Updates to the H2A Hydrogen Production Discounted Cash Flow Model (H2A version 2.0)

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DOE Hydrogen Program

Project ID # AN6

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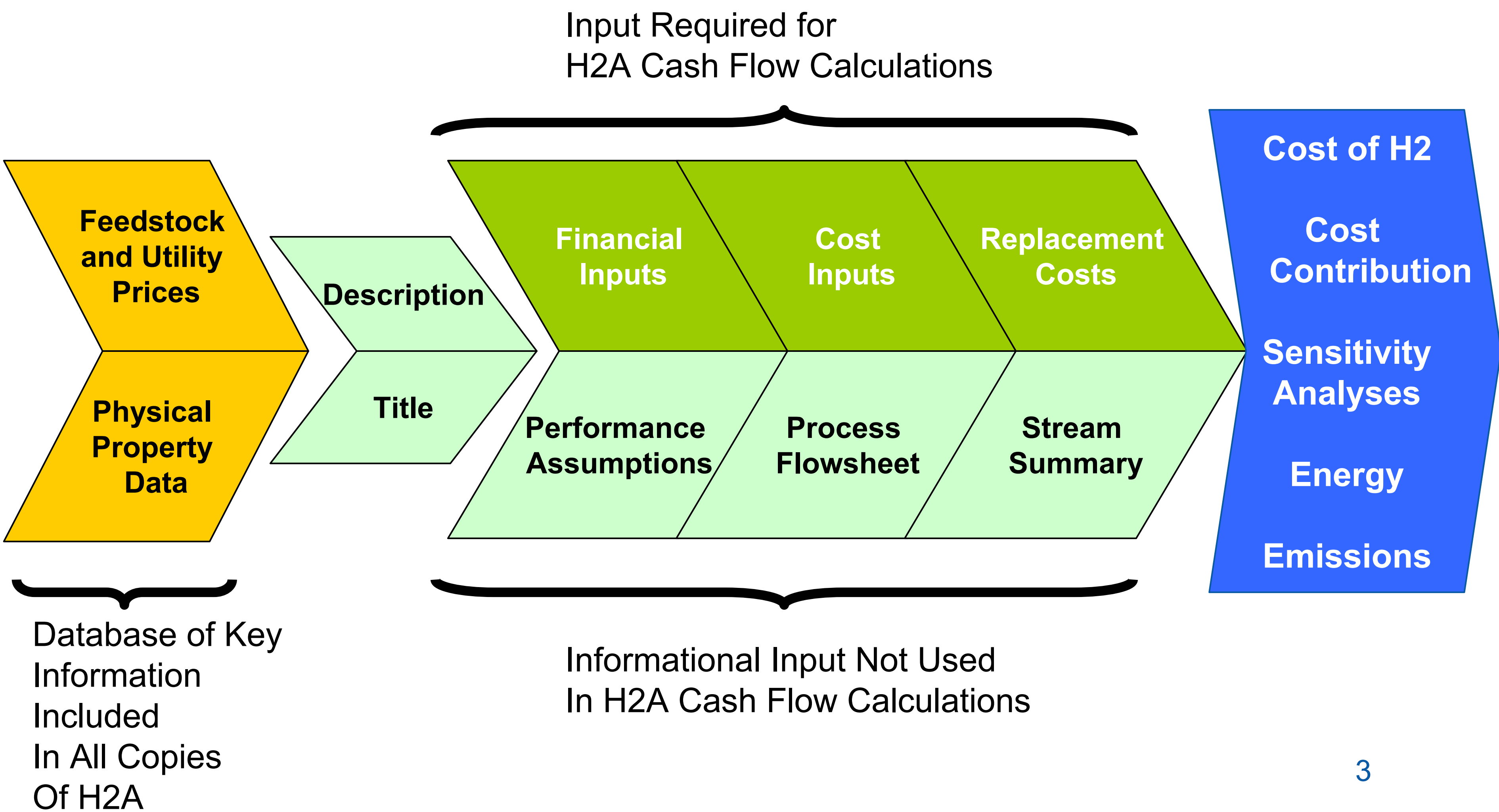
Project Overview

Timeline	Barriers
Project start: December 2006 Project end: April 2008 Percent complete: 100% (H2A version 2.0)	Barriers addressed (MYPP Section 4.5) 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)

Budget		Partners
Total project funding	$265K	NETL, DTI, Technology Insights, ANL
Funding received in FY07	$265K	Project lead - NREL
Funding for FY08	$ 0	

H2A Cash Flow Modeling Tool



Objectives

The H2A hydrogen production cash flow analysis tool was developed to:

– Provide a consistent approach for tabulating the primary cost elements for hydrogen production over the lifetime of the facility.

