

Techno-Economic Modelling with H2A and H2FAST

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ARPA-E Methane Pyrolysis Cohort: Kick-off Meeting
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Techno-Economic Analysis (TEA)

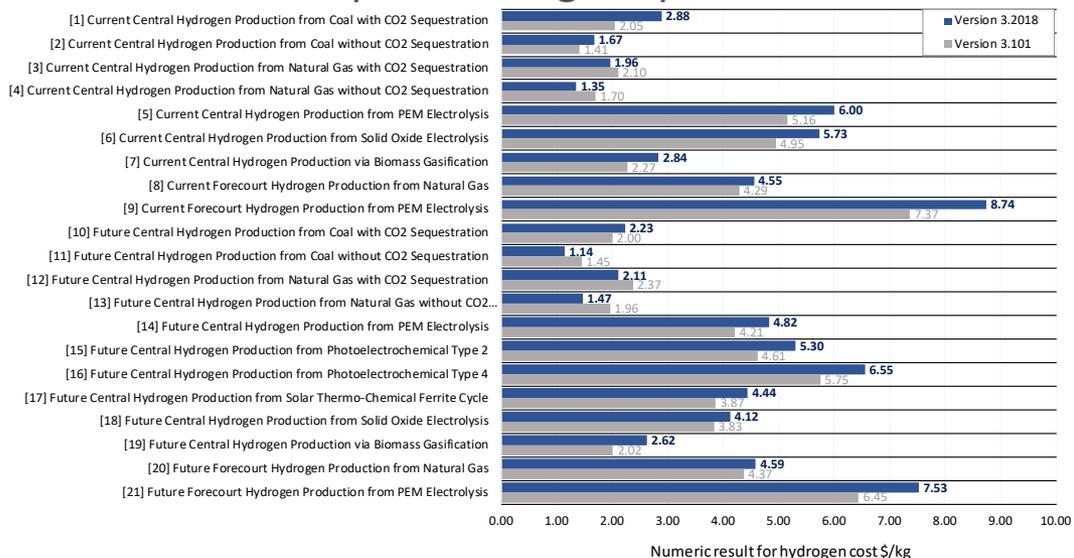
What is TEA?

- Process costing and financial performance estimation
- Consistent basis among technology alternatives (compare technology and not financing schemes)

Why perform TEA?

- Benchmark of technology
- Progress tracking
- Technology target setting
- Impact from macro-economics
- Articulation to stakeholders

Example tracking for published H2A cases



H2A & H2FAST Mission



Improve the transparency and consistency of analysis, improve the understanding of the differences among analyses, and seek better validation from industry.

With H2A, studies are more likely to be:

- Consistent
- Transparent
- Comparable

Model Approach



- Excel spreadsheet
 - (requires PC Excel 2010 or later)
- 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
- Assumptions easy to obtain

Key Definitions: Kilogram H₂ & Nth Plant

1 kilogram of hydrogen = 1 gallon of gasoline

- Gasoline: 108,000 – 123,500 BTU/gal
- Hydrogen: 116,000 BTU/kg (LHV)
- Used as model inputs and outputs basis

Nth Plant:

- modelling of high-volume manufactured plants
- (not first of a kind or prototype)

Purpose of “Nth” plant assumption:

- Focusing on technology potential and not low-volume costs
- Nth plant cost should be at or near “knee in the curve”

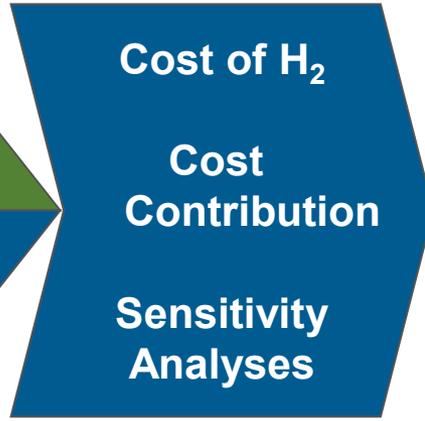
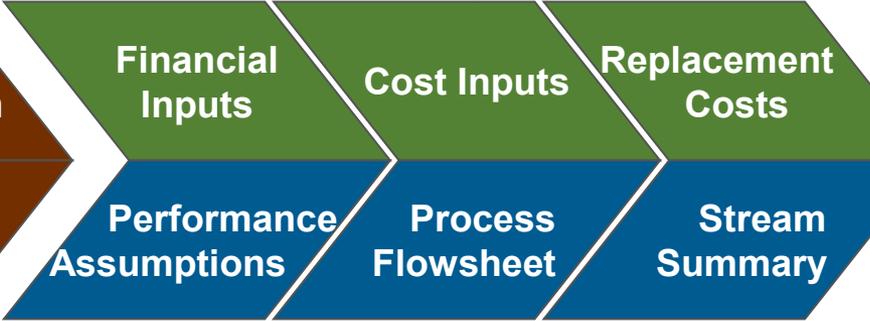
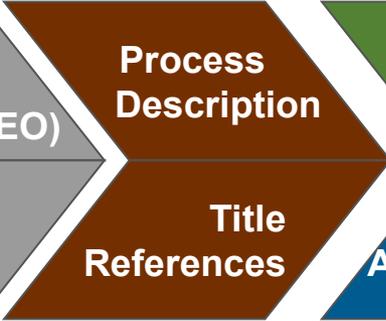
H2A Techno-Economic Modeling Tool

