NREL
NATIONAL RENEWABLE ENERGY LABORATORY

H2A Hydrogen Production Analysis Model Version 3

2012 DOE Hydrogen and Fuel Cells Program Review

Washington DC

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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

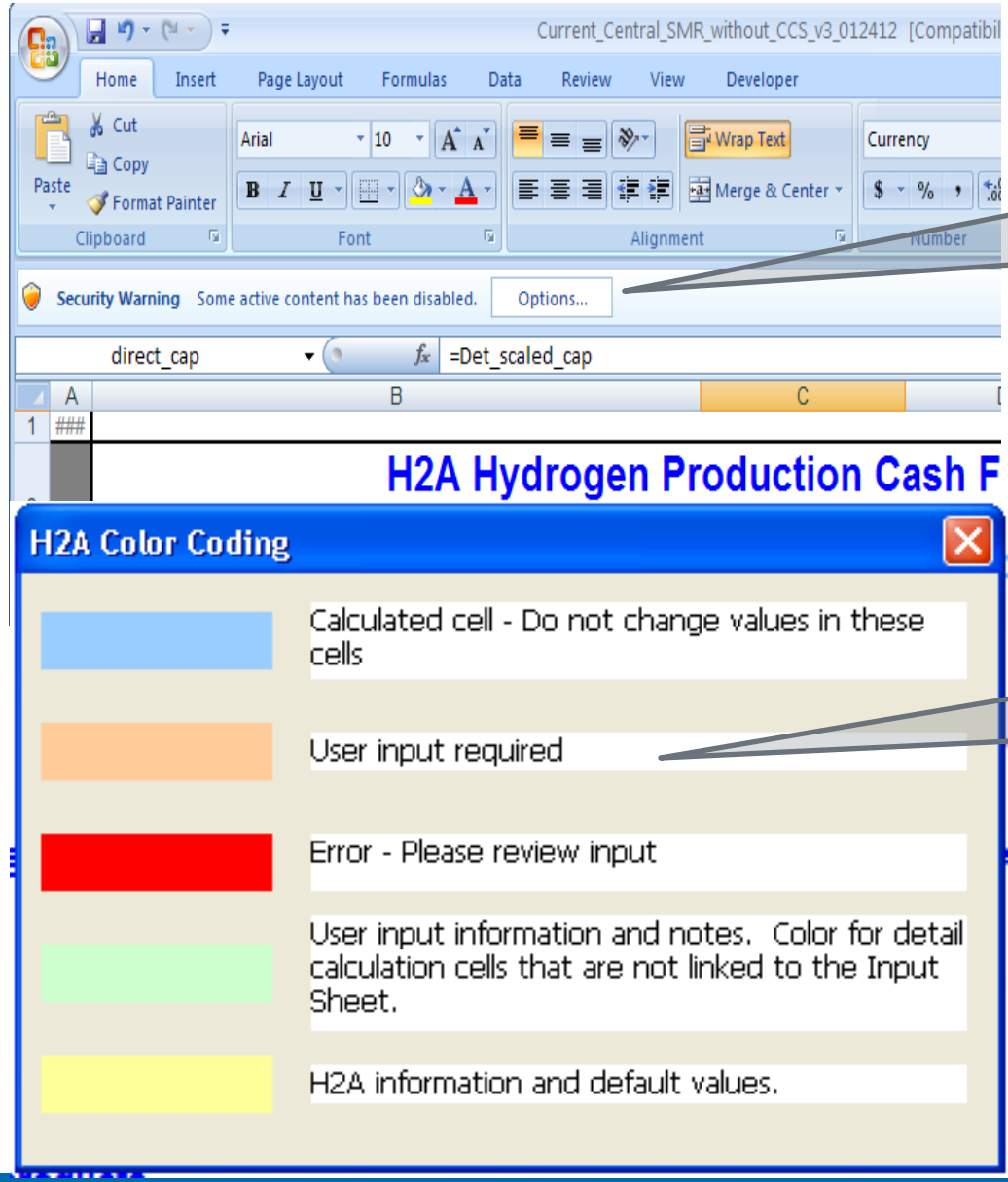
- **Periodic updates are needed to:**
  - Provide a basis for updates to other DOE Program documents
  - Incorporate new knowledge
  - Incorporate new AEO fuel cost projections
  - Update baseline year
  - Re-evaluate assumptions

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

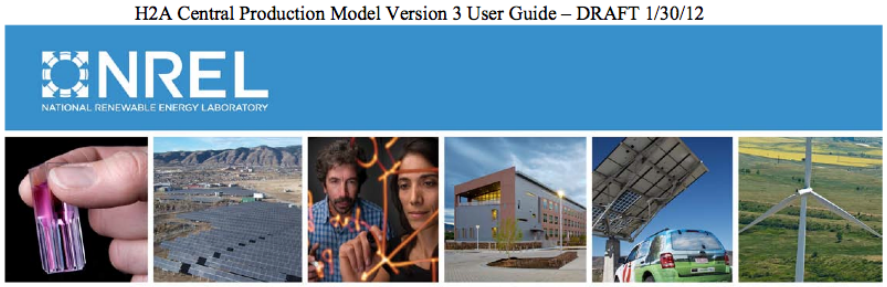


Click the "Options" button and then "Enable this Content"

