# Hydrogen Supply/Demand



Energy Efficiency & Renewable Energy



# IEA North American Roadmap Workshop

January 28, 2014

#### **Eric Miller**

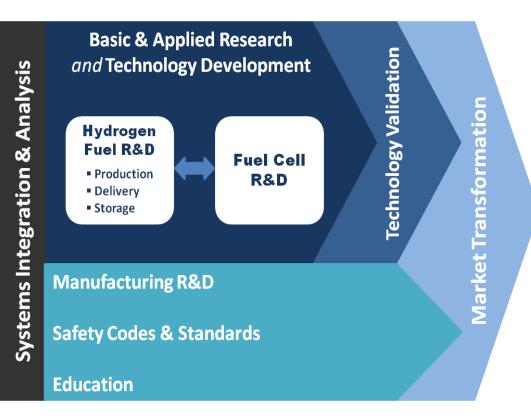
U.S. Department of Energy Fuel Cell Technologies Office Hydrogen Production Technology Manager

# **US DOE Program Overview**



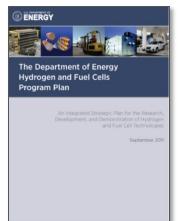
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• The Program is an integrated effort, structured to address all the key challenges and obstacles facing widespread commercialization.



#### WIDESPREAD COMMERCIALIZATION ACROSS ALL SECTORS

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



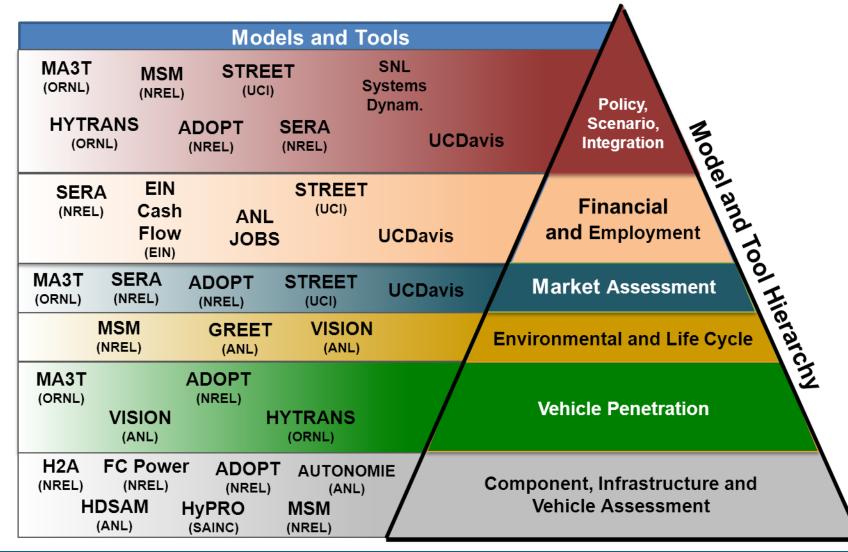
Released September 2011 Update to the Hydrogen Posture Plan (2006) Includes Four DOE Offices EERE, FE, NE and Science

Nearly 300 projects currently funded at companies, national labs, and universities/institutes

