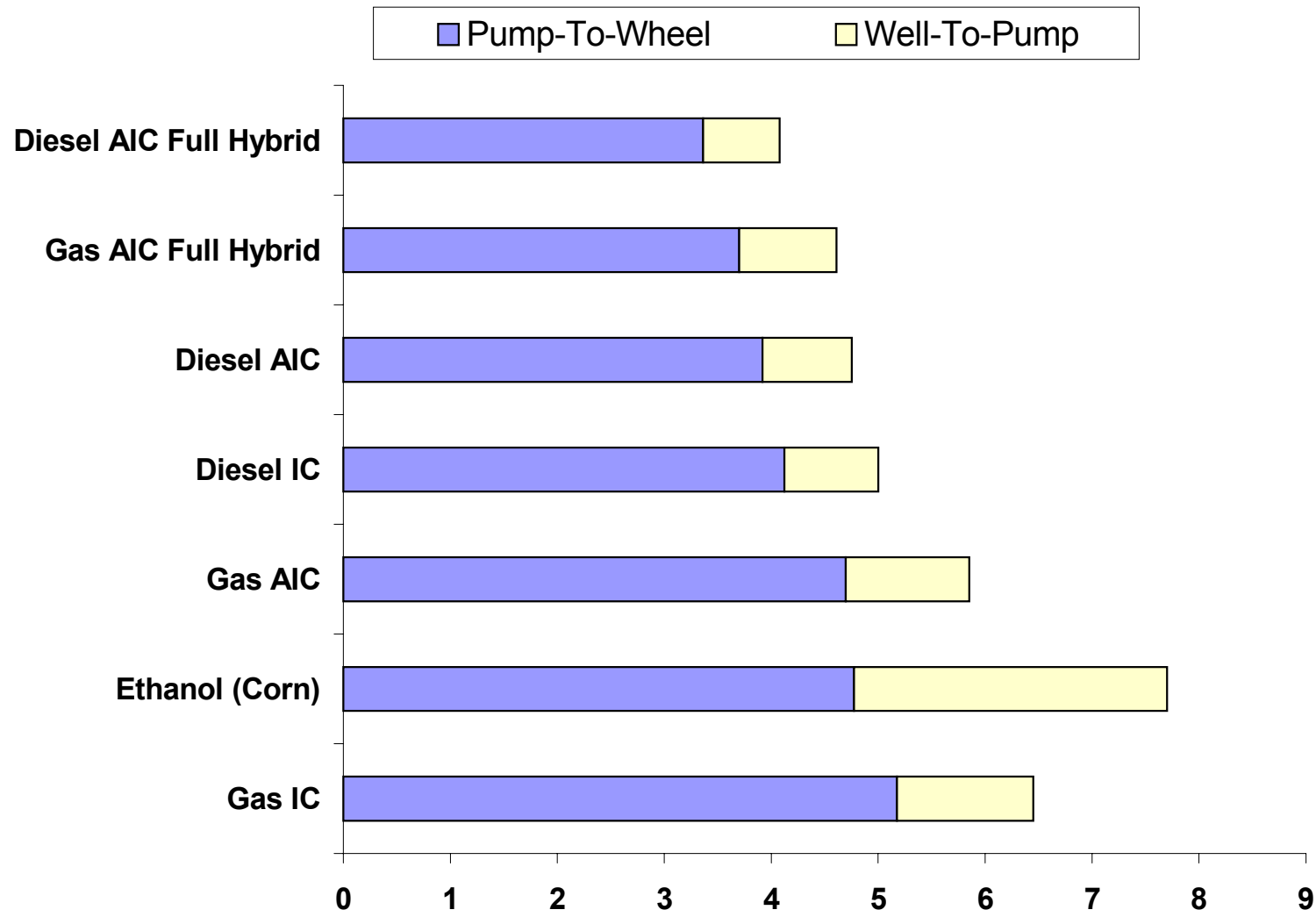


Well-To-Wheel Analysis

- **Per-Vehicle Comparison**
 - Selected technologies
 - Total & petroleum energy
- **Total Well-To-Wheel Results**
 - Default case
- **Example Scenario Analysis**
 - Increased diesel penetration

