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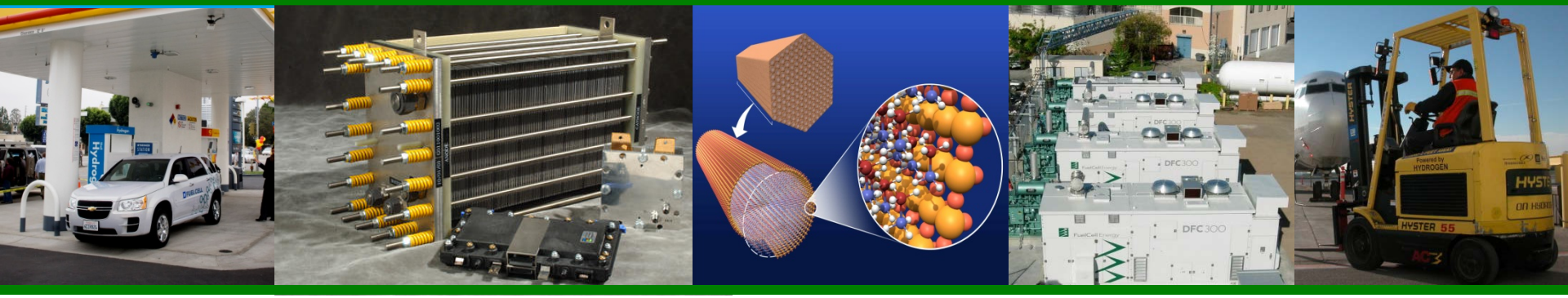

Systems Analysis
- Session Introduction -

Fred Joseck

2013 Annual Merit Review and Peer Evaluation Meeting
May 14, 2013

Goal & Objective

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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

- Assess the Life Cycle Analysis benefits of hydrogen and fuel cells for diverse applications
- Quantify the benefits of integrating hydrogen fuel production with stationary fuel cell power generation
  - Evaluate the potential for biogas, landfill gas, and stranded hydrogen streams
- Evaluate fueling station costs for early vehicle penetration
- Evaluate the use of hydrogen for energy storage and as an energy carrier
- Evaluate socio-economic benefits of the Program such as job creation

Challenges

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Availability, accuracy and consistency of data, 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.

Data availability, accuracy and consistency; 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.

Analysis Portfolio

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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

Systems Analysis url: http://www.hydrogen.energy.gov/systems_analysis.html

Model Hierarchy

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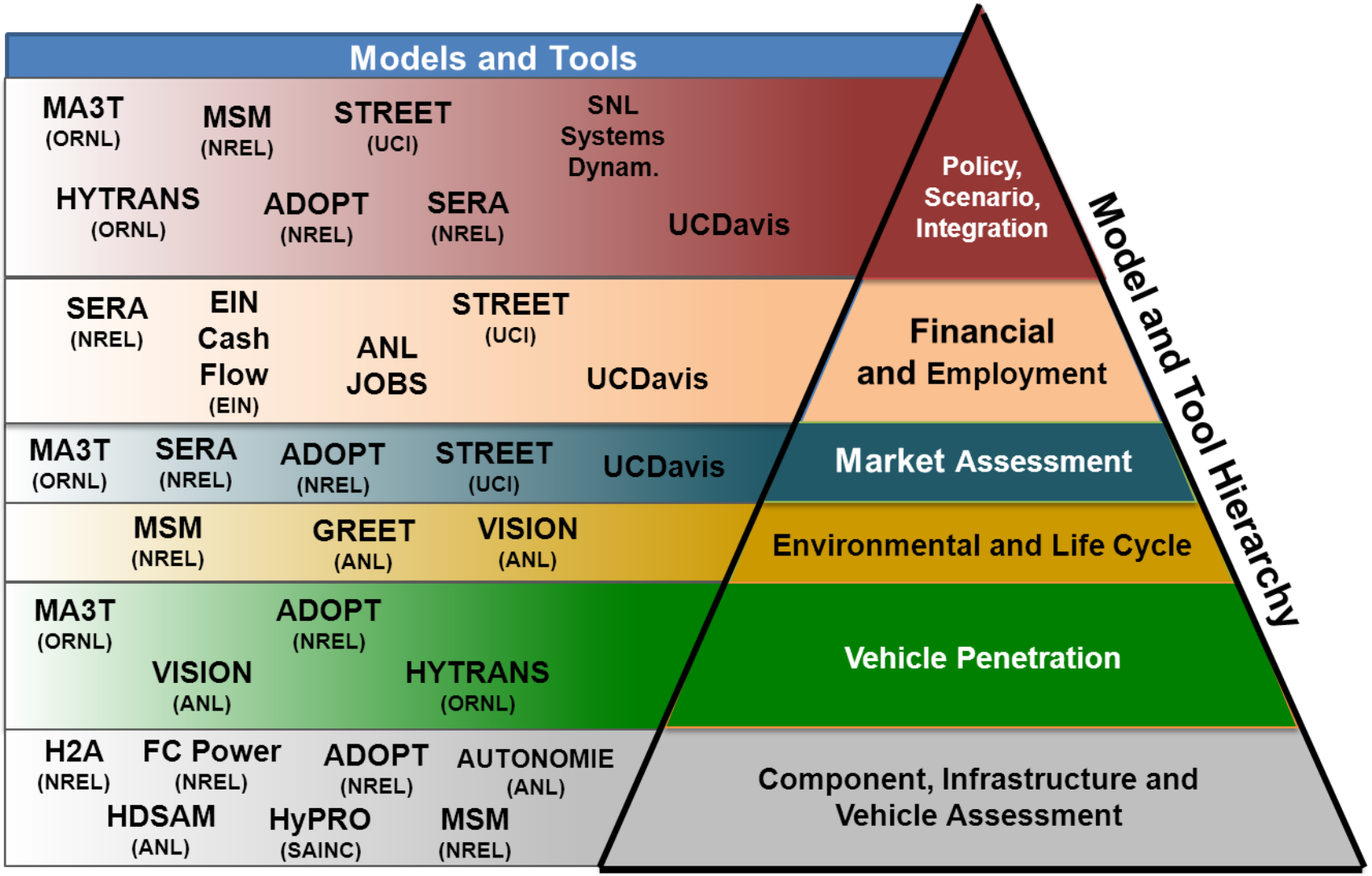
DOE's Fuel Cell Technologies Office model and tool portfolio is comprehensive and multi-functional



