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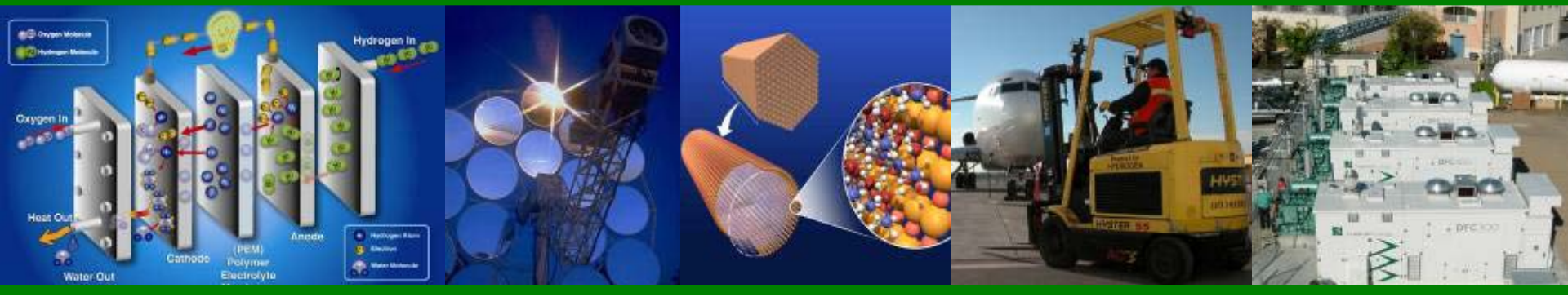

Systems Analysis

Fred Joseck

Lead Technology Analyst

2010 Annual Merit Review and Peer Evaluation Meeting

(June 8, 2010)

Goal & Objectives

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***GOAL*: Provide system-level analysis to support infrastructure development and technology readiness by evaluating technologies and pathways, guiding the selection of RD&D technology approaches/options, and estimating the potential value of RD&D efforts.**

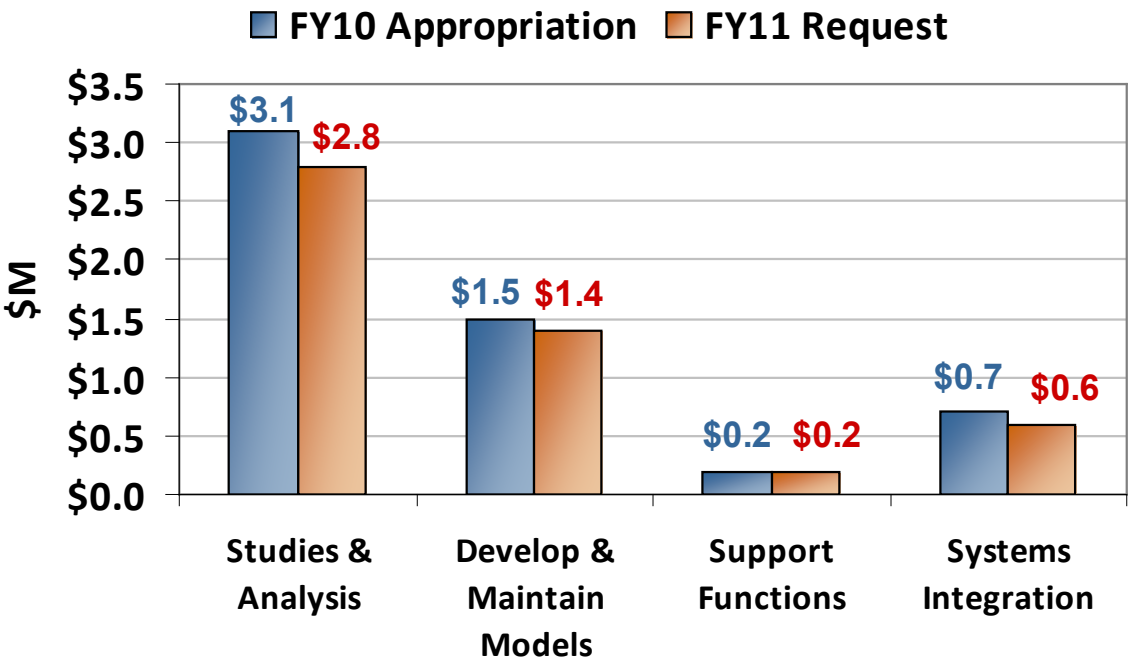
OBJECTIVES

- By 2011, enhance the Macro System Model (MSM) to include stationary electrical generation and infrastructure.
- By 2014, complete environmental studies for technology readiness.
- By 2015, analyze resource requirements, fuel production and infrastructure for penetration of fuel cell vehicles.
- Provide milestone-based analysis, including risk analysis, independent reviews, financial evaluations and environmental analysis, to support Program's needs prior to technology readiness.
- Continuously update well-to-wheels (WTW) analyses for technologies and pathways for the Program to include technological advances or changes.

Budget

FY 2011 Request = $5.0M

FY 2010 Appropriation = $5.5M



EMPHASIS

- Evaluate barriers to and solutions for hydrogen infrastructure development.
- Conduct analysis of renewable resources such as biogas and landfill gas.
- Conduct WTW analysis of criteria pollutants from stationary fuel cells.
- Continue funding for water analysis.
- Complete integration of stationary fuel cells with transportation with the H2A-type power model.

Challenges

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Data inconsistency and market complexities present challenges.

Future Market Behavior

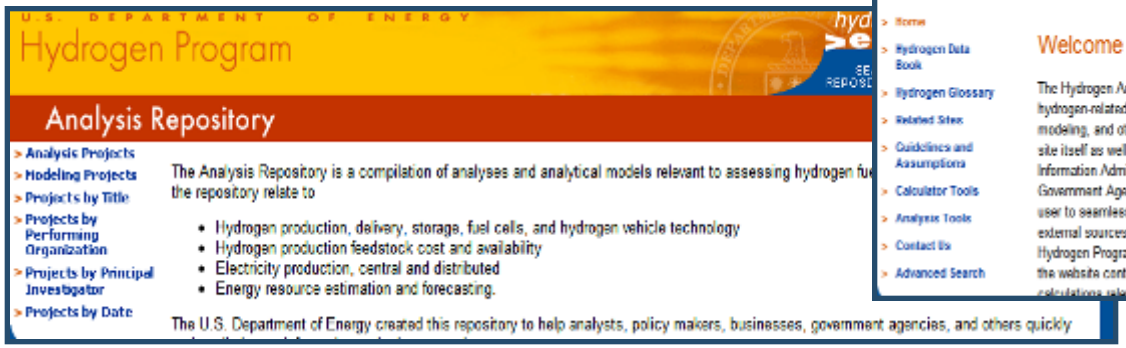
- Understanding of drivers of fuel and vehicle markets needed for long-term projections.
- Models need to adequately address interactions - hydrogen/vehicle supply and demand.