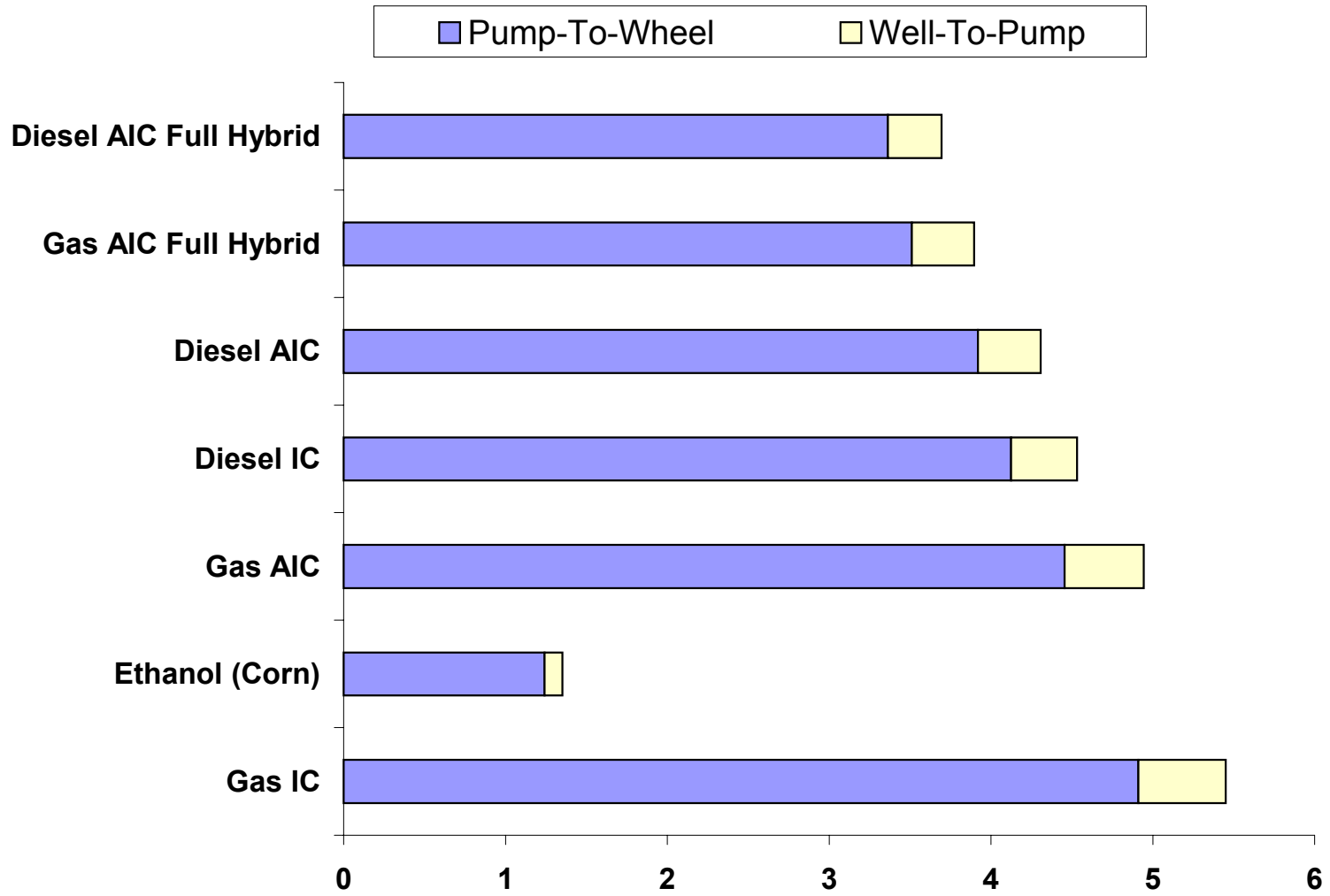
Well-To-Wheel Total Energy Use (GJ/mile)

