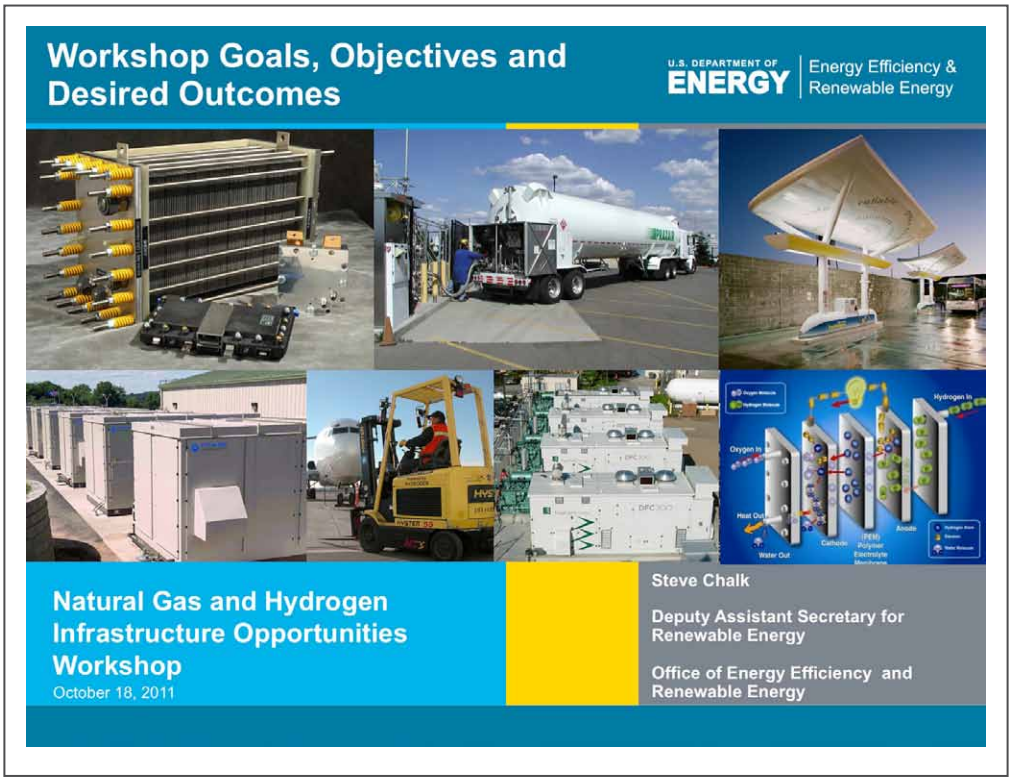
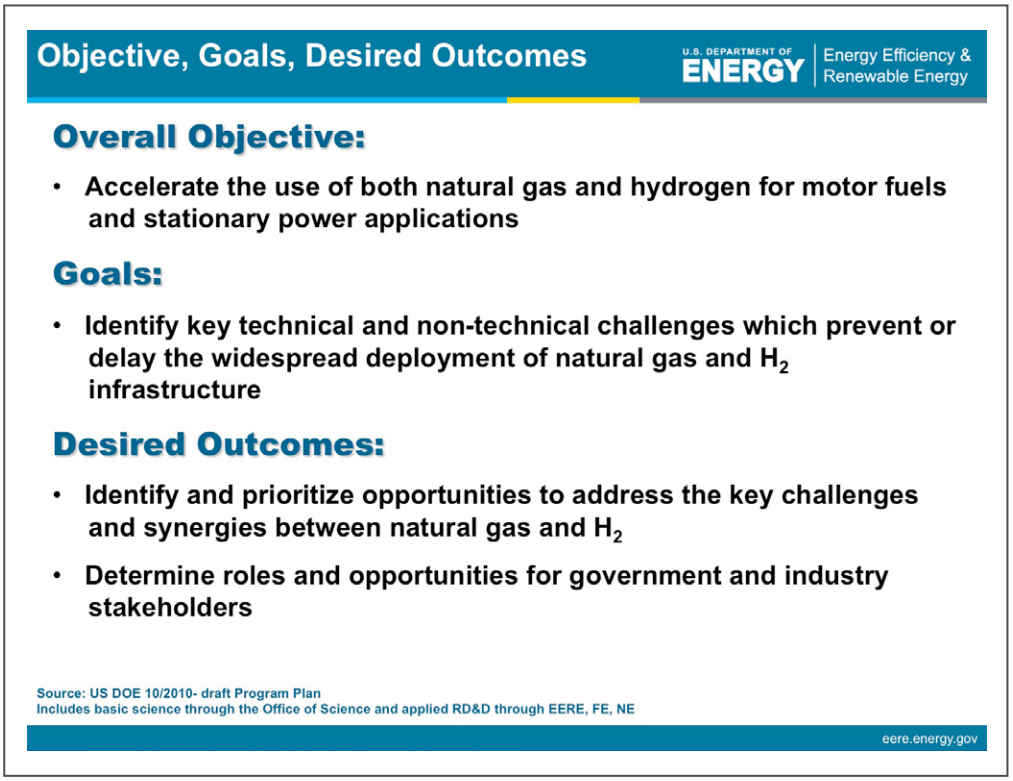
Presentation Slides: Workshop Goals, Objectives, and Desired Outcomes

