A national laboratory of the U.S. Department of E
Office of Energy Efficiency & Renewable E

National Renewable Energy Laboratory

Innovation for Our Energy Future

Hydrogen Technology Analysis: H2A Production Model Update

Todd Ramsden
National Renewable Energy Laboratory

May 15, 2007

Project ID: ANP2

This presentation does not contain any proprietary, confidential, or otherwise restricted information

NREL/PR-560-41547
Presented at the 2007 DOE Hydrogen Program Annual Merit Review and Peer Evaluation on May 15-18, 2007 in Arlington, Virginia.

NREL is operated by Midwest Research Institute . Battelle

Overview

Timeline

- Project start: December 2006
- Project end: October 2007
- Percent complete: 40%

Budget

- Total funding: $265K
  - FY 2007: $265K

Barriers Addressed

- Stove-piped/siloed analytical capabilities (B)
- Inconsistent data, assumptions, and guidelines (C)
- Need for improvement in models for better consistency and usability (D)
- Need flexible capabilities for unplanned studies & analysis (E)

Collaborators

- NETL, DTI, Technology Insights, ANL

Objectives

- The H2A model aims to make analyses:
  - Consistent
  - Transparent
  - Comparable
- Phase II goals:
  - Reflect current DOE program direction
  - Reflect best understanding of available technologies
    - Cost assumptions
    - Performance assumptions
  - Simplify model structure and user interface
  - Improve transparency
  - Provide new features

Model Approach

- Excel spreadsheet
- Discounted cash flow rate-of-return analysis
- Provides the levelized selling price of hydrogen required to attain a specified internal rate-of-return
  - i.e., minimum hydrogen price or profited cost (not market price)
- Model is meant to be a means of reporting assumptions as well as calculating minimum hydrogen selling price
- Transparency is absolute

Revision Approach

- Build on existing H2A model
- Develop specific revisions to the model structure and user interface
- Insure accuracy and detail of specific production cases
- Improve model outputs and user-specified inputs
- Develop model documentation
- Only addressing H2A production, not HD-SAM (H2A delivery)

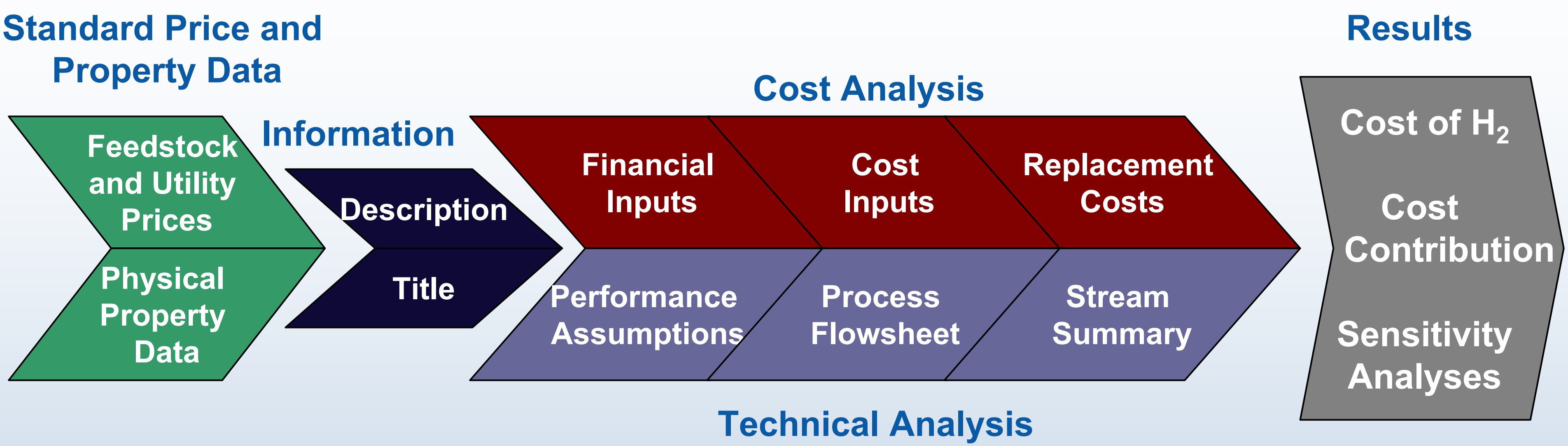
Model Changes

- Simplify underlying spreadsheet structure
- Develop user interface and improve user inputs
- Develop flat-file output capability
- Use Hydrogen Analysis Resource Center data
  - Hydrogen and physical properties data
- Monte Carlo sensitivity analysis
- Develop specific new features
- Develop import/export capabilities