Selected Technologies



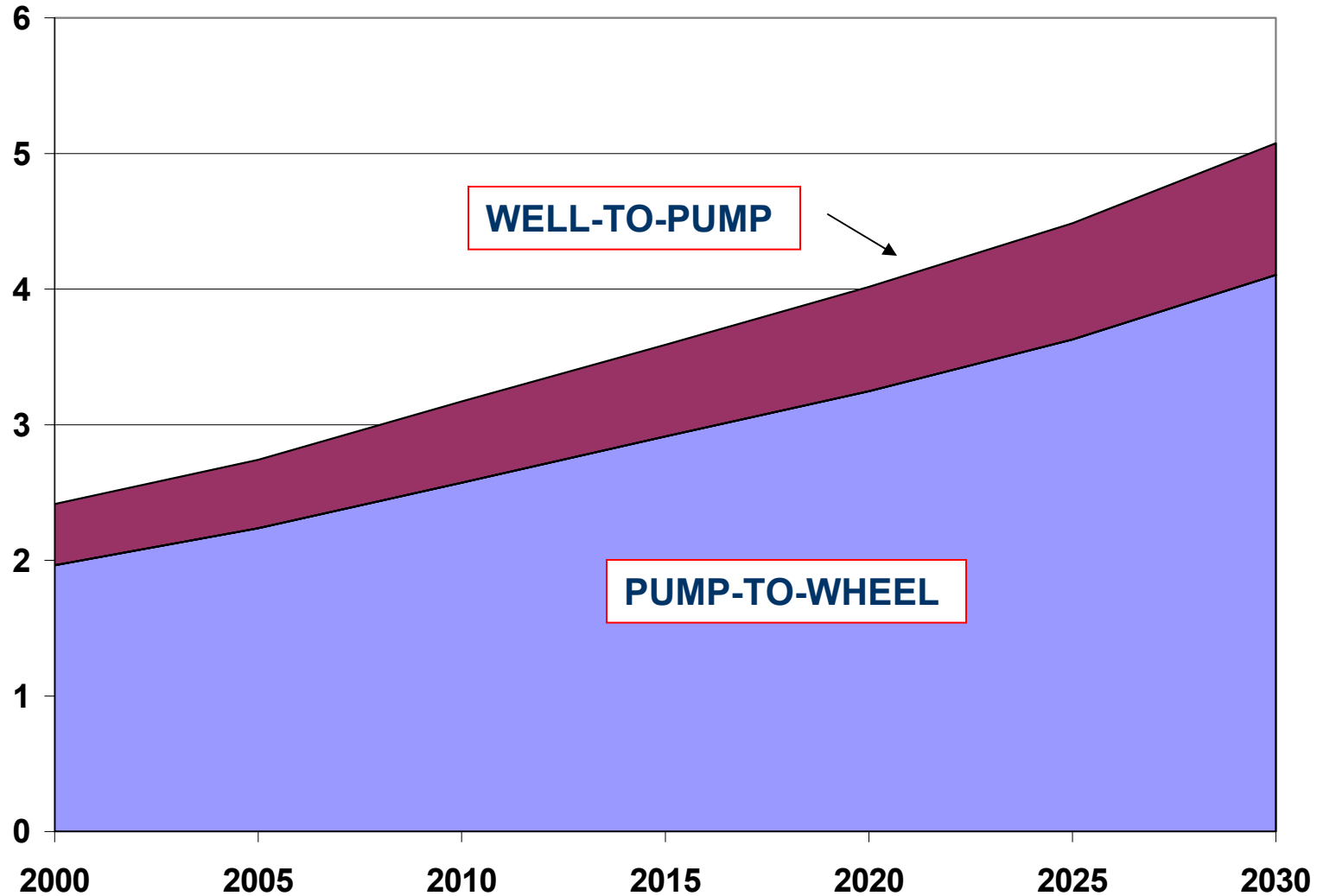
Well-To-Wheel Petroleum Energy Use (GJ/mile)