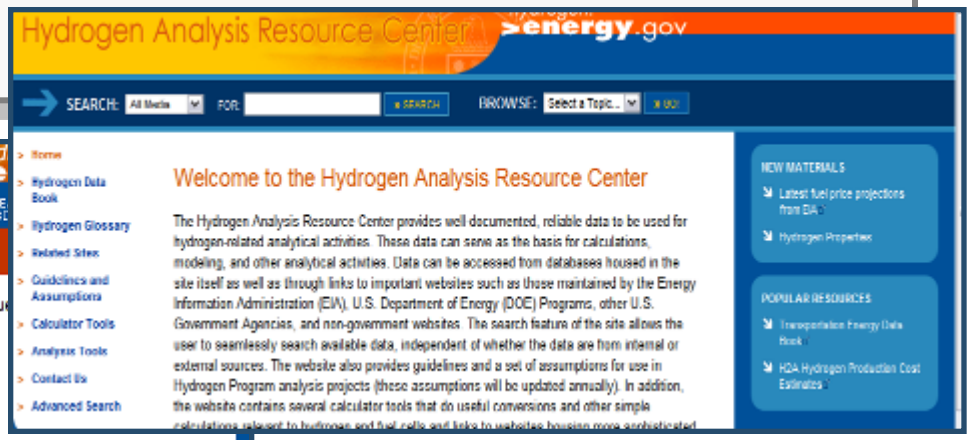
Inconsistent Data, Assumptions & Guidelines

- Analysis results depend on data sets and assumptions used.
- Large number of stakeholders and breadth of technologies - difficult to establish consistency.

Coordination of Analytical Capability

- Analytical capabilities segmented by Program element, organizationally by DOE office, and by performers/analysts.





Types of Analyses

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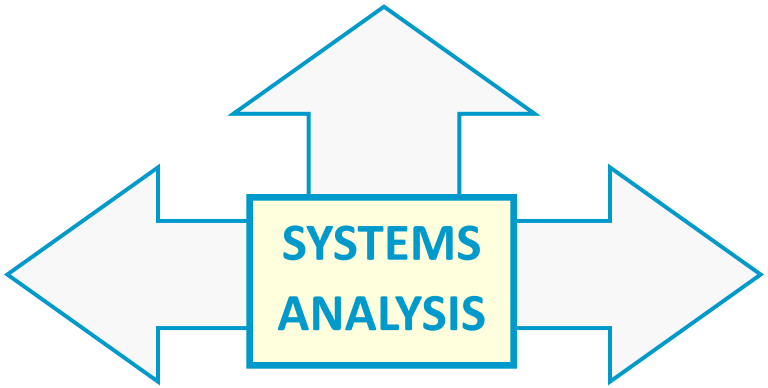
A variety of analysis methodologies are used in combination to provide a sound understanding of hydrogen and fuel cell systems and developing markets, as well as quantifying benefits, impacts, and risks of different hydrogen and fuel cell systems.

MARKETS/BENEFITS & POLICY ANALYSIS

- Energy Market Analysis

TECHNOLOGY ANALYSIS

- Technical Feasibility & Cost Analysis
- Environmental Analysis



IMPLEMENTATION & IMPACT ANALYSIS

- Resource Analysis
- Delivery Analysis
- Infrastructure Development & Financial Analysis

The Role of Fuel Cells in Transportation

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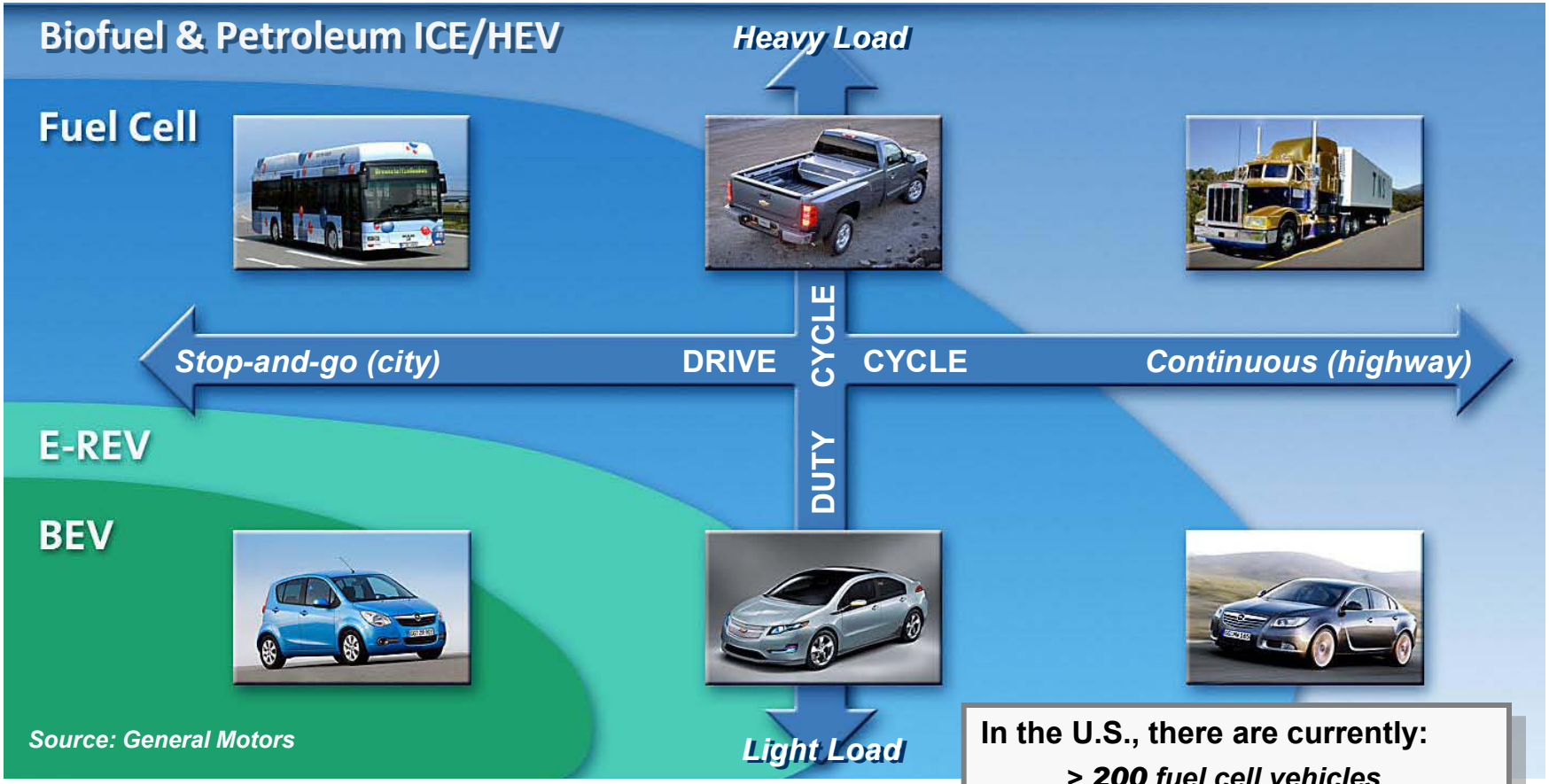
- *A variety of technologies—including fuel cell vehicles, extended-range electric vehicles (or "plug-in hybrids"), and all-battery powered vehicles—will be needed to meet our diverse transportation needs.*
- *The most appropriate technology depends on the drive cycle and duty cycle of the application.*



