

H2A Hydrogen Production Analysis Model Version 3



**2012 DOE Hydrogen and Fuel Cells
Program Review**

Washington DC

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May 15, 2012

Project ID PD089

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

Overview

Timeline

- **Start:** Ongoing
- **End:** September 2012*
- **Complete:** 80% (FY2012 work)

Budget

- **Total Project Funding (FY 2011 and 2012): \$403K**
 - 100% DOE-funded
- **FY2011**:** \$203K
- **Planned FY2012:** \$200K

* Project continuation and direction determined annually by DOE.

** The H2A update project was part of a larger H2A and FCPower model project in 2011.

Barriers

- **Stove-piped/Siloed Analytical Capability [4.5.B]**
- **Suite of Models and Tools [4.5.D]**
- **Unplanned Studies and Analysis [4.5.E]**

Partners

- **NREL Team; Mark Ruth, Marc Melaina, Michael Penev, Genevieve Saur, Matthew Earleywine**
- **Argonne National Laboratory**
- **Pacific Northwest Laboratory**
- **SAINC**
- **Hydrogen Production Tech Team**
- **Delivery Tech Team**

Relevance

- **The H2A model has provided the DOE Fuel Cell Technologies Program with a technology neutral cost calculator for:**
 - Development of cost targets for hydrogen production technologies
 - DOE Program assessment of progress toward goals
 - Researchers to compare process options
- **Periodic updates are needed to:**
 - Provide a basis for updates to other DOE Program documents
 - Incorporate new knowledge
 - Incorporate new AEO fuel cost projections
 - Update baseline year
 - Re-evaluate assumptions

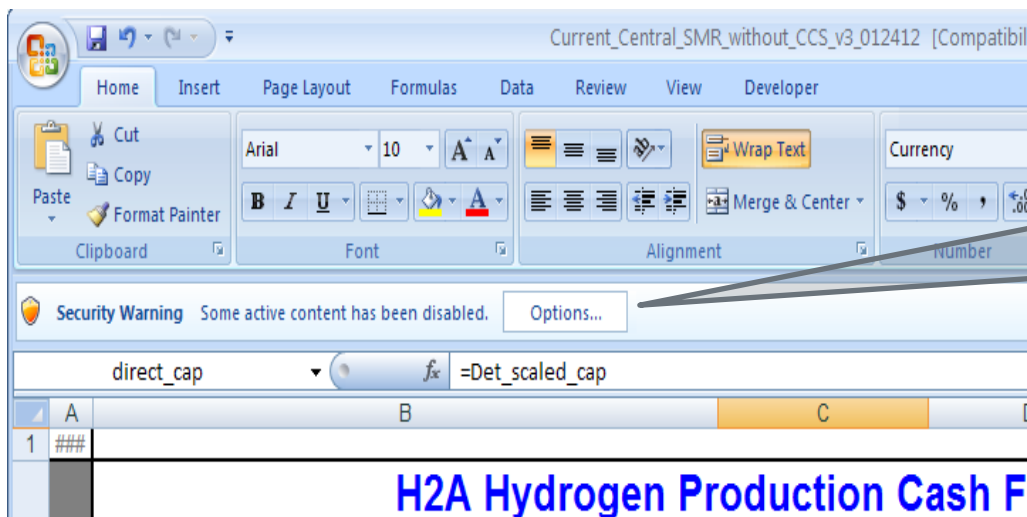
Approach – Update H2A Models

- 1. Update the “templates” for central and forecourt cases**
 - Model structural and usability changes
 - Update to 2007 dollar reference year
 - Review and update assumptions
 - New compression, storage, and dispensing calculations
 - Improve integration of compression, storage & dispensing calculations with production calculations.
- 2. Update bottom-up cost estimates for published H2A case studies based on the new templates**
 - New case studies are available for researchers [H2A is required for hydrogen production cost analysis]
- 3. Update MYRD&D Plan based on analysis of bottom up technology cost estimates**



New Case Studies are Published @
http://www.hydrogen.energy.gov/h2a_production.html

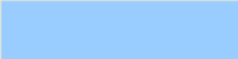


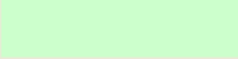

Approach – Webinar “Walk-Through” Available to Users



Click the “Options” button and then “Enable this Content”

H2A Hydrogen Production Cash F

H2A Color Coding

	Calculated cell - Do not change values in these cells
	User input required
	Error - Please review input
	User input information and notes. Color for detail calculation cells that are not linked to the Input Sheet.
	H2A information and default values.

