NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Critical Updates to the Hydrogen Analysis Production Model (H2A v3)

Darlene Steward

NREL

Thursday, February 9, 2012
3:00 PM - 4:30 PM EST

Darlene.steward@nrel.gov

(303) 275 3837

NREL/PR-5600-54276

Outline

Introduction – Sara Dillich

1. Overview of the H2A Model
2. H2A Version 3 Changes
3. Case Study Walkthrough
4. Resources

Outline

Introduction – Sara Dillich

1. Overview of the H2A Model
2. H2A Version 3 Changes
3. Case Study Walkthrough
4. Resources

1 Overview of H2A Model

H2A Model Structure

Getting Around

Key Worksheets

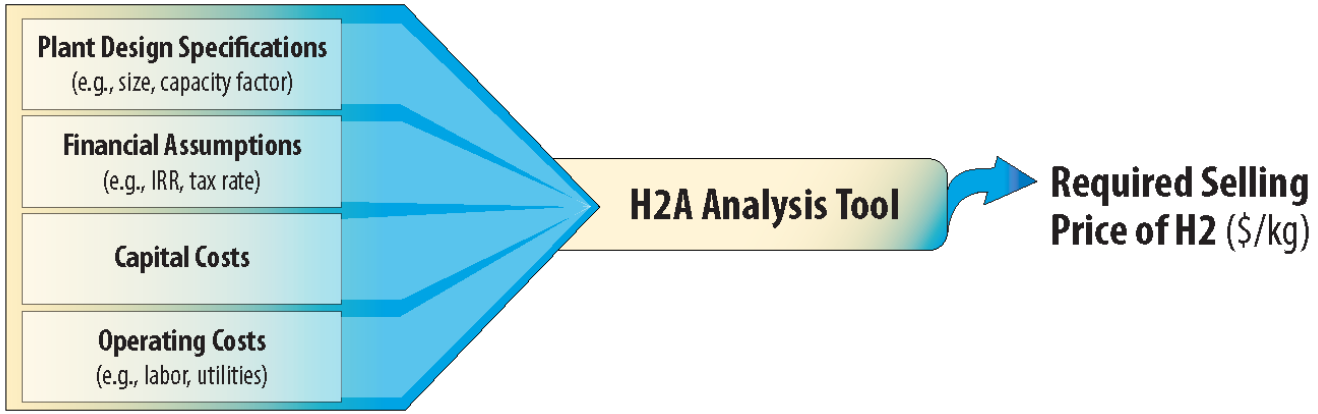
Do's and Don'ts

- Do
  - Enter values in orange cells
  - Use the light green cells for notes and side calculations
  - Fill in the project information sheets
- Don't
  - Enter values in blue cells or on the worksheets at the end of the workbook

