Impact of Policy on Fuels RD&D


Center for Automotive Research

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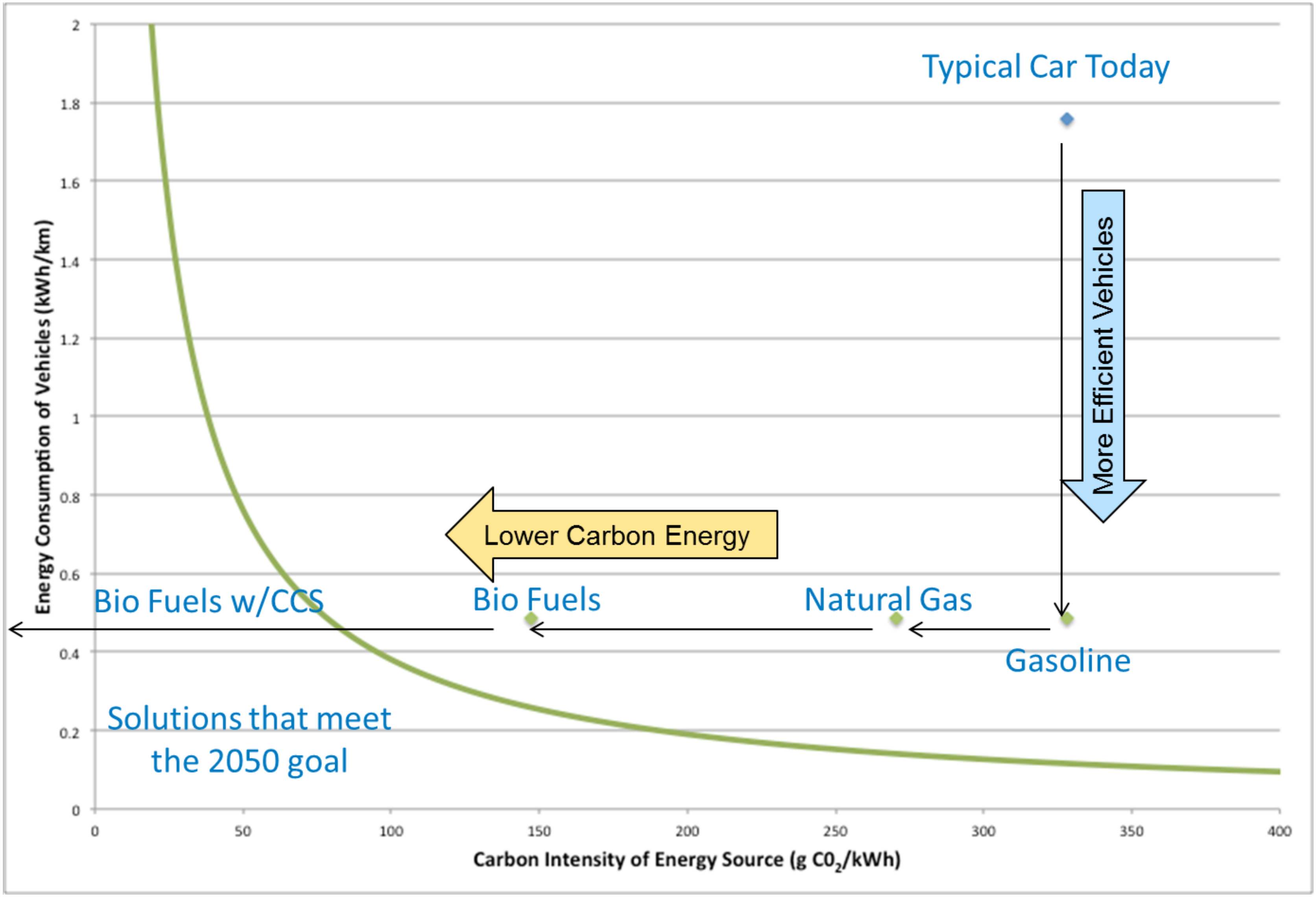
Today's Discussion

