Presentation Overview

**Intro:** Reducing LDV GHGs to 80% below 1990 levels
  - Transportation sector-specific emissions data and policy concerns.

**Part 1:** Metrics for the 80% goal: A Pyramid Framework
  - Three Metrics of the Pyramid Framework
    - Vehicle Miles Traveled (VMT)
    - Vehicle Fuel Economy (FE)
    - Fuel Carbon Intensity (CI)
  - Detailed Scenarios
    - VISION tool

**Part 2:** Major LDV GHG Abatement Strategy: A Portfolio Approach
  - Policy interactions and the technology innovation process

**Conclusion:** A multi-faceted policy and technology approach will be required to reach the 80% goal.
Portfolio of Major Transportation Policies that Influence VMT, FE and CI for GHG Reductions

VMT Reduction
• Reduce vehicle miles traveled (VMT) with public transportation, land-use planning, mode switching
• Also: higher fuel prices

Corporate Average Fuel Economy (CAFE)
• Sets an average fuel economy (FE) for new light duty vehicles.

Renewable Fuel Standard (RFS)
• Reduces fuel carbon intensity (CI) through use of biofuels.

Low Carbon Fuel Standard (LCFS)
• Reduces fuel carbon intensity (CI) through use of variety of alternative fuels and vehicles.

Zero Emission Vehicle Mandates (ZEV)
• Increases fuel economy (FE).
Three Metrics Provide a Simple Conceptual Framework: Guiding Equation is $C = \text{VMT} \times \text{CI} / \text{FE}$

National Annual Energy Outlook 'Reference' Metrics for Light-Duty Vehicles

**GHGs in 2008:** 455 MMTCe

**GHGs in 2050:** 692 MMTCe

Factor Increases between 2008 & 2050

- VMT: +80%, FE: +20%, CI: -1% → GHGs: +50%

GHGs in 2008: 455 MMTCe
GHGs in 2050: 692 MMTCe

Reduction Target

AEO 2008

GAP
621 Million Tonnes Ce

LDV GHG Emissions (MMTCE)
What GHG reductions are achievable from reducing each of the 3 metrics?

2 Illustrative Scenarios for the U.S.: ‘GHG-1’ and ‘GHG-2’

• Each GHG scenario achieves the 2050 goal
• Scenarios are illustrative, not predictive
• Intent of scenarios is to demonstrate types of change needed for 80% GHG goal
• Baseline is AEO 2008.

GHG-1: Modest improvements in VMT and FE; CI improvements achieve remainder of 2050 goal reductions

GHG-2: Aggressive improvements in VMT and FE; CI improvements achieve remainder of 2050 goal reductions
Multiple Pathways: A variety of suggestions have emerged with differing emphasis on metrics

Paths to a Large Reduction

<table>
<thead>
<tr>
<th>VMT</th>
<th>FE</th>
<th>CI</th>
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Blue EV
Blue FCV
Blue Conservative
Blue Map
Act Map
McKinsey
Mixed-Tech 80in50
FCV Intensive
PHEV Intensive
FFV Intensive

**Source:** DRAFT NREL Analysis

**IEA**
Blue Map - 70%
Act Map - 45%
International goal for 2050

**McKinsey** - 40%
National goal for 2030

**U.C. Davis** - 80%
National goal for 2050

**NREL** - 80%
National goal for 2050
Specific scenario characteristics can be elucidated with Argonne’s VISION model.

Argonne model for estimating **fleet-wide energy use**, **oil use** and **carbon emissions**. Inputs include:

- Advanced vehicle market penetration, VMT/LDV, Fuel characteristics, New car fuel efficiency, Fuel-Cycle carbon coefficients (from GREET, based on AEO)

VISION’s calculations are based on vehicle survival and age-dependent vehicle usage characteristics.

Market penetration and fuel economy assumptions are determined exogenously (scenario development).
A large number of input options are combined

- **Gasoline**, $CI = 93.4 \text{ gCO}_2\text{e/MJ}$
- **Diesel**, $CI = 93.2 \text{ gCO}_2\text{e/MJ}$
- **Ethanol**, $CI = -10 - 75 \text{ gCO}_2\text{e/MJ}$
- **Hydrogen**, $CI = 15 - 300 \text{ gCO}_2\text{e/MJ}$
- **Electricity**, $CI = 50 - 225 \text{ gCO}_2\text{e/MJ}$
- **Biodiesel**, $CI = 0 - 90 \text{ gCO}_2\text{e/MJ}$

- **Gas ICE**, Efficiency ratio = 1.0
- **Diesel ICE**, Efficiency ratio = 1.2
- **E-85 FFV**, Efficiency ratio = 1.0
- **FCV**, Efficiency ratio = 2.3
- **PHEV**, Efficiency ratio = 3.0

Fleet-wide

VMT, FE & CI
VISION models the entire population of light-duty and heavy-duty vehicles and fuels over time.
VISION is a ‘stock flow’ or ‘bucket’ model that explicitly tracks vehicle and fuel characteristics over time.

![Vehicle Survival in VISION](image)

Source: DRAFT NREL Analysis

![Passenger Car Survivability by Vehicle Age](image)

VISION-CI

Modified version of the Argonne VISION model.
Incorporates fleet-wide average fuel carbon intensity calculations for different fuels and aggregate vehicle fleet scenarios.

Scalable for region-specific analyses.
Capable of storing and analyzing multiple regions and technology scenarios.
Currently incorporating data for California, Texas and on a national level.
A work in progress.
Examples of Single Technology Scenarios that would fall within the GHG-2 National Compliance Pathway

<table>
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<tr>
<th>FFV fleet running on Cellulosic</th>
<th>PHEV fleet running on Cellulosic Ethanol and Low-Carbon Electricity</th>
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<tbody>
<tr>
<td>VMT (billion miles)</td>
<td>4,621</td>
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<tr>
<td>FE (mpg)</td>
<td>35.1</td>
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<td>CI (MMTCE/Quad)</td>
<td>4.3</td>
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Producing enough ethanol for this scenario may not be feasible. Current projection for corn stover cellulosic CI is 3.0 MMTCE/Quad.

<table>
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<th>FCV fleet running on Hydrogen</th>
<th>Cellulosic</th>
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<tr>
<td>VMT (billion miles)</td>
<td>4,621</td>
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<tr>
<td>FE (mpg)</td>
<td>42.5</td>
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<tr>
<td>CI (MMTCE/Quad)</td>
<td>5.2</td>
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Current Projection for biomass derived hydrogen CI is 10.22 MMTCE/Quad, and for solar derived 5.67 MMTCE/Quad.

Current projection for a renewable grid CI in 2050 is 22.4 MMtCe/Quad. Assume 37% VMT on electricity.

Many different combinations of vehicles and fuels are conceivable. These are simplified examples of (unlikely) “silver bullet” success stories.

Source: DRAFT NREL 80 in 2050 Transportation Scenario Analysis
The amount of biofuel available for transportation is still unclear.
Considerations

The Transportation Sector is Unique

• Long-term support for a portfolio of transportation-specific policies is key to deep reductions in GHGs

Scenarios developed in VISION elucidate issues to be addressed for achieving 80% in 2050.

No Silver Bullet

• Though support for specific technologies is warranted (e.g., batteries), there is no clear winner among viable long-term, low-carbon vehicle/fuel combinations

• Communication among stakeholders (e.g., autos and fuel suppliers) is key to effective alignment of more stringent policies

Local and Regional Variability

• Due to the broad range of vehicles, fuels, market conditions, and the geographic distribution of low-carbon energy resources, policy impacts will vary from city-to-city and region-to-region
Questions?