1 H2A Model Structure

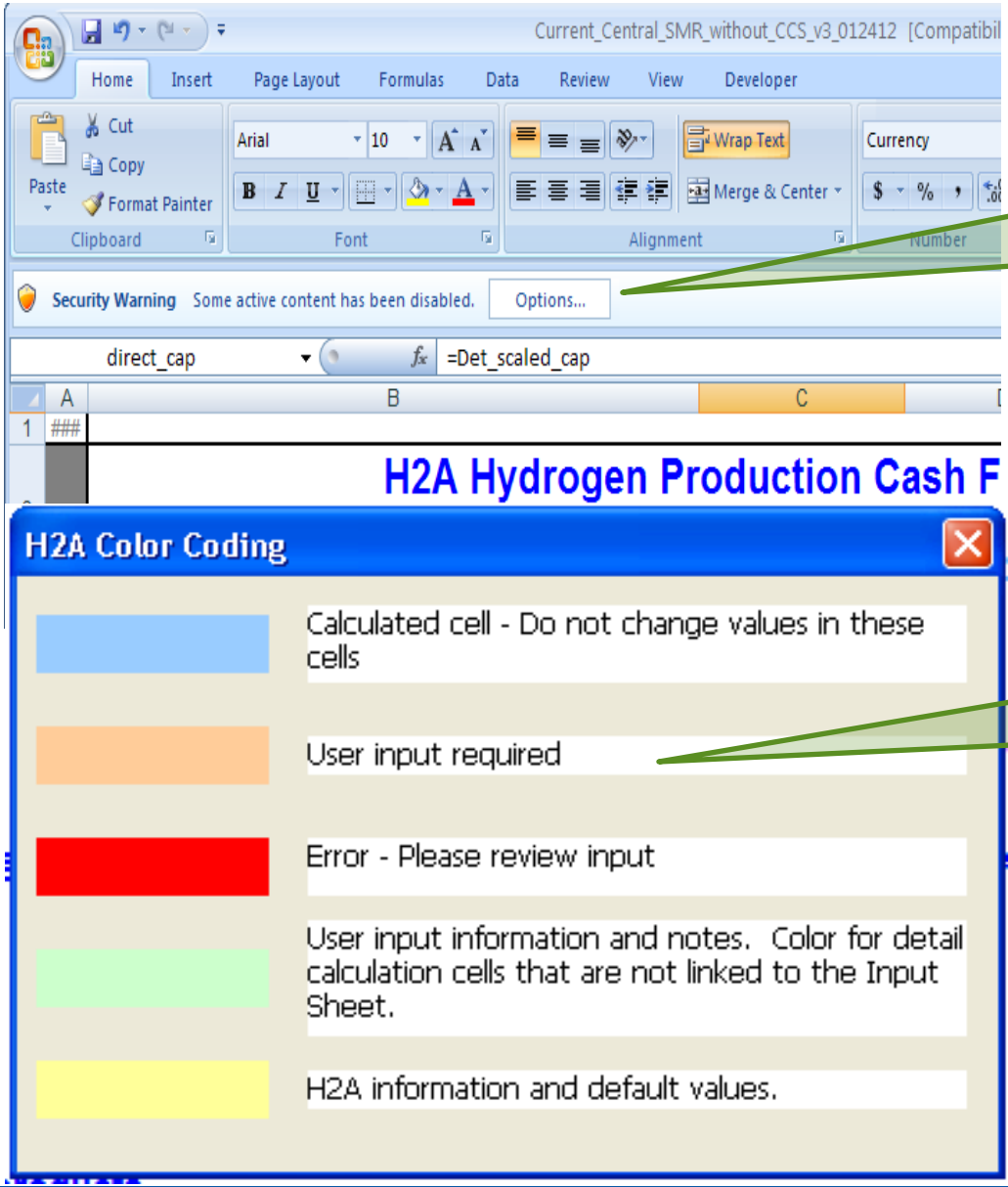
User Input
- Process modeling
- Vendor quotes
- Literature sources

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

1 Overview of H2A Model – Getting Around



Click the "Options" button and then "Enable this Content"

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

1 Overview of H2A Model – Getting Around

Please fill out the information on the first 3 sheets

Use this function to create a new tornado chart – more on this later

Table of Contents

View and edit project information — *Project Info*

H2A cell color coding — *Key*

Use H2A default values — *Use Default Values*

Import and export data, make new price tables, and perform analyses — *Toolkit*

Calculate Hydrogen Cost — *Calculate Cost*

Technical Operating Parameters and Specifications

Financial Input Values

Energy Feedstocks, Utilities and Byproducts

When you're done with input, click here to calculate cost

1 Overview of H2A Model – Key Worksheets

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	

You will be working with these sheets

Don't change these sheets

Outline

Introduction – Sara Dillich

1. Overview of the H2A Model
2. H2A Version 3 Changes
3. Case Study Walkthrough
4. Resources

2 Update to Values and Assumptions

Update to 2007 Dollars

- 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%**

Outline

Introduction – Sara Dillich

1. Overview of the H2A Model
2. H2A Version 3 Changes
3. Case Study Walkthrough
4. Resources

3 Case Study Walkthrough – Financial

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.