Analysis Project Overview

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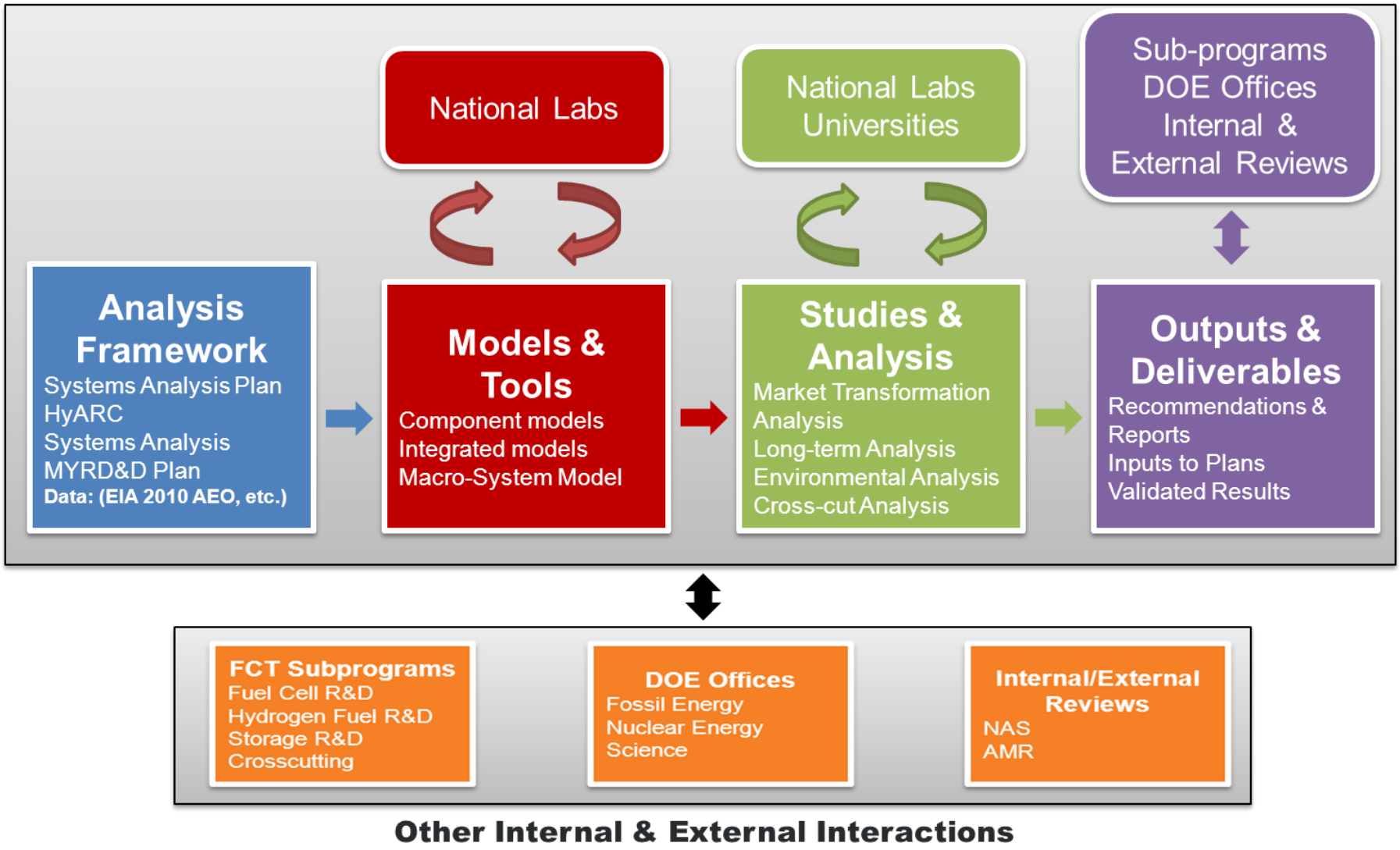
Systems Analysis Process Achieves Consistent and Transparent Results



Model/Analysis Application Matrix

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FCTO model and tool portfolio well equipped to tackle all the analysis tasks

Analysis Category	Technology Analysis					Implementation & Impact Analysis					
Analysis Type / Models	Stationary Power Generation	Pathway & Components Cost	H2 Quality Impact	WTW Energy & GHG Emissions	Vehicle Technology	Infrastructure & Resource Anal.	Consumer Choice	Vehicle Penetration	National Econ. Impacts	Policy Options	Employment
H_2A Production Cost Model[1]		✓									
H_2A Delivery Cost Model[1]		✓									
DTI/SA HyPRO[1]						✓					
Jobs Model (ANL)[1]											✓
SERA (NREL Infrastructure)[1]						✓					
HyDRA[1]						✓					
Autonomie					✓						
HyTrans[1]							✓	✓			
MA3T (ORNL)[1]							✓	✓			
GREET[1]				✓							
Macro-System Model (MSM) [1]	✓	✓	✓	✓		✓					
RCF Agent Based Model[1]						✓					
NEMS									✓	✓	
MARKAL									✓	✓	
FC Power Model	✓										

Notes:

1. The models/projects funded by Systems Analysis are referenced with a "1".
2. A hydrogen module is being added to the NEMS model in 2006.
3. Risk analysis is being incorporated in the models. The GREET Model has risk analysis capabilities.
4. The primary analysis focus of the models are illustrated in the matrix. However, the models are multi-functional and can be applied for other analyses in the matrix.