- Fuel Policy and Regulation
- Low-Carbon and Energy-Efficient Solutions
- Current Fuel and Engine Efficiency RD&D
- Challenges

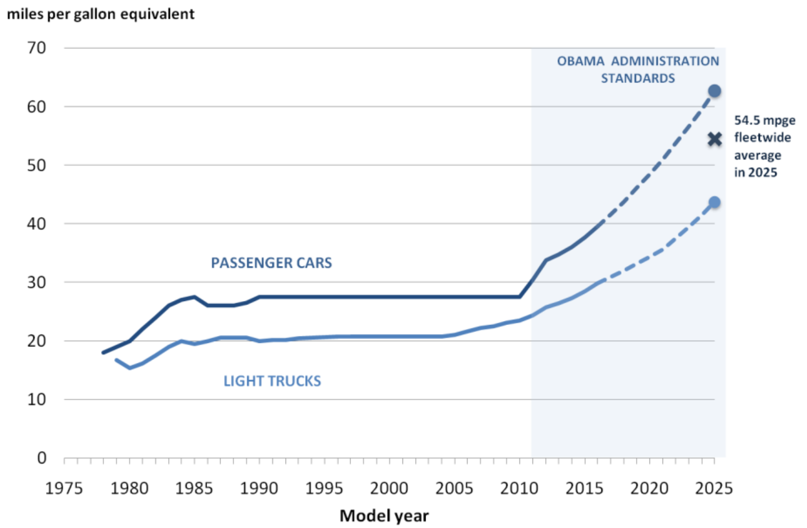
Cover photos by Dennis Schroeder, NREL

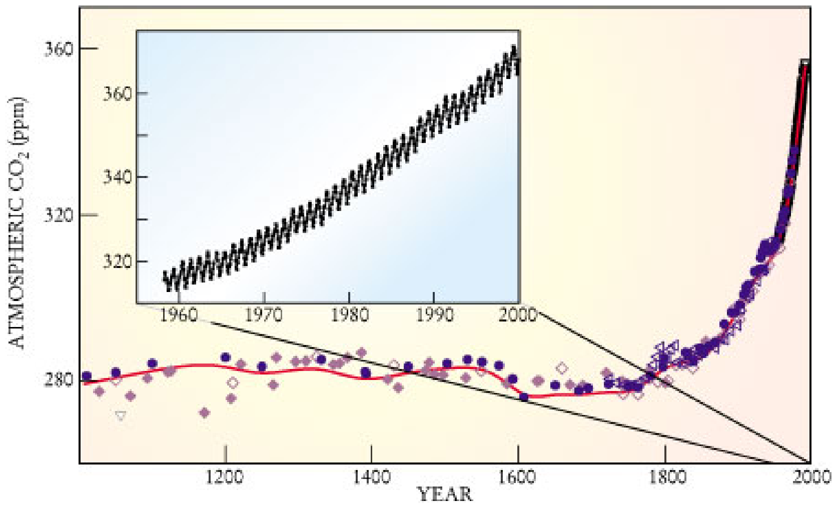
Greenhouse Gas Reduction – Fuels Pathway



Source: *Transitions to Alternative Vehicles and Fuels* (National Academy of Sciences)