New Features

- Plant size scaling
- Automated sensitivity analyses and graphing
- Carbon sequestration costs and amounts
- WTW/WTP emissions calculations
- Maintain 2005 for baseline feedstock and utility prices (AEO2005 High A), but develop toggle to use AEO2007 prices

H2A Cash Flow Modeling Tool



Spreadsheet Examples

***Table A.* Feedstock an**
Spreadsheet Calculatio
2000 $)

Fuels, Feedstocks, Other Inputs and Byproducts
Commercial Natural Gas
Industrial Natural Gas
Electric Utility Natural Gas
Commercial Electricity
Industrial Electricity
Electric Utility Steam Coal
Diesel Fuel

Financing Inputs

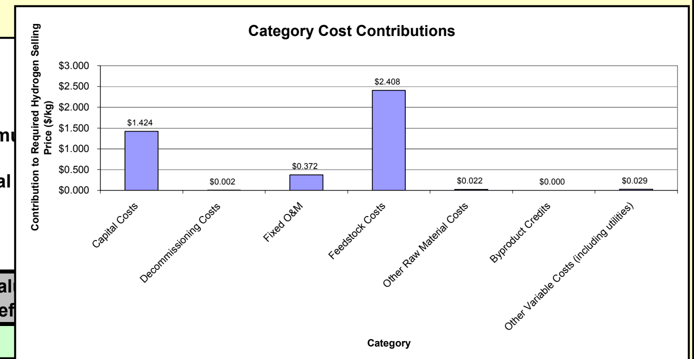
COLOR CODING

- = Calculated Cells (do not change formu
- = Input Required
- = Optional Input; To Provide Additional
- = Information Cells

	Base Case	H2A Guidelines	Val Ref
Reference $ Year (in half-decade increments)	2000	2000	
Assumed Start-up Y			
After-Tax Real IRR			
Depreciation Type (MACRS, Straight L			
Depreciation Schedule Length (No. of Ye			
Analysis Period (ye			
Plant Life (ye			
Assumed Inflation Rate			
State Income Taxes			

Press this button to determine the minimum hydrogen selling price

Solve Cash Flow for Desired IRR



H2A Spreadsheet Features

- Color-coded to facilitate user input

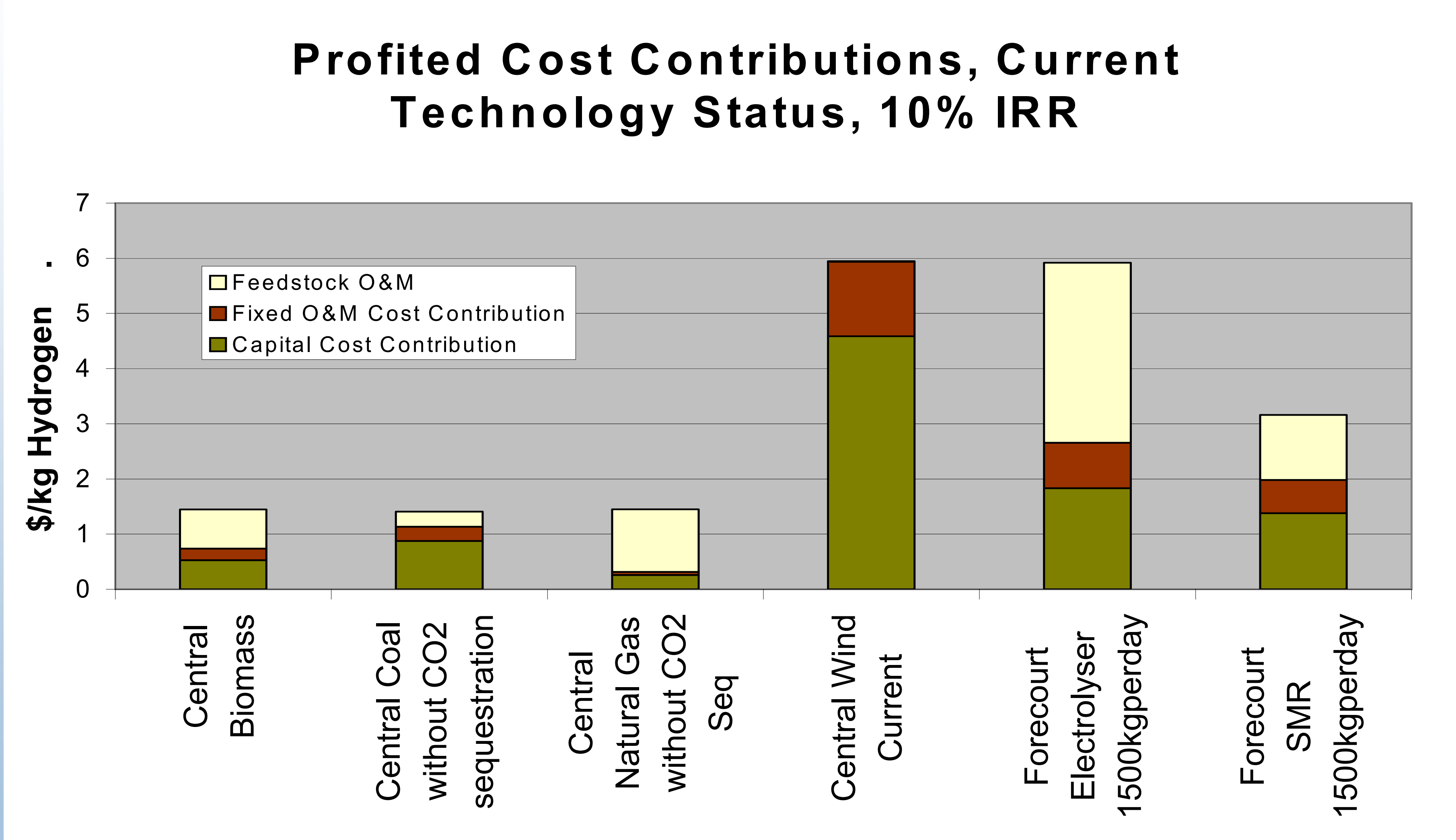
(blue)	Calculated Cells
(orange)	User Input Required
(green)	Optional Input
(yellow)	Information