– Provide a template for reporting analysis assumptions

– Calculate the annualized cost of hydrogen produced as a benchmark for comparison of technologies and measurement of progress

Objectives for Updating the H2A Model

Focus model updates to address the Program barriers

Milestone	Date
Complete draft of changes to model structure	1/08 - complete
Complete draft of 12 case studies	1/08 - complete
Submit updated H2A model and case studies to DOE for review	2/08 - complete
Post updated H2A model and case studies on website	5/08
Related Crosscutting Analysis Activities	
Complete draft additional case studies	8/08
Submit additional case studies to DOE	9/08

Model Update Approach – Focus Changes to Address Program Barriers

Barrier	Strategies
(B) Stove-piped/ siloed analytical capabilities	•**Forecourt compression storage and dispensing calculations from the hydrogen delivery model incorporated into H2A** •Upstream Greenhouse Gas Emissions tables from the GREET* model incorporated into H2A for estimated calculations of GHG emissions. •Flat file output to communicate with other models (e.g., Macro-System Model) •Clarify input and output definitions to enhance consistency between models •Use Excel variable naming to identify and locate critical input and output

*Greenhouse Gas and Regulated Energy and Emissions in Transportation Model

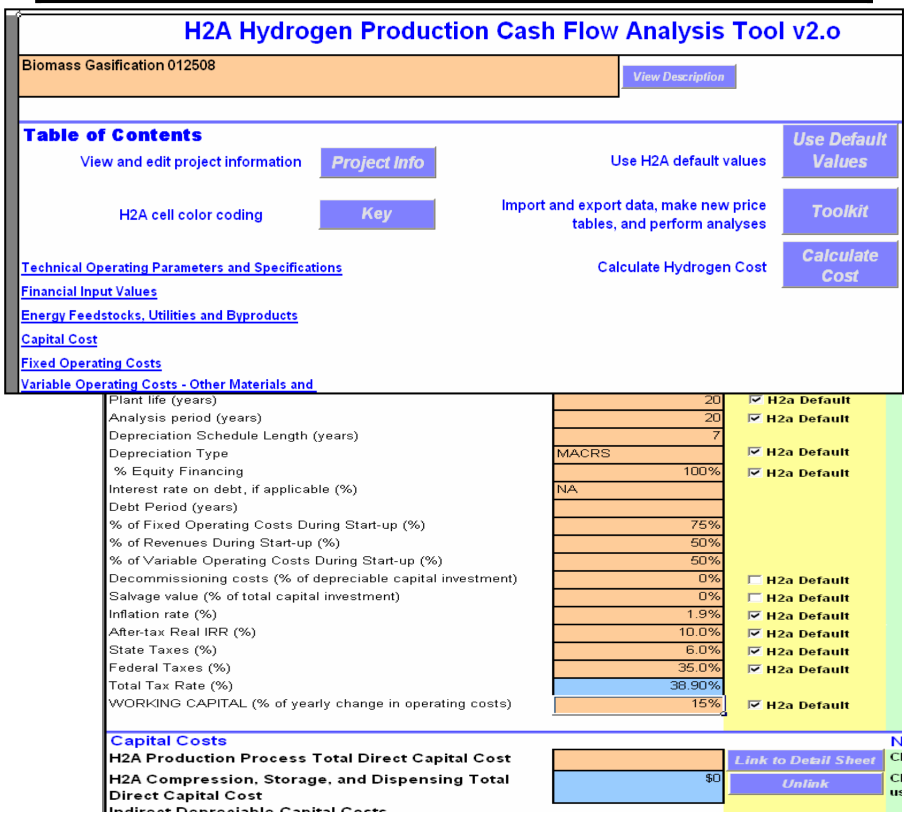
Model Update Approach – Focus Changes to Address Program Barriers

Barrier	Strategies
Inconsistent data, assumptions, and guidelines (C)	•Clarify input and output definitions •Provide default values and clarify their use •Provide additional detail for critical input (e.g., capital costs) **•Provide calculations for complex non-production system components (e.g., carbon sequestration)** •Eliminate redundant or unused tables and data •Provide detailed written documentation of methods and assumptions

Model Update Approach – Focus Changes to Address Program Barriers

Barrier

Need for improvement in models for better consistency and usability (D)