Greenhouse Gas Emissions and Fuel Economy Limits





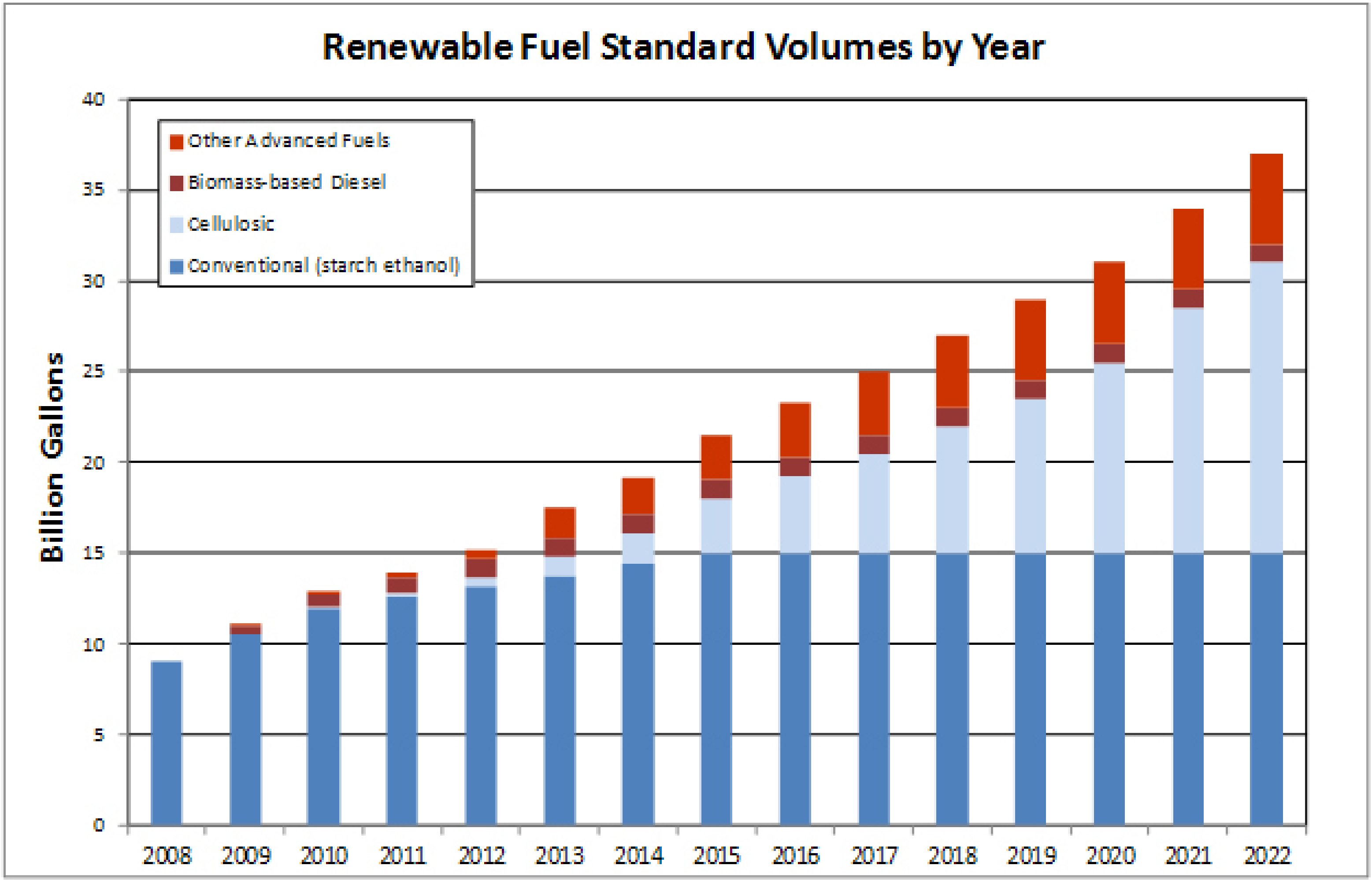
- EPA and NHTSA set standards to reduce greenhouse gases (GHG) and improve fuel economy for model years 2017–2025 cars and light trucks

- Average industry fleetwide level of 163 grams/mile of carbon dioxide (CO_2) in model year 2025 – equivalent to average fleet fuel economy of 54.5 mpg

- GHG emission limit will be met mainly by increasing vehicle fuel economy

Source: *EPA and NHTSA Set Standards to Reduce Greenhouse Gases and Improve Fuel Economy for Model Years 2017-2025 Cars and Light Trucks.* (U.S. Environmental Protection Agency, 2012) http://epa.gov/otaq/climate/documents/420f12051.pdf