You can put static values or your own equations in these cells

http://www1.eere.energy.gov/hydrogenandfuelcells/webinar_archives.html

Approach – Users Guide Provides Detailed Information

H2A Central Production Model Version 3 User Guide – DRAFT 1/30/12



H2A Central Hydrogen Production Model, Version 3 User Guide (DRAFT)

D. Steward, T. Ramsden, J. Zuboy, O. Antonia

Title	Information
Description	
ProcessFlow	
Input_Sheet_Template	Inputs
Replacement Costs	
Capital Costs	
Plant Scaling	
Refueling Station [forecourt model only]	
Carbon Sequestration [central model only]	
Results	Results
Cash Flow Analysis	
Tornado Chart	
Sensitivity_Analysis	
Energy Feed & Utility Prices	Data & Properties
Non-Energy Material Prices	
AEO Data	
HyARC Physical Property Data	
Debt Financing Calculations	Standard Calculations & Variables
Depreciation	
Constants and Conversions	
Lists	

http://www.hydrogen.energy.gov/h2a_production.html

Technical Report (DRAFT)
NREL/TP-xxxx-xxxxx
January 2012

Accomplishments – The “New & Improved” H2A Model

User Input

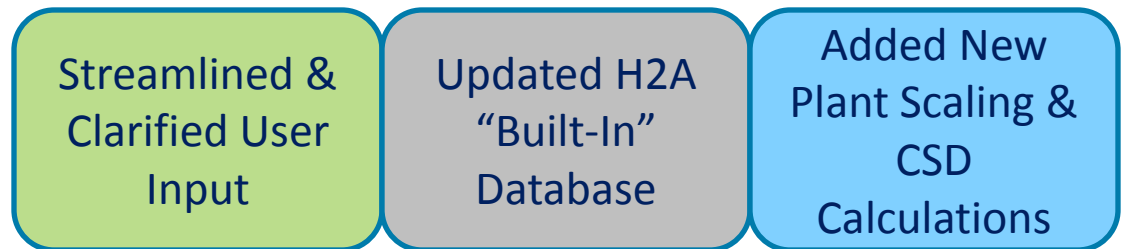
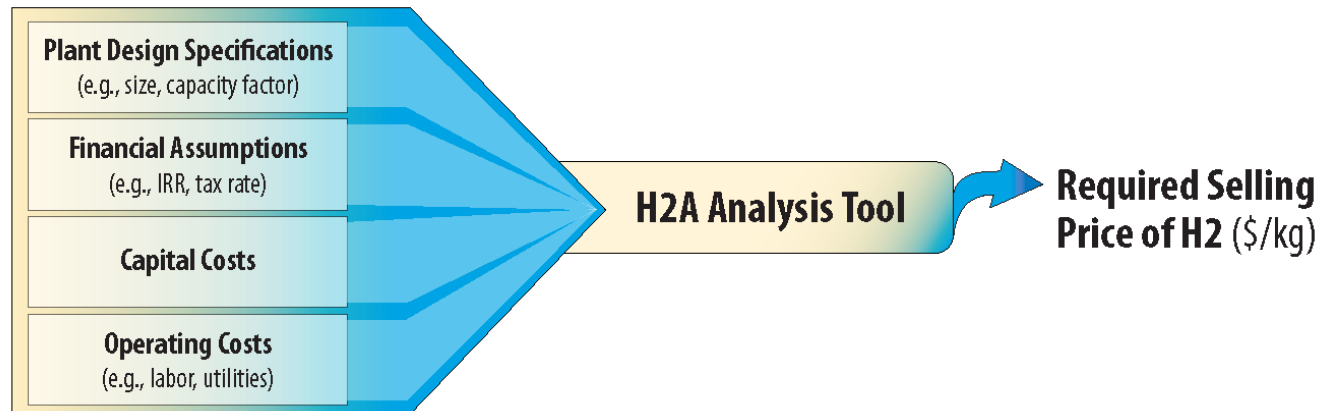
- Process modeling
- Vendor quotes
- Literature sources

H2A Values

- AEO fuel prices
- Fuel properties
- GREET emissions factors
- Industry cost indexes

H2A Calculations

- Cost escalation
- Plant scaling
- Financial calculations
- Cash flow calculations and levelized cost of hydrogen