Source: General Motors

In the U.S., there are currently:

- ***> 200** fuel cell vehicles*
- ***> 20** fuel cell buses*
- ***> 50** fueling stations*

2010 Progress and Accomplishments

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Focus this year:

- Assessing infrastructure build-out needs.
- Optimizing capital costs while enabling favorable market entry conditions.
- Reducing stranded resources and capital.

Addressing barriers and how to overcome them:

- Models and analyses are evaluating value proposition of *combined heat, hydrogen and power (CHHP)* applications.
- Workshop was conducted to evaluate business needs and to develop practical solutions to infrastructure development.
- Techno-economic evaluation performed for using biogas, a stranded resource, to create valuable heat and electricity.

WHAT'S NEW?

- Infrastructure Analysis
- Market Analysis
- Production of H_2 and Power from Biogas
- Model Updates

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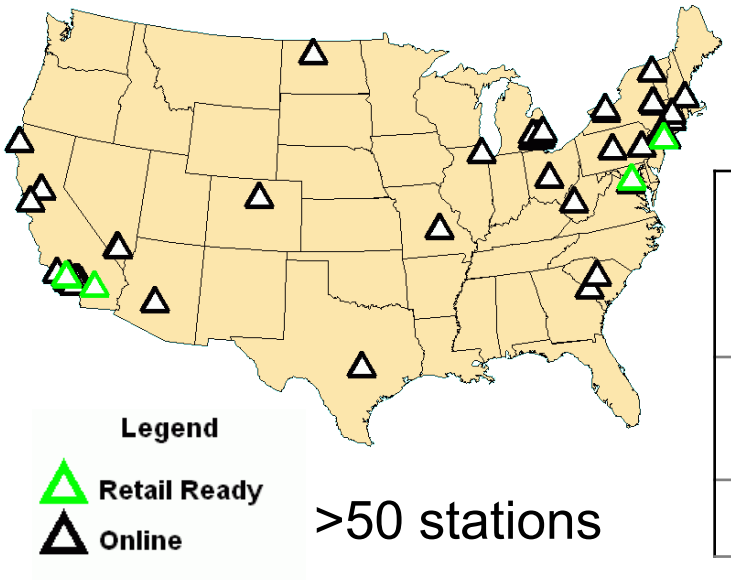
Hydrogen fuel cell vehicles are being introduced in the U.S. and worldwide over the next 5 years. It is essential to have adequate hydrogen fueling stations available to fuel these vehicles.

H_2 Fueling Stations—Enabling 2015 Commercialization:

- Automobile companies have indicated they plan on commercializing hydrogen fuel cell vehicles in 2015 in Japan, Germany and the US.
- An *IPHE Infrastructure Workshop* held in Sacramento, CA on February 25 and 26, 2010 assessed different technology approaches and business cases for station development.



>50 stations

Industry Survey Results from the CA Fuel Cell Partnership*

	Phase 1 (hundreds) 2011	Phase 2 (thousands) 2012-14	Phase 3 (tens of thousands) 2015-17
Pass. vehicles	710	4,300	49,600
Buses	15	20-60	150

* **For details, see full report at:**
http://www.cafcp.org/hydrogen-fuel-cell-vehicle-and-station-deployment-plan

Infrastructure Analysis
H_2 Infrastructure Workshop

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An infrastructure workshop was jointly organized by IPHE, CAFCP, NREL and DOE - to explore market implementation needs for H_2 infrastructure development in near-term and to develop creative and practical solutions.

Objectives – to determine:

- Business cases.
- Number and size of stations needed by 2018-2020.
- Factors that will motivate, hinder, or prevent investments.
- Possible financing scenarios.
- Policies, regulations, etc.
- Opportunities for international programs to leverage their efforts.

Fuel Retailers' Business Environment

- Non-traditional fuel retailers ("big box stores," etc.) gaining market dominance.
- Fuel retailers make profits from their convenience stores, rather than fuel sales.
- Station owners must achieve 3-5 year return on investment to justify investment.
- Consumer demand and gasoline price most important factors in determining investment in alternative fuels.