# U.S. H2 & Fuel Cell Analysis



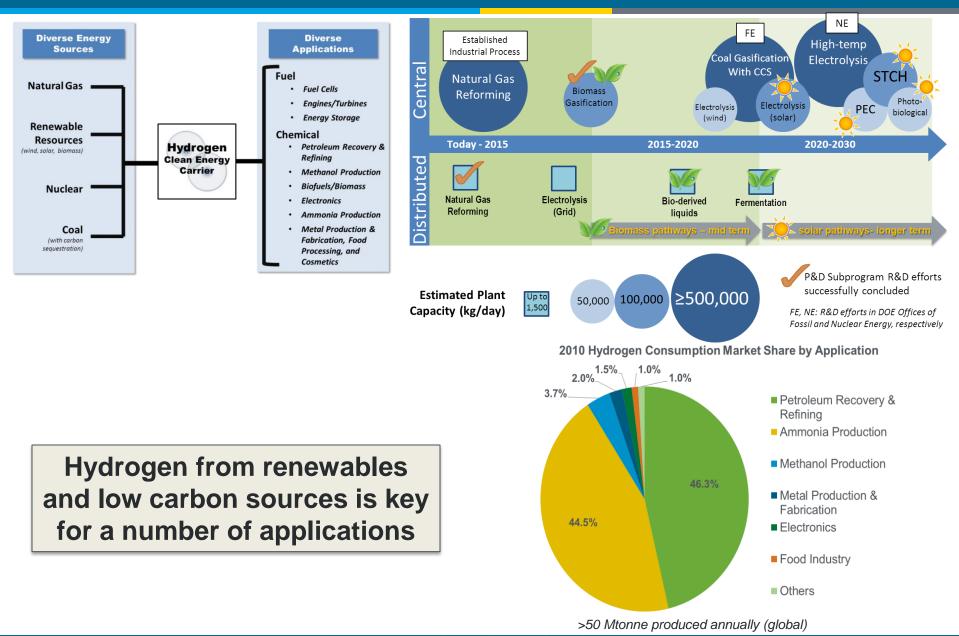
#### DOE's Fuel Cell Technologies Office model and tool portfolio is comprehensive and multi-functional



# Hydrogen: Sources & Applications

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#### Source: US DOE 1/28/2014

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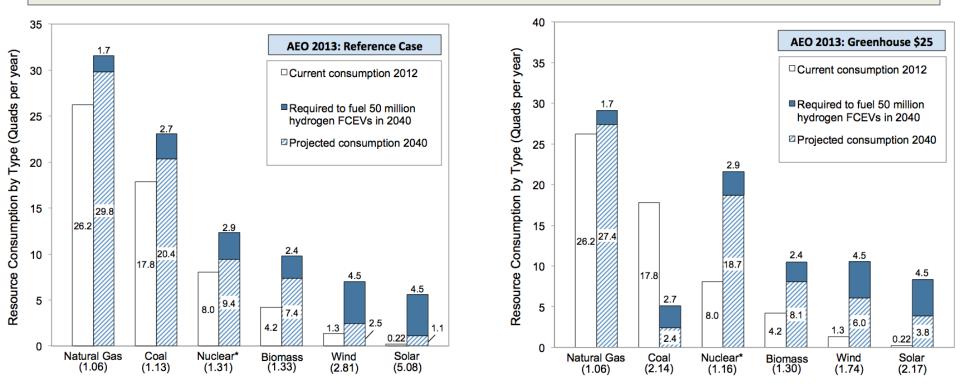
# **Resource Requirements Analysis**



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Hydrogen demand from future market success with FCEVs would not place excessive strain on resources or production capacity for natural gas or coal, would comprise a significant portion of total demand for nuclear and biomass, and would significantly exceed expected demand for wind and solar.

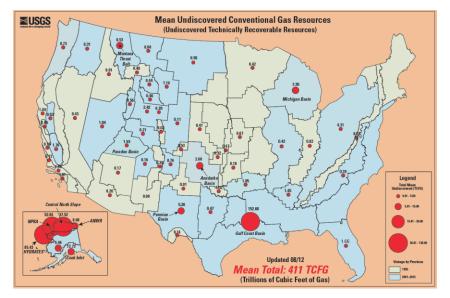
Current and projected *Reference Case* and Greenhouse Gas \$25 Scenario energy consumption across all energy sectors by resource type, with requirements for 50 million FCEVs

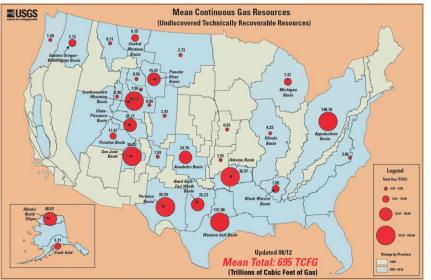


NREL report to be published (Q1 FY2014)

Report identifies percent increase in resources required for 20-50M FCEVs.