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



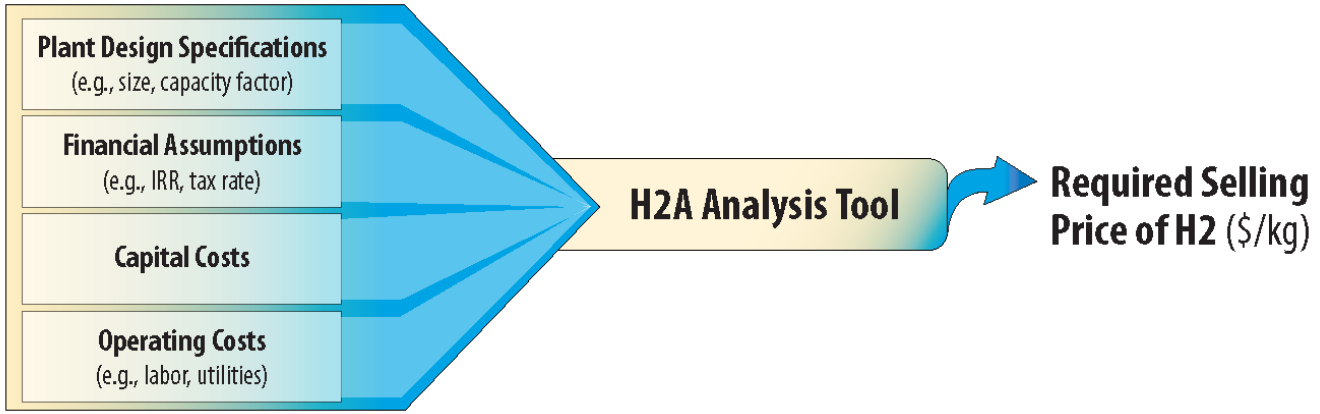
Title	Information
Description	
ProcessFlow	
Input_Sheet_Template	Inputs
Replacement Costs	
Capital Costs	
Plant Scaling	
Refueling Station [forecourt model only]	
Carbon Sequestration [central model only]	
Results	Results
Cash Flow Analysis	
Tornado Chart	
Sensitivity_Analysis	
Energy Feed & Utility 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

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

Streamlined & Clarified User Input

Updated H2A "Built-In" Database

Added New Plant Scaling & CSD Calculations

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.

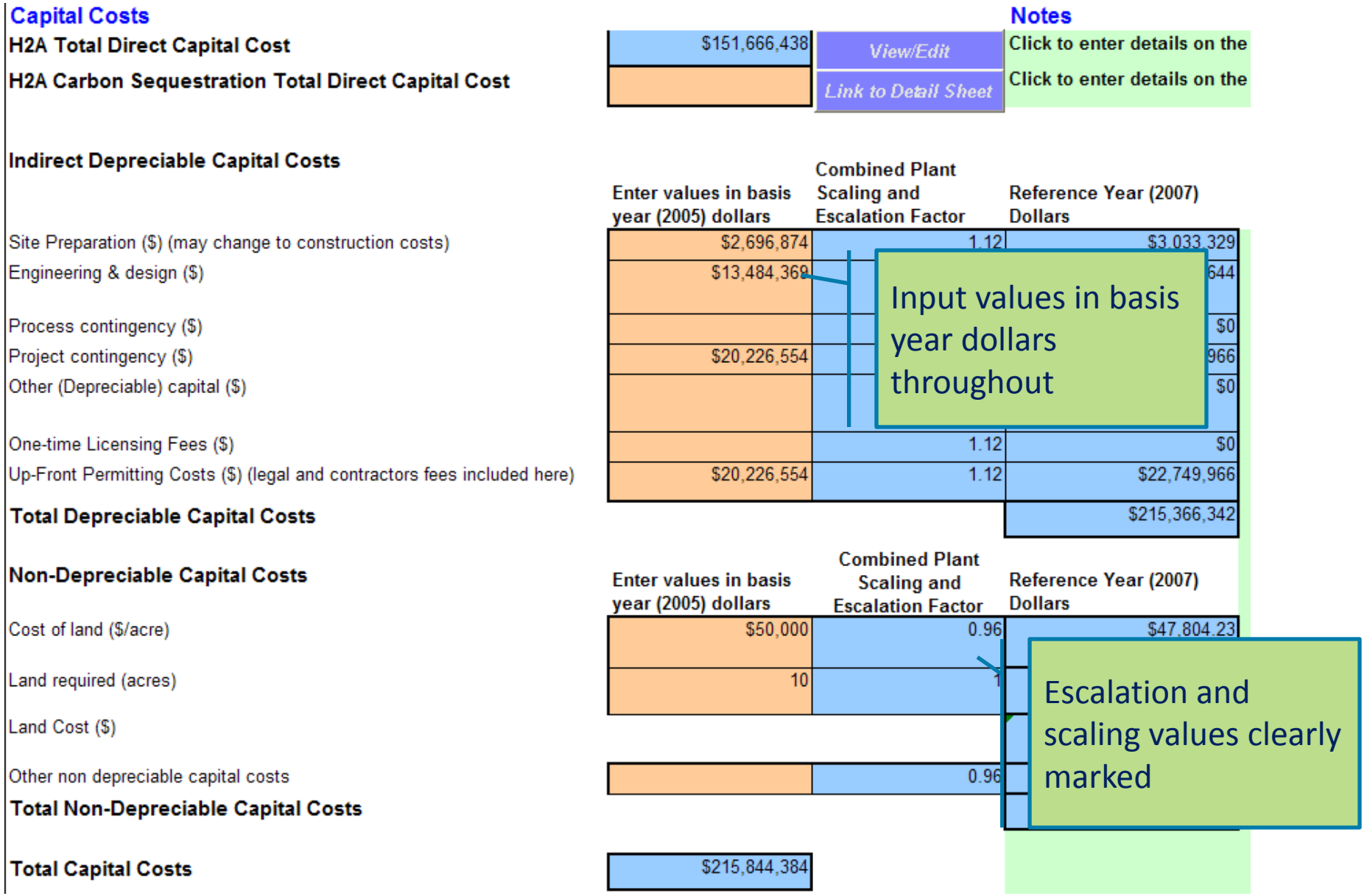
The default construction period for central cases is 3 years;