Accomplishments – Streamlined User Input (Workflow)

Technical Operating Parameters and Specifications

Operating Capacity Factor (%)	90.0%
Plant Design Capacity (kg of H2/day)	379,387
Plant Output (kg/day)	341,448
Plant Output (kg/year)	124,628,630

Financial Input Values

Reference year	2007
Assumed start-up year	2010
Basis year	2005
Length of Construction Period (years)	3
% of Capital Spent in 1st Year of Construction	8%
% of Capital Spent in 2nd Year of Construction	60%
% of Capital Spent in 3rd Year of Construction	32%
% of Capital Spent in 4th Year of Construction	
Start-up Time (years)	1
Plant life (years)	40
Analysis period (years)	40
Depreciation Schedule Length (years)	20
Depreciation Type	MACRS
% Equity Financing	100%
Interest rate on debt, if applicable (%)	
Debt period (years)	
% of Fixed Operating Costs During Start-up (%)	75%
% of Revenues During Start-up (%)	50%
% of Variable Operating Costs During Start-up (%)	75%
Decommissioning costs (% of depreciable capital investment)	10%
Salvage value (% of total capital investment)	10%
Inflation rate (%)	1.9%
After-tax Real IRR (%)	10.0%
State Taxes (%)	6.0%
Federal Taxes (%)	35.0%
Total Tax Rate (%)	38.90%
WORKING CAPITAL (% of yearly change in operating costs)	15%

Start at the top of the input sheet and work down

- All costs are calculated and presented in reference year dollars (2007)
- The assumed startup year for current technology cases is 2010
- The basis year is the year for which cost estimates are available. Cost input values must be in basis year dollars. The basis year must be between 1992 and 2009.

The default construction period for central cases is 3 years;

- 8% of capital in year 1
- 60% of capital in year 2
- 32% of capital in year 3

This can be changed for specific cases

Use the default values (checkboxes) for all other financial input values

Accomplishments – Streamlined User Input (Basis Year)

Capital Costs

H2A Total Direct Capital Cost

\$151,666,438

[View/Edit](#)

Notes

Click to enter details on the

H2A Carbon Sequestration Total Direct Capital Cost

[Link to Detail Sheet](#)

Click to enter details on the

Indirect Depreciable Capital Costs

	Enter values in basis year (2005) dollars	Combined Plant Scaling and Escalation Factor	Reference Year (2007) Dollars
Site Preparation (\$) (may change to construction costs)	\$2,696,874	1.12	\$3,033,329
Engineering & design (\$)	\$13,484,369		644
Process contingency (\$)			\$0
Project contingency (\$)	\$20,226,554		966
Other (Depreciable) capital (\$)			\$0
One-time Licensing Fees (\$)		1.12	\$0
Up-Front Permitting Costs (\$) (legal and contractors fees included here)	\$20,226,554	1.12	\$22,749,966
Total Depreciable Capital Costs			\$215,366,342

Input values in basis year dollars throughout

Non-Depreciable Capital Costs

	Enter values in basis year (2005) dollars	Combined Plant Scaling and Escalation Factor	Reference Year (2007) Dollars
Cost of land (\$/acre)	\$50,000	0.96	\$47,804.23
Land required (acres)	10		
Land Cost (\$)			
Other non depreciable capital costs		0.96	
Total Non-Depreciable Capital Costs			
Total Capital Costs	\$215,844,384		

Escalation and scaling values clearly marked

Accomplishments – Streamlined User Input (Feed Prices)

Other Materials and Byproducts

Select the Material

Cooling Water

Byproduct

Feed or utility

Cooling Water

\$(2007)/ gal

Use H2A Default

\$0.000086

Or click to enter a price

Usage per kg H2

Cost in Startup Year

\$0

Lookup Prices

Yes

Add

Delete

Dropdown list is tied to the Non-Energy Material Prices sheet

Feed or utility	\$(2007)/ gal	Usage per kg H2	Cost in Startup Year	Lookup Prices
Demineralized Water	0.005422998	3.355	\$2,267,513	Yes
Feed or utility	\$(2007)/ gal	Usage per kg H2	Cost in Startup Year	Lookup Prices
Cooling Water	8.6275E-05	1.495	\$16,075	Yes

Non-Energy Material Prices

Other Inputs and Byproducts	Units	Source Data Year	Reference Year Conversion - Chemical price index used to update cost reference year do
Cooling Water	gal	2005	1.09
Demineralized Water	gal	2005	1.09
Process Water	gal	2005	1.09
Oxygen	kg	2005	1.09
Sulfuric Acid	kg	2005	1.09
Steam	kg	2007	1
Compressed Inert Gas	kg	2002	1.29

To add a new feed, insert a row in the Other Inputs and Byproducts Table.

