Systems Analysis Session

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2008 DOE Hydrogen Program Merit Review and Peer Evaluation Meeting

June 10, 2008
U.S. Department of Energy
DOE Hydrogen Program

Introduction

What Questions Should Analysis and Models Answer?

Analysis Progression

<table>
<thead>
<tr>
<th>Initial Questions and Problems to Address with Analysis</th>
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<tbody>
<tr>
<td>• What are the key technology drivers?</td>
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<td>• What is the hydrogen cost of the technologies?</td>
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<td>• Where do we focus our research i.e. which technology/ies and what area of the technologies?</td>
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<td>• What are the resource requirements/limitations?</td>
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<td>• What are the hydrogen quality requirements and cost implications?</td>
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<td>• What technologies will be needed to meet the hydrogen quality specifications?</td>
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<thead>
<tr>
<th>Integrating Questions and Problems to Address with Analysis</th>
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<tbody>
<tr>
<td>• Which portfolio of technologies will best fit and where (cost, resource availability, infrastructure availability, etc.)</td>
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<td>• How will the infrastructure evolve?</td>
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<td>• What are the infrastructure requirements in cost?</td>
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<td>• What will be the impacts on petroleum use and greenhouse gas emissions as the infrastructure and technologies are introduced?</td>
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<td>• What and where are the infrastructure constraints to meet the technology requirements?</td>
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<td>• Does the vehicle need to be built first or is a fueling infrastructure required first (how to manage the &quot;chicken and egg&quot; issue)?</td>
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<table>
<thead>
<tr>
<th>Long Term Questions and Problems to Address with Analysis</th>
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<tbody>
<tr>
<td>• What policies will be needed to enable hydrogen production, delivery and vehicles?</td>
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<td>• Which policies will be more effective for vehicle introduction and for hydrogen/infrastructure introduction?</td>
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<td>• What is the impact of switching from a petroleum based transportation fuel to a hydrogen based fuel?</td>
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Analysis Strategy and Domains

**Technical Analysis**
- Resource, technical feasibility, environmental, delivery, and infrastructure development analysis
- Assists in defining the appropriate slate of projects for the hydrogen research portfolio, and increasing the effectiveness of research projects
  - Example models:
    - PSAT
    - GREET
    - HyDS
    - Macro-System Model
    - HYPRO

**Cost Analysis**
- Analysis to assess the economic feasibility of various infrastructure and vehicle processes
- Assists in choosing research paths which offer the best possibilities of competitive costs for hydrogen production, delivery, vehicle configurations, etc.
  - Example models:
    - H2A
    - TIAx Logistics Model

**Market/Benefits Analysis**
- Analysis to estimate the benefits of its portfolio of R&D and deployment programs and to perform various types of policy analyses
- Examination of the interactions of hydrogen production and consumption with the rest of the energy system
  - Example models:
    - NEMS
    - MARKAL
    - HyTrans
    - VISION
Challenges

• Establish consistent data, assumptions and guidelines for analysis tasks

• Understand behaviors and drivers of the fuel and vehicle markets

• Coordinate and integrate analysis resources and capabilities across analytical domain

• Understand vehicle, fuel and socio-economic policy impacts

• Establish and develop an integrated portfolio of models and tools
Analysis Portfolio

- **Programmatic analysis**
  - Risk analysis of Hydrogen Program targets and goals
  - Petroleum and CO₂ reduction benefits
  - Analysis of integrating stationary and transportation fuel cells
  - Program benefits for program-related product commercialization

- **Program element analysis**
  - Hydrogen production and delivery pathway analysis
  - Platinum recycling impact on fuel cell cost

- **Environmental Analysis**
  - Atmospheric impacts of hydrogen
  - Well-to-Wheels analysis of greenhouse gas (GHG) emissions

- **Policy Analysis**
  - CO₂ analysis
  - Fuel, infrastructure and vehicle subsidy evaluation

- **Early Market Analysis**
  - Cost and GHG benefit analysis of early market applications
## Systems Analysis Progress

<table>
<thead>
<tr>
<th>Year</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
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<tbody>
<tr>
<td>2004</td>
<td>✔ Systems Analysis function established</td>
<td>✔ Established process for developing hydrogen cost target</td>
<td>✔ Well-to-Wheels analysis process established</td>
<td>✔ WTW analysis completed</td>
<td>✔ Preliminary water analysis analysis completed</td>
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<tr>
<td>2005</td>
<td>✔ Revised hydrogen cost target to $2.00-3.00/gge</td>
<td>✔ H2A Production Model issued</td>
<td>✔ Systems Analysis Plan issued</td>
<td>✔ Macro-System Model test version completed and validated</td>
<td>✔ Macro-System Model completed and issued</td>
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<td>✔ Identified analytical gaps and “missing pieces”</td>
<td>✔ HyDS model completed</td>
<td>✔ Cross-Cut team established</td>
<td>✔ Scenario Analysis for Transition completed</td>
<td>✔ H2A Production Model revised and issued</td>
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<td>2006</td>
<td>✔ Hydrogen Analysis Resource Center issued</td>
<td>✔ Systems Analysis Plan issued</td>
<td>✔ Resource and infrastructure analysis started</td>
<td>✔ CO2 policy analysis completed</td>
<td>✔ Early market analysis</td>
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<td>✔ Well-to-Wheels analysis process established</td>
<td>✔ HyDS model completed</td>
<td>✔ Pt recycling cost analysis completed</td>
<td>✔ Hydrogen quality analysis of impact on production and fuel cell completed</td>
<td>✔ Hydrogen quality analysis of impact on production and fuel cell completed</td>
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</tbody>
</table>
2008 Accomplishments/Results