Renewable Fuels Standard



Source: Alternative Fuels Data Center. http://www.afdc.energy.gov/laws/RFS

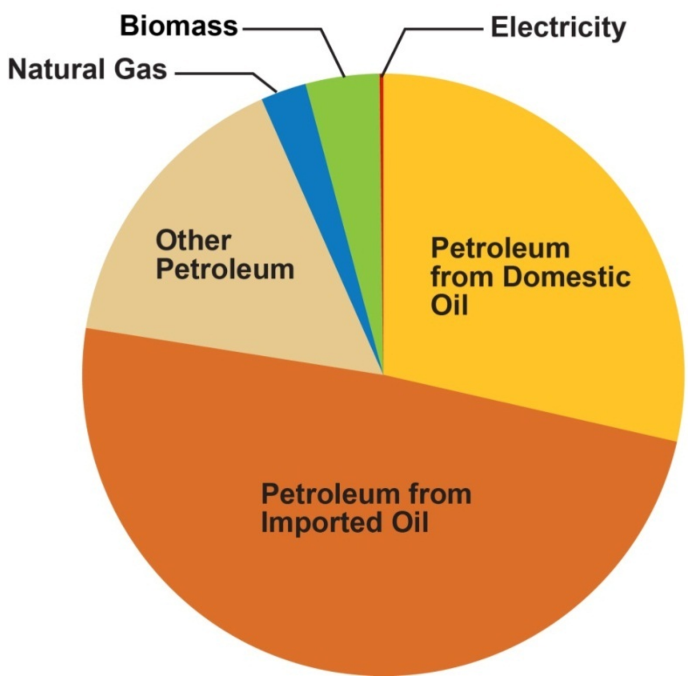
Advanced & Cellulosic Diesel Biofuels

- ***Biomass-Based Diesel and Advanced Biofuel***
  - 50% reduction in GHG emissions, EPA approved
    - Production process path + feedstock path
  - Biomass-based diesel—EPA approved
    - Biodiesel: from soy, canola, animal fat, waste grease, and other
    - Hydrotreated Renewable Diesel: from same feedstocks
  - Other future processes approved by EPA
  - Other fuel derived from cellulosic biomass
- ***Cellulosic Biofuel***
  - 60% reduction in GHG emissions
  - Derived from cellulose, hemicellulose, or lignin

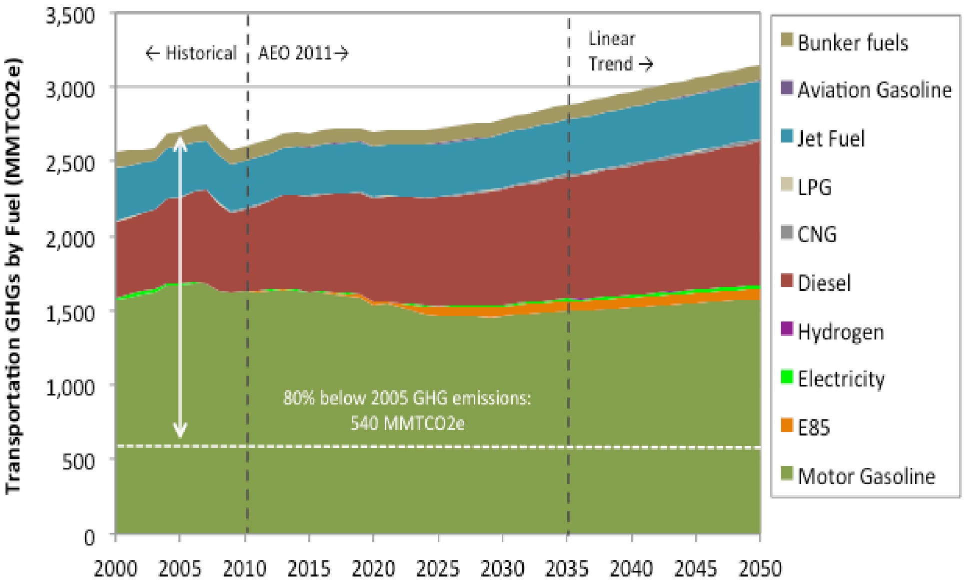
Photos by Warren Gretz , NREL

A Market Dominated by Petroleum

2011 Transportation Fuel Use



GHG Projections by Transportation Fuel Type



Source: Melaina, M.W.; Heath, G.; Sandor, D.; Steward, D.; Vimmerstedt, L.; Warner, E.; Webster, K.W. (2013). *Alternative Fuel Infrastructure Expansion: Costs, Resources, Production Capacity, and Retail Availability for Low-Carbon Scenarios.* Transportation Energy Futures Series.