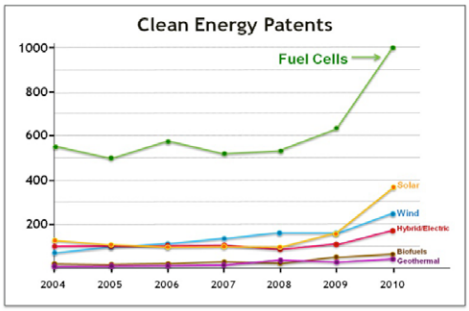
Steve Chalk, DOE





Fuel Cell Patent Growth and Markets

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

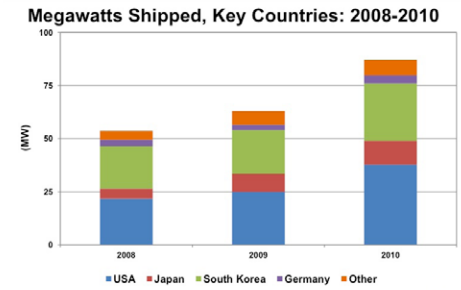


Fuel cell patents lead in the clean energy field with nearly 1,000 fuel cell patents issued in 2010.

- Number of fuel cell patents grew > 57% in 2010.

Fuel cell market continues to grow

- ~36% increase in global MWs shipped
- ~50% increase in US MWs shipped



Various analyses project that the global fuel cell/hydrogen market could reach maturity over the next 10 to 20 years, producing revenues of $14 to $139 billion/year in stationary, portable and transportation sectors.

Widespread market penetration of fuel cells could lead to:
180,000 new jobs in the US by 2020
675,000 jobs by 2035

FuelCells2000, Pike Research, Fuel Cell Today, ANL

http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/program_plan2010.pdf

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Current Program Structure

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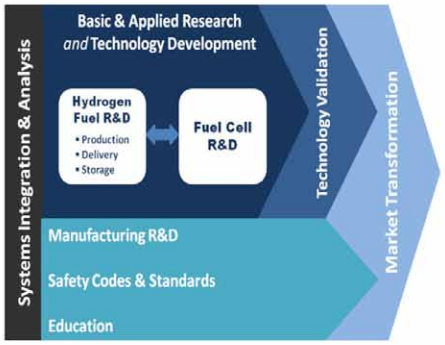
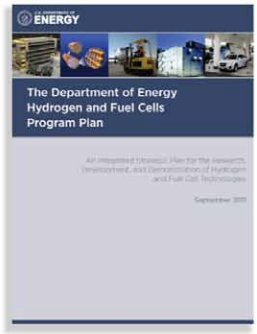
The Program is an integrated effort, structured to address all the key challenges and obstacles facing widespread commercialization.



WIDESPREAD COMMERCIALIZATION ACROSS ALL SECTORS

- Transportation
- Stationary Power
- Auxiliary Power
- Backup Power
- Portable Power

Updated Program Plan detailing strategic RD&D plan released October 2011.



http://www1.eere.energy.gov/hydrogenandfuelcells/

The Program includes activities within the Offices of Energy Efficiency & Renewable Energy, Fossil Energy, Nuclear Energy, and Science.