Legend

✓ Models and Tools available for analysis

Analysis Process Flow

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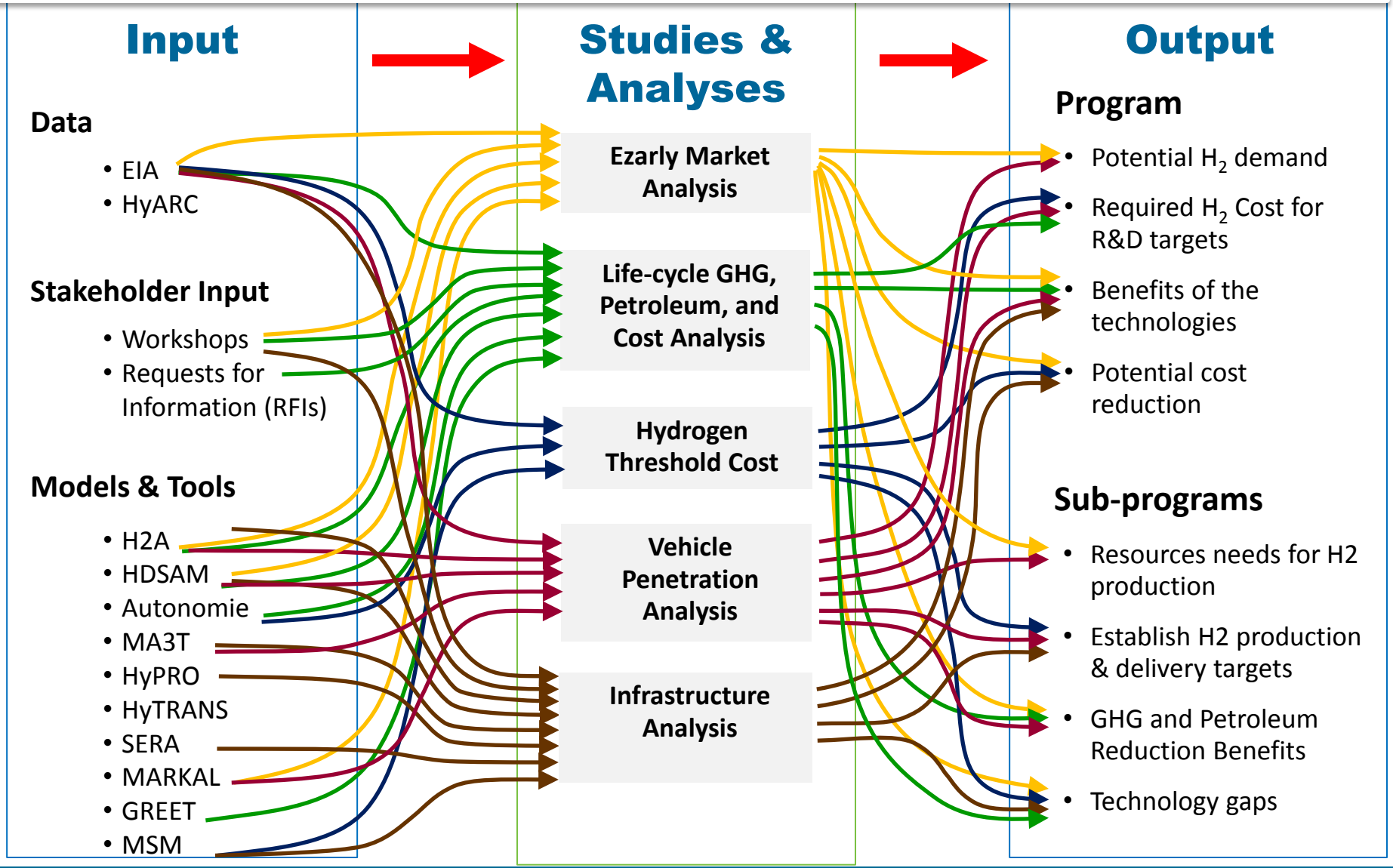
A portfolio of models and tools with transparent data for studies is used to influence Program direction and input



Systems Analysis Budget

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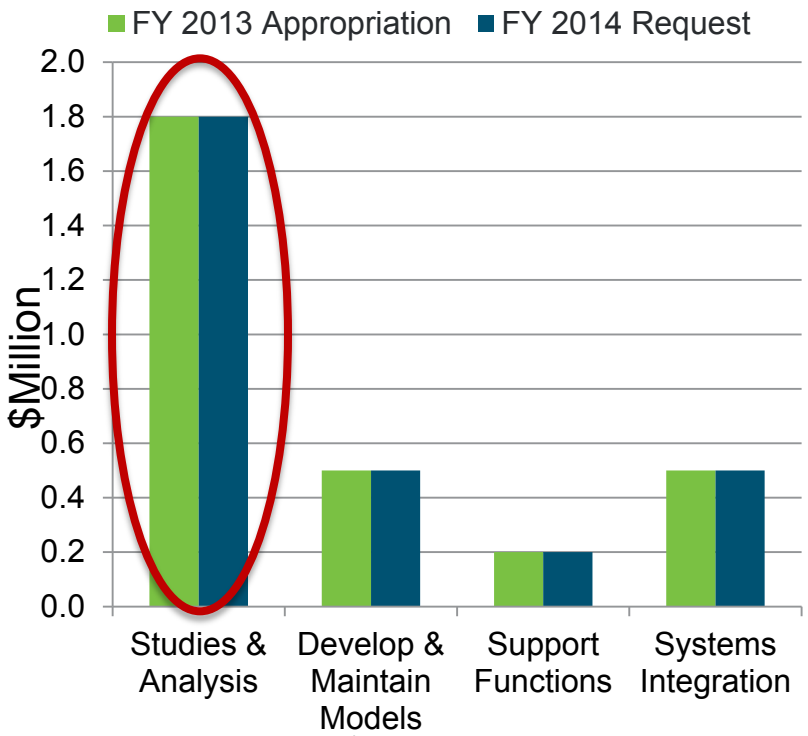
Focus: Determine technology gaps, economic/jobs potential, and benefits of key technology advances; and quantify 2013 technology advancement

FY 2013 Appropriation= $3.0 M

FY 2014 Request = $3.0 M



* Subject to appropriations, project go/no go decisions and competitive selections. Exact amounts will be determined based on R&D progress in each area and the relative merit and applicability of projects competitively selected through planned funding opportunity announcements (FOAs).

EMPHASIS

- Update and refine models for program analysis using cost, performance and environmental (emissions, etc.) information.
- Continue life-cycle analyses of cost, greenhouse gas emissions, petroleum use and criteria emissions, and impacts on water use.
- Assess gaps and drivers for early market infrastructure cost for transportation and power generation applications
- Assess programmatic impacts on market penetration, job creation, return on investment, and opportunities for fuel cell applications in the near term.