Selected Technologies

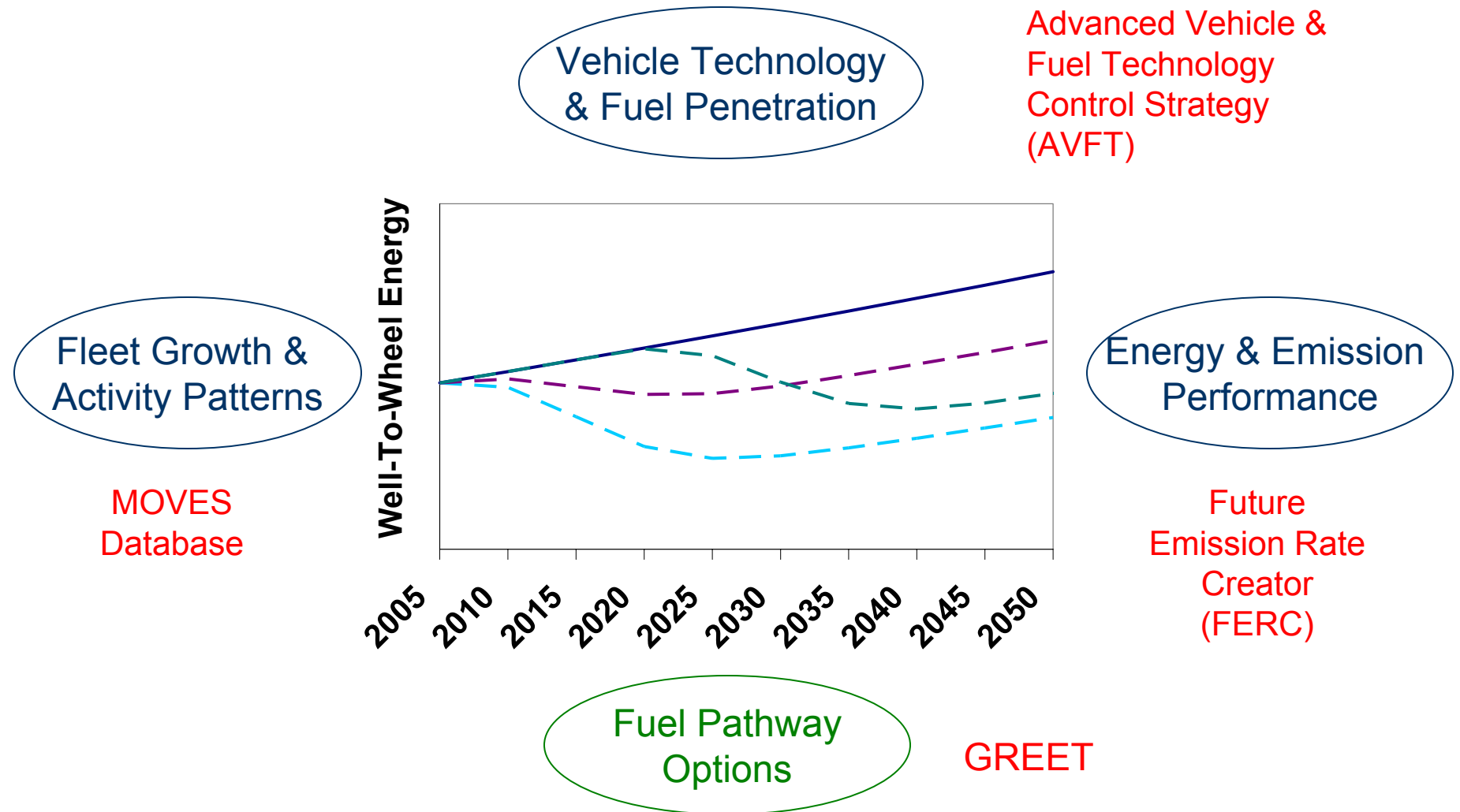


Total Well-To-Wheel Results

U.S. On-Road Energy Consumption (10^{19} Joules)