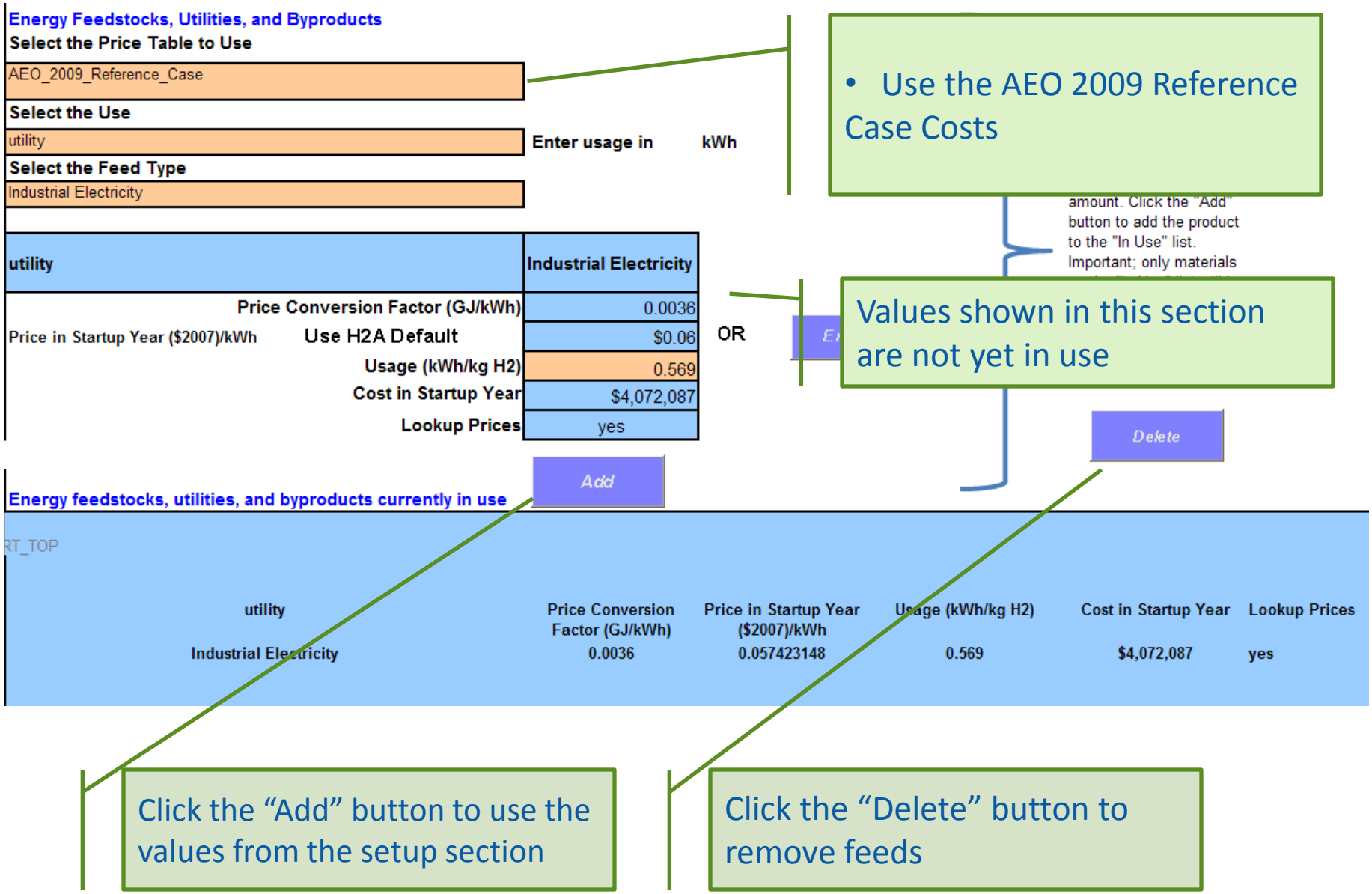
The default construction period for central cases is 3 years;

- 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

3 Case Study Walkthrough – Feedstock



3 Case Study Walkthrough – Capital

Capital Costs

H2A Total Direct Capital Cost	$151,666,438	View/Edit	Click to e
H2A Carbon Sequestration Total Direct Capital Cost		Link to Detail Sheet	Click to e

Notes

- Click the "View/Edit" button to enter capital costs

Design Plant Hydrogen Production (kg/day)	379,387	Capital costs for the design plant (baseline) are entered on this sheet. Use the Pl baseline plant. Enter the output kg/day for the plant you wish to analyze on the In
Basis year for capital costs	2005	
Enter current year for capital costs	2010	
CEPCI Inflator (2005 to 2010)	1.176	The Chemical Engineering Plant Cost Index
Consumer Price Inflator (2010 to 2007)	0.956	The Consumer Price Inflator (CPI) is used t

Use 2010 for the current year for capital costs

CAPITAL INVESTMENT (Inputs REQUIRED in Basis Year, (2005) $)

