2005 DOE Hydrogen Program Review

Hydrogen Analysis Support

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Pacific Northwest National Laboratory
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Project ID # ANP5

This presentation does not contain any proprietary or confidential information.
Overview

Timeline
- Project start date: 11/04
- Project end date: 11/05
- Percent complete: 30%

Barriers
- Barriers addressed: Feedstock Cost and Availability

Budget
- Total project funding: $150K (all DOE) to date
- No funding received in FY04
- Funding for FY05: $150K

Partners
- Other national laboratories and contractors
Objectives

- Long-term objective: Support the development of tools, methods and data for the conduct of sound analysis of hydrogen production/delivery costs, markets, policy options and other key analysis topics.

- Objectives for FY05: (1) Better understand uncertainty of future oil, gasoline and natural gas prices (2) develop a protocol for collection and use of standard data and assumptions to be used in HFCIT analytical efforts
Approach

- **Task 1 (Oil/Gas Prices):** Use the PNNL-developed MiniCAM model to project oil and gas prices under a variety of assumptions.

- **Task 2 (Data Book):** Develop suggested contents and format of standard “data book” for HFCIT and begin populating it with appropriate data.
PNNL Modeling Approach: Global Scale with Regional Detail

- Origins in the carbon dioxide issue – specifically studying future carbon emissions from human activities.

- Focus on energy production and consumption – the major source of anthropogenic carbon emissions.
  - Requires detail on all fossil fuels and non-fossil alternatives.

- Relevant scale for energy markets and carbon emissions study is global.
  - Greenhouse gas emissions have global impact and energy is traded internationally.
  - Global demand for oil and other fuels affects supply availability and price.

- Regional details are critical.
  - Regions vary in key drivers of energy and related emissions, e.g.,
    - Population and economic growth,
    - Fossil fuel resource bases,
    - Renewable and land resources,
    - Technology
PNNL’s Top-Down Modeling Approach: Economic Market Equilibrium

Market equilibrium modeling – model “solves” by finding the set of prices that clears all markets.
- Model finds prices that equilibrate all supplies and demands.
- Theoretically similar to optimization solution (e.g., LP).

Equilibrium approach produces internal consistency across all model outcomes.
- Is inherently both a “systems” approach and a “life-cycle” approach in that all physical interactions and their economic impacts are explicitly considered on a consistent basis.
- Captures system feedbacks, price responses, take-backs, etc.
- Avoids double-counting of impacts. Consider substitutes and complements.

Although we start at the top with the integrated system or economy, there is no inherent methodological limit as to how much inner detail can be incorporated.
- Regions, sectors, fuels, technologies, etc.
MiniCAM Energy Markets: Regional Supply and Conversion

- Oil Production
- Biomass Production
- Coal Production
- N. Gas Production
- Synfuel Conversion
- Gas Processing
- Liquids Refining
- Solids
- Hydrogen
- Electric Power Generation
- Liquids Market
- Solids Market
- Natural Gas Market
- Hydrogen Market
- Electricity Market

Production: Oil, Biomass, Coal, N. Gas
Conversion: Synfuel, Liquids Refining, Solids
Processing: Gas, Hydrogen
Generation: Electric Power
Markets: Liquids, Solids, Natural Gas, Hydrogen, Electricity
Task 2: Data Book

Approach

- Develop an outline and format
- Define data categories that will be collected
- Populate the data fields

Note: Work will involve considerable interaction with HFCIT office managers and project managers to ascertain their needs and solicit opinions on key parameters important to analysis topics.

Work may also involve seeking advice of outside experts in other parts of DOE or in industry.
Technical Accomplishments: Summary of Status

- Oil/Gas Analysis has been completed.
- Data Book design effort will be accomplished in Summer ‘05.
## Future Price Path Case Definitions

<table>
<thead>
<tr>
<th>Case</th>
<th>Assumed Oil Resources --Total Conventional (10^9 barrels)</th>
<th>Economic Growth</th>
<th>Additional Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2970</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2970</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2312</td>
<td>Moderate</td>
<td></td>
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<tr>
<td>4</td>
<td>2312</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>3628</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>4286</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>4286</td>
<td>Moderate</td>
<td>Higher technical improvement reduces costs of production from new resources</td>
</tr>
<tr>
<td>8</td>
<td>2312</td>
<td>High</td>
<td>Mideast production is constrained to half of current levels in 2020 and 2035</td>
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</table>
## Economic Growth Rates
(GDP, Annual Average Growth 2006-2050)