KEY OUTCOMES

- Develop low-cost, 100 kg/day ***starter station*** model.
- ***Policies:*** including tax incentives, subsidies, gas/carbon tax, low-cost financing, and regulations.
- ***Information and education campaigns:*** for legislators and public.
- ***Risk Reducing Strategies:*** Public/private partnerships, insurance pool, cost-share, OEM commitments.
- ***Innovative ways to boost H_2 demand:*** target fleets and other fuel cell applications, leverage natural gas industry, increase competition.
- ***Novel Business Models:*** seek new methods of financing, leverage existing H_2 industry.

IPHE International Partnership for the Hydrogen Economy

California Fuel Cell Partnership

NREL National Renewable Energy Laboratory

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Infrastructure Analysis
Geospatial and Temporal Evaluations

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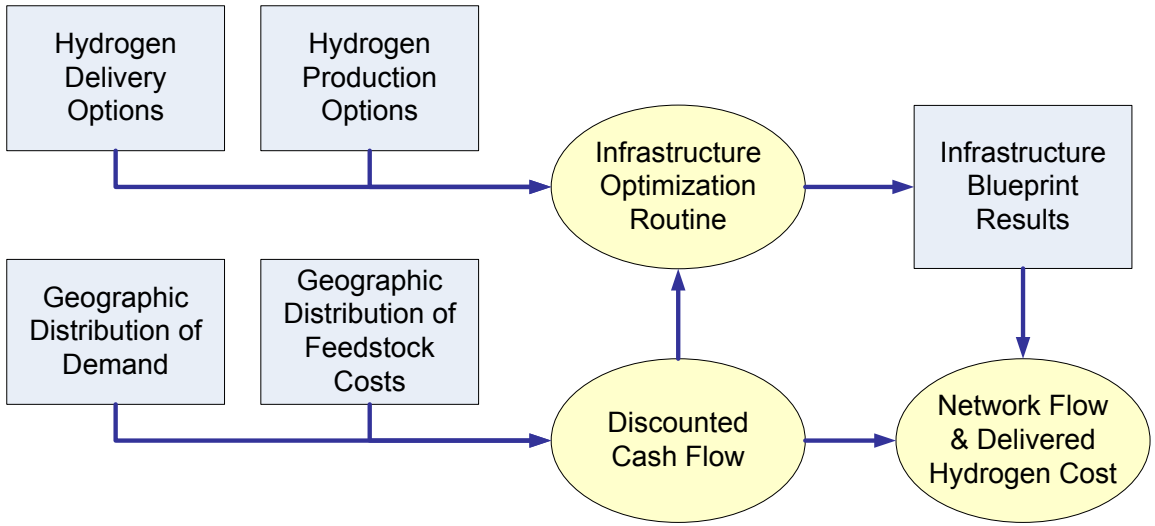
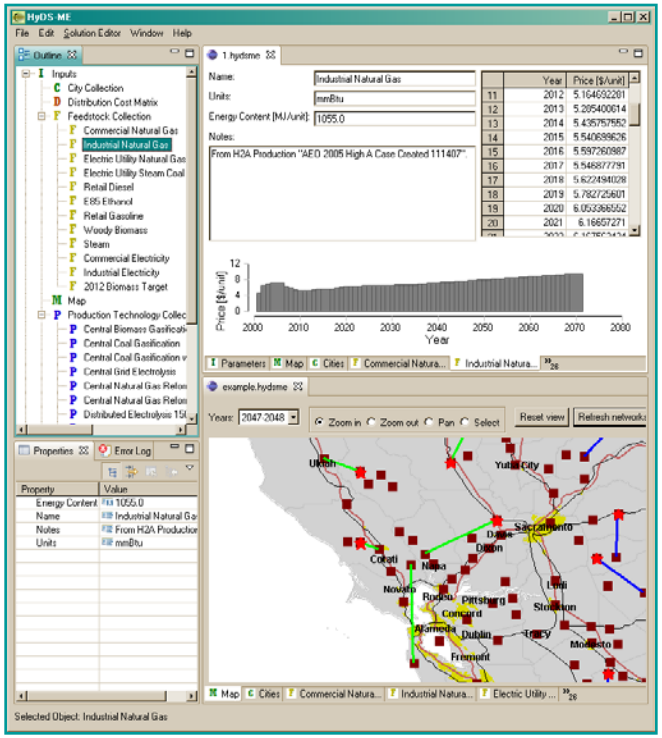
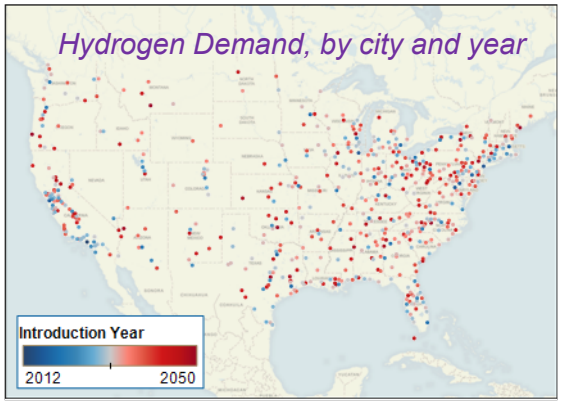
SERA (Scenario Evaluation, Regionalization & Analysis) model searches for optimal combinations of hydrogen production and delivery infrastructure components to meet time-varying demand in multiple urban areas in a given region - given resource availability and technology cost.





Key Analysis Questions

- Which technologies will be used to provide hydrogen during the deployment?
- What synergies are there between production site locations and their distance to potential markets?
- How can cities leverage one another's demand, thereby reducing cost and risk of stranded investments?
- Where can centralized versus distribution production technologies be most effective?