Major pieces/systems of equipment	Baseline Uninstalled Costs $2005 Dollars	Baseline Uninstalled Costs $2007 Dollars	Installation Factor	
Process Plant Equipment	49,969,788	$ 56,203,888	1.92	$ 107,911,464
Balance of Plant and Offsites	19,964,651	$ 22,455,388	1.92	$ 43,114,346
SCR NOx Control on Stack	296,651	$ 333,660	1.92	$ 640,628
		$ -		$ -
		$ -		$ -
		$ -		$ -
		$ -		$ -
		$ -		$ -
		$ -		
		$ -		
		$ -		
		$ -		
		$ -		
		$ -		
		$ -		
		$ -		
		$ -		
		$ -		$ -
		$ -		$ -
	70,231,090	$ 78,992,936		$ 151,666,438

Enter process equipment costs (in basis year dollars) and installation factors here.

3 Case Study Walkthrough – Replacement Costs

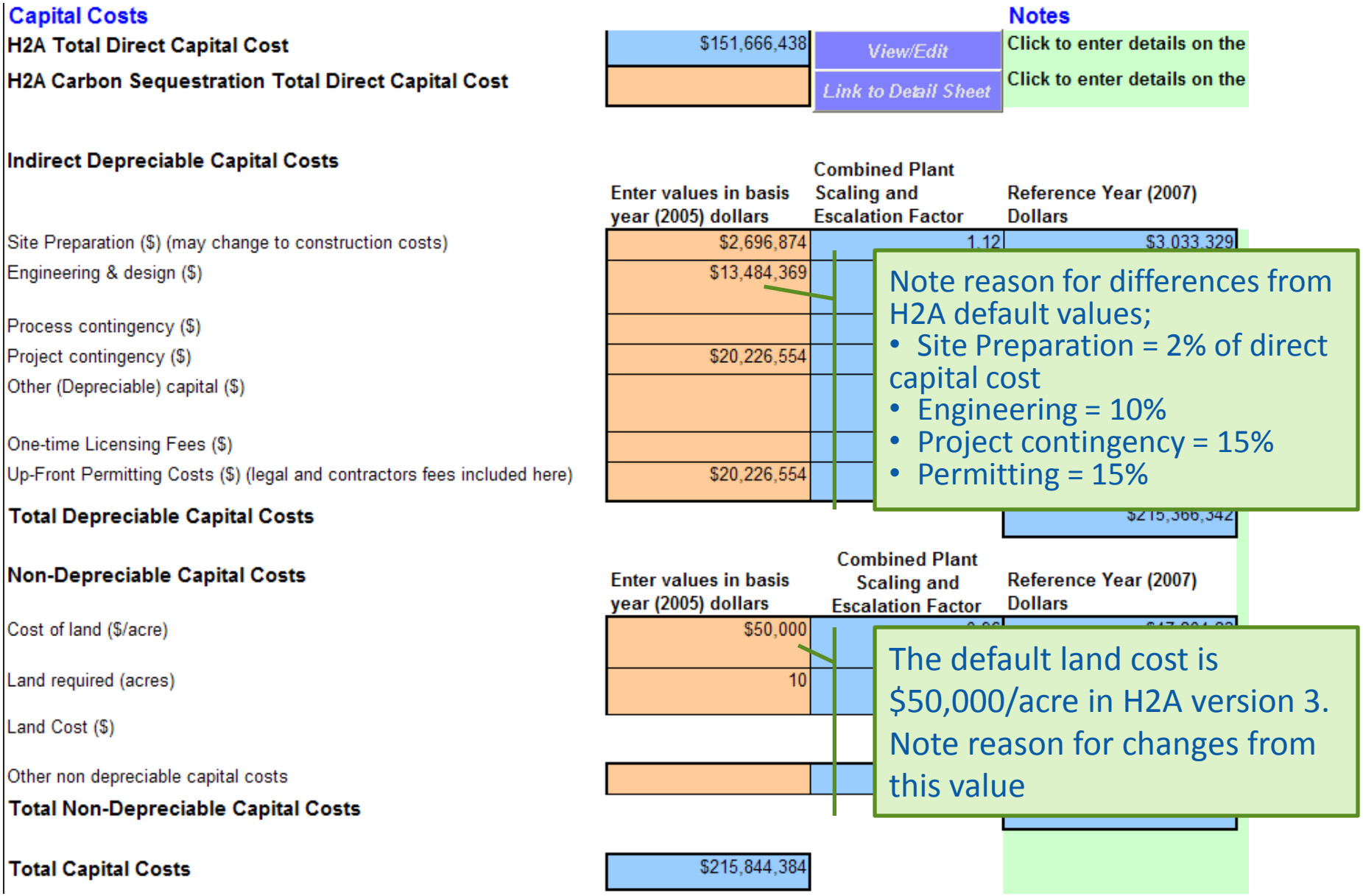
Replacement Costs

NOTE: Enter costs in year 2005 $ - Do not inflate
NOTE: All replacement costs are assumed to be equity financed.