<table>
<thead>
<tr>
<th>Region</th>
<th>Moderate</th>
<th>High</th>
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<tbody>
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<td>Africa</td>
<td>5.4%</td>
<td>6.2%</td>
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<tr>
<td>Australia_NZ</td>
<td>1.6%</td>
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<td>Canada</td>
<td>1.6%</td>
<td>2.0%</td>
</tr>
<tr>
<td>China</td>
<td>6.1%</td>
<td>7.8%</td>
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<tr>
<td>Eastern Europe</td>
<td>4.6%</td>
<td>5.5%</td>
</tr>
<tr>
<td>Former Soviet Union</td>
<td>4.2%</td>
<td>5.0%</td>
</tr>
<tr>
<td>India</td>
<td>6.1%</td>
<td>7.8%</td>
</tr>
<tr>
<td>Japan</td>
<td>0.5%</td>
<td>0.9%</td>
</tr>
<tr>
<td>Korea</td>
<td>2.8%</td>
<td>3.6%</td>
</tr>
<tr>
<td>Latin America</td>
<td>4.0%</td>
<td>4.8%</td>
</tr>
<tr>
<td>Middle East</td>
<td>4.0%</td>
<td>4.8%</td>
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<tr>
<td>Southeast Asia</td>
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<tr>
<td>USA</td>
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<td>2.0%</td>
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<tr>
<td>Western Europe</td>
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<td>1.3%</td>
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World Oil Price Results in Context of Historical Annual World Oil Prices
### Oil Price Results: US Refiner Crude Acquisition Cost

(EIA/AEO’s Definition of World Oil Price)

2003 $/barrel

<table>
<thead>
<tr>
<th>Case</th>
<th>2005</th>
<th>2020</th>
<th>2035</th>
<th>2050</th>
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<tbody>
<tr>
<td>1</td>
<td>30.3</td>
<td>33.0</td>
<td>39.0</td>
<td>42.0</td>
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<td>2</td>
<td>30.3</td>
<td>33.6</td>
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<td>30.4</td>
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<td>42.1</td>
<td>46.1</td>
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<tr>
<td>4</td>
<td>30.4</td>
<td>35.9</td>
<td>44.8</td>
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<td>30.2</td>
<td>32.2</td>
<td>36.1</td>
<td>39.5</td>
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<td>30.2</td>
<td>31.6</td>
<td>34.1</td>
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<td>30.2</td>
<td>28.6</td>
<td>28.1</td>
<td>28.2</td>
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<tr>
<td>8</td>
<td>30.6</td>
<td>37.3</td>
<td>47.2</td>
<td>64.7</td>
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### US Average Delivered Unleaded Gasoline Price With Taxes
(2003 $/gallon)

<table>
<thead>
<tr>
<th>Case</th>
<th>2005</th>
<th>2020</th>
<th>2035</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.63</td>
<td>1.69</td>
<td>1.82</td>
<td>1.89</td>
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<tr>
<td>2</td>
<td>1.63</td>
<td>1.70</td>
<td>1.87</td>
<td>1.98</td>
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<tr>
<td>3</td>
<td>1.64</td>
<td>1.73</td>
<td>1.89</td>
<td>1.97</td>
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<tr>
<td>4</td>
<td>1.64</td>
<td>1.75</td>
<td>1.95</td>
<td>2.08</td>
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<td>5</td>
<td>1.63</td>
<td>1.67</td>
<td>1.76</td>
<td>1.83</td>
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<tr>
<td>6</td>
<td>1.63</td>
<td>1.66</td>
<td>1.72</td>
<td>1.79</td>
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<tr>
<td>7</td>
<td>1.63</td>
<td>1.60</td>
<td>1.59</td>
<td>1.59</td>
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<tr>
<td>8</td>
<td>1.64</td>
<td>1.78</td>
<td>2.00</td>
<td>2.37</td>
</tr>
</tbody>
</table>
95% and 99% Probabilistic Ranges for Spot Oil Prices versus Historical Daily Spot Prices

2003 $/bbl

Jun 02, 1985
Feb 27, 1988
Nov 23, 1990
Aug 19, 1993
May 15, 1996
Feb 09, 1999
Nov 05, 2001
Aug 01, 2004

Daily Spot (Actual)  C1 Upper 97.5%  C1 Annual Projection
C1 Lower 2.5%  C1 Upper 99.5%  C1 Lower 0.5%
Probabilistic Ranges Applied to Case 1 Annual Projections

95% Probabilistic Range of Spot Prices for Refiner Crude Oil Acquisition Cost

95% Probabilistic Range of Spot Prices for US Average Gasoline, with Taxes
Probabilistic Ranges Applied to Case 8 Annual Projections

95% Probabilistic Range of Spot Prices for Refiner Crude Oil Acquisition Cost

95% Probabilistic Range of Spot Prices for US Average Gasoline, with Taxes
Future Work

- Task 1: Conduct analysis of hydrogen markets using Mini-CAM model (see next slide)

- Task 2: Continue and update Data Book
Anticipated Future Work:
Update Previous PNNL analyses of hydrogen (see below) using new H2A technology characterizations

Final Energy Use by Energy Carrier (EJ/year)

No carbon policy & no advanced technology = no hydrogen

Carbon constraints & no technology improvements = no hydrogen

No carbon policy, but dramatic technology improvements = hydrogen penetration

Carbon constraints & dramatic technology improvements = hydrogen penetration
Publications

Hydrogen Safety

The most significant hydrogen hazard associated with this project is:

None