Strategies

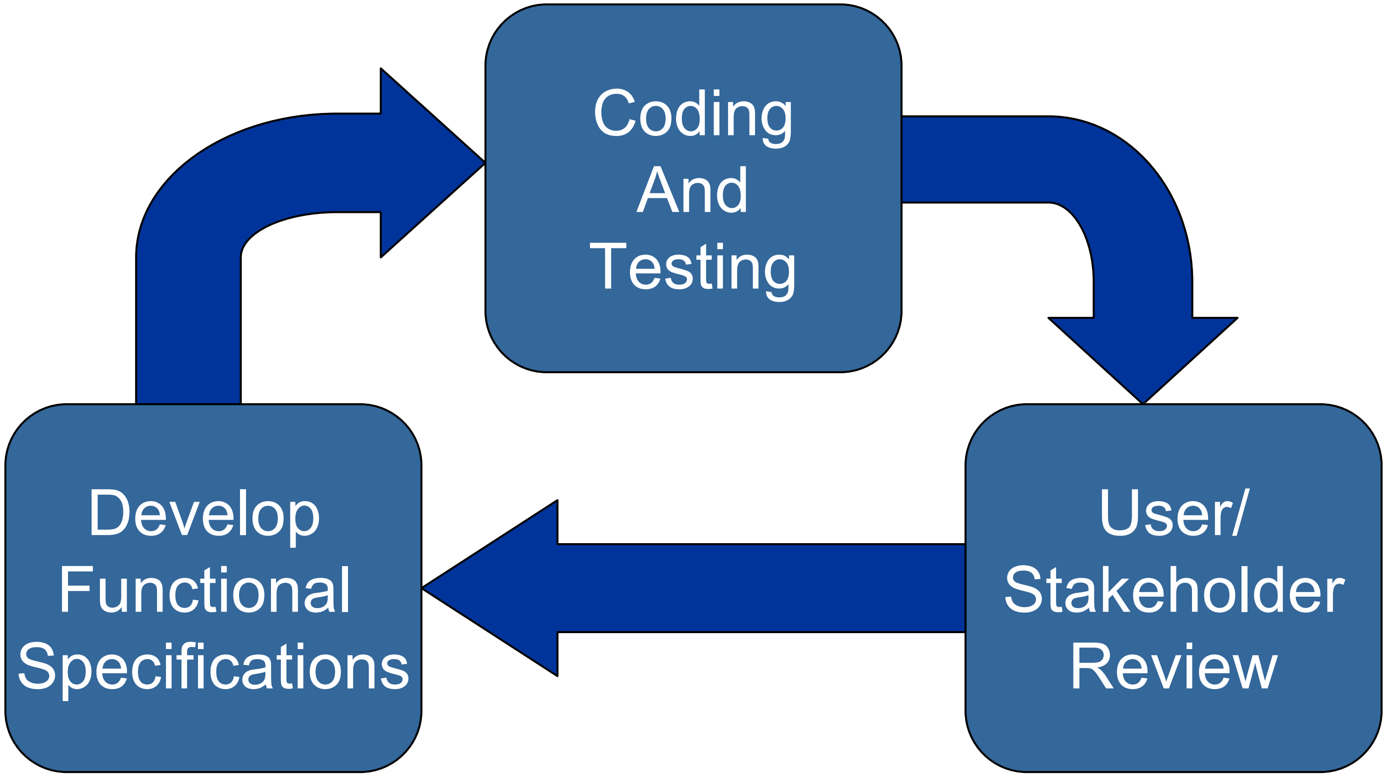
- Layer input detail: Summary values on the primary input sheet with links to additional detail.
- Provide usability tools such as color coding, keys, hyperlinks, and cell notes.
- Use the “Toolkit” to localize special functions and tools “out of the way” of standard use of the model.
- Keep calculations visible and traceable
- Clarification of feeds, utilities, and byproducts and addition of “user-defined” feeds

Model Update Approach – Focus Changes to Address Program Barriers

Barrier	Strategies
Need flexible capabilities for unplanned studies & analysis (E)	•Develop a robust method for users to define and use their own feedstocks •Formalize plant scaling method to enhance consistency and traceability •Make calculations and data tables accessible to users

H2A can be used to analyze costs for production of materials other than hydrogen!