Infrastructure Analysis: Single Station Cash Flow Analysis

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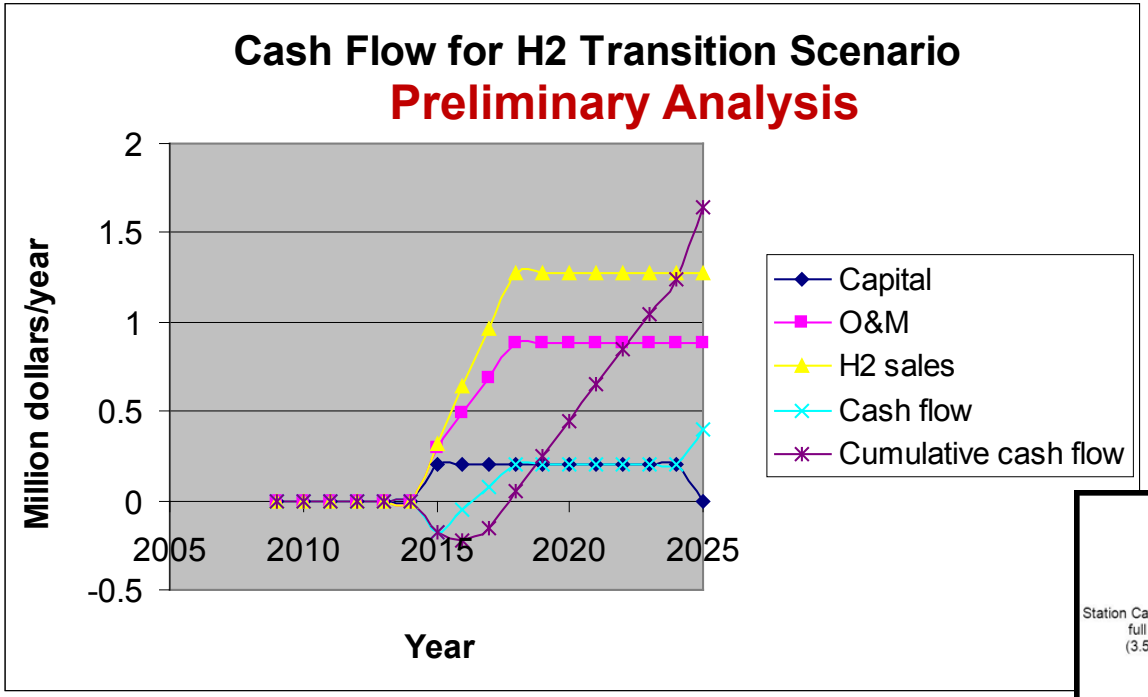
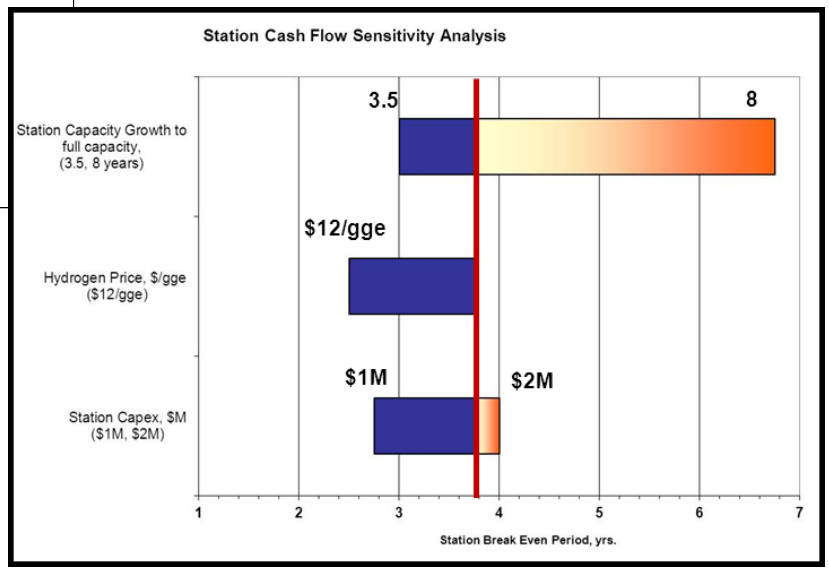
Hydrogen Fueling Station positive cash flow is sensitive to station utilization

500 kg per day Station Financial Analysis



Single 500 kg/d Hydrogen Station with Compressed Hydrogen delivery from Central production facility



Source: UCDavis

Assumptions:

- Delivered H_2 @ $6/gge
- H_2 selling price $10/gge
- H_2 station cost $1.5 million
- Full station utilization in 4 yrs.
- Loan 5.5% for 10 yrs.
- 700 bar dispensing
- O&M: $100,000

Resource Analysis

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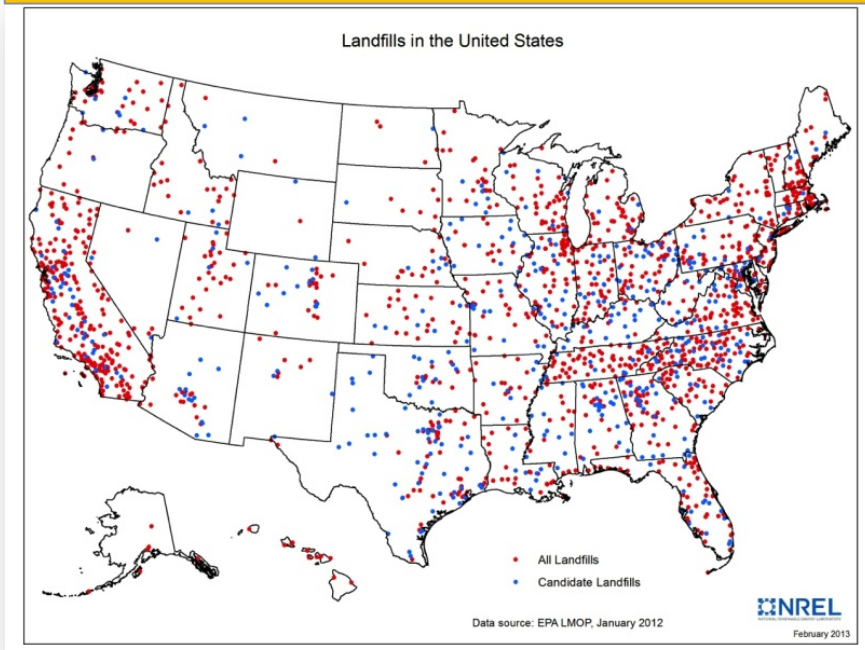
The U.S. has an abundance of regionally distributed domestic resources to produce renewable hydrogen

- **Renewable hydrogen can be produced from a variety of domestic resources including solar, wind, biomass and biogas.**
- **Abundance of resources for hydrogen production quantified below:**

Solar > Wind > Biomass and Biogas (Source: NREL)

- **Renewable resources are regionally concentrated which limit the distribution of the resultant hydrogen production to urban demand centers.**
- **Each resource faced with barriers such ecological, physical and environmental restrictions.**

Landfill Gas Resource



Net CH_4 Potential	1,600 thousand tonnes
Net H_2 Potential	493 thousand tonnes
FCEV Supported	2.8 million vehicles

Data Source: EPA's Landfill Methane Outreach Program [2]