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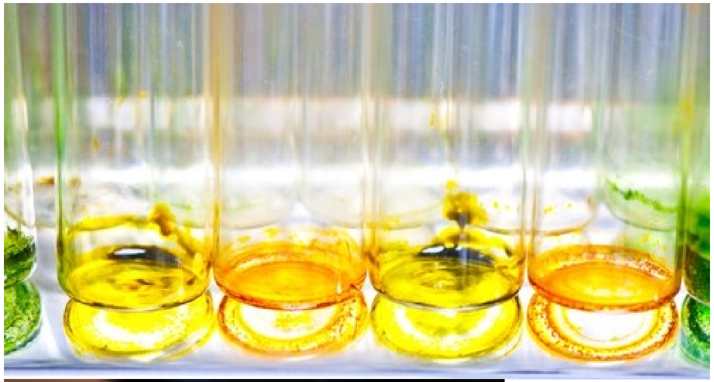
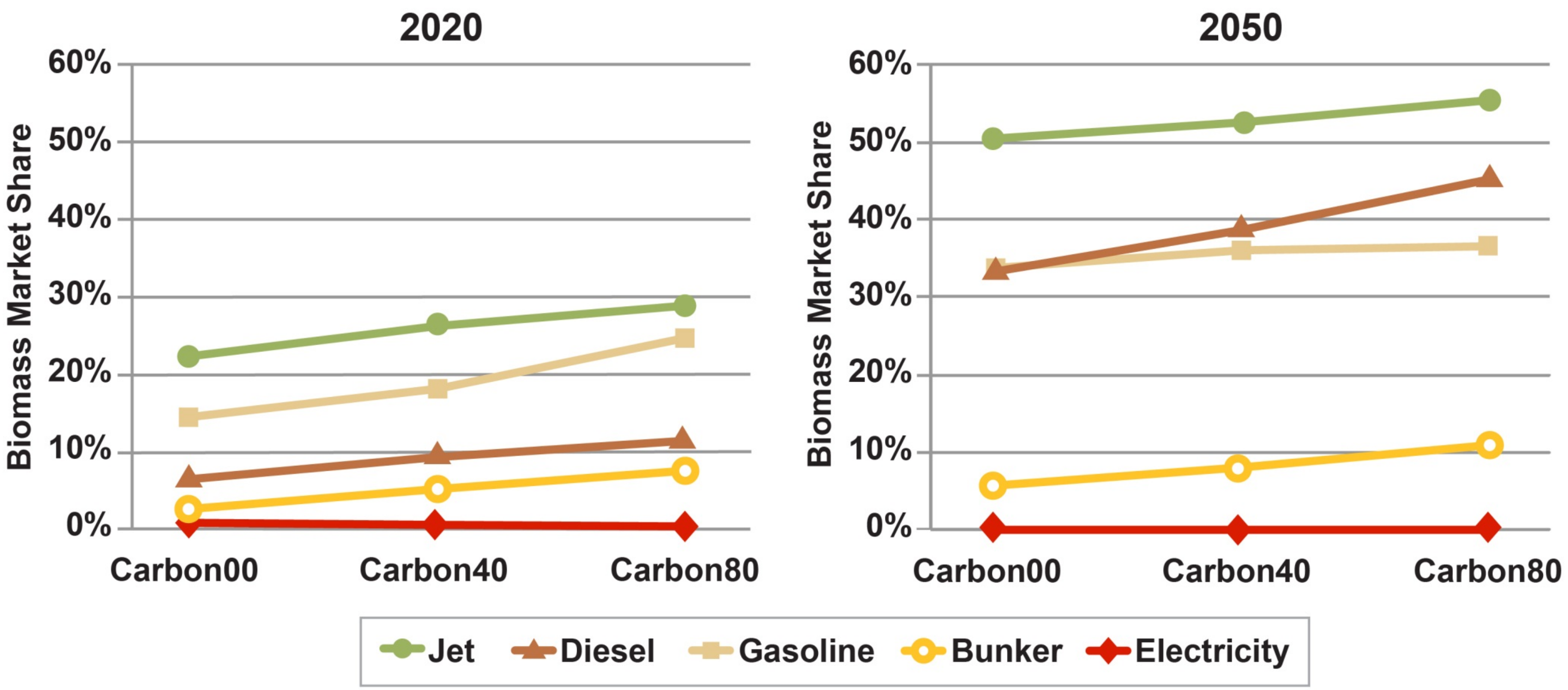
Solution Part 1: Advanced Biofuels