Infrastructure Analysis
CHHP vs. SMR

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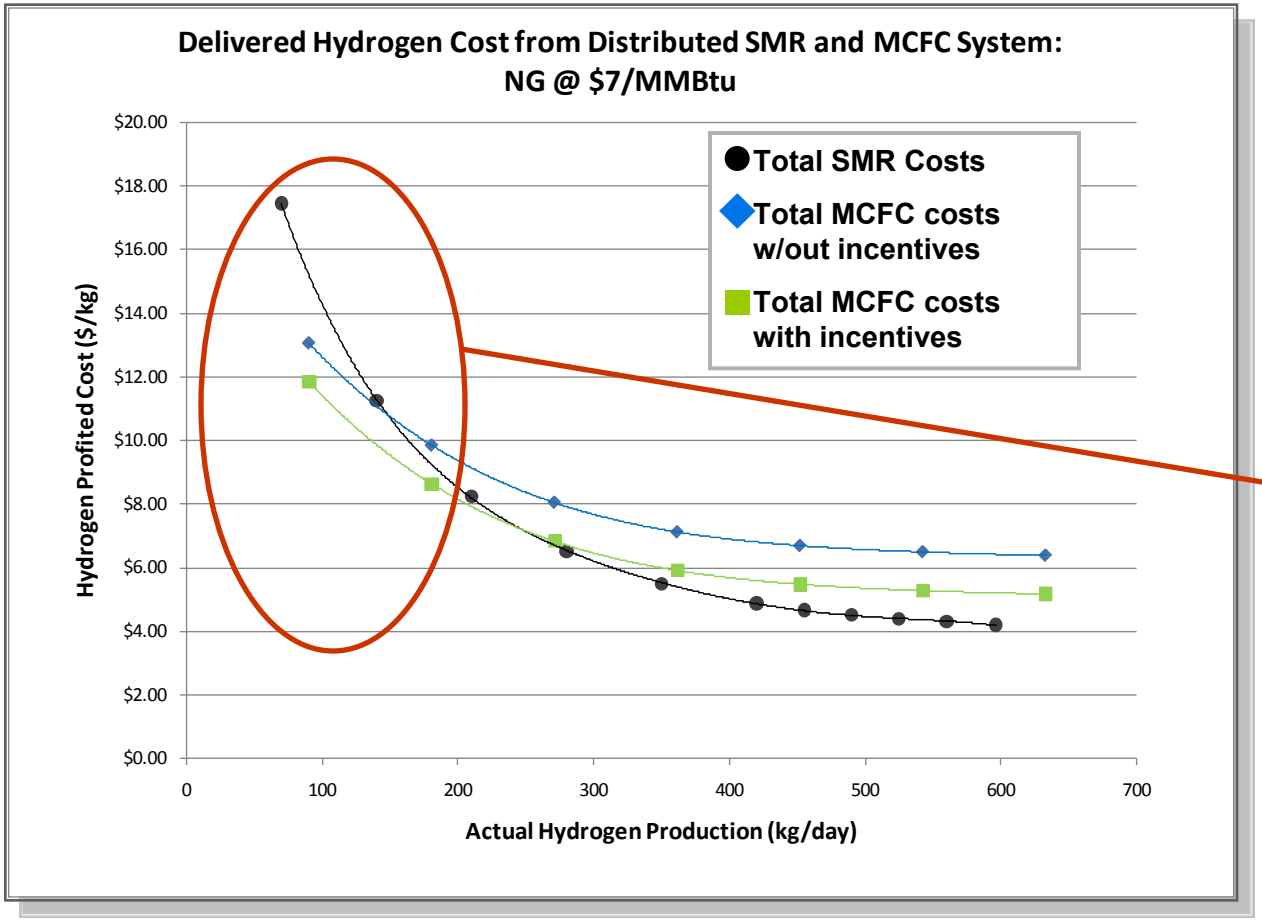
Hydrogen production costs for a stand-alone steam methane reforming (SMR) station and high-temperature CHHP application were compared. Costs are dependent on natural gas costs. CHHP applications may be more cost-effective at lower production capacities.



In cases where there is a low demand for hydrogen in early years of fuel cell vehicle deployment, CHHP may have cost advantages over on-site SMR production.