Accomplishments – Updated “Database” & Assumptions

Update to 2007 Dollars to Match Program Plans and Analyses

- All capital equipment costs updated to \$2007 dollars using CEPCI indexes
- AEO 2009 Reference Case used for feedstock price projections
- Labor costs updated to \$2007 dollars using labor indexes
- Other costs updated to \$2007 dollars using consumer price indexes

Changes to Assumptions for Central Plants

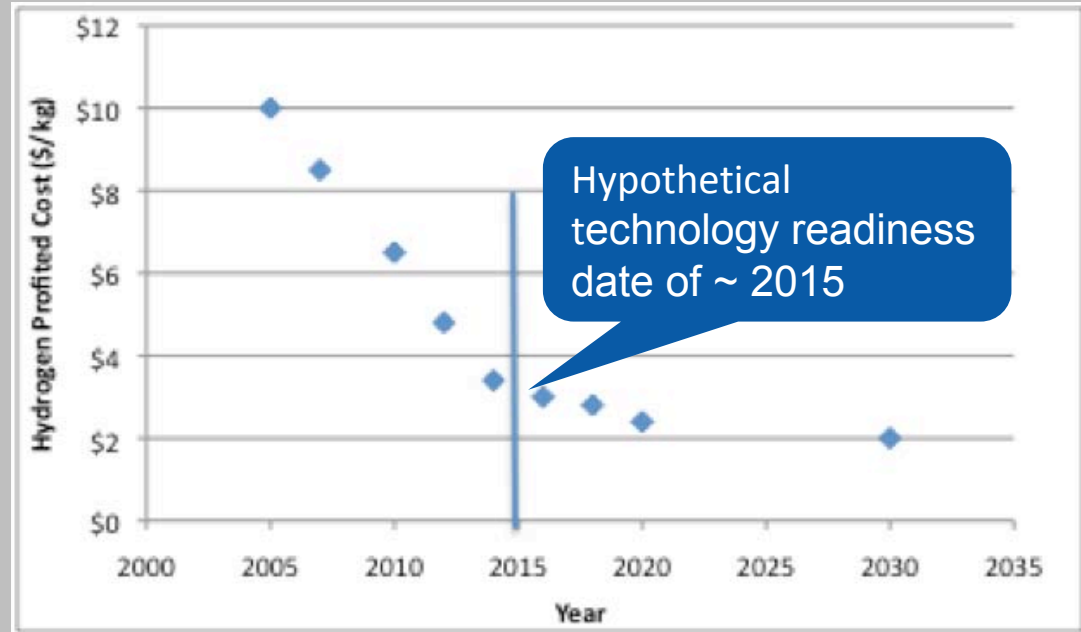
- Startup year changed from 2005 to 2010
- Cost of land increased from \$5,000 to \$50,000 per acre.
- Construction period increased from 2 to 3 years with little expenditure during the first year of construction
 - % of Capital Spent in 1st Year of Construction **60% → 8%**
 - % of Capital Spent in 2nd Year of Construction **40% → 60%**
 - % of Capital Spent in 3rd Year of Construction **0% → 32%**

Accomplishments - Forecourt Production Model Template

Revised “Nth Plant” Assumptions

The Nth plant assumption provides a context for estimating the effect of prior experience on capital and indirect costs for forecourt stations

At the Technology Readiness Date, Nth Plant Assumptions Apply; Substantial reductions in cost have occurred due to learning, production economies, and modularization of design



Nth Plant Assumptions:

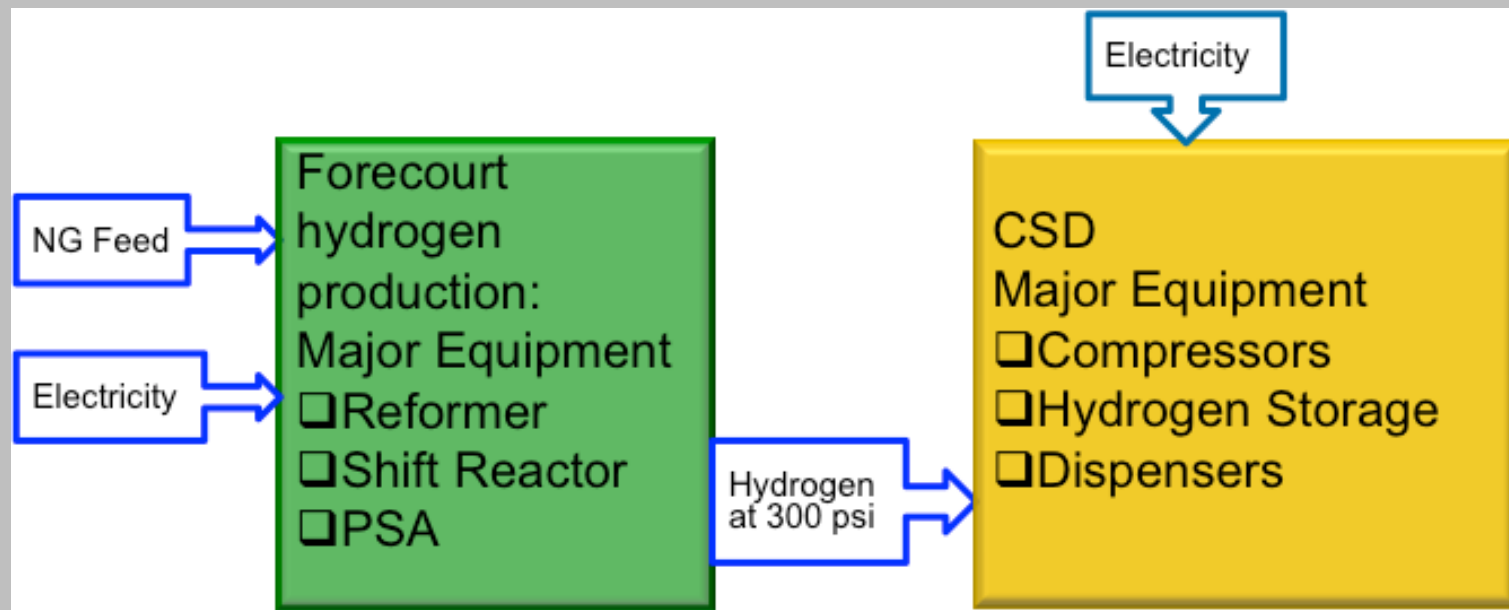
- Moderate annual system production rate: 50-150 system per year
- Substantial reduction in system cost but not full automation
- Corresponding markups: could be ~50% gross margin

Nth Plant also applies to stations

- Station design assumed to be modular
- But recognize that every design has site-specific features
- Leads to increased engineering and site preparation costs

Accomplishments – Improved Integration & Updated Calculations

Production and compression, storage & dispensing (CSD) are treated separately in the forecourt H2A model