- Cellulosic ethanol
- Renewable diesel
- Advanced biofuels



Photos by Dennis Schroeder, NREL

Displacement Potential



Source: Ruth, M.; Mai, T.; Newes, E.; Aden, A.; Warner, E.; Uriarte, C; Inman, D.; Simpkins, T.; Argo, A. (2013). *Projected Biomass Utilization for Fuels and Power in a Mature Market*. Transportation Energy Futures Series..

Potential of Ethanol for Meeting RFS Targets

- **Ethanol is currently limited to a 10% blend**
  - 15% in 2001 and newer cars
- **Options**
  - Dramatic expansion of availability and use of "flex fuel" (E85)
    - Requires rapid increase in number of flex fuel vehicles (FFVs) and refueling pumps
  - High-level ethanol blends for high compression ratio, high-efficiency engines
    - State and federal regulatory hurdles
    - ASTM standards
    - Not backward compatible (new class of vehicles)

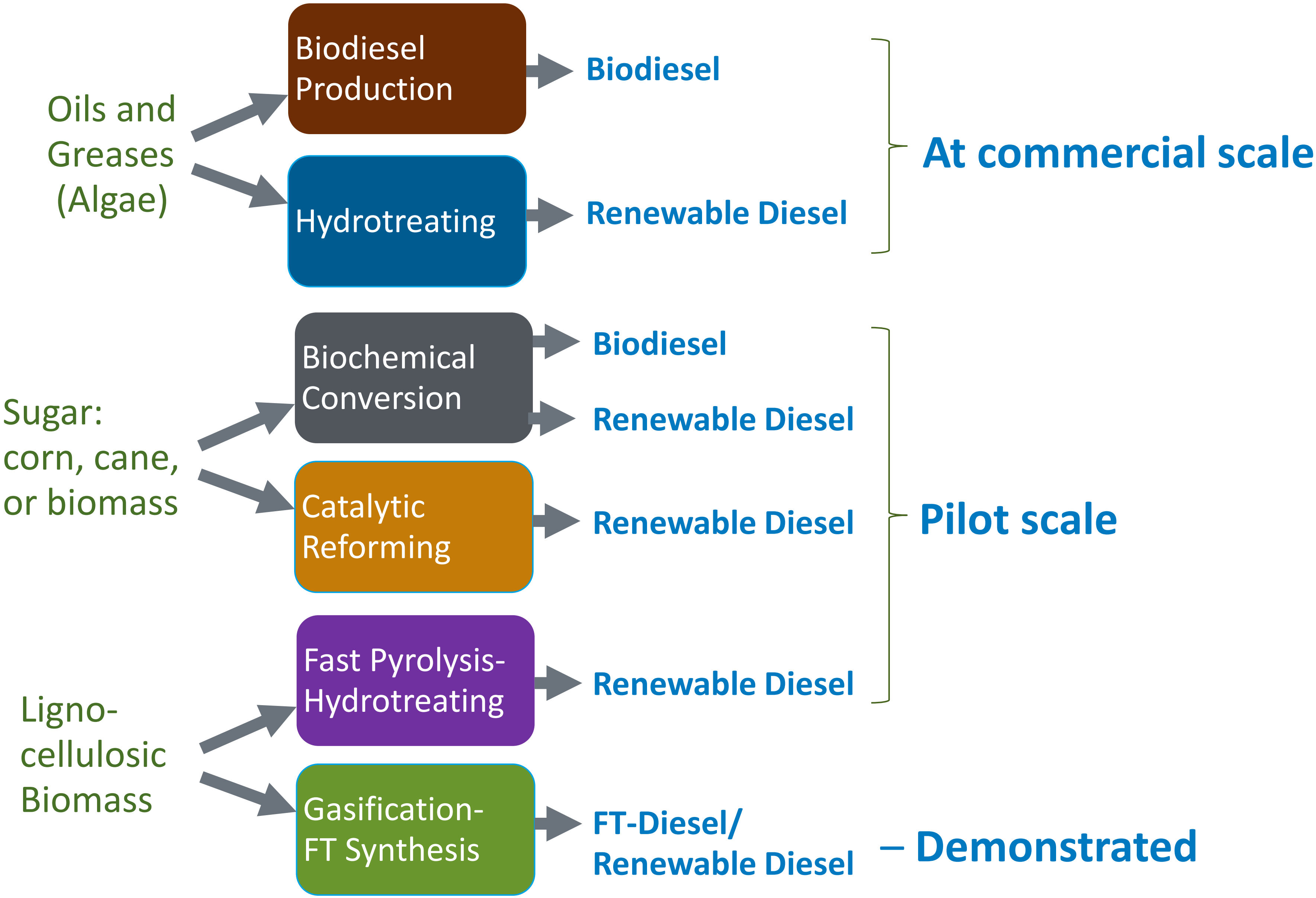
Potential of Biomass-Based Diesel