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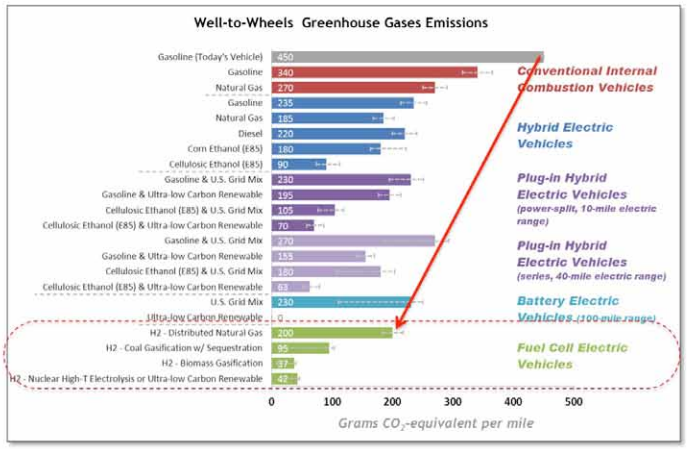
Well-to-Wheels CO_2 Analysis

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Analysis by Argonne National Lab, DOE Vehicle Technologies Program, and FCT Program shows benefits from a portfolio of options



H_2 from Natural Gas

Even FCEVs fueled by H_2 from distributed NG can result in a **>50% reduction in GHG emissions** from today's vehicles.

Use of H_2 from NG decouples carbon from energy use—i.e., it allows carbon to be managed at point of production vs at the tailpipe.

Even greater emissions reductions are possible as hydrogen from renewables enter the market.

Notes:
For a projected state of technologies in 2035-2045. Ultra-low carbon renewable electricity includes wind, solar, etc. Does not include the lifecycle effects of vehicle manufacturing and infrastructure construction/decommissioning.
Analysis & Assumptions at: http://hydrogen.energy.gov/pdfs/10001_well_to_wheels_gge_petroleum_use.pdf

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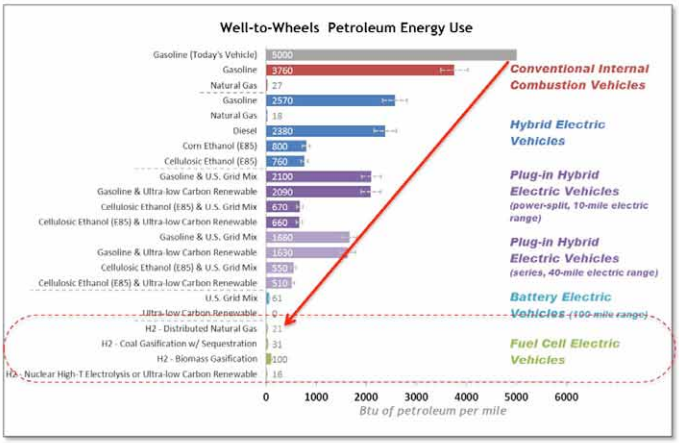
Well-to-Wheels Petroleum Analysis

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Analysis by Argonne National Lab, DOE Vehicle Technologies Program, and FCT Program shows benefits from a portfolio of options.



H_2 from Natural Gas

FCEVs fueled by H_2 from distributed natural gas can almost completely eliminate petroleum use.

1 million FCEVs would only increase current natural gas consumption by **less than 0.2%***

** 1 million FCEVs would require ~1 billion cubic meters/year of NG; current NG consumption is about 600 billion cubic meters/yr*

Notes:
For a projected state of technologies in 2035-2045. Ultra-low carbon renewable electricity includes wind, solar, etc. Does not include the life-cycle effects of vehicle manufacturing and infrastructure construction/decommissioning.
Analysis & Assumptions at: http://hydrogen.energy.gov/pdfs/10001_well_to_wheels_gge_petroleum_use.pdf

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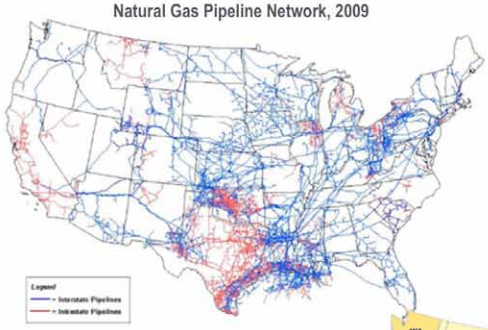
Natural Gas Infrastructure

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Natural Gas Pipeline Network, 2009