Production model

Update to 2007 Dollars as for Central Template

In-depth review of “Nth plant” and resulting cost assumptions

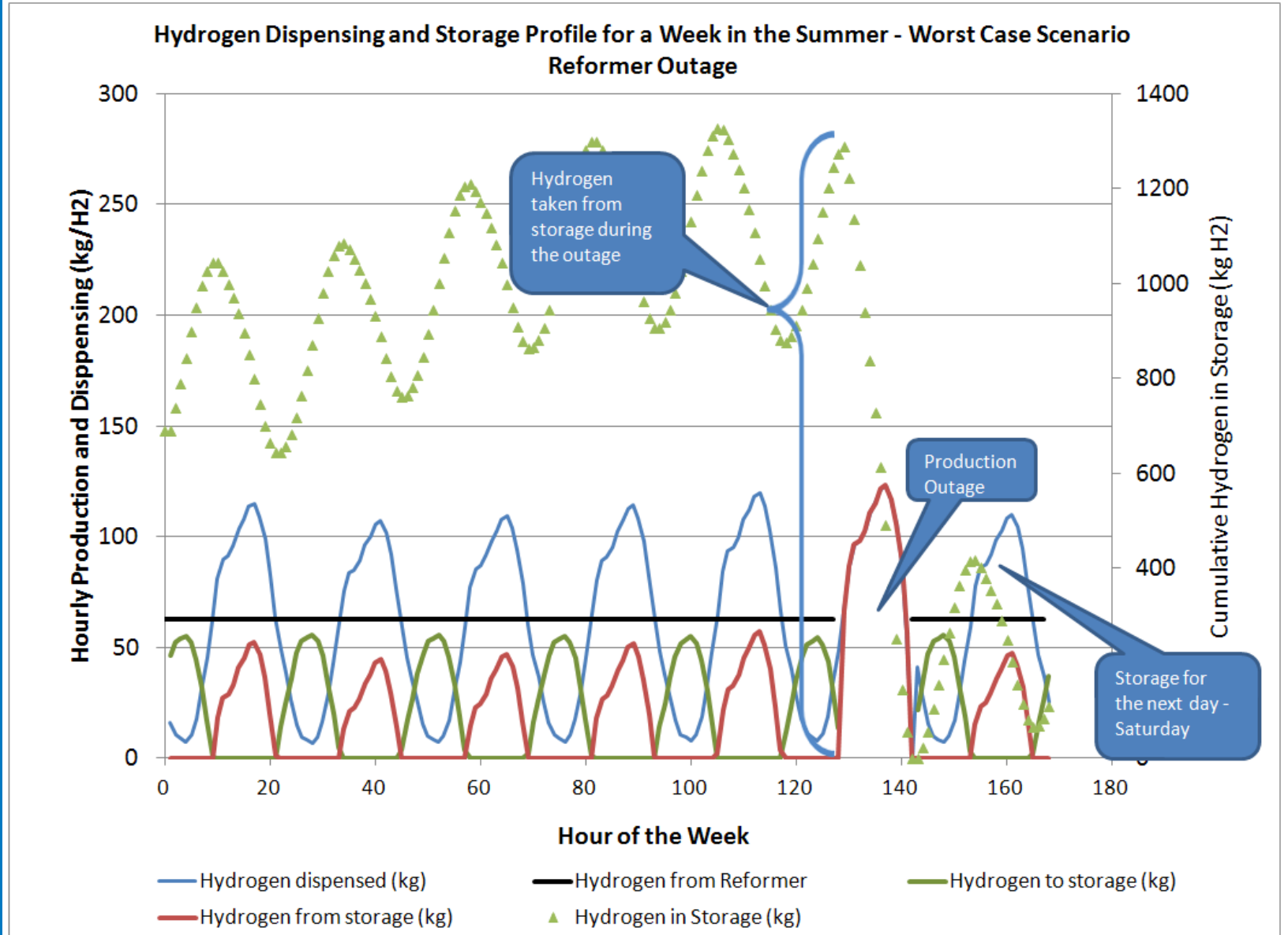
CSD model

Import new forecourt station tab from the H2A Delivery Components model
-update to 700 bar refueling*

Make adjustments for forecourt operation

* NREL, 2010: http://www.hydrogen.energy.gov/h2a_delivery.html

Accomplishments – User-Defined Daily/Weekly Profiles & Improved Calculation of Storage Requirements



Accomplishments – Additional Information in Results Section

Table of Contents

View and edit project information

Project Info

Use H2A default values

Use Default Values

H2A cell color coding

Key

Import and export data, make new price tables, and perform analyses

Toolkit

Technical Operating Parameters and Specifications

Financial Input Values

Energy Feedstocks, Utilities and Byproducts

Calculate Hydrogen Cost

Calculate Cost

COST RESULTS

Lang Factor	2.73
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Specific Item Cost Calculation		
Cost Component	Cost Contribution (\$/kg)	Percentage of H2 Cost
Capital Costs	\$0.33	17.5%
Decommissioning Costs	\$0.00	0.0%
Fixed O&M	\$0.06	3.4%
Feedstock Costs	\$1.41	74.9%
Other Raw Material Costs	\$0.00	0.0%
Byproduct Credits	\$0.00	0.0%
Other Variable Costs (including utilities)	\$0.08	4.2%
Total	\$1.88	

After completing all inputs, click the "Calculate Cost" button

Lang factor is the ratio of total project investment to purchased equipment cost

Accomplishments – Toolkit Tornado Charting Function

H2A Toolkit

Import and Export Data

Print Input Report Print Result Report Export Data

Editing

Delete Feed, Utility, and B...

Select the type of input to...