- **Current production from fats, oils, greases – resource limited to roughly 2.5 billion gallons**
- **Future production from biomass by pyrolysis, sugar dehydration/oligomerization, and fermentation is not yet economical at large scale**



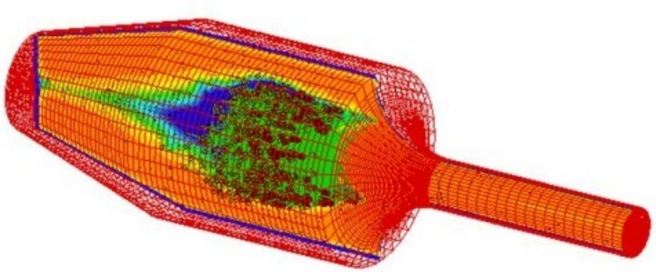
Photos by Warren Gretz , NREL (left & right); Dennis Schroeder, NREL (center)

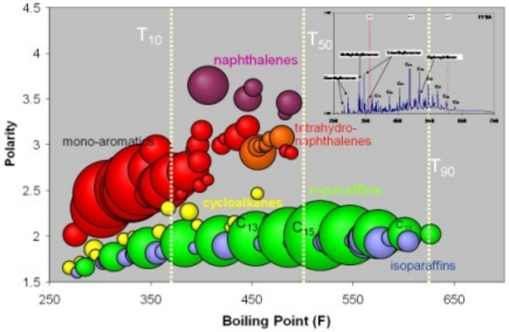
Biomass-Based Diesel Options



Solution Part 2: More Efficient Engines

- SI and CI engine efficiency
- Emissions control technologies
- Advanced fuels
- Blending components





Top photo by Dennis Schroeder, NREL
Bottom photo courtesy of Cummins
Illustration and figure: NREL

Internal Combustion Engine (ICE) Vehicles Have Room for Improvement

A large fraction of energy is lost to friction, unrecoverable heat losses, and vehicle inefficiencies:

- **63.4% engine losses**
- **17.2% standby-idle losses**
- **3.5% driveline losses**
- **2.9% accessories losses**