Gross Availability: 10,500 thousand tonnes, ~2,000 records with waste data

Net Availability: 445 candidate* sites identified by EPA

Methane range: 40%-60% methane by volume of biogas

* Candidate sites must meet certain waste requirements and have no operational or under construction energy project

Vehicle Penetration Analysis: Impact of Driving Range and Consumer Choice on FCEV Penetration

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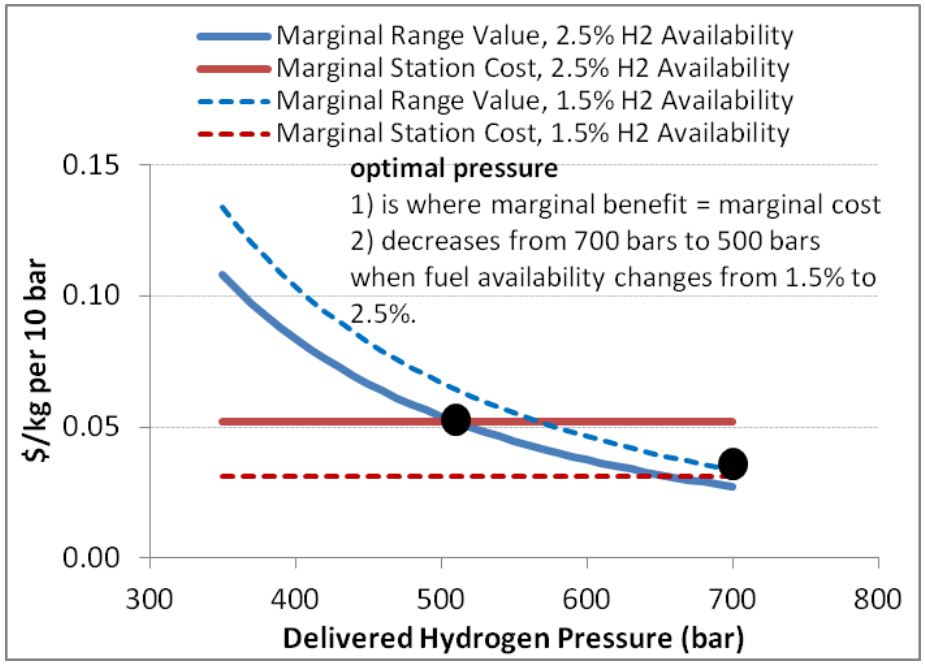
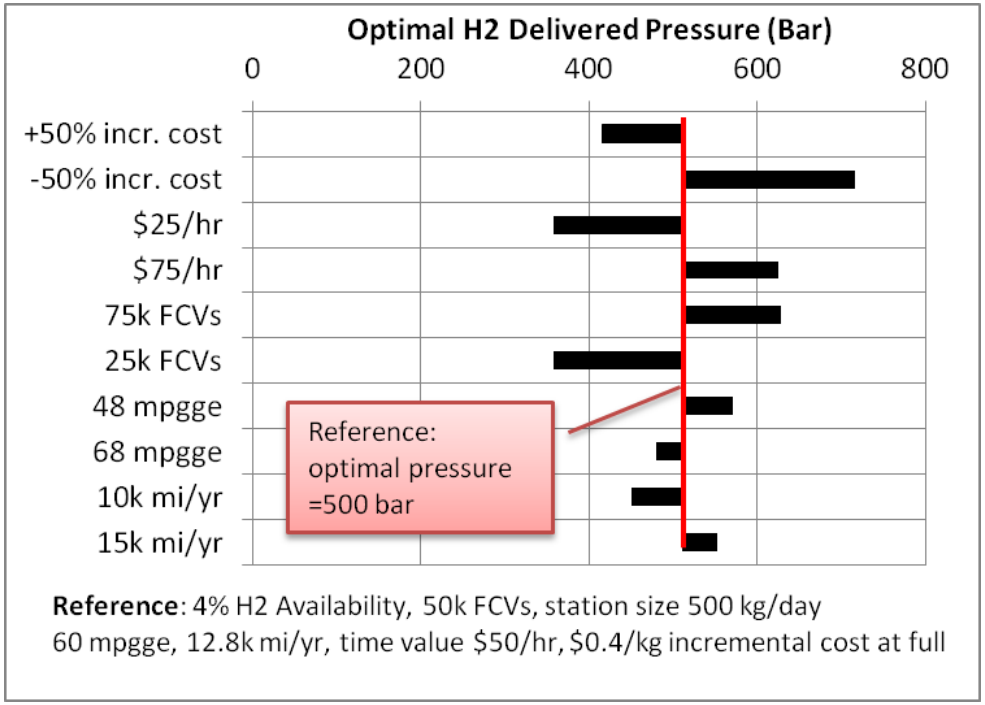
Optimal Delivered Hydrogen Pressure to the vehicle may fall between 350 and 700 bar depending on the tradeoff between consumer refueling convenience, time value and infrastructure costs



Optimal fueling pressure (vehicle range) is more sensitive to consumer's value of time, incremental station cost, and number of FCEVs available to obtain fuel (hydrogen).



Note: Analysis assumes the vehicle tank is designed for 700 bar hydrogen pressure.