## **Natural Gas Resources**





- 304.6 trillion scf in 2010 for proven reserves
  - 61% comes from tight gas, shale gas, and coalbed methane
- 1,930 trillion scf estimate for unproved natural gas reserves
  - 25% shale gas, 22% tight gas, 14%
    offshore of the lower 48 states, and
    14% on- and offshore in Alaska
- Estimates for natural gas shale reserves have grown rapidly, increasing by a factor of 4 between 2008 and 2010
- Adding unproven reserves yields an estimate for total technical and economic potential for natural resources of ~2,200 trillion scf

### **Biogas as an Early Source of Renewable Hydrogen and Power- Preliminary Analysis**

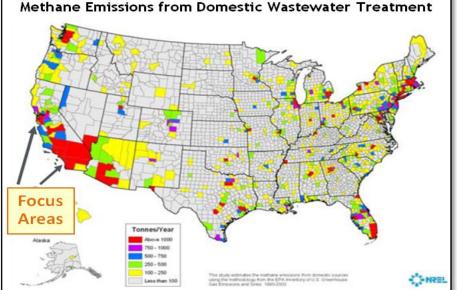
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- The majority of biogas resources are situated near large urban centers—ideally located near the major demand centers for hydrogen generation for hydrogen fuel cell vehicles (FCEVs) and power generation from stationary fuel cells.
- Hydrogen can be produced from this renewable resource using existing steam-methane-reforming technology.

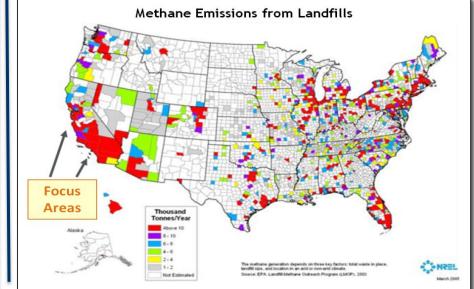
U.S. biogas resource has capacity to produce ~5 GW of power at 50% electrical efficiency.

#### Hydrogen generated from biogas can fuel ~8-13M FCEVs/day.

- 500,000 MT per year of methane is available from wastewater treatment plants in the U.S.
- ~50% of this resource could provide ~340,000 kg/day of hydrogen.

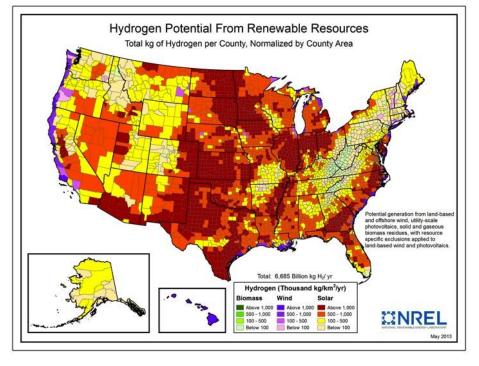


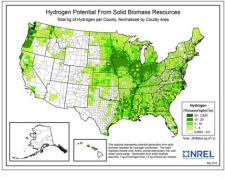
- 12.4 million MT per year of methane is available from landfills in the U.S.
- ~50% of this resource could provide ~8 million kg/day of hydrogen.

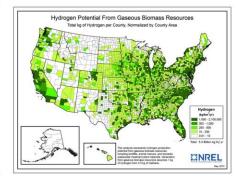


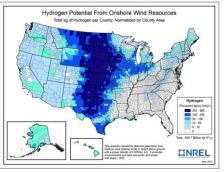
## Hydrogen Potential from Renewable Resources

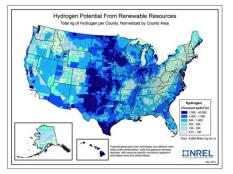
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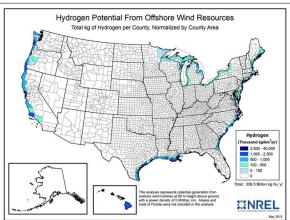


