Macro-System Model

Mark Ruth 

May 26, 2005

This presentation does not contain any proprietary or confidential information

Project ID # ANP6
Overview

**Timeline**
- Start date: Feb 8, 2005
- End date: Continuing
- Percent complete: 1% (New Start)

**Budget**
- Total funding:
  - 100% DOE funded
- FY04 funding: $0
- FY05 funding: $250K

**Barriers**
- Lack of a Macro-System Model (C)
- Lack of understanding of the transition of a hydrocarbon-based economy to a hydrogen-based economy (E)

**Partners**
- Will be identified
Objectives

Develop a transition macro-system model (MSM) to support decisions regarding programmatic investments

- Investment levels
- Focus of funding
- Potential effects of funding changes

Why a transition model?

- Due to transitioning infrastructure, technology timing is critical for decision-making
- Necessary for conduct overarching and trade-off comparisons
Need for a MSM

Current Situation:
- Numerous element models
- Funding spread around
- PBA beginning to put H2 in NEMS
- Transition modeling emerging
- Feb 04 NRC recommendation

Need for a Modeling Effort:
- Support Systems Analysis, to help guide R&D
- Focused investment of DOE funding
- Standardization of element models
- Address the overall H2 infrastructure, particularly Transition
- Complementary to PBA models and to Integrated Baseline

Feb 04 NRC Report
The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs:
“Systems modeling for the hydrogen supply evolution should be started immediately, with the objective of helping guide research investments and priorities for the transportation, distribution, and storage of molecular hydrogen.”

2005 EERE Multi-Year RD&D Plan
Lack of a Macro-System Model. Although numerous models exist to analyze components and subsystems of an eventual hydrogen economy, a modeling architecture does not exist that addresses the overarching hydrogen fuel infrastructure as a “system.” Such a macro-system model is critical to assessing the transition from the existing energy infrastructure to one including hydrogen. Individual models spanning a wide range of modeling platforms (operating systems, software, inputs, outputs, boundary conditions, etc.) must be integrated into a common macro-system model.
Role in EERE Modeling Domain

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

Planning according to systems engineering principles

I. Define Requirements
   - List issues the MSM should address
   - Determine features the MSM needs
   - Record requirements for the MSM

   **Documented Requirements**

   **Input from Analysts**

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. Recommend Approach
   - Develop Proposed WBS, Schedule & Budget
   - Develop & Evaluate Options
   - Recommendations for Establishing Model Capability

   **Architecture Options**
Progress

• Step I (defining requirements)
  – Developed straw-man list of issues the MSM must address
    • Analysts within the community will review and add to it
  – Developed list of features the MSM must have
  – Starting to list requirements
    • Output
    • Input / Integration
    • Functional (timeframes, data management system, etc.)
    • Non-functional (user interface, reports, etc.)

• Step II (evaluating alternatives)
  – Started gathering information on existing element models
  – Completed a Request for Information (RFI) for macro-system model architecture tools
  – Reviewed some additional potential tools that integrate distributed element models
Issues the MSM Will Address

- Financial
  - R&D Transition
  - 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

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

Are the current technical targets the best ones?
What relationships and inter-depencies do they have?
How should components and interfaces be optimized?

What is the full cost per mile driven and how will it evolve over time?

R&D

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

Given funding and resource limitations, which components/technologies/processes should be funded? When?

What are the critical paths/components/technology hurdles?
How can risks be mitigated by funding competing technologies?
Transition Issues

Defining and comparing different transition pathways

What are the regional variances in transition scenarios?

How do hydrogen as a fuel and fuel cell vehicles compete with and affect other markets?

What will a hydrogen infrastructure cost? How might it be paid for?

What legacy issues might affect development of a hydrogen infrastructure?

Transition

Market Issues

Regional Issues

Comparison of Pathways

Infrastructure & Legacy
Financial and Environmental Issues

Financial

What requirements do corporations have before they will invest in hydrogen technologies?

How should the government best invest to bring about the hydrogen economy?