Programmatic Analysis: Water Life-Cycle Analysis

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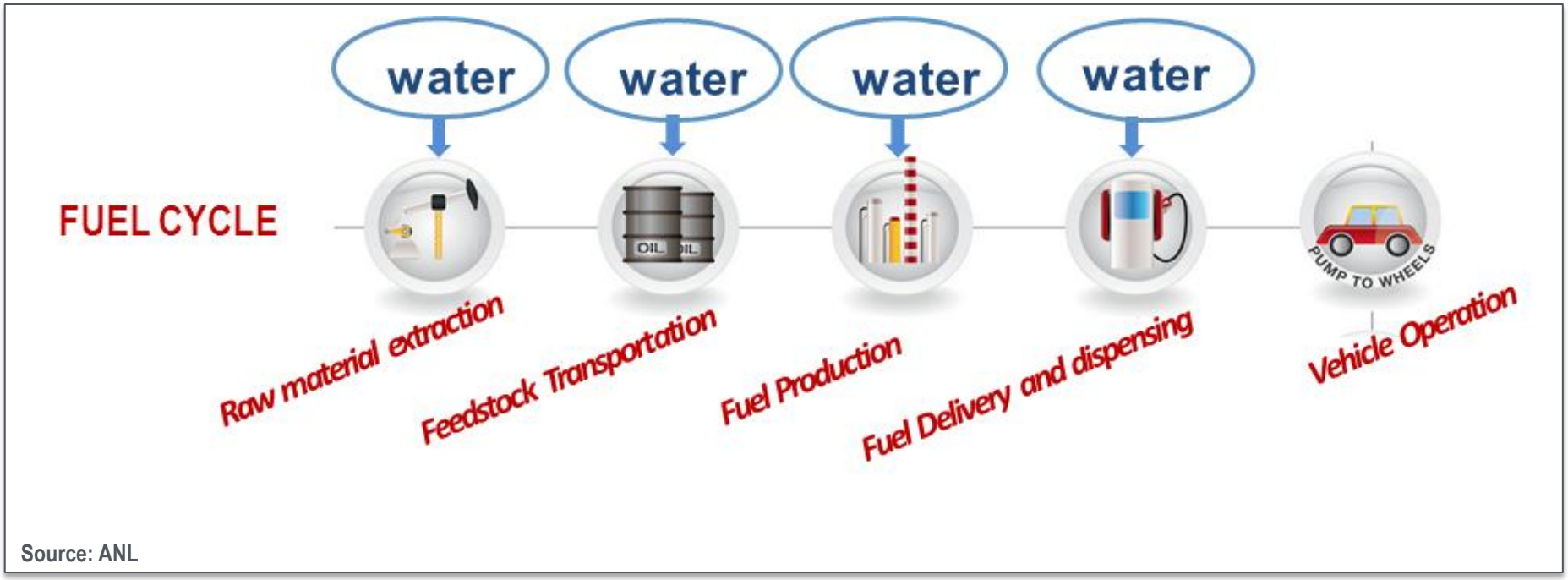
On a life-cycle basis, analysis capabilities will be added to GREET to assess water consumption for hydrogen production pathways

GREET = the Greenhouse gases, Regulated Emissions, and Energy use in Transportation Model



Source: ANL

- **GREET LCA analysis capabilities are being expanded to include fuel cycle water consumption for hydrogen and other fuels.**
- **Model will be able to assess water consumed on a "per gge" and "per mile" basis.**

Technology Analysis: Life Cycle Analysis of On-Board Storage Options

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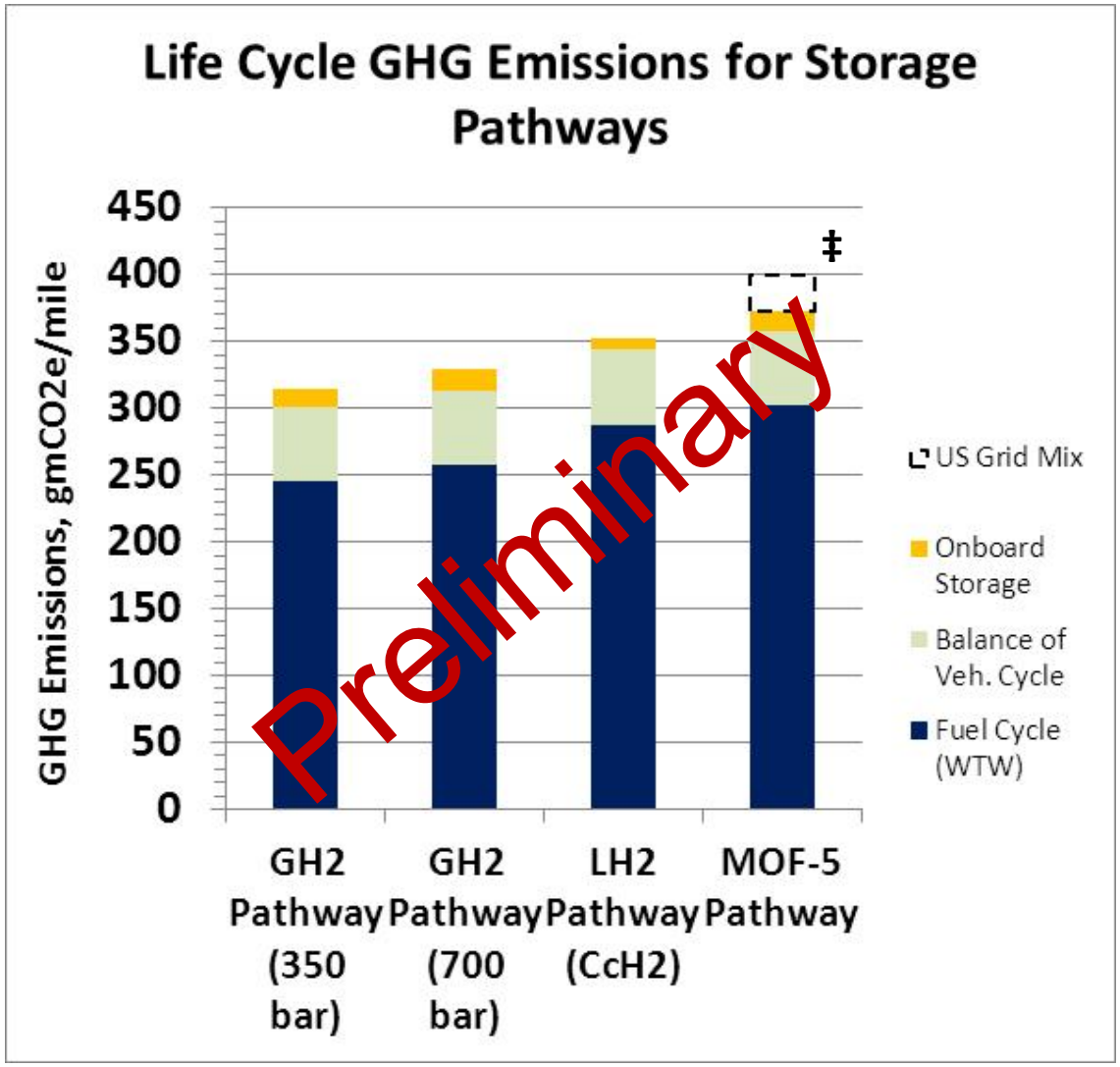
Onboard storage represents 3-5% of total LCA GHG emissions of compressed GH2, LH2 and MOF-5 pathways