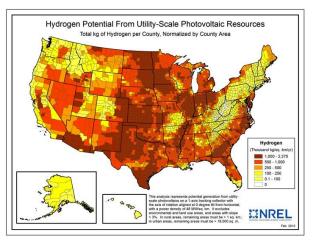












## Major Regional Differences Need to be Reflected in H2 "Roadmap"

#### IEA-HIA Task 30: Global Hydrogen Resource Analysis for the Transport Sector: Key Results

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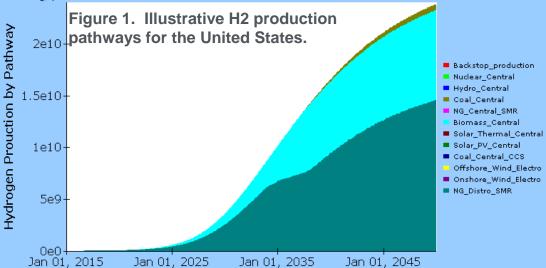
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- Resources are not a limiting factor to a hydrogen economy -- there are a large number of potential pathways for providing hydrogen to fuel a significant FCEV fleet:
- Every participating country has identified options for producing hydrogen domestically or importing hydrogen, where preferred.
- In a low-natural-gas-price world, it is difficult for other feedstocks to compete with natural gas for a share of the hydrogen production in the absence of CO<sub>2</sub> prices or policies limiting its use.
- For a wide range of scenarios, emissions could be lowered 40% 44%.
- Resource, market and policy factors shape the regional 'hydrogen roadmaps'
- Regional 'hydrogen roadmaps' are diverse, but should share common goals & reflect cross-cutting challenges and opportunities
- Significant recent analysis is available from the US (and elsewhere) to support major messaging for regional/ international road-mapping efforts

#### Source: US DOE 1/28/2014

kg/yr Figure 2. Illustrative H2 production Pathway pathways in Europe. Backstop\_production 6e9-Nuclear\_Central Hydrogen Prouction by Hydro Central Coal\_Central NG\_Central\_SMR Biomass\_Central Solar\_Thermal\_Central Solar\_PV\_Central Coal\_Central\_CCS 3e9-Offshore Wind Electro Onshore\_Wind\_Electro NG\_Distro\_SMR 0e0<sup>.</sup> Jan 01, 2015 Jan 01, 2025 Jan 01, 2035 Jan 01, 2045

#### kg/yr





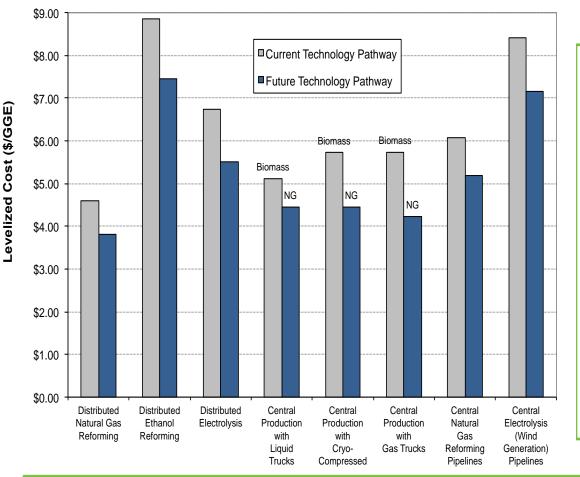
# Backup

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#### Source: US DOE 1/28/2014