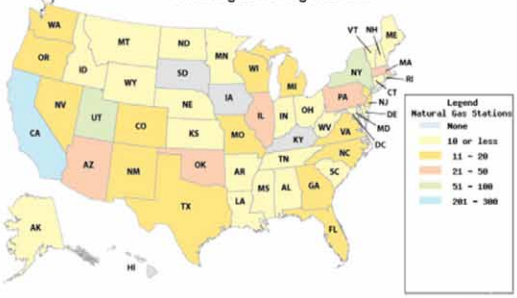


Potential Opportunities:

Cost reduction: Pipelines, compressors, tanks (materials issues), dispensing, onsite reformers)

Non technical barriers: Siting, permitting, regulatory issues, codes and standards

Natural gas fueling stations



Source: Energy Information Administration, Office of Oil & Gas, Natural Gas Division, Gas Transportation Information System

> 300,000 miles of interstate and intrastate transmission pipelines

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Hydrogen from Distributed Natural Gas — *The Near-term Approach*

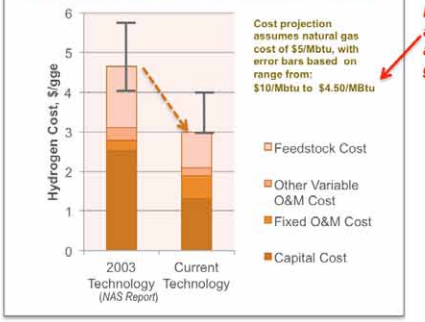
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

DOE-funded efforts have reduced the cost of hydrogen produced from natural gas (at the fueling station) to $3/gallon gasoline equivalent (gge), assuming high-volumes.

Program Success in Distributed NG Reforming:

- Completed R&D phase
- Achieved $3/gge cost for H_2 dispensed at the station *(validated by independent panel*)*
- Near-term option for commercialization has potential to reduce transportation sector GHG emissions by > 50%

Cost of H_2 Produced from Natural Gas—at the Station
(projected to high-volume, includes all station costs)



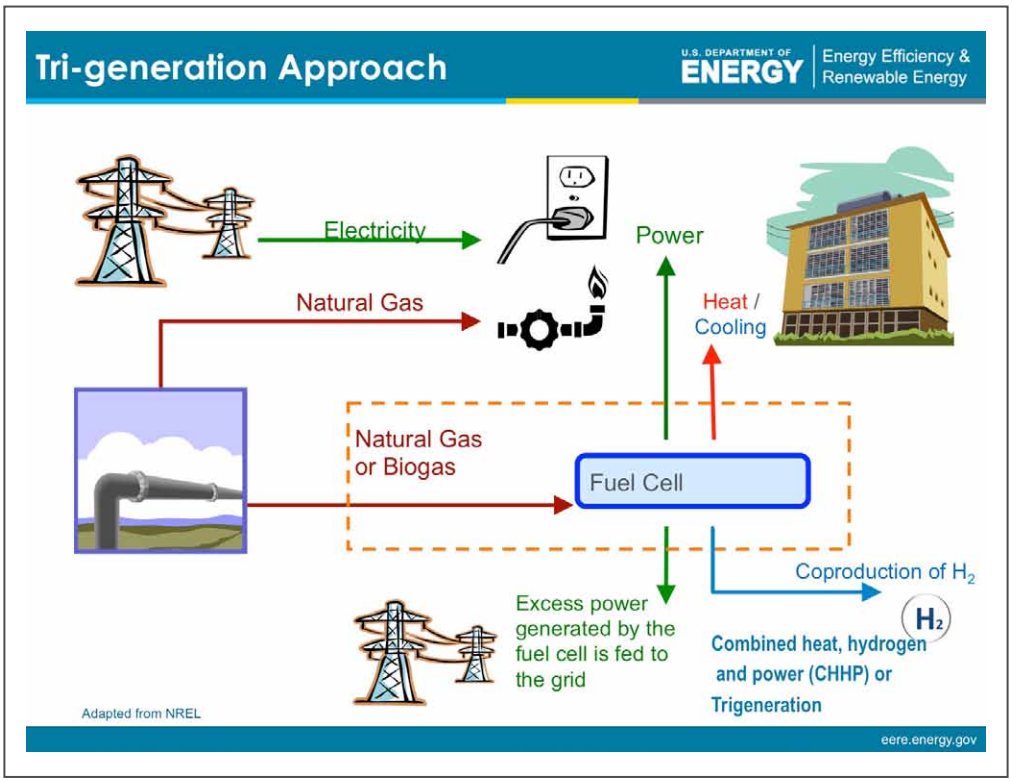
DNG reforming is an affordable option for a range of natural gas prices.