Source: Fuel Cell Power Model

Market Analysis
Hydrogen and Fuel Cell Industry

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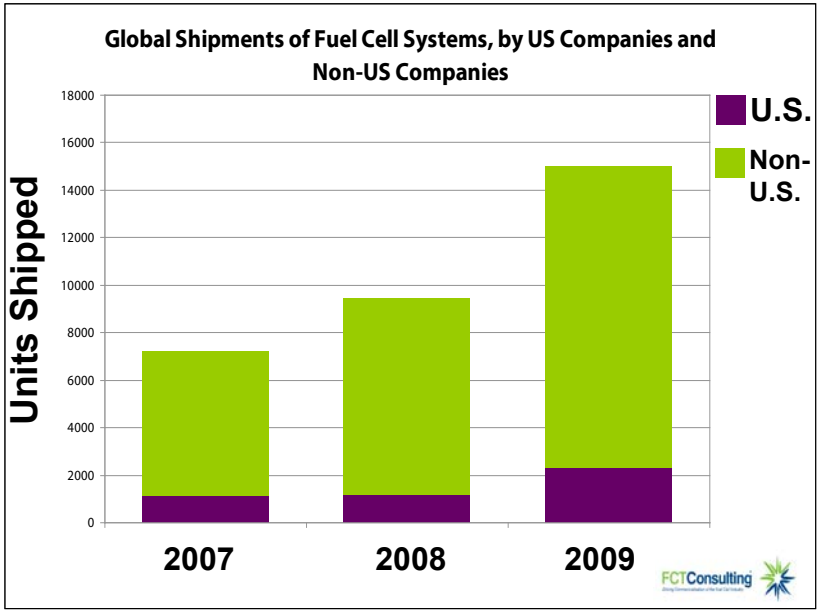
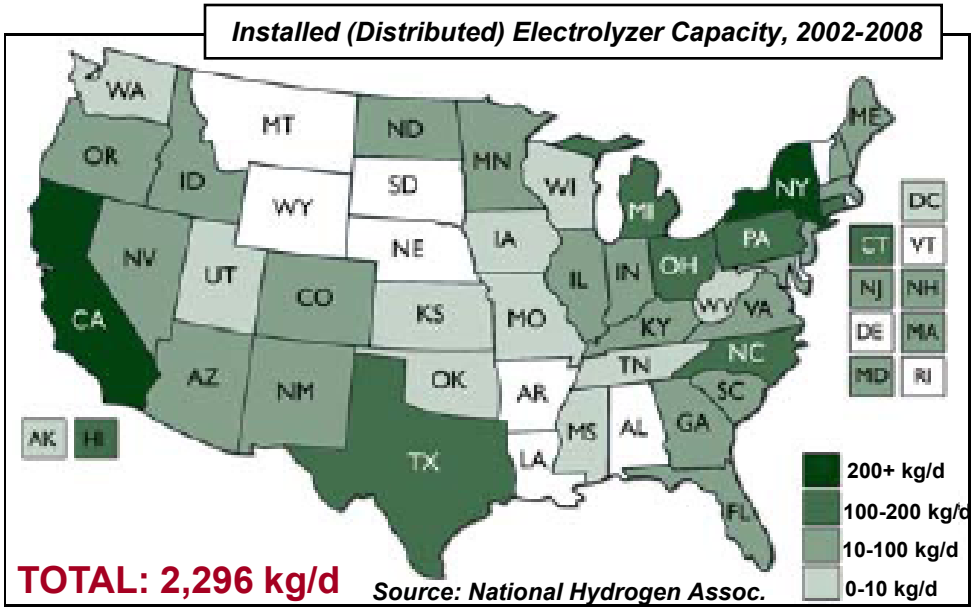
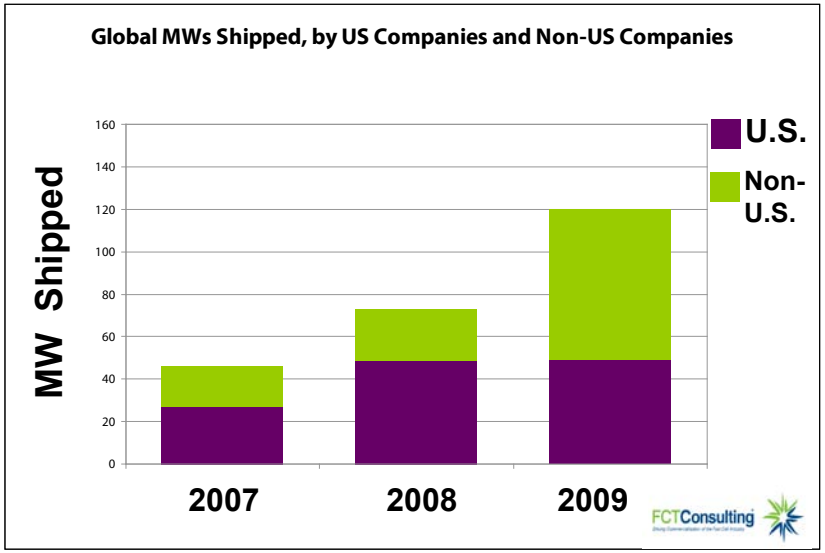
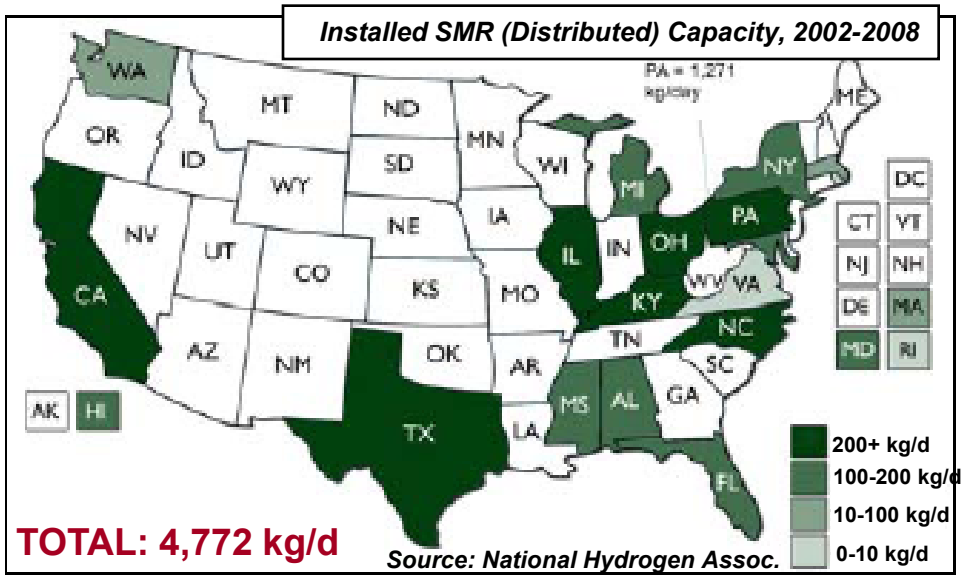
The hydrogen and fuel cell industry is demonstrating a considerable growth pattern while serving key near-term markets.