Standard Price and Property Data

Information

Cost Analysis

Results

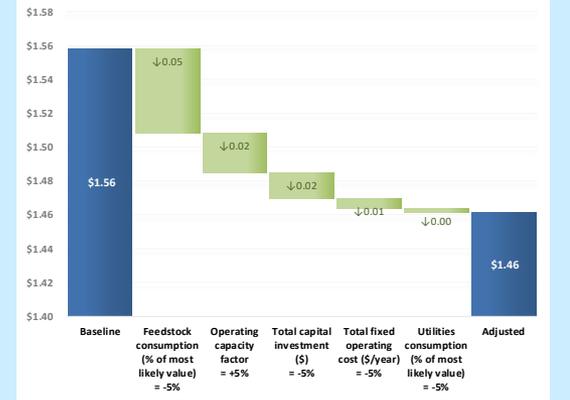
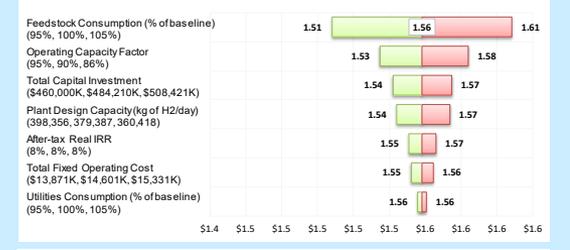
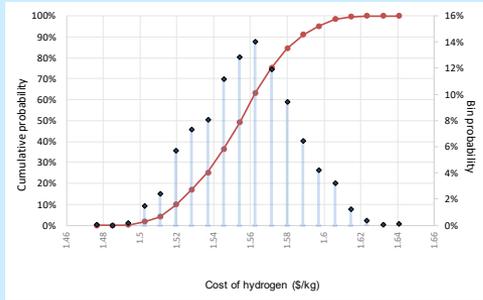


Technical Analysis

Spreadsheet Examples

AEO_2017_Reference_Case	
Year	
Feedstock Type	
Residential Natural Gas	
Commercial Natural Gas	
Industrial Natural Gas	
Electric Utility Natural Gas	
Woody Biomass	
Electric Utility Steam Coal	
Commercial Electricity	
Industrial Electricity	
Residential Electricity	

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	2016
Assumed start-up year	2015
Basis year	2005
Length of Construction Period (years)	
% 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	40%
Interest rate on debt, if applicable (%)	3.70%
Debt period (years)	Constant debt
% 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 (%)	8.0%
State Taxes (%)	6.0%
Federal Taxes (%)	21.0%
Total Tax Rate (%)	25.74%
WORKING CAPITAL (% of yearly change in operating costs)	15%



Example Specification: Steam Methane Reformer (SMR)

Technical Operating Parameters and Specifications

Operating Capacity Factor (%)	90.0%	
Plant Design Capacity (kg of H2/day)	618,936	
Plant Output (kg/day)	557,042	
Plant Output (kg/year)	203,320,476	

Financial Input Values

Reference year	2016	<input checked="" type="checkbox"/> H2a Default
Assumed start-up year	2015	
Basis year	2007	Costs must be entered in basis year dollars
Length of Construction Period (years)	3	
% of Capital Spent in 1st Year of Construction	40%	
% of Capital Spent in 2nd Year of Construction	35%	
% of Capital Spent in 3rd Year of Construction	25%	
% of Capital Spent in 4th Year of Construction		
Start-up Time (years)	0.5	
Plant life (years)	30	
Analysis period (years)	30	
Depreciation Schedule Length (years)	20	
Depreciation Type	MACRS	<input checked="" type="checkbox"/> H2a Default
% Equity Financing	40%	<input checked="" type="checkbox"/> H2a Default
Interest rate on debt, if applicable (%)	3.70%	
Debt period (years)	Constant debt	
% of Fixed Operating Costs During Start-up (%)	75%	
% of Revenues During Start-up (%)	50%	
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Federal Taxes (%)	21.0%	<input checked="" type="checkbox"/> H2a Default
Total Tax Rate (%)	25.74%	
WORKING CAPITAL (% of yearly change in operating costs)	15%	<input checked="" type="checkbox"/> H2a Default

Financial assumptions
are consistent
between cases to focus
on technology
differences.