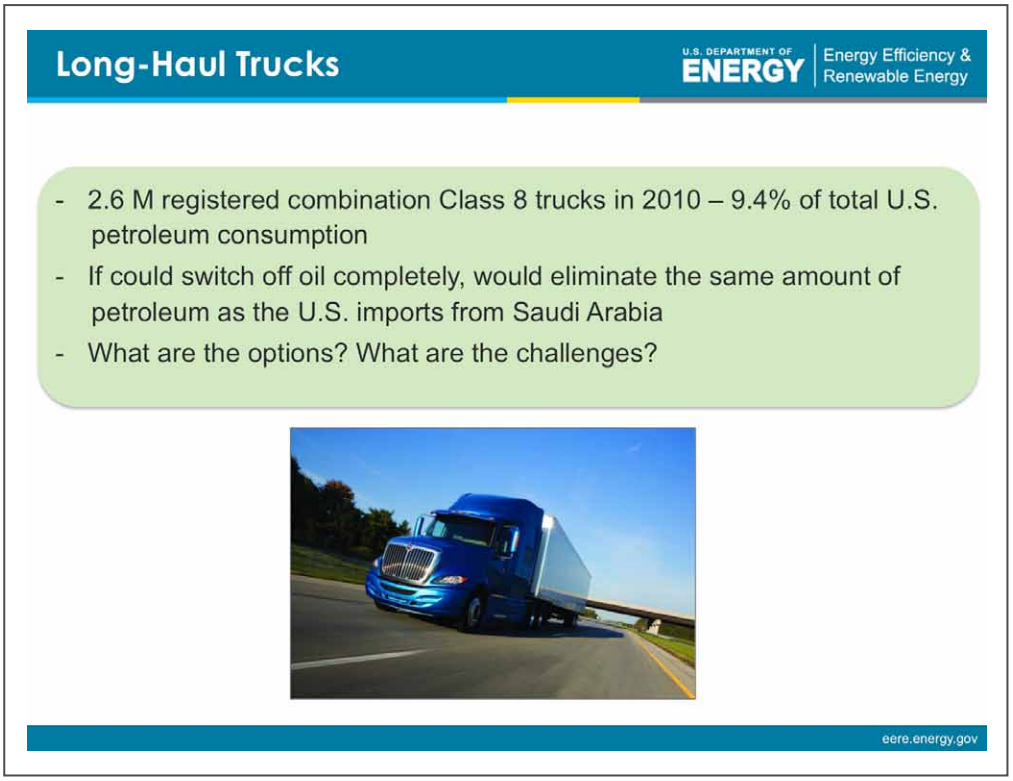
Progress & Plans in Renewable Hydrogen *(all costs assume high-volume production**)*

- **$4.60 – $5.70/gge** for distributed production *(including all station costs)* from electrolysis, pyrolysis oil reforming
- As low as **$2.70/gge** for centralized production from renewables *(high-volume production, at plant gate)*
- **Direct solar conversion** — progress in several pathways *(photoelectrochemical, biological, and thermochemical)*
- **Renewable electrolysis** — **$5/gge or less** if Sunshot and other DOE renewable targets are met
  *(**<$4/gge** with improvements in catalysts and membranes and corrosion-resistant and more-durable materials)*

* Program Record #10001, www.hydrogen.energy.gov/program_records.html.
** Distributed costs assume station capacities of 1500 kg/day, with 500 stations built per year; costs for centralized production assume a range of production capacities, from 50,000 kg/day to 194,000 kg/day.

eere.energy.gov


Tri-generation Approach
U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy
Electricity
Power
Natural Gas
Heat / Cooling
Natural Gas or Biogas
Fuel Cell
Coproduction of H_2
H_2
Excess power generated by the fuel cell is fed to the grid
Combined heat, hydrogen and power (CHHP) or Trigeneration
Adapted from NREL
eere.energy.gov


Long-Haul Trucks
U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy
- 2.6 M registered combination Class 8 trucks in 2010 – 9.4% of total U.S. petroleum consumption
- If could switch off oil completely, would eliminate the same amount of petroleum as the U.S. imports from Saudi Arabia
- What are the options? What are the challenges?
eere.energy.gov