MOVES2004 provides unprecedented “what-if” capability



Example Scenario Analysis

- **Well-To-Wheel assessment of diesel penetration scenario:**
 - Conventional IC penetrates to 10% of light car & truck sales between 2010 and 2020
 - Advanced IC & Hybrids penetrate to 25% of light car & truck sales between 2015 and 2025

Alternative Vehicle Fuels & Technologies Control Strategy

MOVES - C:\EPA\MOVES\scenario.mrs

File Edit Pre Processing Action Post Processing Settings Help

Loaded objects: diesel scenario

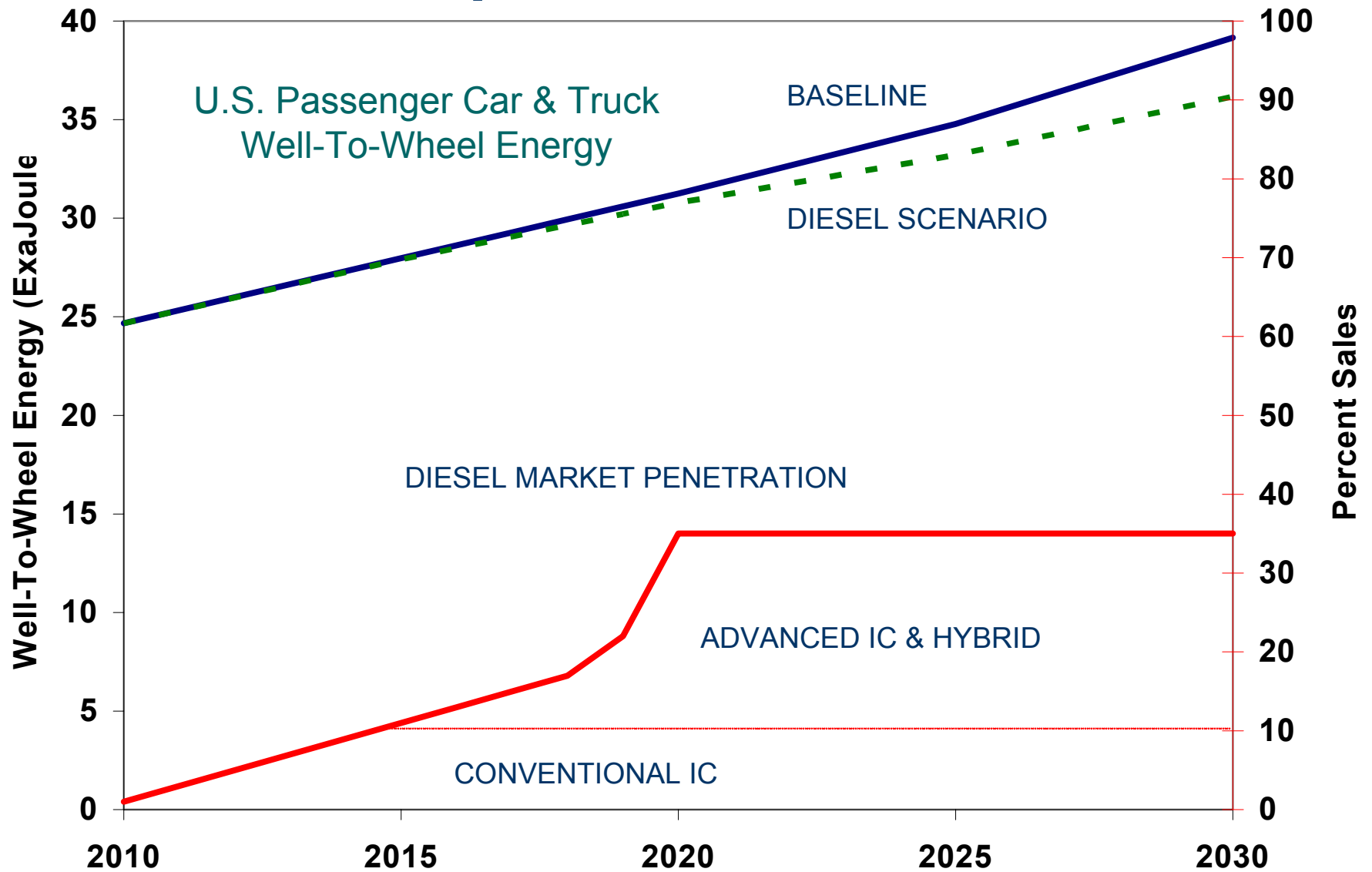
Source Type: 21 Passenger Car

Normalize Add Model Year

	Gasoline Conventional Internal Combustion	Diesel Fuel Conventional Internal Combustion	Advanced Gasoline >>	Advanced Diesel >>	Alternative Fuel >>	Sum
2001	99.70%	0.08%	0.18%	0.00%	0.04%	100.00%
2002	99.51%	0.07%	0.38%	0.00%	0.04%	100.00%
2003	99.10%	0.10%	0.77%	0.00%	0.04%	100.00%
2004	96.37%	0.18%	3.41%	0.00%	0.04%	100.00%
2005	95.95%	0.19%	3.83%	0.00%	0.04%	100.00%
2006	95.17%	0.19%	4.60%	0.00%	0.04%	100.00%
2007	94.11%	0.23%	5.62%	0.00%	0.03%	100.00%
2008	92.95%	0.24%	6.78%	0.00%	0.03%	100.00%
2009	90.86%	0.24%	8.85%	0.00%	0.03%	100.00%
2010	88.19%	1.00%	10.41%	0.36%	0.04%	100.00%
2011	85.09%	2.01%	12.50%	0.37%	0.04%	100.00%