Example Specification (capital cost inputs)

CAPITAL INVESTMENT (Inputs REQUIRED in Basis Year, (2007) \$)				
Major pieces/systems of equipment	Baseline Uninstalled Costs \$2007 Dollars	Baseline Uninstalled Costs \$2016 Dollars	Installation Cost Factor	Baseline Installed Costs
Coal handling	28,007,000	\$ 32,057,820	1.00	\$ 32,057,820
Coal prep & feed	43,459,000	\$ 49,744,736	1.00	\$ 49,744,736
Feedwater & misc. BOP systems	14,703,000	\$ 16,829,583	1.00	\$ 16,829,583
GEE quench gasifier system	443,870,000	\$ 508,069,579	1.00	\$ 508,069,579
Gas cleanup & piping	181,909,000	\$ 208,219,589	1.00	\$ 208,219,589
Hydrogen PSA & Compressor	40,538,000	\$ 46,401,254	1.00	\$ 46,401,254
HRSO Ducting Stack	20,409,000	\$ 23,360,876	1.00	\$ 23,360,876
Steam Turbine Generator & Piping	26,007,000	\$ 29,768,548	1.00	\$ 29,768,548
Cooling water system	13,416,000	\$ 15,356,437	1.00	\$ 15,356,437
Ash Spent Sorbent Handling system	56,864,000	\$ 65,088,581	1.00	\$ 65,088,581
Accessory electric plant	16,131,000	\$ 18,464,123	1.00	\$ 18,464,123
Instrumentation & controls	17,887,000	\$ 20,474,104	1.00	\$ 20,474,104
CO2 compressor & drying	29,442,000	\$ 33,700,373	1.00	\$ 33,700,373
Total plant capital of transport	80,430,000	\$ 92,063,073	1.00	\$ 92,063,073
Total plant capital of storage	50,160,000	\$ 57,414,942	1.00	\$ 57,414,942
Capital fund for life-cycle CO2 monitoring costs	33,000,000	\$ 37,772,988	1.00	\$ 37,772,988
	1,096,232,000	\$ 1,254,786,607		\$ 1,254,786,607

Articulation of process modelling & cost estimation to total cost of capital.

H2A Outputs

A

Real Levelized Values (per kg H2)



B

Operating Capacity Factor
(95%, 90%, 86%)

Total Capital Investment
(\$1,678,913K, \$1,767,277K, \$1,855,641K)

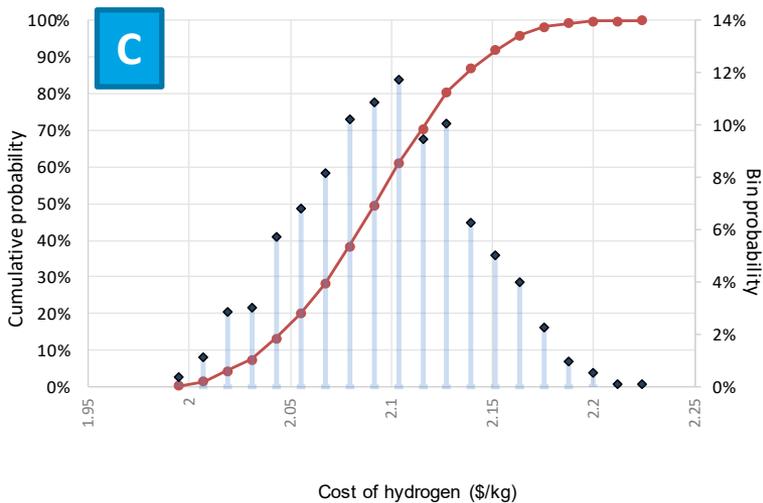
Total Fixed Operating Cost
(\$87,086K, \$91,669K, \$96,252K)

After-tax Real IRR
(8%, 8%, 8%)

Utilities Consumption (% of baseline)
(95%, 100%, 105%)

Feedstock Consumption (% of baseline)
(95%, 100%, 105%)

Plant Design Capacity (kg of H2/day)
(649,883, 618,936, 587,989)