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# Hydrogen Pathways Report



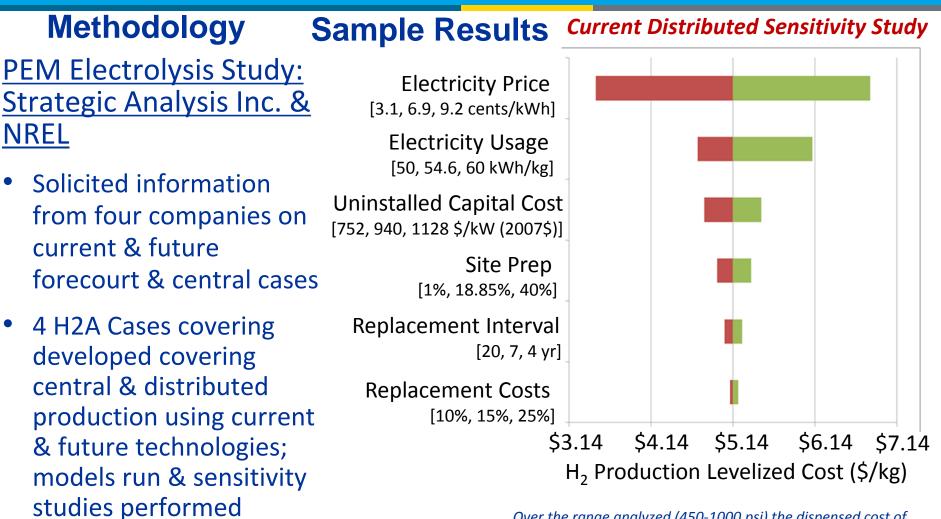
Report Published by NREL

- Life-cycle assessment conducted by NREL of 10 hydrogen production, delivery, dispensing, and use pathways.
- Evaluated for cost, energy use, and GHG emissions. Updates and expands on a previous assessment of seven pathways conducted in 2009.
- Takes a life-cycle approach, addressing both the "well-to-wheels" transportation fuel cycle and also the portion of the vehicle cycle that considers the manufacturing of FCEVs and decommissioning and disposal/recycling of FCEVs.
- Hydrogen production, delivery, and dispensing costs range from \$4.60/kg H<sub>2</sub> to almost \$9.00/kg H<sub>2</sub>.
- Hydrogen production costs are at or near DOE's \$2.00/kg target for four of the production pathways (representing 7 of the total 10 overall pathways evaluated).
- Station CSD costs range from about \$1.00/kg to \$2.50/kg, showing the need for R&D advancements to lower the cost of dispensed hydrogen.

## Technoeconomic Study of PEM Electrolysis using H2A Tool

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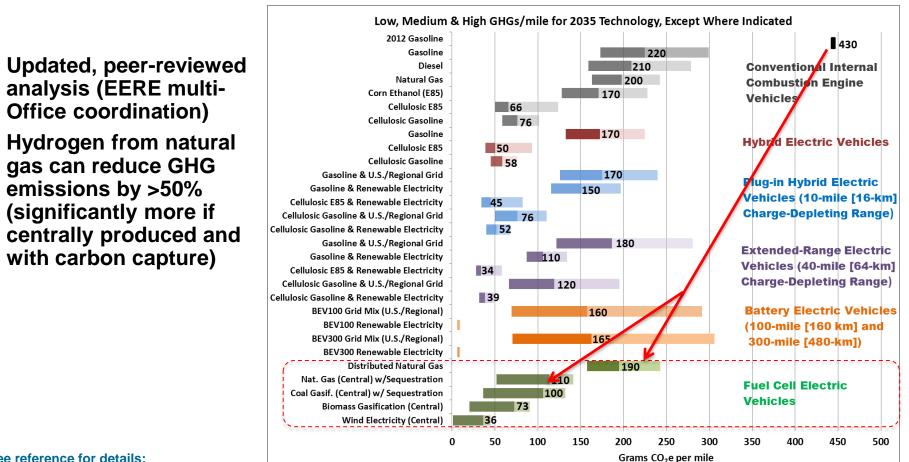
Electricity cost and usage remain key factors in projected H<sub>2</sub> costs



Over the range analyzed (450-1000 psi) the dispensed cost of  $H_2$  appears to be relatively insensitive to production pressure

## Well-to-Wheels GHG Emissions

Analysis by Argonne National Lab, National Renewable Energy Lab and EERE (Vehicles, Fuel Cells, & Bioenergy Technologies Offices) shows benefits from a portfolio of options



Well-to-Wheels Greenhouse Gas Emissions for 2035 Mid-Size Car (Grams of CO2-equivalent per mile)

See reference for details: http://hydrogen.energy.gov/pdfs/130 05\_well\_to\_wheels\_ghg\_oil\_ldvs.pdf

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Low/medium/high: sensitivity to uncertainties associated with projected fuel economy of vehicles and selected attributes of fuels pathways, e.g., electricity credit for biofuels, electric generation mix, etc.