Environmental

What resource requirements and emissions profiles do transition scenarios have? How do they compare?
Features of a Macro-System Model

• Dynamic engineering transition model
• Simulate performance and evolution of infrastructure
• Use distributed architecture to link existing and emerging models that analyze individual elements
• Include both fuel and vehicle supply and demand estimates to capture competition
• Include both hydrogen and gasoline supply chains
• Capture regionality of hydrogen infrastructure
• Capture influence of early-adopters on transition
The MSM will simulate possible transitions between today’s hydrocarbon economy and tomorrow’s hydrogen economy.

The MSM will be designed to adapt and grow as the program advances. It will be continuously updated and maintained to reflect the current status of technologies, technical milestones, thoughts on transition, and other programmatic factors.
Distributed Architecture

Core dynamic model will integrate and utilize existing and emerging component and element models to the extent possible.

Share standard inputs, credible/documented data, and outputs that can be used by the economic/market model and program model domains.

Hydrogen Production Models

Reefinery Model

Distribution Location Models

Distribution Cost Models

Consumer Demand Models

Fuel Cell Cost Models

Gasoline Vehicle Cost Models

Vehicle Selection Model

Environmental Performance Model
High Level Structure for Core Dynamic Model

- Competition captured endogenously
- Addition of electricity module and other transportation modules at a later date
Example: Hydrogen Supply Chain

Energy Resources
Solar
Wind
Biomass
Nuclear
Fossil

Water Resources

Module Boundary

Hydrogen Production Systems
Inputs for production costs will be from H2A and other cost tools

Co-products
Heat

Hydrogen Delivery Systems
Delivery, storage, and refueling infrastructure will require integration with regional optimization and costing tools

Hydrogen Dispensing Systems
Dispensing system costs will require input from regional optimization models

Examples:

Natural Resources
Component/Equipment Manufacturers
Legacy System Infrastructure (grid, pipelines, etc.)

Electricity

H_2

Hydrogen

H_2
Regionality

Energy source, delivery, and demand are all regional issues; therefore, the macro-system model must have a regional structure that captures those issues and helps identify the mix of production and delivery schemes.
Early-Adopters

Many models only capture the actions of the “average” consumer

This model will need to simulate the early-adopters who switch first to understand initial infrastructure needs.
Response to Previous Year Reviewers’ Comments

• This is a new project so no comments have been made
Future Work (Planning)

<table>
<thead>
<tr>
<th>Step I</th>
<th>Step II</th>
<th>Step III</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY05 Q3</td>
<td>FY05 Q4</td>
<td>FY06 Q1</td>
</tr>
<tr>
<td>Complete list of issues the MSM must address and report on them (July 31, 2005)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complete list of requirements (September 30, 2005)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FY06 Q2</td>
<td>FY06 Q3</td>
<td>FY06 Q4</td>
</tr>
<tr>
<td>Continue gathering information on existing element models</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Review existing transition models for usability as core dynamic models (November 30, 2005)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complete review of potential tools that integrate distributed element models (November 30, 2005)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Select transition model for use as core dynamic model (December 31, 2005)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Select model-integration tool (December 31, 2005)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FY07 Q1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capture MSM requirements, description, and usage in a requirements document (February 28, 2006)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peer review of MSM plan by the hydrogen modeling community (August 31, 2006)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Future Work (Model Development)

<table>
<thead>
<tr>
<th>FY05 Q3</th>
<th>FY05 Q4</th>
<th>FY06 Q1</th>
<th>FY06 Q2</th>
<th>FY06 Q3</th>
<th>FY06 Q4</th>
<th>FY07 Q1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design prototype architecture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial integration of several elements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First version of the MSM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Design prototype model architecture (December 31, 2005)
- Initial integration of several element models (April 30, 2006)
- Complete first version of the macro system model (January 31, 2007)
Supplemental Slides

• 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.
  – Presentations
    • Dale Gardner presented this work to the “National Academy of Sciences Committee to Review the FreedomCar & Fuel Partnership” on January 24, 2005.