- Inputs may be either H2A standard inputs or user-defined
- Error messages included to alert user when input errors are made
- Documentation available for model support

Key Financial Parameters

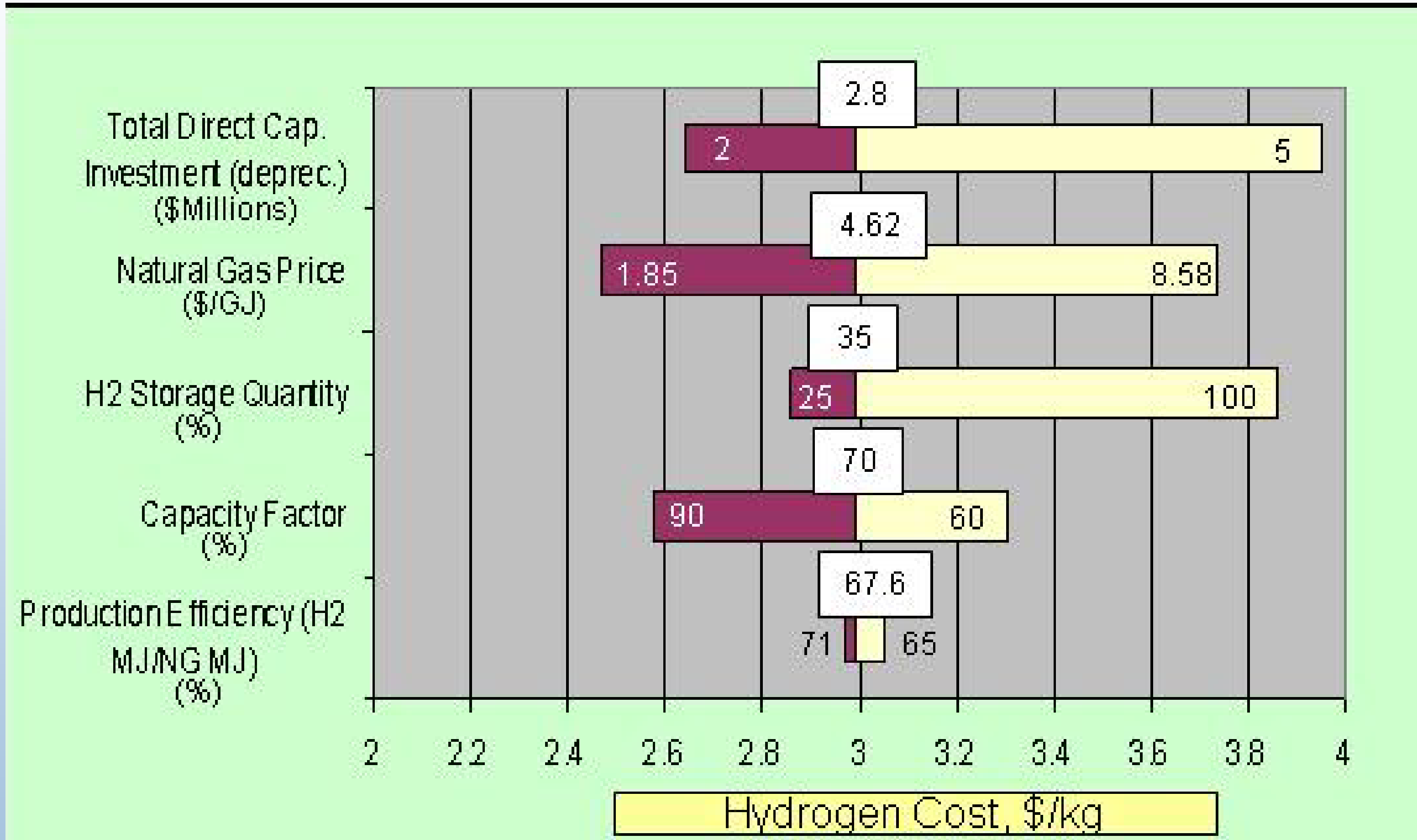
- Reference year (2005 $)
- Debt versus equity financing (100% equity)
- After-tax internal rate-of-return (10% real)
- Inflation rate (1.9%)
- Effective total tax rate (38.9%)
- Design capacity (varies)
- Capacity factor (90% for central [exc. wind]; 70% for forecourt)
- Length of construction period (0.5 - 3 years for central; 0 for forecourt)
- Production ramp-up schedule (varies according to case)
- Depreciation schedule (MACRS – 20 yrs for central; 7 yrs for forecourt)
- Plant life and economic analysis period (40 yrs for central; 20 yrs for forecourt)
- Cost of land ($5,000/acre for central; land is rented in forecourt)
- Burdened labor cost ($50/hour central; $15/hour forecourt)
- G&A rate as % of labor (20%)