Percentile	Value
0%	1.989
5%	2.028
10%	2.044
15%	2.053
20%	2.061
25%	2.068
30%	2.075
35%	2.080
40%	2.087
45%	2.093
50%	2.098
55%	2.103
60%	2.108
65%	2.114
70%	2.121
75%	2.127
80%	2.132
85%	2.142
90%	2.152
95%	2.166
100%	2.230

A: Point estimate of hydrogen cost with cost attribution

B: Sensitivity around pre-selected parameters

C: Monte-Carlo distribution of results

H2FAST Overview

What is H2FAST

- Financial model for hydrogen systems*
- Simple interface, rigorous analysis
- Fully reviewed by financial industry experts

What analysis does it do

- Production pathways, for example:
 - steam methane reformers
 - electrolysis
 - fuel cell combined heat, hydrogen, power
- Delivery & distribution
 - pipelines
 - truck delivery
- Retail station finances

Who uses the model

- Retail station operators
- Government & policy makers
- Equity and debt investors
- Strategic investors (gas suppliers, car makers)
- Equipment manufacturers
- Academic institutions & national laboratories

Metric	H2A	H2FAST
Ease of use	+	+++
Side-by-side analysis	+	+++
Rigorous financials	++	+++
Emissions analysis	++	
Risk analysis	+	+++
Explicit inputs	+++	++

* H2FAST is not a capital cost estimator.

Model Framework

User inputs

- Capital costs
- Incentives (grants, operating incentives, take or pay contracts)
- Maintenance cost
- Demand profile (e.g. construction time, demand ramp-up)
- Feedstock use (consumption, prices, escalation)
- Retail price of hydrogen
- Financial parameters (e.g. depreciation schedule, interest rates, etc.)

Model computation framework: Generally Accepted Accounting Principles (GAAP)*

- **Income statement** projections (revenues, expenses, taxes)
- **Cash flow statement** projections (cash on hand, capital expenditures, financing transactions)
- **Balance sheet** projections (assets, liabilities, equity)

Model outputs

- **Financial performance parameters** (e.g. Internal rate of return, pay-back period, break-even price of hydrogen)
- **Time series charts** for all line item parameters
- Per-kilogram **cash flows break-down** (revenues, expenses, financing cash flows)
- Uncertainty distributions (for risk analysis studies)

* Model can perform analysis compatible with International Financial Reporting Standards (IFRS)

H2FAST Example Case: Multiple Scenarios

Installation name	Current Central Natural Gas Reforming without CO2 Capture and Sequestration	Current Central Proton Exchange Membrane (PEM) Electrolysis	Current Central Biomass Gasification
Capacity (kg/day)	379,387	50,000	155,236
Reforming equipment	\$ 174,611,028		
Electrolysis equipment		\$ 118,258,606	
Gasification equipment			\$ 144,875,057
Capital_item 4			
Capital_item 5			
Capital_item 6			
Capital_item 7			
Capital_item 8			
Capital_item 9			
Capital_item 10			
Non-depreciable assets	\$ 550,362	\$ 275,181	\$ 2,751,813
Installation cost	\$ 73,336,632	\$ 47,578,623	\$ 60,847,524
End of project sale of non-depreciable assets			
Total annual maintenance	\$ 1,049,006	\$ 3,547,758	\$ 724,376
Maintenance escalation (% annually)			
Feedstock Use			
Ind.nat.gas (mmBTU/kg)	0.156		
Ind.electr (kWh/kg)	0.569	54.300	
Biomass (kg/kg)			13.490
Process water (gal/kg)	3.355	4.760	1.321
Cooling water (gal/kg)	1.495		79.260
Comm.nat.gas (units of feedstock 6/kg)			0.006
Comm.electr (units of feedstock 7/kg)			0.980

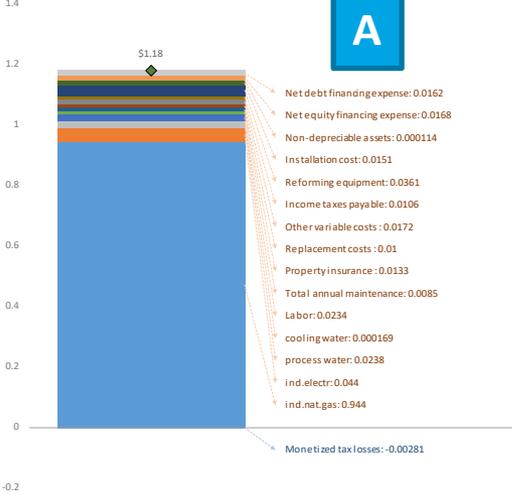
Inputs are simplified for transparency and legibility.