Potential Options

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

	Diesel with Improved Efficiency	Liquefied Natural Gas	Drop-In Biofuels	Electrification
Cost	Vehicle minimal, but fuel prices rising and unpredictable	Vehicle cost is higher, but fuel costs low and more consistent	Vehicle minimal, but fuel not currently at cost	Vehicle cost extremely high; no practical payback period
Energy security	Imported fuel; could reduce demand but not eliminate	Domestic; could completely fulfill need	Domestic could fulfill some need, but aviation may have higher demand	Domestic; will be in-demand for light-duty
Feasibility	High	High	Medium	Low

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Challenges and Responses

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Infrastructure build-out:1,000-5,000 new stations
  - Private industry investing
  - Potential unique financing mechanisms
- Uncertainty of change
  - UPS Recovery Act pilot project
- Secondary market
  - Recovery Act projects in multiple applications
- Vehicle cost differential
  - Potential for further R&D

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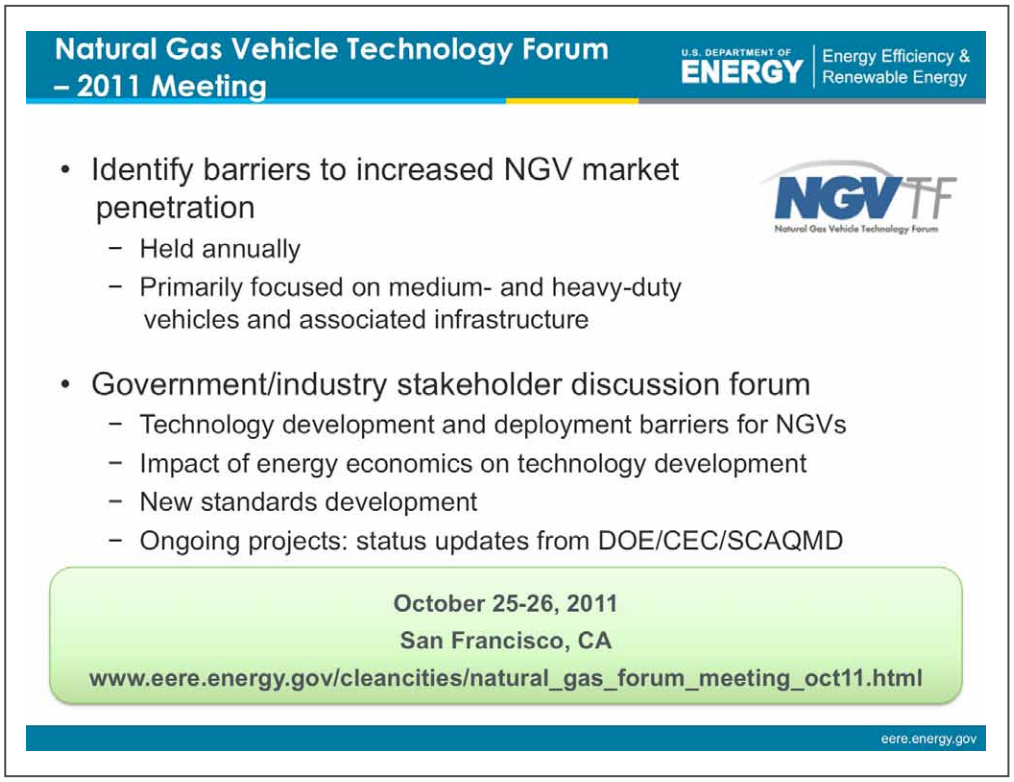
Natural Gas Vehicle Technology Forum – 2011 Meeting
U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy
• Identify barriers to increased NGV market penetration
– Held annually
– Primarily focused on medium- and heavy-duty vehicles and associated infrastructure
NGVTF
Natural Gas Vehicle Technology Forum
• Government/industry stakeholder discussion forum
– Technology development and deployment barriers for NGVs
– Impact of energy economics on technology development
– New standards development
– Ongoing projects: status updates from DOE/CEC/SCAQMD
October 25-26, 2011
San Francisco, CA
www.eere.energy.gov/cleancities/natural_gas_forum_meeting_oct11.html
eere.energy.gov