Work plan


Coding
And
Testing
User/
Stakeholder
Review
Develop
Functional
Specifications

Technical Accomplishments – Addition of Carbon Sequestration Calculations to H2A Central Production Model

	H2A version 1	H2A version 2
Capital and operating cost for carbon capture included in plant capital costs	✓	✓
Calculation of CO_2 compression operating costs		✓
Calculation of CO_2 pipeline and injection capital and operating costs		✓
Input provided for carbon capture credit		✓
Input provided for carbon tax		✓

Technical Accomplishments

Toolkit Utility – Plant Scaling

The scaling utility sets the H2A case up so that when the capacity is changed, the capital costs and other values are scaled according to equations selected by the user.

- Keeps track of the baseline (original) values
- Range of plant capacities for which scaling is valid
- Scaling factor exponents for individual or aggregate capital equipment
- User selected scaling equations for indirect capital and non-feed operating costs
- Revert to the original values by turning plant scaling off

leave this sheet as is for scaled costs

Plant Scaling Factors		
Baseline Design Capacity (kg H2/day)	1,500	Design capacity for original H2A case. Imported from inp
Scale Ratio	1.00	Ratio of new design capacity (enter on Input Sheet) to the Design Capacity. Used for linear scaling
Scale Factor	1.00	Ratio of total scaled installed capital capital cost to total installed capital costs. Used for exponential scaling.
Default Scaling Factor Exponent	0.60	Scaling factor exponent used for scaling all capital equipr where an individual factor has not been entered below.
Lower Limit for Scaling Capacity (kg H2/day)		
Upper Limit for Scaling Capacity (kg H2/day)		

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

Major pieces/systems of equipment	Baseline Uninstalled Costs	Scaling Factor Exponent	Scaled Uninstalled Costs	Installati Fac
Production unit including housing	$ 885,017		$ 885,017	
Overall Control and Safety Equipment	$ 7,433		$ 7,433	
0	$ -		$ -	
0	$ -		$ -	
0	$ -		$ -	
0	$ -		$ -	
0	$ -		$ -	
0	$ -		$ -	
0	$ -		$ -	
0	$ -		$ -	
0	$ -		$ -	
0	$ -		$ -	
0	$ -		$ -	
0	$ -		$ -	
TOTALS (including scaling)	$ 892,450		$ 892,450	

Plant Scaling Example

Cost of Carbon Sequestration as a Function of Plant Size

Set up Scaling for the H2A Case Study - Central Coal Plant with CCS

Plant Scaling Factors	
Baseline Design Capacity (kg H2/day)	246,478
Scale Ratio	1.00
Scale Factor	1.00
Default Scaling Factor Exponent	0.60
Lower Limit for Scaling Capacity (kg H2/day)	200,000
Upper Limit for Scaling Capacity (kg H2/day)	350,000

Scaling exponent for capital equipment (factor for individual unit operation overrides default)

Range for which scaling is valid

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

Major pieces/systems of equipment	Baseline Uninstalled Costs	Scaling Factor Exponent	Scaled Uninstalled Costs	Ins
Coal Handling Prep & Feed	$ 22,881,590	0.77	$ 22,881,590	
Feedwater & Misc. BOP Systems	$ 6,401,057		$ 6,401,057	
Gasifier & Accessories	$ 50,541,901	0.70	$ 50,541,901	
Air Separation Unit	$ 34,786,960	0.50	$ 34,786,960	
Hydrogen Separation & Gas Cleanup	$ 53,972,240		$ 53,972,240	
Expander/Generators & SOFC/CT	$ 58,342,063		$ 58,342,063	

Plant Scaling Example

Cost of Carbon Sequestration as a Function of Plant Size

Select scaling method for other variables

Plant Scaling Method	Select Method	Baseline Value	Notes
Engineering & design ($)	Use Scale Factor	36575790.16	Scale engineering costs with capital costs
Site Preparation ($)	Use Scale Ratio	3657579.016	Site preparation costs scale linearly with capacity for this analysis
Process contingency ($)	Skip	0	
Project contingency ($)	Use Scale Factor	91439475.4	
One-time Licensing Fees ($)	Skip	0	
Other (Depreciable) capital ($)	Skip	0	
Up-Front Permitting Costs ($)	Use Baseline Value	36575790.16	Permitting is a fixed cost that does not change with capacity
Land required (acres)	Use Scale Ratio	250	
Total plant staff (number of FTEs employed by plant)	Use Scale Factor	120	