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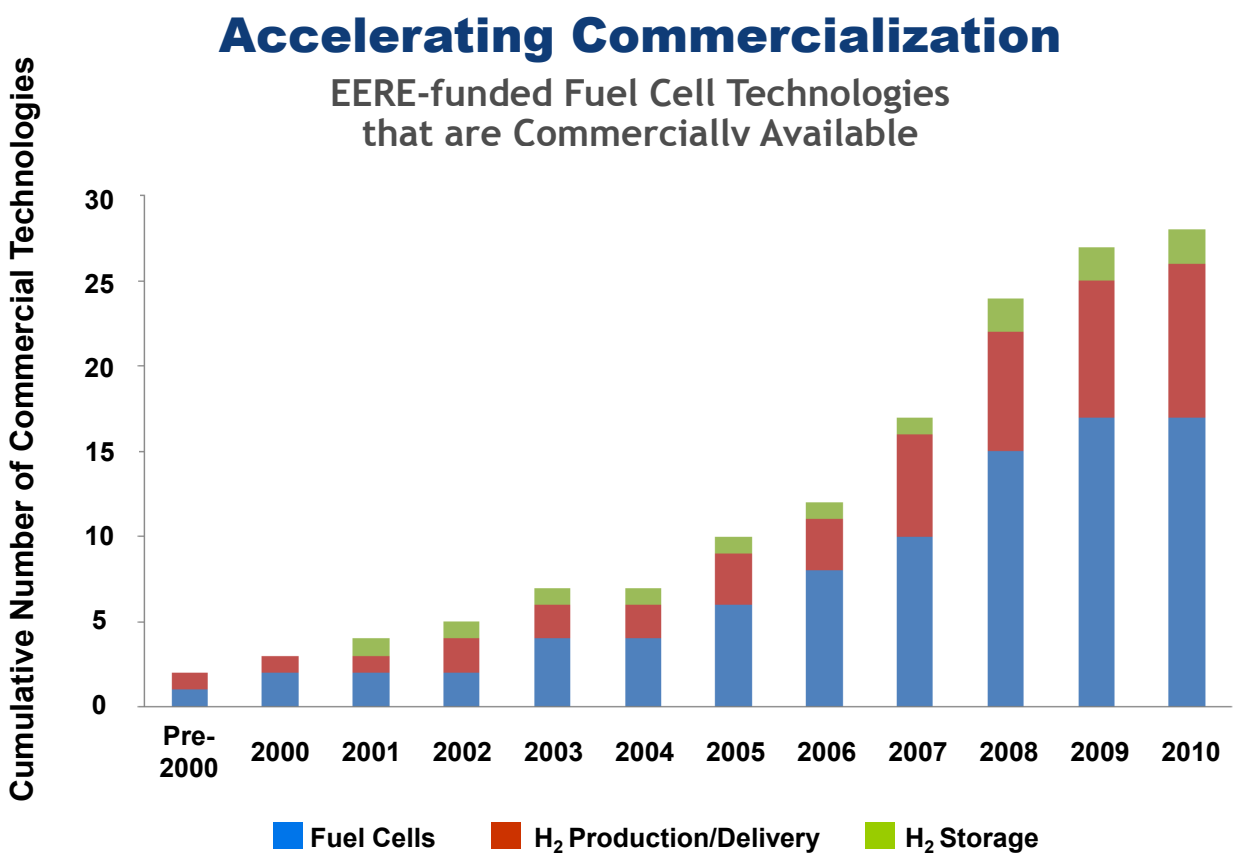
***Close to 30** hydrogen and fuel cell technologies developed by the Program have been entering the market at an accelerating pace.*



143 PATENTS resulting from EERE-funded R&D:

- **73** fuel cell
- **49** H_2 production and delivery
- **21** H_2 storage

Source: Pacific Northwest National Laboratory

Transformation of Biogas to Fuel & Power

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Models were developed to quantify the benefits of fuel cells operating on bio-methane, or hydrogen derived from bio-methane. These applications may mitigate energy and environmental issues and provide an opportunity for the commercialization of fuel cells.

Source

Animal Waste

Landfills

Water Treat. Plant

Production & Cleanup

Anaerobic Digester

Biogas

Clean-Up System

Distribution & Utilization

Reformation / Fuel Cell Systems

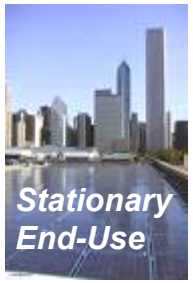
Biomethane

Injection in NG Pipelines

Power Grid

Electricity

Heat



Hydrogen

Vehicle Fueling Station

H2A Production Model
Platform for new cost analysis model aimed at calculating levelized cost of biomethane (from biogas).

Fuel Cell Power Model
Analysis of stationary fuel cell systems—in standalone and CHHP models.

SERA Model
Optimization tool, may also be used for related infrastructure analysis upon modification.

! 13M tons/yr of bio-methane from biogas are available in the U.S. for fuel and power production.

Source: National Renewable Energy Laboratory

Model Updates

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Models are continuously being enhanced to be more inclusive of different factors, reflect near-term technology applications, and maximize communication between different models.

- GREET model updated to include life-cycle consideration of criteria pollutants.
- MSM linked to other models:
  - ***HyPro*** – transient analysis of GHGs and pathway evolution; also allows HyPro to be linked with H2A and HDSAM.
  - ***HyDRA*** – spatial dimension, to create geographically-specific outputs.
- Models incorporating CHHP analysis to be able to comprehend business benefits:
  - Fuel Cell Power Model.
  - New cost analysis model to calculate levelized cost of bio-methane from biogas.

Summary

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- Diverse portfolio and expanded capability of models developed by the Systems Analysis sub-program to address barriers to technology development and commercialization.
- Emphasis on *early market analysis*:
  - Focus on issue of stranded resources in trying to spread capital costs while at the same time creating markets.
  - Comprehensive approach in looking at PHEVs, FCEVs, and the electric sector to realize economic, environmental and social benefits.
- Plans continue to enhance existing models and expand analyses.

FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Complete 2nd version of MSM with electrical infrastructure.	**Complete jobs analysis.**		**Complete analysis and studies of resource/ feedstock, production/delivery and existing infrastructure for technology readiness.**	**Complete analysis of H_2 quality impact on H_2 production cost and FC cost for long range techs and tech readiness.**
Complete analysis of H_2 infrastructure and technical target progress for H_2 fuel and vehicles.				**Complete analysis of H_2 infrastructure and technical target progress for tech readiness.**
Complete risk analysis.				**Complete environmental analysis of tech env impacts for H_2 scenarios and tech readiness.**

Session Instructions

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- Talks will be **20 minutes** and **Q&A 10 minutes**.
- Reviewers have priority for questions over the general audience.
- Reviewers should be seated in front of the room for convenient access by the microphone attendants during the Q&A.
- Please mute all cell phones, BlackBerries, etc.

Feedback from 2009 AMR

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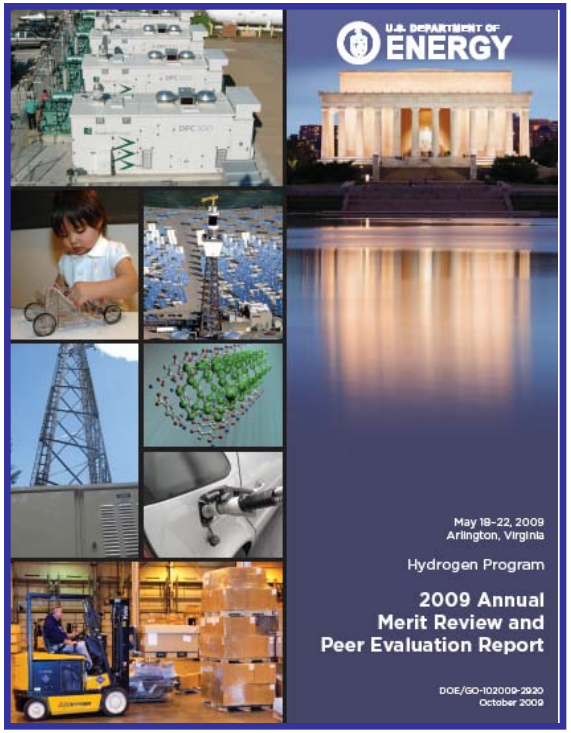
Positive feedback received with suggestions for further improvements and emphasis areas.