Modeling and Model Development

Macro-System Model

Completed first version of the model

- Completed peer review of the model.
- Analyzed the hydrogen cost and greenhouse gas emissions for 7 hydrogen pathways
- Utilized model for EU/US model comparison

H2A Production Model Update

Completed peer reviewed revision of H2A model

- Added scaling feature for various production rates
- Added cost for CO2 sequestration
  - Capital cost
  - Pipeline cost
  - Cost of CO2 injection
**CO₂ Analysis**

- Preliminary sensitivity analysis of hydrogen pathways show CO₂ reduction benefits of 1.7 to 2.3 Giga tons of CO₂/yr

**Platinum Recycling Cost Analysis**

- Currently, platinum only regarded as cost input for fuel cell analysis

**Hydrogen Quality Analysis**

- Preliminary analysis shows the hydrogen production cost increases ~$0.20-0.40/gge to meet hydrogen quality specifications for the fuel cell

- Preliminary analysis determined hydrogen cost to achieve quality to optimize fuel cell performance.

Source: Brookhaven National Laboratory MARKAL model
2008 Accomplishments/Results

Analysis

Resource Analysis

Developed “Well-to-Wheels” analysis approach for water

• Utilized for hydrogen pathways and conventional fuel pathways analysis
• Used as a screening tool to create a Water Resource Analysis project with LLNL

![Water Use for Technologies per Mile](image)

Water Use per Mile

- Conventional
- Hydrogen Pathways
- Fuel Pathways

- Water requirements for hydrogen based on H2A model.
- Used ANL Water report for analysis data.
- Distributed electrolysis assumes electricity is coming from the grid.

Early Market Analysis

- Preliminary Well-to-Wheels analysis for GHG emissions for early market shows H₂ fork lifts lower than fossil fuel pathways

![Fuel-cell Forklift: (Source: Toyota)](image)

Fuel Cycle GHGs Emissions For Forklift Technologies

- H₂ Fuel Cells
- Battery
- ICEs

Source: ANL GREET model
Systems Analysis Partners

- Office of Planning, Budget & Analysis (PBA)
- Fossil Energy
  - Nuclear Energy
  - Other EERE Programs
- H2 Program Elements
- Other Agencies
- National Laboratories
- Systems Integration
- Fuels Pathways Integration Tech Team (FPITT)

(Paths and labels for collaboration and analysis)
## Systems Analysis
### Session Schedule

Analysis Sessions will be held EVERYDAY!

### 2008 DOE HYDROGEN PROGRAM MERIT REVIEW AND PEER EVALUATION MEETING BLOCK SCHEDULE

<table>
<thead>
<tr>
<th>Session Salon</th>
<th>Monday June 9</th>
<th>Tuesday June 10</th>
<th>Wednesday June 11</th>
<th>Thursday June 12</th>
<th>Friday June 13</th>
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**Notes:**

- 15 minute talk, starts 15 minutes after listed time.
- Raffaelli Liberali, Director for Non-Nuclear Energy in the Directorate General for Research, Technology and Development (DG-RTD) of the European Commission
Tuesday, June 10
Start: 8:45 AM   Focus: Modeling and Fuel Cell Vehicle in Transportation

- Systems Analysis Introduction
- AN 1: HyTrans Model: Analyzing the Transition to Hydrogen-Powered Transportation
  by David Greene
- AN 2: Fuel-Cycle Analysis of Hydrogen-Powered Fuel Cell Systems with the GREET Model
  by Michael Wang
- AN 3: Discrete Choice Analysis of Consumer Preferences for Refueling Availability
  by Marc Meliana

Wednesday, June 11
Start: 9:00 AM   Focus: Modeling and Analysis of Hydrogen Production

- AN 4: Macro-System Model
  by Mark Ruth
- AN 5: Analysis of the Hydrogen Production and Delivery Infrastructure as a Complex Adaptive
  System by George Tolley
- AN 6: Updates to the H2A Hydrogen Production Discounted Cash Flow Model (H2A version 2.0)
  by Darlene Steward
Thursday, June 12
Start: 9:00 AM  Focus: Hydrogen Resource Requirements and Infrastructure
AN 7: H2-W The Production Value of Water in a Hydrogen Economy
    by Richard White
AN 8: HyDRA: Hydrogen Demand and Resource Analysis
    by Mitt Sparks
AN 9: Lessons Learned for Fueling Infrastructure
    by Marc Meliana

Friday, June 13
Start: 9:00 AM  Focus: Fuel Cell Analysis and Environmental Impacts of Hydrogen
AN 10: Hydrogen and Fuel Cell Analysis: Lessons Learned from Stationary Power Generation
    by Mr. Dogan
AN 12: Hydrogen Quality Issues for Fuel Cell Vehicles
    by Romesh Kumar
AN 13: Update on Platinum Availability and Assessment of Platinum Leasing Strategies for Fuel Cell
    Vehicles by Matt Kromer
AN 14: Evaluation of the Potential Large-Scale Use and Production of Hydrogen in Energy and
    Transportation Applications by Don Wuebbles
AN 15: Potential Environmental Impacts of Hydrogen- Based Transportation and Power Systems
    by Tom Grieb
Thank You
For More Information
Systems Analysis

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