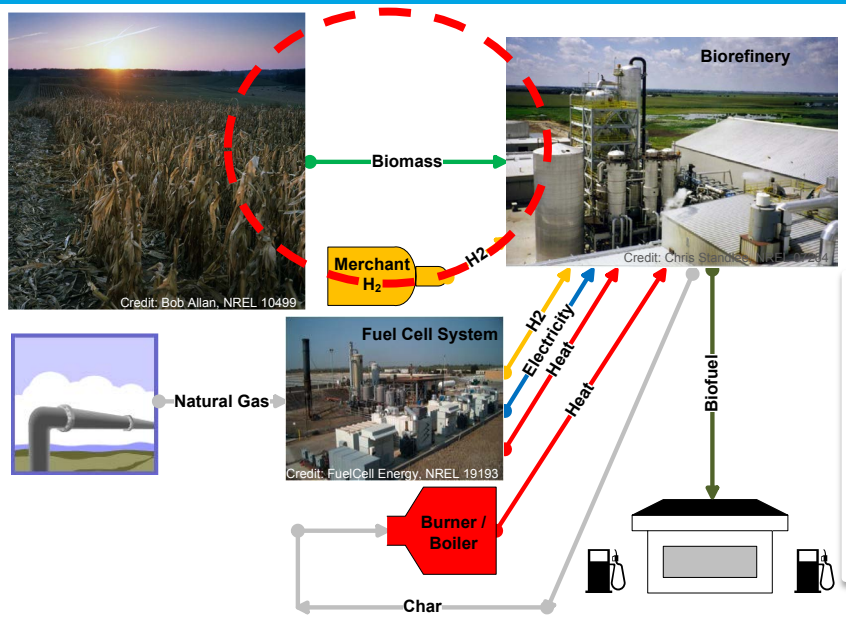
* Assumed 60 mi/kg H_2 fuel economy for FCEVs, and 160,000 lifetime VMT

‡ Assumed electricity from US grid mix for H_2 liquefaction

Hydrogen for the pathways assumed to be produced from central steam methane reforming of natural gas.

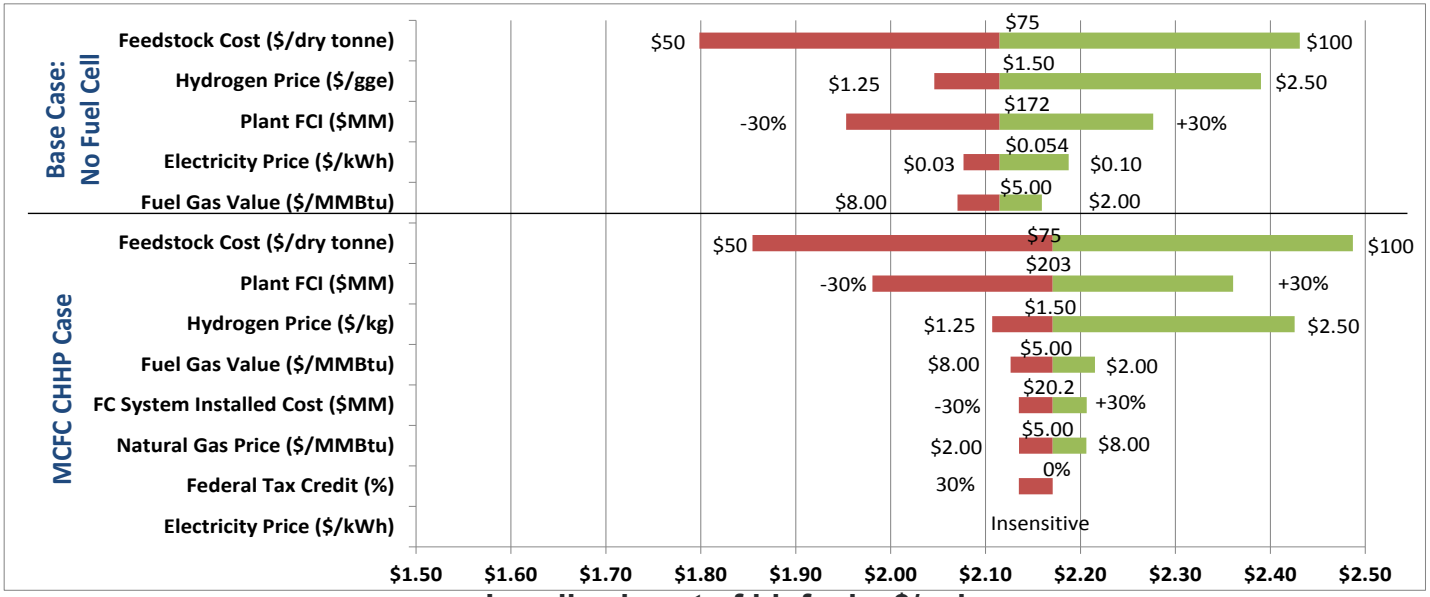
Source: ANL

Technology Analysis: Fuel Cell Technologies Integration with Bioenergy Technologies



Biorefineries require electricity, heat and hydrogen that can be supplied by Combined Heat, Hydrogen and Power (CHHP) Fuel Cells

The MCFC CHHP integration with a biorefinery case is cost-competitive when the electricity to natural gas cost ratio is high or there are concerns about electricity or hydrogen price volatility



Programmatic Analysis: Socio-Economic Benefits of FCTO ARRA Projects Impact on Employment