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

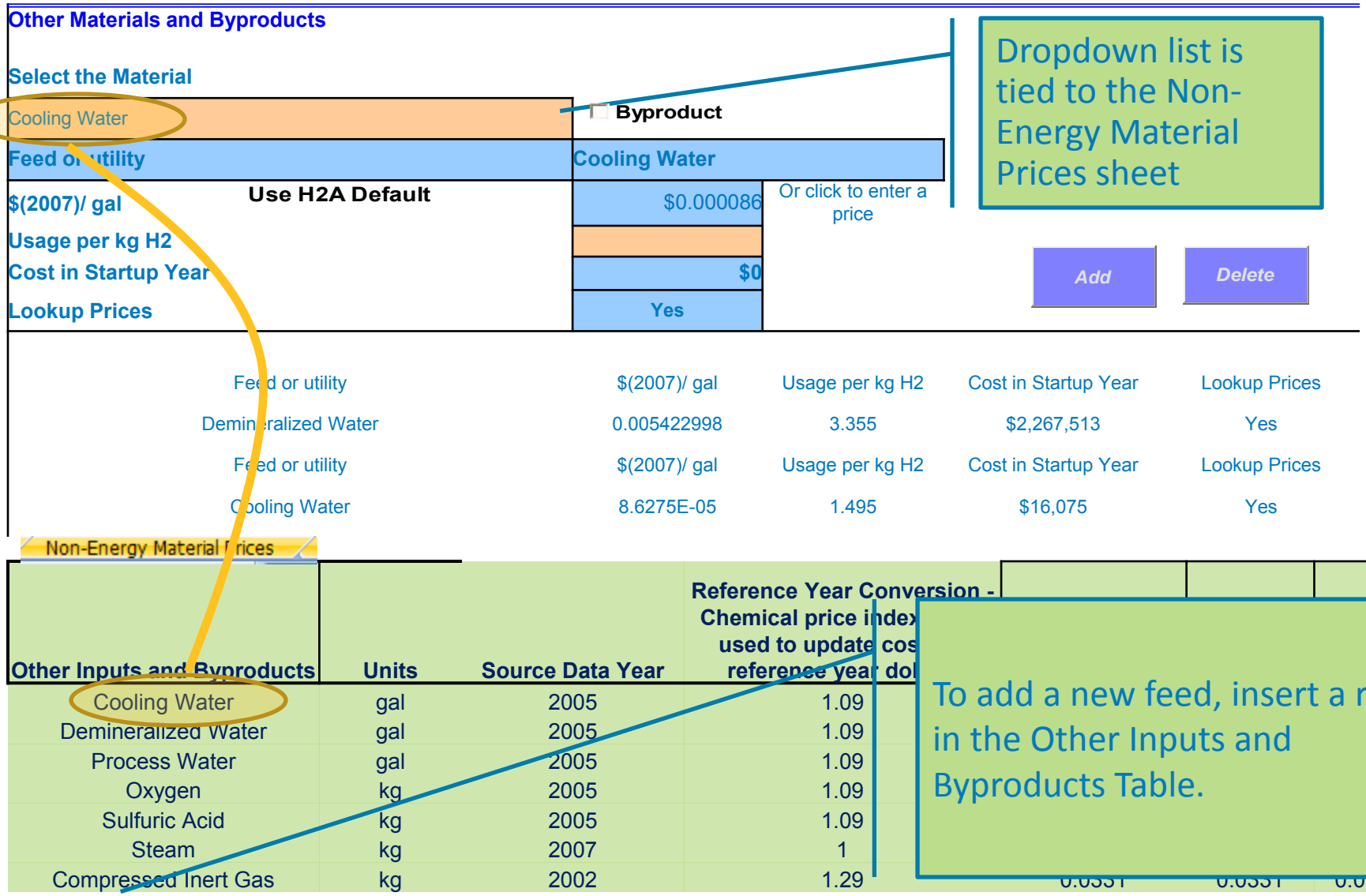
This can be changed for specific cases

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

Accomplishments – Streamlined User Input (Basis Year)



Accomplishments – Streamlined User Input (Feed Prices)



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

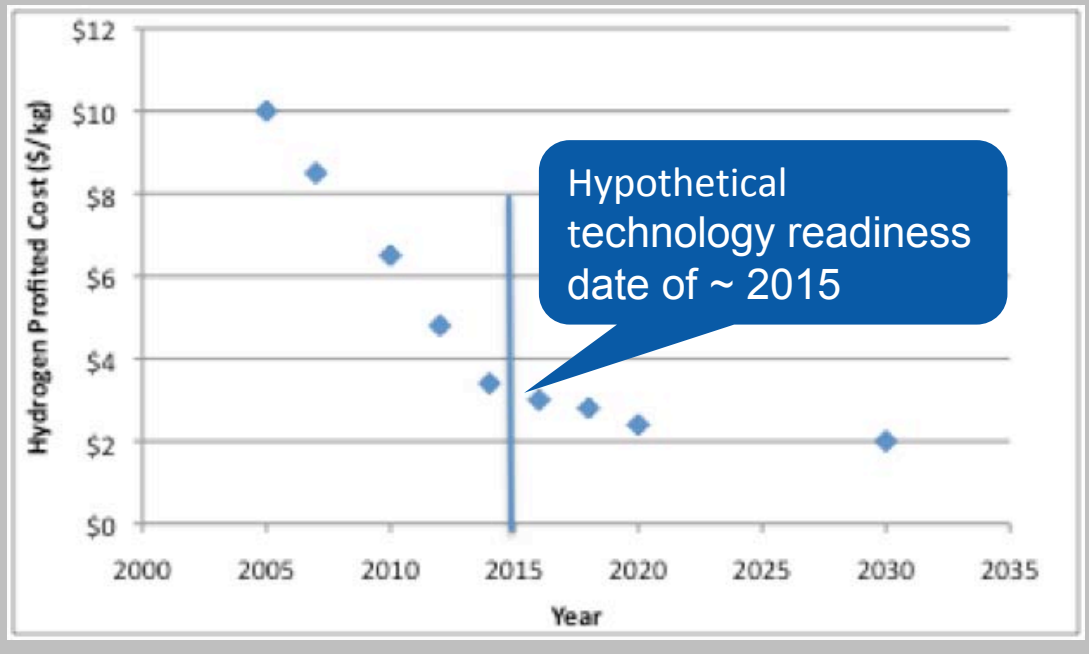
Changes to Assumptions for Central Plants

- 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:

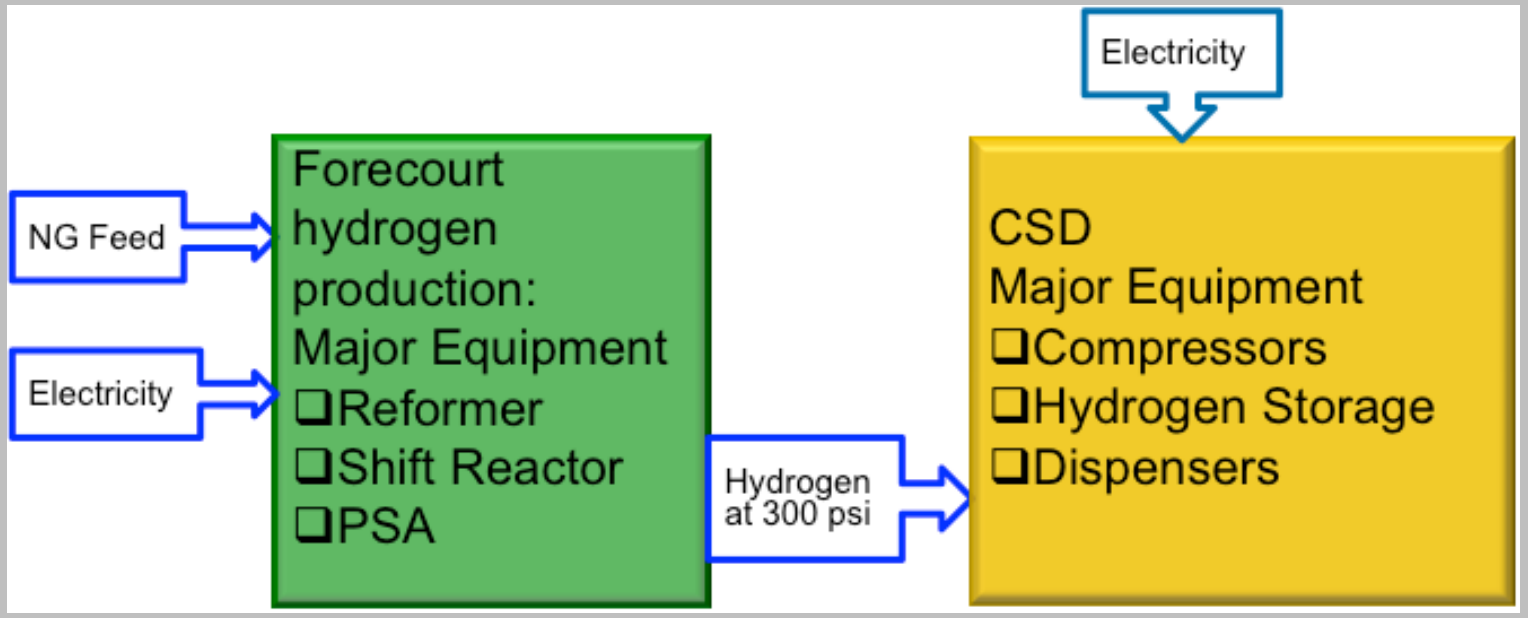
- Moderate annual system production rate: 50-150 system per year
- Substantial reduction in system cost but not full automation
- Corresponding markups: could be ~50% gross margin

