Macro-System Model

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This presentation does not contain any proprietary or confidential information

Project ID # AN5

NREL/PR-840-41723
Overview

Timeline
• Start date: Feb 2005
• Completion: Sept 2010
• Percent complete: 15%

Budget
• Total funding:
  – 100% DOE funded
• FY05 funding:
  – $170K NREL/SIO
  – $50K Sandia NL
• FY06 funding
  – $276K NREL/SIO
  – $280K Sandia NL
  – $60K other national lab work

Barriers
• Lack of consistent data, assumptions and guidelines (B)
• Lack of a Macro-System Model (C)
• Stove-piped/siloed analytical capabilities (D)

Partners
• Sandia National Laboratory (computational development)
• NREL (inclusion of H2A Production & well-to-wheel analysis validation)
• ANL (inclusion of HDSAM & GREET & well-to-wheel analysis validation)
• Others to be identified
Project Objectives

• Overall objectives
  – Develop a macro-system model (MSM) aimed at
    • Performing rapid cross-cutting analysis
      – Utilize and link other models
      – Improve consistency between models
    • Supporting decisions regarding programmatic investments and focus of funding
    • Supporting estimates of program outputs and outcomes

• 2005/2006 objectives
  – Define analysis issues / model requirements
  – Evaluate alternatives for the MSM structure and select an approach for development
  – Initial integration of models
  – Initial analysis: Comparison of hydrogen production/delivery pathways
  – Begin validation
MSM Development Approach

I. Define Requirements

- List issues the MSM should address
- Determine features the MSM needs
- Record requirements for the MSM

II. Evaluate Alternatives

- Gather Information on Existing Models
  - Evaluate Relative to Requirements
    - Don’t Use
    - Use as Is
    - Use with Modification
    - Develop to Fill Gap
- Define Model Architecture
  - Inputs
  - Functions
    - Model
    - Equations
    - Look up Tables
    - Assumptions
    - Interfaces

III. Begin Development

- Develop Proposed WBS, Schedule & Budget
- Link initial set of models and start first analysis
- Validate MSM: Model use, links, mapping, & results

Input from Analysts
Progress: Analysis Issue Categories

Financial

- R&D
- Hypothetical Fuel Cycle Costs
- Technical Targets
- R&D Costs and Timeframes
- R&D Probability and Risk

Environmental

- Transition
- Market Issues
- Regional Issues
- Comparison of Pathways
- Infrastructure & Legacy

Overlap:

- R&D
Progress: High Priority Issues

Financial

- What effects could policy and incentives have on transition?

Environmental

- How does a hydrogen economy affect the environment?

R&D

- ID critical / risky links in potential hydrogen pathways?
- Are the current technical targets the best ones? What interdependencies do they have?
- How should components and interfaces be optimized?

Transition

- Compare potential transition pathways.
- ID stumbling blocks that could affect transition paths? Could R&D overcome them?
- What impacts could competing technologies have on transition?
Progress: Initial Analysis Issues

What effects could policy and incentives have on transition?

How / how much does a hydrogen economy affect the environment?

What is the emissions profile if hydrogen is produced to meet a given city's demands?

ID critical / risky links in potential hydrogen pathways?

Compare potential transition pathways.
ID stumbling blocks that could affect transition paths? Could R&D overcome them?

What impacts could competing technologies have on transition?

Comparison of hydrogen costs at the pump using different hydrogen production technologies.

How much hydrogen needs to be produced to supply a given city its demands?

What are the raw material needs to meet those demands?
Option 1: A new model could be built that captures information from all other models and the interactions between them.