Click “Finish Scaling” to transfer equations to input cells

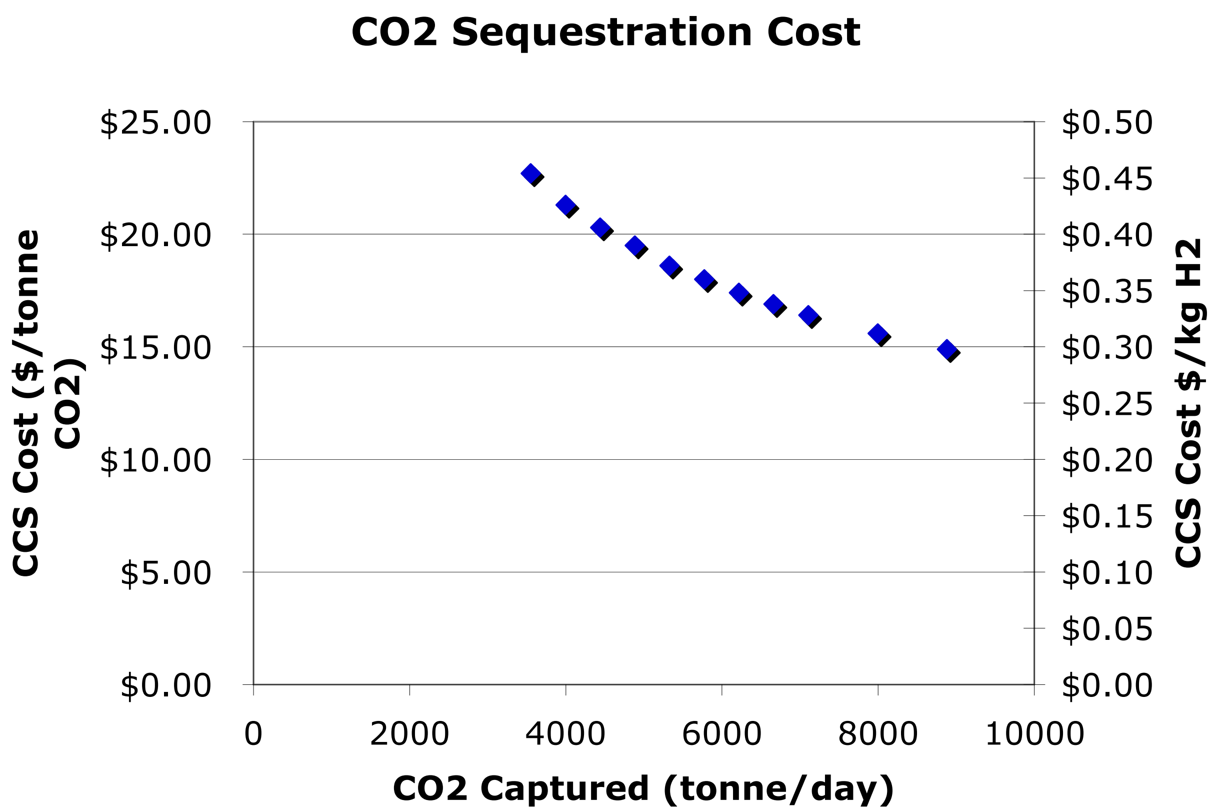
prep fx =3657579.016*Scale_Ratio

B	C
Indirect Depreciable Capital Costs	
Site Preparation ($)	$3,657,579
Engineering & design ($)	$36,575,790
Process contingency ($)	
Project contingency ($)	$91,439,475

Plant Scaling Example

Cost of Carbon Sequestration as a Function of Plant Size

Change the plant capacity over the desired size range to calculate CCS costs



Updated Case Studies Developed

- **Central Hydrogen Production (>50tpd)**
  - Biomass gasification
  - Nuclear
    - High Temperature Steam Electrolysis
    - Thermo-chemical Sulfur Iodine
    - Hybrid Sulfur Iodine/electrolysis
  - Grid-based Electrolysis
  - Coal Gasification (with and without CCS)*
  - Natural Gas (SMR) (with and without CCS)*
- **Forecourt Production (1.5 tpd)**
  - Natural Gas Reforming (SMR)
  - Electrolysis
  - Ethanol Reforming

* Adapted from published cases

Summary

- H2A model updated to
  - Enhance usability
  - Clarify definitions, assumptions, default values
  - Add features to increase flexibility and broaden the range of analyses that can be performed with the model
- New cases developed

Future Work
(Related Crosscutting Analysis Projects)

- Analysis of a variety of new cases (e.g., hybrid feed systems)
- Systems economic analyses (e.g., cost of carbon policy)
- Support for model users and maintenance of the model.