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

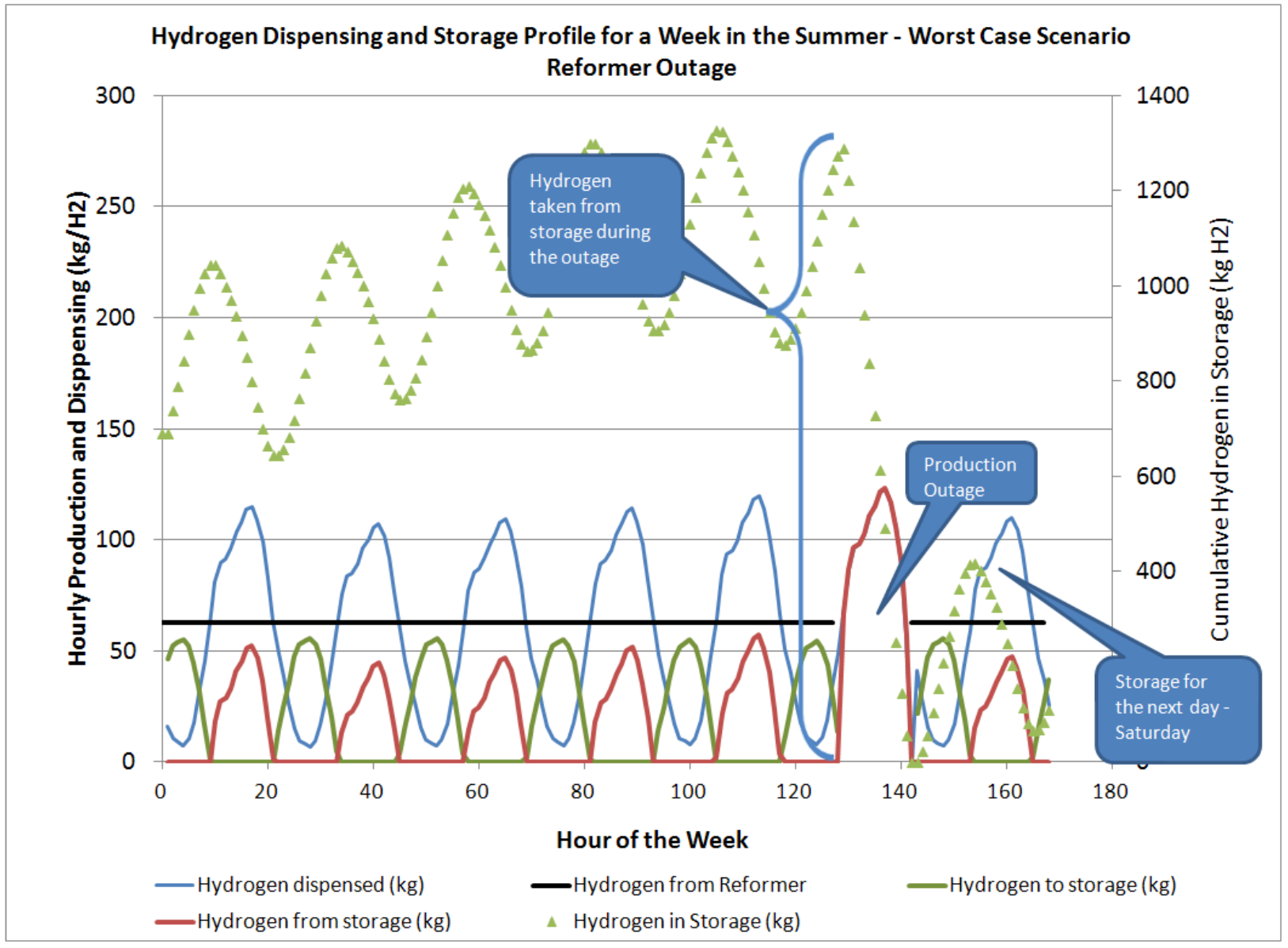
CSD model

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