Unplanned Yearly Replacement Capital (Depreciable)						
		Comments		Source	Information	
Total Unplanned Replacement Capital Cost Factor (% of total depreciable capital costs/year)	0.50%				Enter a fixed percentage input is me include, in t Flow Analys factor for u capital expe	
Actual Year	Analysis Year	Operations Year	Specified Yearly Replacement Costs	Specified Yearly Replacement Costs	Unpla Replaceme	
			Year 2005 $	Year 2007 $	Year 2007 $	Inflated to Start-up Year
2007	4	1		$0	$1,076,832	$1,139,385
2008	5	2		$0	$1,076,832	$1,139,385
2009	6	3		$0	$1,076,832	$1,139,385
2010	7	4		$0	$1,076,832	$1,139,385
2011	8	5		$0	$1,076,832	$1,139,385
2012	9	6		$0	$1,076,832	$1,139,385
2013	10	7		$0	$1,076,832	$1,139,385
2014	11	8		$0	$1,076,832	$1,139,385
2015	12	9		$0	$1,076,832	$1,139,385
2016	13	10		$0	$1,076,832	$1,139,385
2017	14	11		$0	$1,076,832	$1,139,385
2018	15	12		$0	$1,076,832	$1,139,385
2019	16	13		$0	$1,076,832	$1,139,385
2020	17	14		$0	$1,076,832	$1,139,385
2021	18	15		$0	$1,076,832	$1,139,385
2022	19	16		$0	$1,076,832	$1,139,385
2023	20	17		$0	$1,076,832	$1,139,385

Tip: Enter an equation here to automatically scale costs if the plant size changes

3 Case Study Walkthrough – Indirect Costs



3 Case Study Walkthrough – Fixed Operating Costs

Fixed Operating Costs	Enter values in basis year (2005) dollars	Combined Plant Scaling and Escalation Factor	Reference Year (2007) Dollars
Total plant staff (number of FTEs employed by plant)	20	1	20
Burdened labor cost, including overhead ($/man-hr)	$50	0.99	$49.69
Labor cost, $/year			$2,067,311
G&A rate (% of labor cost)	20%		
G&A ($/year)			$413,462
Licensing, Permits and Fees ($/year)	$0	1.12	$0.00
Property tax and insurance rate (% of total capital investment per year)	2%		
Property taxes and insurance ($/year)			$ 4,316,888
Rent ($/year)	$0	0.96	$0.00
Material costs for maintenance and repairs ($/year)	$810,097	1.12	$911,163
Production Maintenance and Repairs ($/year)	$0	1.12	$0.00
Other Fees ($/year)	$0	1.12	$0
Other Fixed O&M Costs ($/year)	$0	1.12	$0.00
Total Fixed Operating Costs			$7,708,823

Use the default values of;

- $50/hour for labor $(2005)
- 20% G&A
- 2% Property Tax & Insurance

3 Case Study Walkthrough – Other Materials

Other Materials and Byproducts

Select the Material

Cooling Water

Feed or utility	**Cooling Water**	
$(2007)/ gal	$0.000086	Or click to enter a price
Usage per kg H2		
Cost in Startup Year	**$0**	
Lookup Prices	**Yes**	

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 indexes are used to update costs to reference year dollars	2001		
Cooling Water	gal	2005	1.085424453	8.627		
Demineralized Water	gal	2005	1.085424453	0.0054		
Process Water	gal	2005	1.085424453	0.0018		
Oxygen	kg	2005	1.085424453	0.0217		
Sulfuric Acid	kg	2005	1.085424453			
Steam	kg	2007	1	0.0135	0.0135	0.0135
Compressed Inert Gas	kg	2002	1.292434838	0.033086332	0.03308633	0.033086 3