OBSERVATIONS

- LLNL water analysis important mainly in its worst case scenario for areas forecasted to be afflicted at the hydrogen-water nexus.
- Macro System Model considered apex of DOE modeling, important in linking other models together for meaningful results.
- ORNL transition to hydrogen modeling recognized as highly relevant to program objectives.
- ANL hydrogen quality cost implications very important and key interface between manufacturers and fuel providers.
- Environment impacts of hydrogen transportation and power systems analysis by Stanford University absolutely needed to explore future hydrogen showstoppers.



RECOMMENDATIONS

- Clarify and illustrate priorities to allow information gleaned from analysis to present clear options for policy decisions.
- Clarify interactions between the variety of models.
- Consider efforts to more appropriately incorporate H_2 technologies into national energy models.
- Consider case with more limited deployment of H2 vehicles.
- Use existing markets for H_2 in central H_2 generation cases.
- Compare early use of stationary FCs to other technologies.

IN SHORT…

- Systems Analysis subprogram a significant activity within DOE.
- Subprogram comprises broad range issues that present challenges but progress and modeling follow logical path without significant gaps.
- Analysis and model portfolio sufficiently diverse and useful tools to industry and academia.

Infrastructure Analysis
H_2 Infrastructure Workshop

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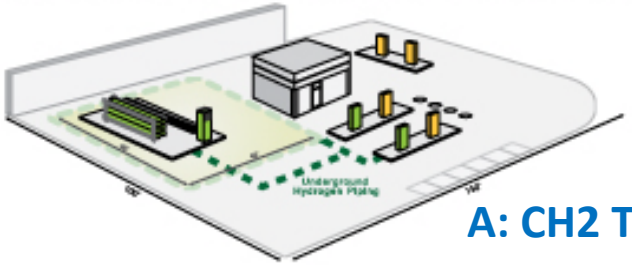
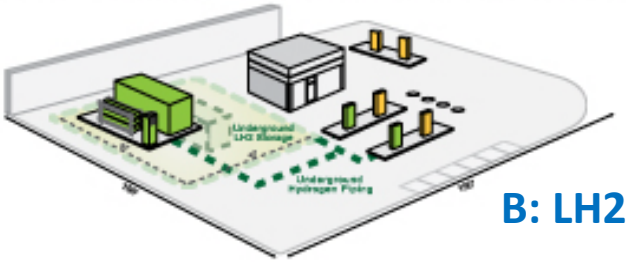
Five "standard" hydrogen station business cases were presented to fuel retailers as part of a focus group effort prior to the hydrogen infrastructure workshop. Feedback from fuel retailers helped start workshop discussions.

Station A: Hydrogen is delivered as a compressed gas



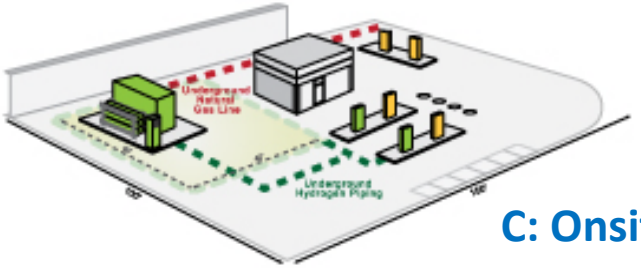
A: CH2 Truck

Station B: Hydrogen is delivered and stored as a liquid



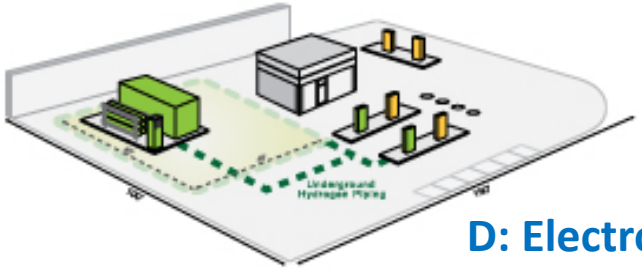
B: LH2 Truck

Station C: Hydrogen is produced onsite from natural gas



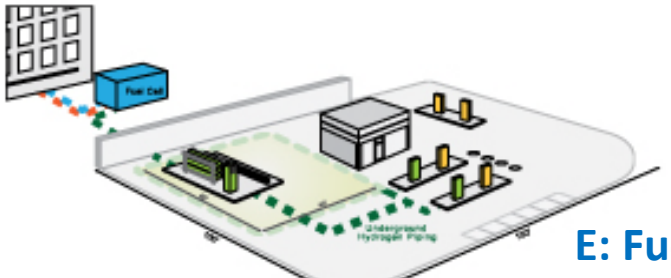
C: Onsite SMR

Station D: Hydrogen is produced by electrolysis



D: Electrolysis

Station E: An offsite fuel cell uses natural gas to produce electricity, heat and hydrogen



E: Fuel Cell CHHP

Feedstock Prices (for station and/or fuel cell owner):

Natural Gas ($/mmBtu)	$7.00
Premium for renewable biogas ($/mmBtu)	$4.00
Grid Electricity ($/kWh)	$0.082

Each station has a capacity of 700 kgH_2/day, or 200 FCVs per day.

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Reviewer Reminders

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- Deadline for final review form submittal is **June 18th**.
- ORISE personnel are available on-site for assistance. A reviewer lab is set-up in room 8216 and will be open Tuesday –Thursday from 7:30 AM to 6:00 PM and Friday 7:30 AM to 3:00 PM.
- Reviewer feedback session – **Tuesday, at 5:45pm (after last Systems Analysis session), in room of that session.**

For More Information

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