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

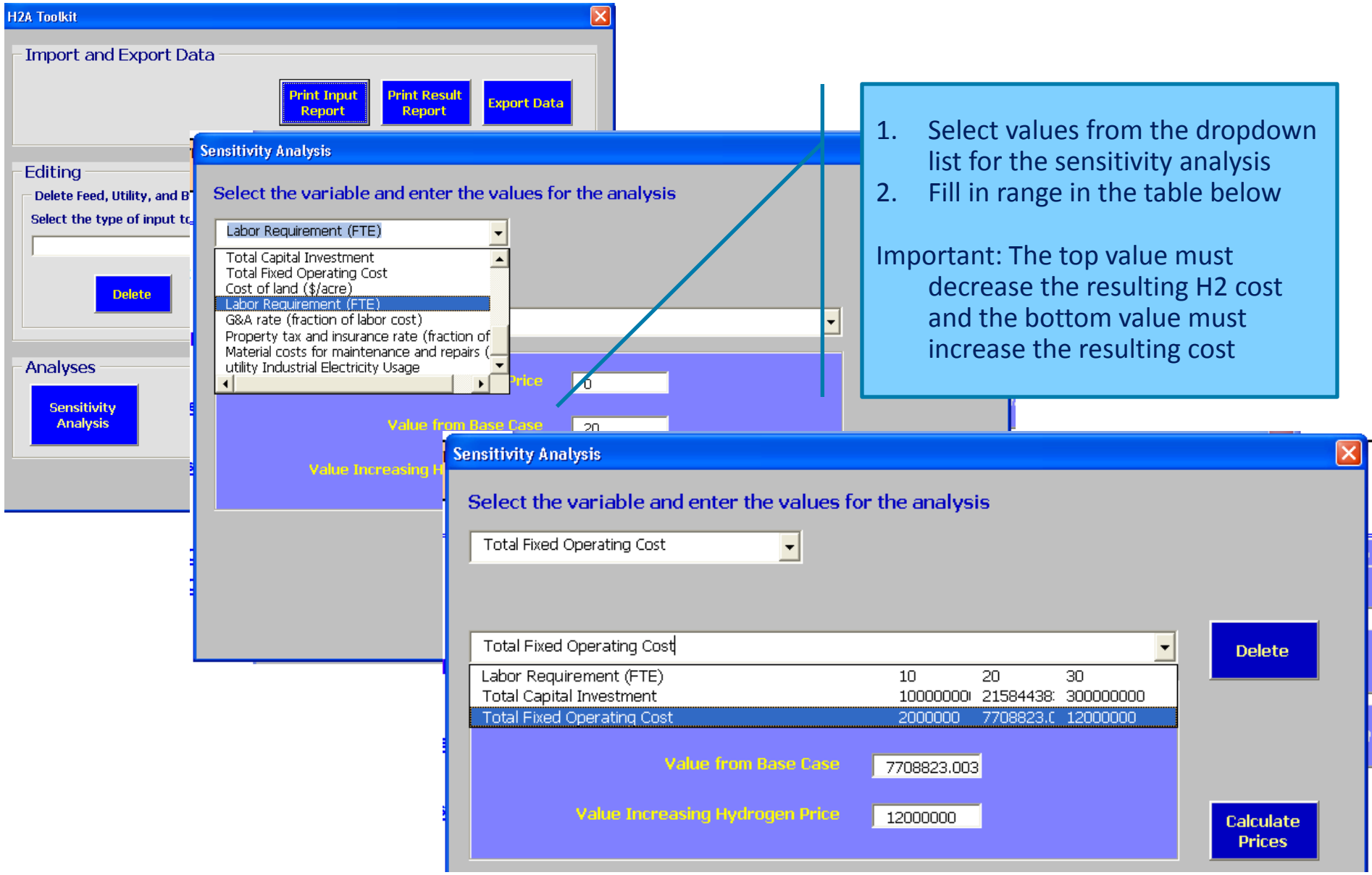
Lang Factor	2.73

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 project investment to purchased equipment cost