Approaches to Increasing SI Engine Efficiency

- **Engine downsizing**
  - Smaller engines operating at low speed and higher load are more efficient
  - Optimized with 6- to 9-speed transmission
- **Turbocharging**
  - Recovering energy from the engine exhaust
  - Required for engine downsizing
- **Direct injection**
  - Fuel evaporates in the combustion cylinder, cooling the air-fuel mixture
  - Also required for engine downsizing
- **Increased compression ratio**
  - Greater thermodynamic efficiency

Limiting Factor: Engine Knock

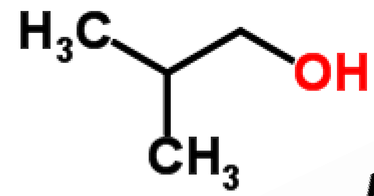
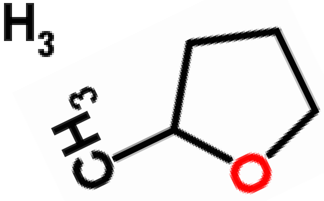
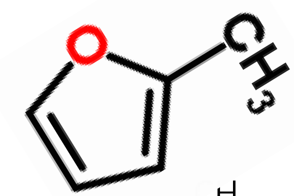
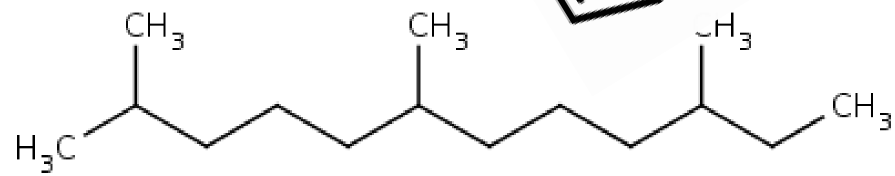
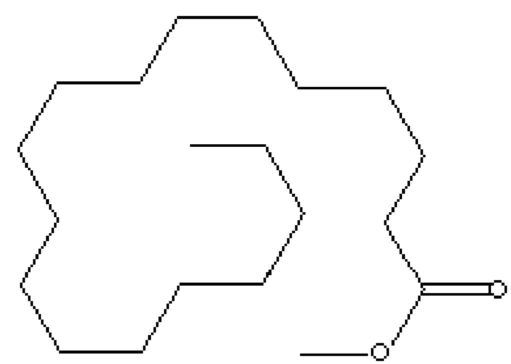
- All of the approaches to increasing engine efficiency require a fuel with higher knock resistance
- Knock occurs when unburned gas auto-ignites ahead of the flame front
- The unburned gas temperature and pressure become too high for the knock resistance of the fuel

Ethanol Has High RON and Heat of Vaporization

- Ethanol research octane number (RON) is higher than that of today's hydrocarbon gasoline
- For direct injection engines, fuel evaporation occurs in the cylinder – cooling the charge and reducing knock tendency
- Alcohols have significantly higher heat of vaporization (HoV) leading to a higher "effective RON"

Challenges in Introducing New Fuels

- **Many steps and years to introduce a new fuel**
  - Higher ethanol level like E30
  - New oxygenate
- **Impact on**
  - Vehicle performance and durability
  - Emissions and emission control system durability
  - Infrastructure compatibility
  - Fuel quality standards
  - Fire codes and safety regulations
  - Consumer protection laws
  - RFS pathway
  - Federal, state, and local regulations/laws

Conclusions

- **Current government policies are driving R&D on more efficient vehicles and low carbon fuels**
  - Cellulosic ethanol: limited by blend wall
  - Drop-in hydrocarbon biofuels
- **Unique knock-resistant properties of ethanol may enable higher efficiency**
  - Combined high RON and high heat of vaporization
  - High GHG emission reduction of cellulosic ethanol (>60% relative to petroleum)
- **Challenges to introduction of ≈E30 blend**
  - Regulatory compliance under Clean Air Act
  - Infrastructure compatibility
  - Introduction of a new vehicle class

Learn more at
www.nrel.gov/vehiclesandfuels

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