2012	80.88%	4.05%	14.36%	0.67%	0.04%	100.00%
2013	77.43%	5.96%	15.90%	0.68%	0.04%	100.00%
2014	73.58%	7.94%	17.59%	0.85%	0.04%	100.00%
2015	69.84%	9.93%	19.31%	0.88%	0.04%	100.00%
2016	66.36%	9.93%	20.81%	2.86%	0.04%	100.00%
2017	62.87%	9.94%	22.31%	4.85%	0.04%	100.00%
2018	59.76%	9.94%	23.43%	6.83%	0.04%	100.00%
2019	53.57%	9.93%	24.55%	11.91%	0.04%	100.00%
2020	38.88%	9.93%	25.33%	25.81%	0.04%	100.00%
2021	37.58%	9.93%	26.63%	25.82%	0.04%	100.00%
2022	32.84%	9.93%	27.39%	29.80%	0.04%	100.00%
2023	31.10%	10.13%	28.32%	30.40%	0.04%	100.00%
2024	25.97%	10.24%	28.92%	34.82%	0.05%	100.00%

Save active RunSpec

Example Scenario Results



Summary

- **MOVES2004 incorporates many features not in MOBILE, including: a GUI, a relational database system, inventory estimation, well-to-pump analysis, and advanced technology modeling**
- **MOVES national fuel consumption results are close to top-down estimates; state-by-state results vary**
- **MOVES MPG is generally lower than FE trends**
- **Fuel consumption projections are higher than AEO2005 due to differing assumptions regarding technology evolution**

Summary, continued...

- CH_4 and N_2O results are significantly lower than previous inventory due to new emission rates
- MOVES provides many options for “what-if” scenario analysis