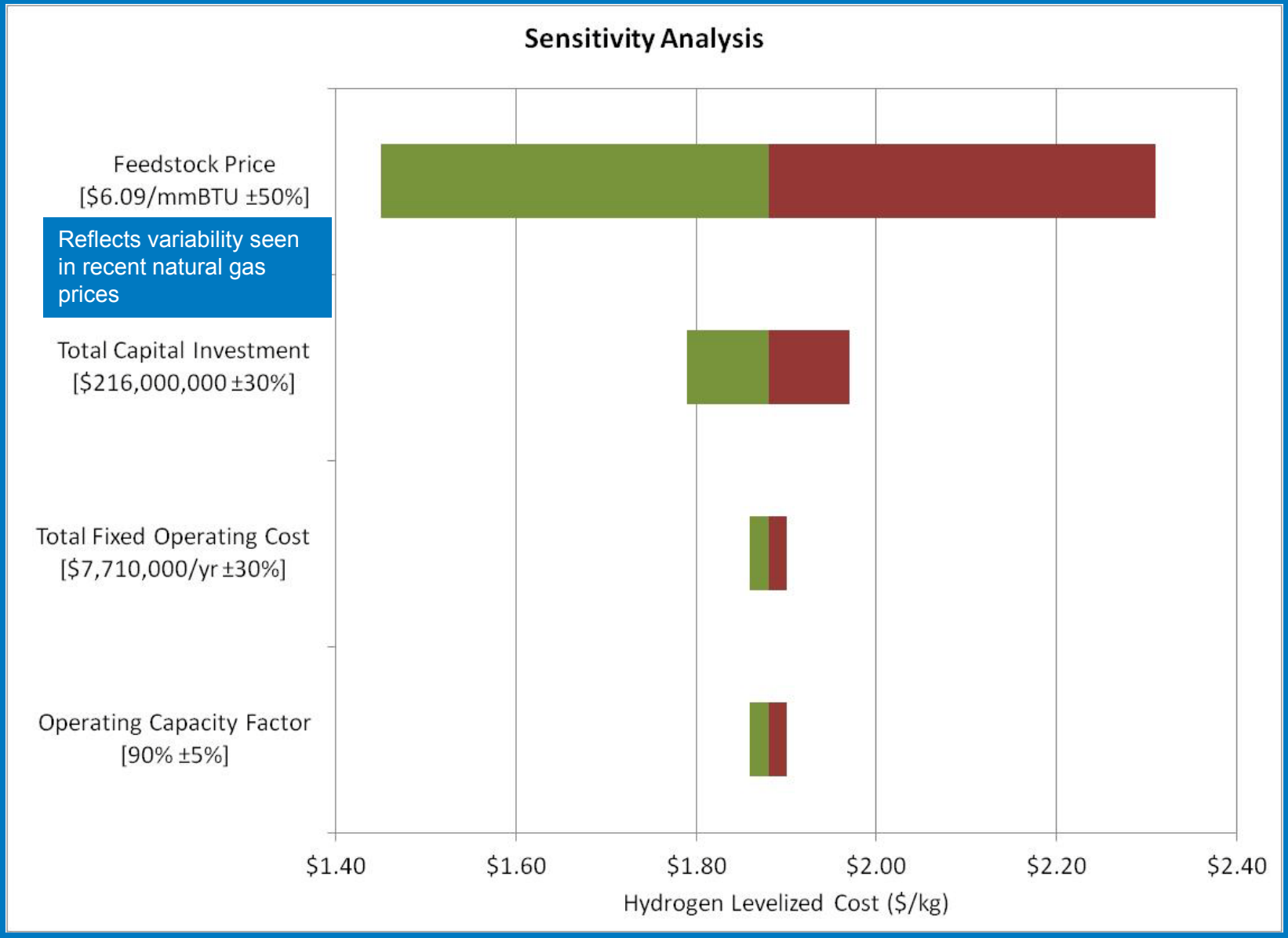
Accomplishments – Toolkit Tornado Charting Function