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

3 Case Study Walkthrough – Other Variable Costs

Other Variable operating costs (for the first year)	Enter values in basis year (2005) dollars	Combined Plant Scaling and Escalation Factor	Reference Year (2007) Dollars
Other variable operating costs (e.g. environmental surcharges) ($/year)	$2,123,000	1.09	$2,304,356
Other Material Costs ($/year)	$0	1.09	$0
Waste treatment costs ($/year)	$0	1.09	$0
Solid waste disposal costs ($/year)	$0	1.09	$0
Total Unplanned Replacement Capital Cost Factor (% of total direct depreciable costs/year)	0.50%		Value added to match other central cases. Use this value for all central cases
Royalties ($/year)	$0	0.96	$0
Operator Profit ($/year)	$0	0.96	$0
Subsidies, Tax Incentives ($/year)	$0	0.96	$0
CO2 sequestration O&M costs and credits ($/year)			
Process Carbon Tax ($/metric ton carbon produced as CO2)	$0	0.96	$0
Process Carbon Tax ($/year)			$0
Upstream Carbon Tax ($/metric ton upstream GHG CO2 eq)	$0	0.96	$0
Upstream Carbon Tax ($/year)			
Total Variable Operating Costs ($/year)			

Use the default unplanned replacement factor of 0.5% of total capital cost per year

Royalties, profits and tax incentives are assumed to be zero.