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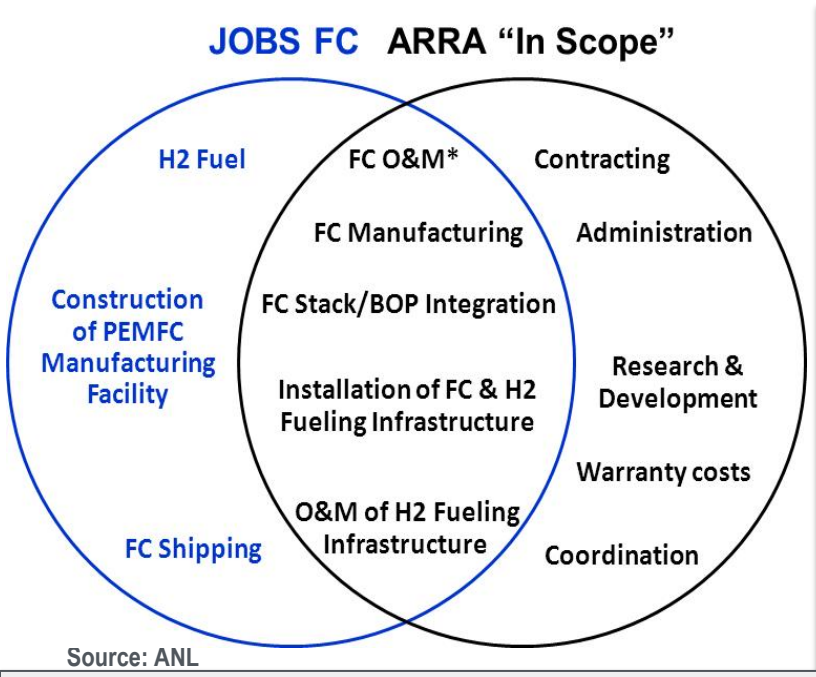
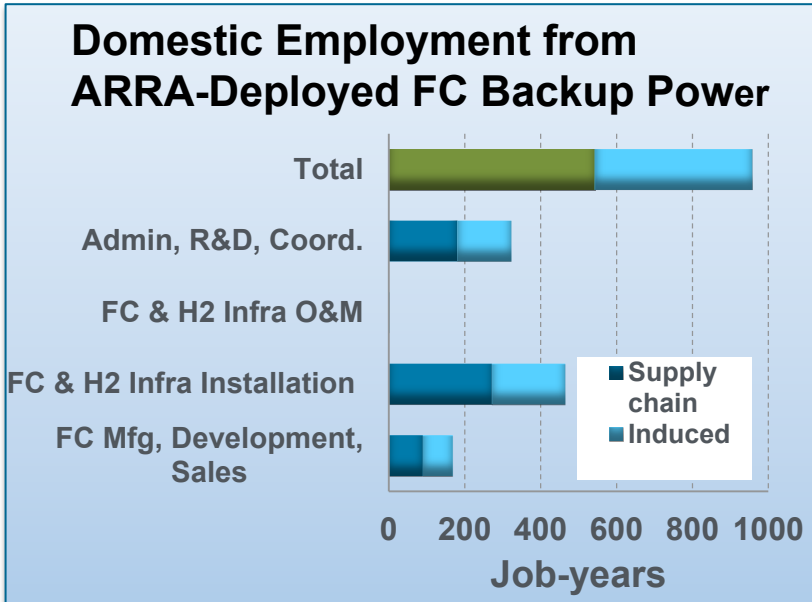
~1300 Domestic Job-years Created/Retained as a result of FCTO Funding for ARRA Projects for Fuel Cell Forklifts and Backup Power



Source: ANL



- ~950 total job-yrs created/ retained
- ~45% from FC & H2 infrastructure installation
- Induced employment = 44% of BUP employment
- BUP = 73% total ARRA-related FC employment

…another ~350 job-yrs. created by fuel cell forklifts

NEXT STEPS

- ANL-RCF is expanding the JOBS FC model to include module for analysis of infrastructure development employment impacts.
- Beta test of infrastructure planned for end of 2013.
- Jobs model module will enable analysis of gross and net jobs, and revenues generated from hydrogen infrastructure installation and investment. See ANL JOBS FC website: http://JOBSFC.es.anl.gov

Summary

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- Diverse portfolio and expanded capability of models developed by the Systems Analysis sub-program are enabling analysts to address barriers to technology development and commercialization.
- Emphasis on *early market and infrastructure analysis* :
  - Focus on utilizing biogas as a resource for an alternative fuel.
  - Comprehensive approach to evaluate a portfolio of fuel cell applications for light duty transportation, stationary generation, backup power and material handling equipment, and the electric sector to realize economic, environmental and societal benefits.
- Plans continue to enhance existing models and expand analyses.

FY 2013	FY 2014	FY 2015	FY 2016-2020
Complete analysis of job growth for MHE	Complete analysis of resources/ feedstock, production/ delivery and existing infrastructure for technology readiness	Provide analysis of Program milestones and technology readiness goals—including risk analysis, independent reviews, financial evaluations, and environmental analysis—to identify technology and risk mitigation strategies	Complete analysis of Program technology performance and cost status and potential to enable use of fuel cells for a portfolio of commercial applications
Complete analysis of biogas resources for H_2 production and stationary power generation	Complete analysis of job growth for distributed power generation		Complete analysis of H_2 quality impact on H_2 production cost and FC cost for long-range technologies and technology readiness
Complete analysis for fuel cell CHP application with bio-fuels	Complete infrastructure analysis for H2USA		Complete environmental analysis of impacts for H_2 scenarios
Complete coordinated well-to-wheel and Total-Cost-of-Ownership (TCO) with Vehicles and Biomass Technologies Offices			

Summary

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Systems Analysis is an integral component of EERE and the Fuel Cell Technologies Program

The Systems Analysis sub-program will

- Identify the synergies of hydrogen and fuel cells with other fuels and technologies to minimize barriers to market entry
- Confirm the technology advances needed to reduce infrastructure cost and show the similarity among costs for hydrogen fueling infrastructure and conventional or other alternative fueling infrastructure
- Assess impact of domestic and international growth in hydrogen demand on renewable resource availability and cost
- Assess water consumption of hydrogen production from natural gas and renewable resources
- Show the socio-economic benefits of various fuel cell applications

Participating Organizations

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- **Systems Analysis**
  - ANL
  - NREL
  - ORNL
  - PNNL
  - SNL
  - UC – Davis
  - RCF Economic & Financial Consulting, Inc.
  - Navigant/Pike Research

For More Information

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Systems Analysis Team

Fred Joseck, Team Leader
202-586-7932
Fred.joseck@ee.doe.gov

Tien Nguyen
202-586-7387
tien.nguyen@ee.doe.gov

Monterey Gardiner
202-586-1758
monterey.gardiner@ee.doe.gov

Joe Stanford
202-586-6757
Joseph.stanford@ee.doe.gov

Jeni Keisman (AAAS Fellow)
202-586-5153
Jeni.keisman@ee.doe.gov

Support:
Elvin Yuzugullu (SRA)

Kathleen O'Malley (SRA)

Session Instructions

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- This is a review, not a conference.
- Presentations will begin precisely at the scheduled times.
- 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 and other portable devices.
- Photography and audio and video recording are not permitted.

Reviewer Reminders

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- Deadline to submit your reviews is Friday, **May 24th at 5:00 pm EDT.**

- ORISE personnel are available on-site for assistance.
  - **Reviewer Lab Hours:**
    - Monday, 5:00 pm – 8:00 pm (Gateway ONLY)
    - Tuesday – Wednesday, 7:00 am – 8:00 pm (Gateway)
    - Thursday, 7:00 am – 6:00 pm (Gateway)
    - Tuesday – Thursday, 7:00 am – 6:00 pm (City)
  - **Reviewer Lab Locations:**
    - Crystal Gateway Hotel—*Rosslyn Room* (downstairs, on Lobby level)
    - Crystal City Hotel—*Roosevelt Boardroom* (next to Salon A)