Delete

Analyses

Sensitivity Analysis

Sensitivity Analysis

Select the variable and enter the values for the analysis

Labor Requirement (FTE)

Total Capital Investment

Total Fixed Operating Cost

Cost of land (\$/acre)

Labor Requirement (FTE)

G&A rate (fraction of labor cost)

Property tax and insurance rate (fraction of

Material costs for maintenance and repairs (

utility Industrial Electricity Usage

Price

Value from Base Case

Value Increasing Hydrogen Price

1. Select values from the dropdown list for the sensitivity analysis
 2. Fill in range in the table below
- Important: The top value must decrease the resulting H2 cost and the bottom value must increase the resulting cost

Sensitivity Analysis

Select the variable and enter the values for the analysis

Total Fixed Operating Cost

Total Fixed Operating Cost

Labor Requirement (FTE)	10	20	30
Total Capital Investment	100000000	21584438	300000000
Total Fixed Operating Cost	2000000	7708823.0	12000000

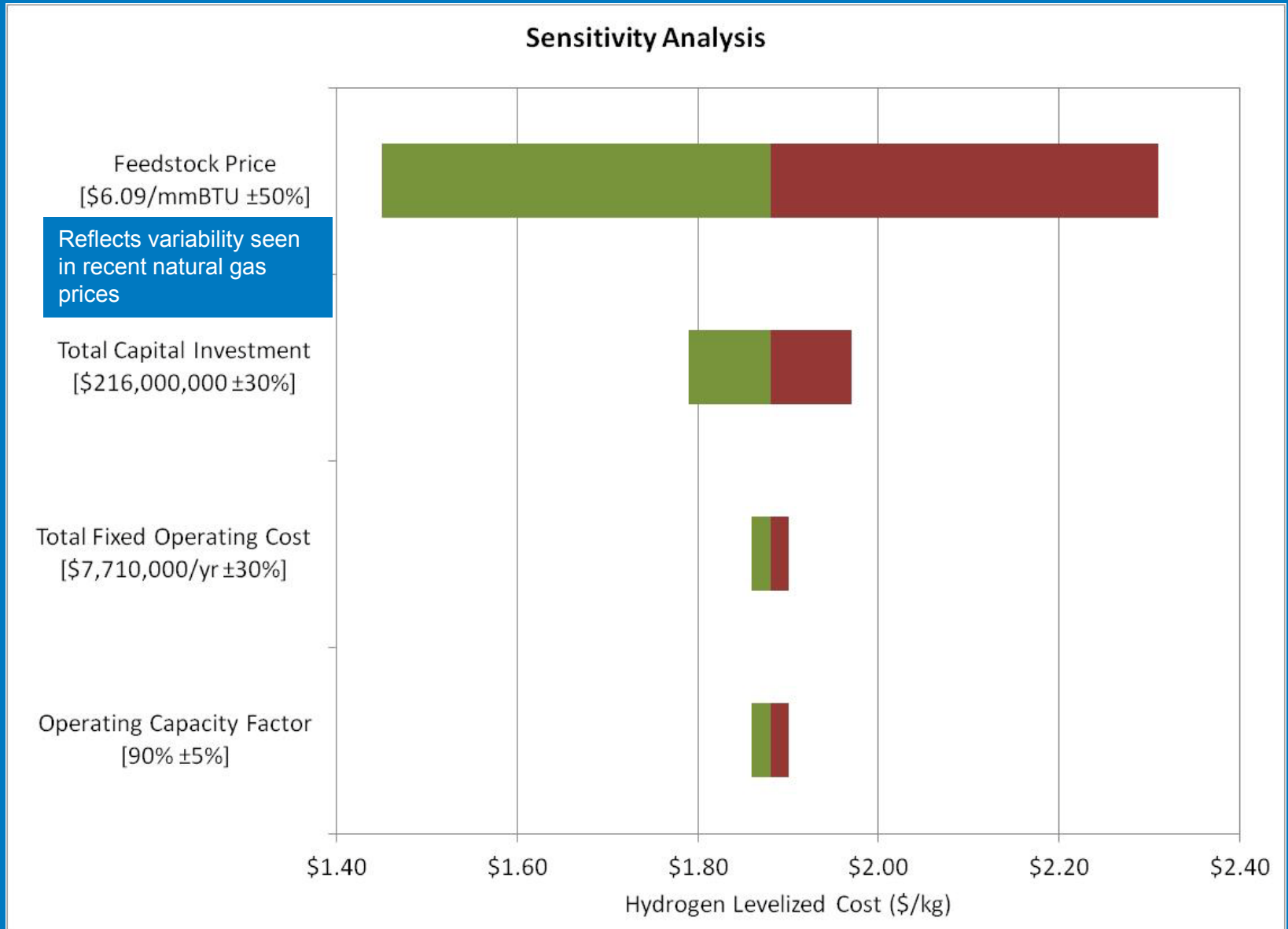
Value from Base Case

Value Increasing Hydrogen Price

Delete

Calculate Prices

Accomplishments – Sample Tornado Chart



Accomplishment - New Bottom-up Analysis for Early Development Technologies

Pathway (TR)