3 Case Study Walkthrough – Results

Table of Contents

View and edit project information — Project Info

H2A cell color coding — Key

Use H2A default values — Use Default Values

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

Calculate Hydrogen Cost — Calculate Cost

Technical Operating Parameters and Specifications

Financial Input Values

Energy Feedstocks, Utilities and Byproducts

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

COST RESULTS

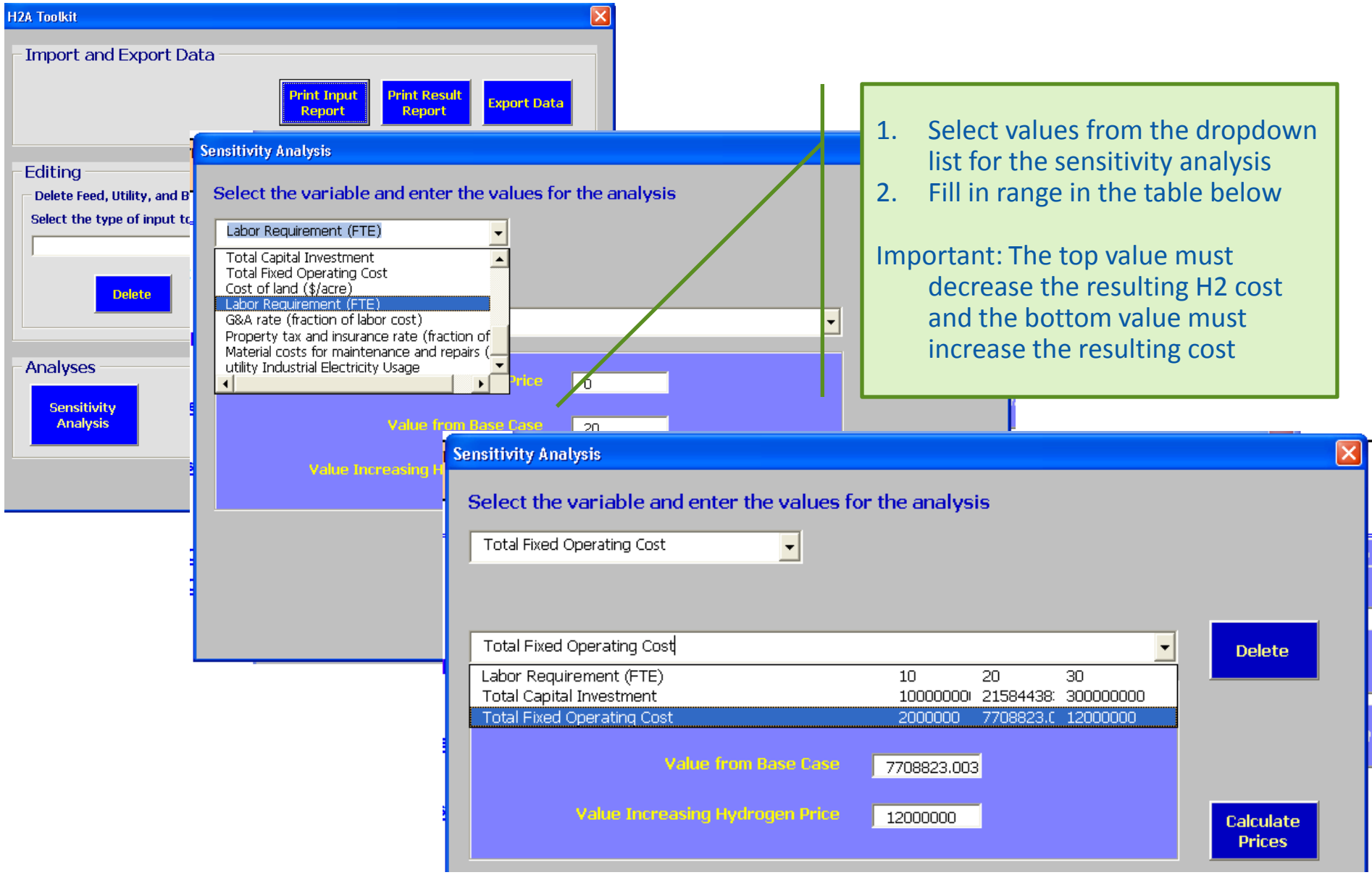
Lang Factor	2.73

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**	

Lang factor is the ratio of total installed cost to equipment cost

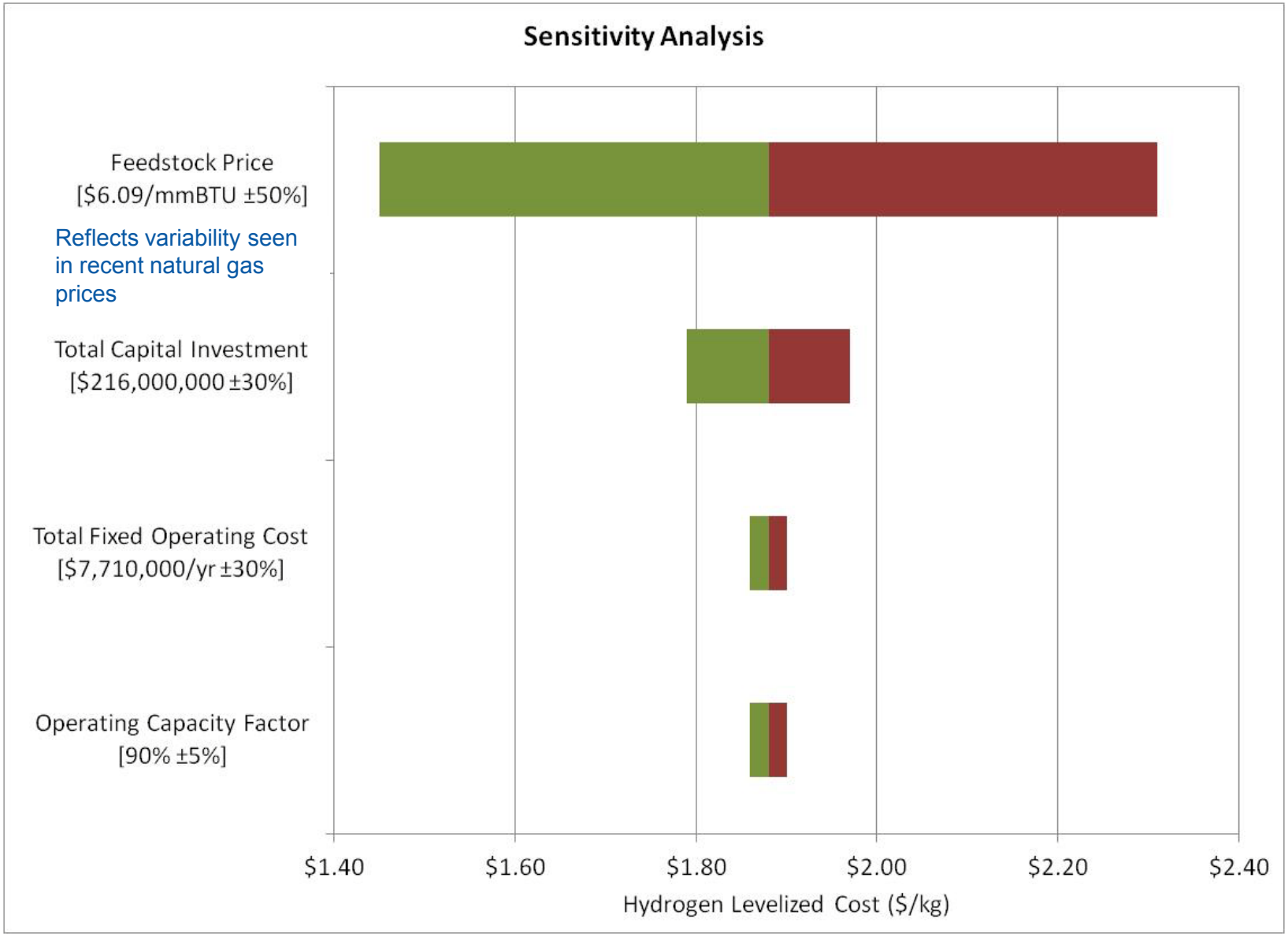
3 Case Study Walkthrough – Sensitivity



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

3 Case Study Walkthrough – Tornado Chart



Outline

Introduction – Sara Dillich

1. Overview of the H2A Model
2. H2A Version 3 Changes
3. Case Study Walkthrough
4. Resources

4 Other Financial Parameters

- After tax real IRR: 10% (KIC)
- 100% equity financing (KIC)
- Start-up Year: 2010 (Definition in H2A V3)
- Plant life: 40 yr (KIC)
- Operating capacity factor: 90% (KIC)
- Construction Period: 3 years (Update explained in user guide)
- Start up time: 1 year (KIC)
- Depreciation Schedule: 20 years MACRS (KIC)
- State Taxes: 6% (KIC)
- Federal Taxes: 35% (KIC)
- Working Capital: 15% (KIC)

- There are others that have smaller effects.

4 Website and Contact Information

H2A Website access to

- Users Guide
- "blank model"
- Case studies

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

For additional information contact

Marc Melaina: Marc.Melaina@nrel.gov

Darlene Steward: Darlene.Steward@nrel.gov

Thanks

Example Supporting Materials