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

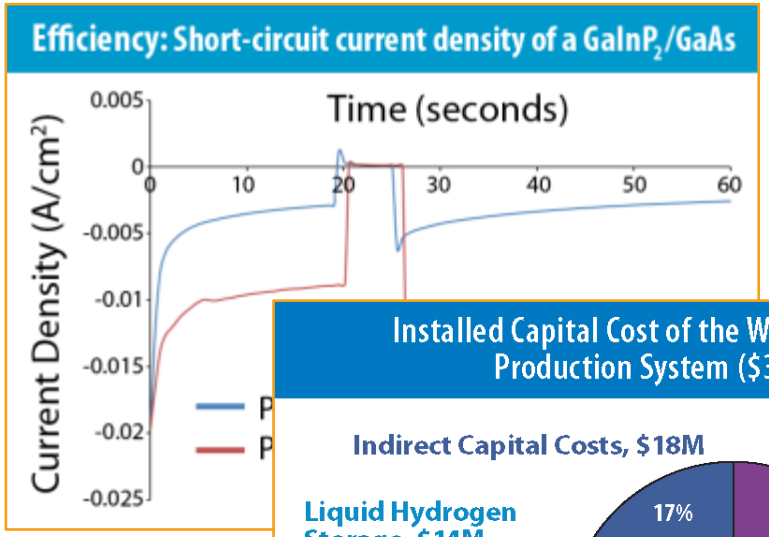
Accomplishments – Sample Tornado Chart



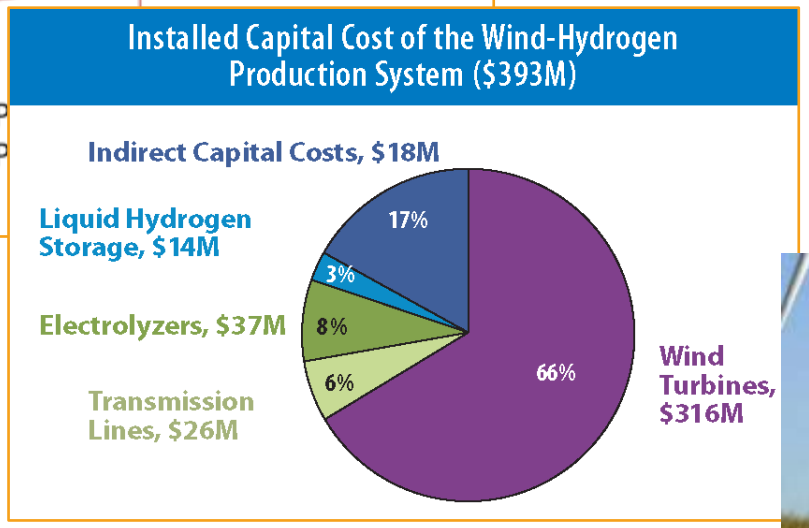
Accomplishment - New Bottom-up Analysis for Early Development Technologies

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)

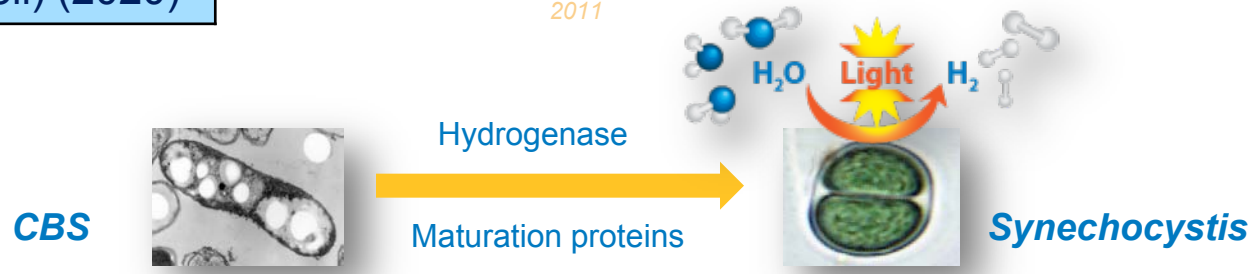
Data provided by Todd Deutsch, last updated February 2011



NREL increased the current density which improved efficiency.



Data provided by Olga Sozinova & Darlene Steward, February 2011



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

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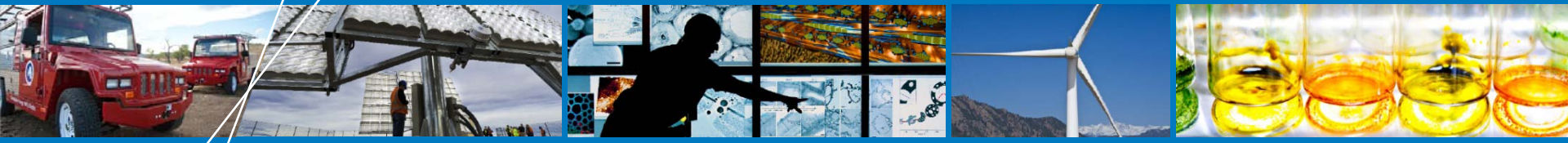

Thank You