Photoelectrochemical (PEC) hydrogen production (2025)

Solar thermo-chemical (Ferrite cycle) (2025)

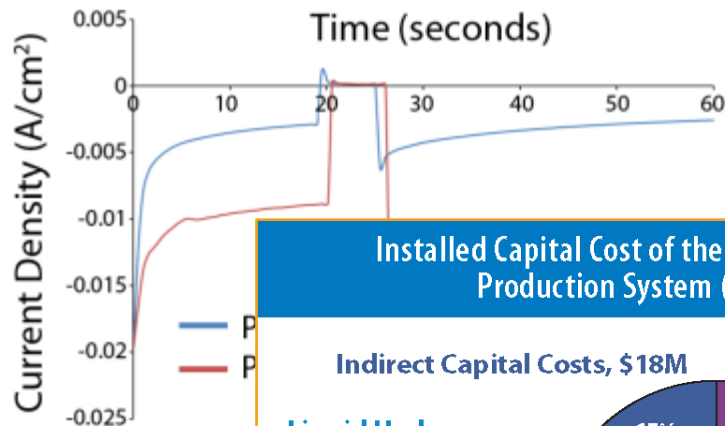
Review of Electrolysis Technologies (Alkaline and PEM)

Biological production of hydrogen (2025)

Reforming of bio-derived liquids (pyrolysis oil) (2020)

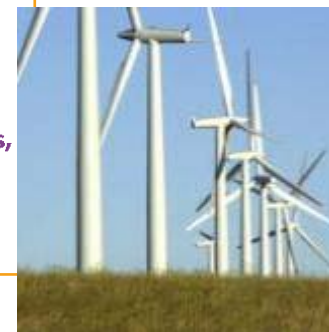
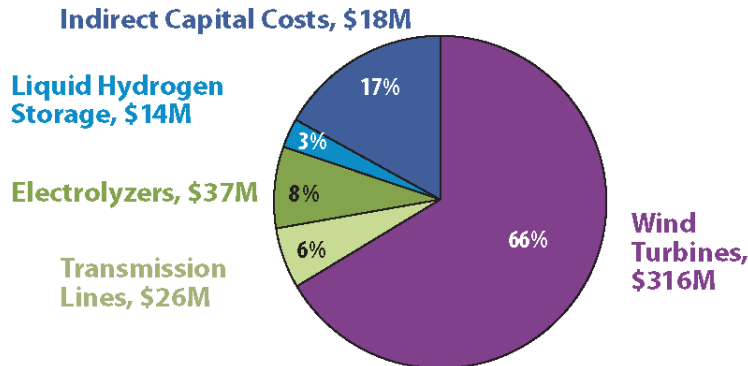
Data provided by Todd Deutsch, last updated February 2011

Efficiency: Short-circuit current density of a GaInP₂/GaAs



NREL increased the current density which improved efficiency.

Installed Capital Cost of the Wind-Hydrogen Production System (\$393M)



Data provided by Olga Sozinova & Darlene Steward, February 2011

CBS



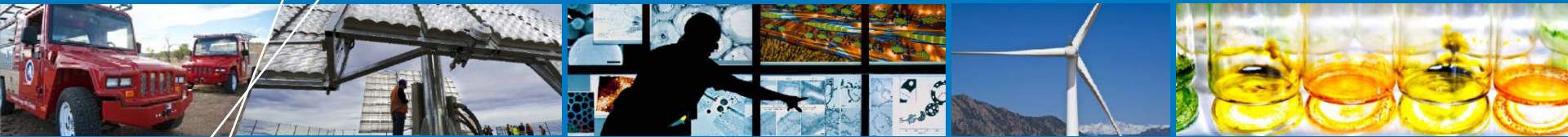
Hydrogenase

Maturation proteins



Synechocystis

Data provided by Pin-Ching Maness, last updated February 2011



Thank You