Rutkowski et al., 2002. Hydrogen Production Facilities Plant Performance and Cost Comparisons, Final report March 2002. Prepared for the U.S. Department of Energy. http://www.netl.doe.gov/energy-analyses/pubs/finalcompreport.pdf

- Includes early version of H2A Central SMR plant, with some details on costs and performance.

Rath, 2010. *Assessment of Hydrogen Production with CO2 Capture Volume 1: Baseline State-of-the-Art Plants. NETL report: DOE/NTEL-2010/1434.*

http://www.netl.doe.gov/energy-analyses/pubs/H2_Prod_Vol1_2010.pdf

- Includes detailed cost and performance information on a larger version of the Central SMR wCCS plant.

McCollum and Ogden, 2006. Techno-Economic Models for Carbon Dioxide Compression, Transport, and Storage & Correlations for Estimating Carbon Dioxide Density and Viscosity. University of California at Davis, ITS Report: UCD-ITS-RR-06-14. http://pubs.its.ucdavis.edu/publication_detail.php?id=1047

- Includes cost and performance information on the CCS system used in the Central SMR CCS cases.

Comparison to Rath 2010 SMR Study (NETL)

ITEM	Current SMR H2A V3	Rath 2010
NG feed	450 psia	450 psia
Plant capacity factor	90%	90%
Design Natural Gas Analysis	26-City Survey	Nat. Ave.
PSA Hydrogen recovery	80%	80%
• Rath: "performance is based upon POLYBED ten-bed unit by UOP, LLC (a Honeywell company)		
Hydrogen purity	99.9%	99.9%

In Progress

Gas Analysis

Rath 2010

Exhibit 1-5
Design Natural Gas Analysis

Volume share	National Average
Methane	93.90%
Ethane	3.20%
Propane	0.70%
C4+	0.40%
CO_2+N_2	2.60%
Water	85-105ppmv
Sulfur	6ppmv

H2A V3

STREAM NUMBER	1
	Natural Gas
Mole Fraction	
Ar	0.0000
CH4	0.9000
C2H6	0.0500
CO2	0.0000
H2	0.0000
H2O	0.0000
N2	0.0500
O2	0.0000
NOx	----
Total Flow (lbmol/hr)	6,981
Total Flow (lb/hr)	121,060
Temperature (°F)	59
Pressure (psia)	450.0