Option 2: Model interactions could be defined and interfaces between them could be built.
Federated Object Model (FOM) – capable of integrating and utilizing existing and emerging component models (federates) to the extent possible

Standard inputs, credible / documented data, and outputs can be shared between models utilizing a single interface
FOM Architecture

- Translators and interface currently in a single Excel workbook
- Java/COM is used to transfer information into translators
Progress: Initial Model Integration

- Information that needs to be transferred has been identified.
- A linking interface has been developed in Excel.
- Sandia has developed a Java/COM application to transfer data between the linking spreadsheet and the models.
- The Java/COM application also launches VBA macros in models.
- Links are being reviewed by model developers.
Preliminary Results

Pathway Well-to-Wheels

Hydrogen Produced In Central Plant and Transported as Liquid via Truck

- 278,000 Btu Biomass
- 6,000 Btu Electricity

Central Production

- 157,000 Btu Energy Lost

Liquification & Transport

- 41,000 Btu Electricity
- 1,000 Btu Diesel

Storage and Compression for Dispensing

- 1,000 Btu Electricity for Forecourt
- 11,000 Btu Hydrogen Lost
- 42,000 Btu Energy Lost

Table:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well-to-Wheels Total Energy Use (Btu/mile)</td>
<td>7,133</td>
</tr>
<tr>
<td>Well-to-Wheels Petroleum Energy Use (Btu/mile)</td>
<td>206</td>
</tr>
<tr>
<td>Well-to-Wheels Greenhouse Gas Emissions (g/mile)</td>
<td>-5</td>
</tr>
<tr>
<td>Profited Cost of H2 at Pump ($/GGE)</td>
<td>5.23</td>
</tr>
</tbody>
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Production Process

- Energy Efficiency: 45%
- Pathway Efficiency: 35%
- WTP Emissions (g CO2 Equivalent / GGE fuel available): -1

Case Definition

- Year: 2005
- Hydrogen as Liquid
- Central Production
- Woody Biomass Feedstock
- Sequestration: No
- Transport for Delivery: Truck

Do not cite: Results shown are preliminary and require validation/correction. They are only intended to be examples of the type of results the MSM will generate.
Preliminary Results

Energy Sources for Hydrogen Pathways

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Preliminary Results

Petroleum Requirements for H2 Pathways

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Approach: Validation of the MSM

• Discussions with model developers
  – Determine that parameters are being addressed properly
  – Verify that the mapping of links between models is correct

• Comparison to other analyses
  – Explain differences between results when they are different

• Analysis community symposiums
  – Presentations by analysts
  – Discussions of methodology
  – Develop consensus on proper modeling approach for each analysis issue
# Future Work

<table>
<thead>
<tr>
<th>FY06</th>
<th>FY07</th>
<th>FY08</th>
<th>FY09</th>
<th>FY10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First version of MSM</strong></td>
<td><strong>Transportation sector / consumer model</strong></td>
<td><strong>Include electrical gen.</strong></td>
<td><strong>Stochastic Capability</strong></td>
<td></td>
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</tbody>
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- First version of the MSM (H2A Production, HDSAM, GREET)
  - Validation of the MSM
  - Initial analysis of production/delivery pathways (September 30, 2006)
  - Create a friendly user-interface for the MSM
  - Make MSM available on password protected internet site (September 28, 2007)
- Integrate transportation sector / consumer models into MSM
  - Determine next set of issues that need to be addressed
  - Add of temporal and spatial aspects to the MSM
  - Include either HyDS or HyTrans (April 30, 2007)
  - Include the model not chosen previously (April 30, 2008)
  - Review transition strategies using the MSM (January 31, 2009)
- Include stationary electrical generation and infrastructure for a full hydrogen economy (February 28, 2010)
- Include stochastic modeling capability (August 31, 2010)
Summary

- The MSM is being built to address priority analysis issues
- The Federated Object Model approach is being used to develop the MSM
- H2A Production, HDSAM, and GREET have been linked in the initial version of the MSM
- Preliminary results have been generated
- Validation of the MSM and development of a user interface are underway
Questions
Supplemental Slides

• Responses to previous year reviewers’ comments
  – Not reviewed previously

• Hydrogen safety
  – This is a modeling effort. There are no hydrogen hazards directly associated with it.

• Publications and presentations
  – There have been no publications on this work.
  – There have been no presentations outside the HFCIT program
Role in EERE Modeling Domain

- Macro-system model will simulate system performance and enable evaluation of components/interfaces from system level perspective.