H2A Current Technology Results



Sample Sensitivity Analysis

Distributed Steam Methane Reforming



"Tornado" Chart: Single-parameter sensitivity

Production Case Updates

- Up-to-date technology assumptions
  - Performance assumptions, cost assumptions (capital, fixed O&M)
- Consistency and robustness
  - Consistent assumptions, level of detail, process flow diagrams, conversions
- Improve transparency
  - More detailed break down of costs, technologies modeled, components and subsystems used

Case Studies: Central Technologies

	Coal Gasification	Coal Gasification w/ CO_2 Sequestration	Coal Gasif w/ CO_2 Seq & Power Co-Production	Biomass Gasification
Prod Rate	250 tpd	250 tpd	250 tpd	155 tpd
Current	Conventional	Conventional	Conventional	Distinct
Future	+Membrane	+Membrane Separation	+Membrane Separation	Integrated

	Natural Gas Reforming	Nat Gas Reforming w/ CO_2 Sequestration	Nuclear-Steam Electrolysis	Nuclear Sulfur-Iodine
Prod Rate	250 tpd	250 tpd	700 tpd	700 tpd
Current	Conventional	Conventional	N/A	N/A
Future	Improved Efficiency	Improved Efficiency	High-Temp Steam Electrolysis	SI Thermo-Chemical

	Electrolysis (Grid Electricity)	Electrolysis (Wind + Grid)	Electrolysis (Low-Temp Nuclear)
Prod Rate	100 tpd	100 tpd	700 tpd
Current	Low Pressure	Low Pressure	Low Pressure
Future	High Pressure	High Pressure	High Pressure

Note: tpd = tons of hydrogen per day

Case Studies: Forecourt Technologies

Type of Station	Small (100 kg/day)	Large (1,500 kg/day)	Current Technology / Design Assumptions
Natural Gas Reformer	X	X	SMR with PSA cleanup, 6250 psi piston compressors, cascade dispensing
Methanol Reformer	X	X	Comparable to SMR design, low temperature
Ethanol Reformer	X	X	Comparable to SMR design
Electrolysis	X	X	Electrolyzer, 6250 psi piston compressors, cascade storage and dispensing

Note: All cases include assessment of current and future technologies.

Future Work

- Expand model to address hydrogen quality
- Address other environmental concerns
  - e.g., water use and water quality
- Develop city-gate/semi-central production cases
- Expand available production cases
  - Coal to Fischer-Tropsch liquids
  - Forecourt aqueous phase reactor
  - Advanced bio-derived liquids

Project Summary

- Specific revisions to existing H2A model structure and interface
- Add new model features
  - Plant scaling, carbon sequestration, WTP emissions, automated sensitivity analyses
- Improve model outputs and user-specified inputs
- Insure accuracy/detail of specific production cases and improve transparency
- Develop model documentation
- Only addressing H2A production, not HD-SAM (H2A delivery)