Researchers can use exogenous cost estimations to supply inputs or use sizing formulas as inputs.

Sample H2FAST Outputs

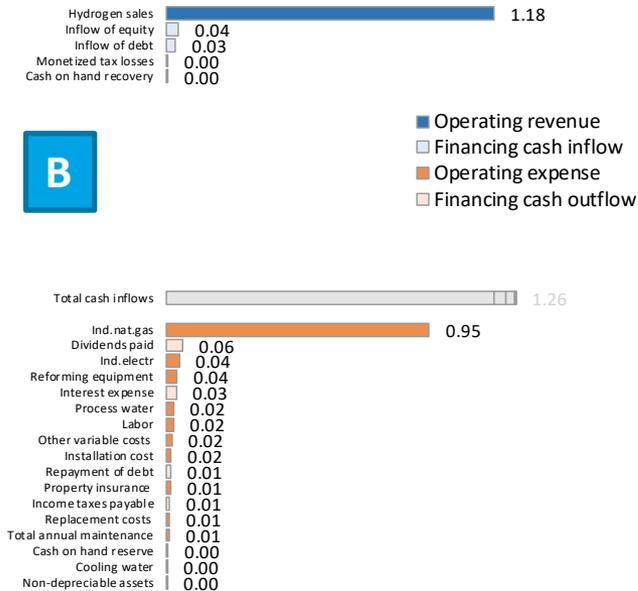
Real levelized value breakdown of hydrogen (\$/kg)

A



Real levelized value breakdown of hydrogen (\$/kg)

B



A: Fully allocated levelized cost chart

B: Levelized cash flow attributions

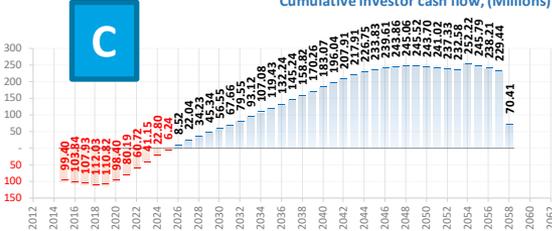
C: Time series charts for any financial line item

D: Cost of goods sold (individual year costs)

E: Risk analysis results available for all specified parameters.

Current Central Natural Gas Reforming without CO2 Capture and Sequestration Cumulative investor cash flow, (Millions)

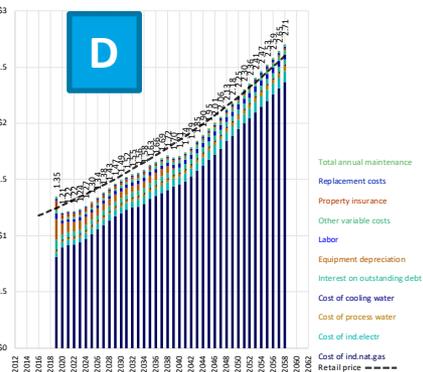
C



Cost of goods sold breakdown (\$/kg)

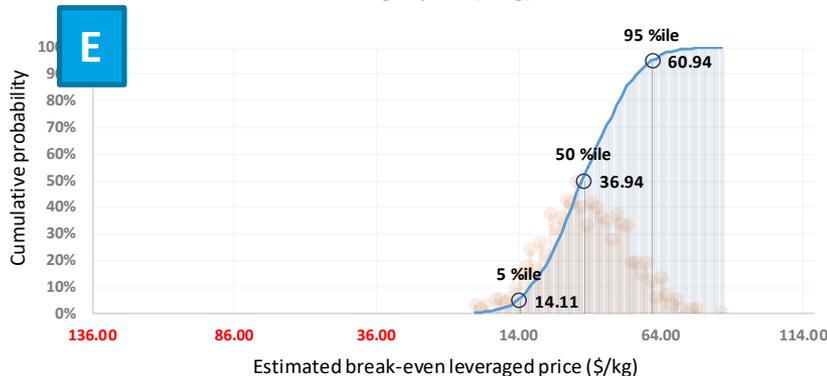
● Nominal \$
 ○ Real 2016\$

D



Estimated break-even leveraged price (\$/kg)

E



H2FAST

Live Demo: H₂ production with
carbon co-product

Thank you.

Contact information:

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www.nrel.gov

H2FAST model, case studies, and documentation:

<https://www.nrel.gov/hydrogen/h2fast.html>

H2A model, case studies, and documentation:

<https://www.nrel.gov/hydrogen/h2a-production-models.html>



BACKUP

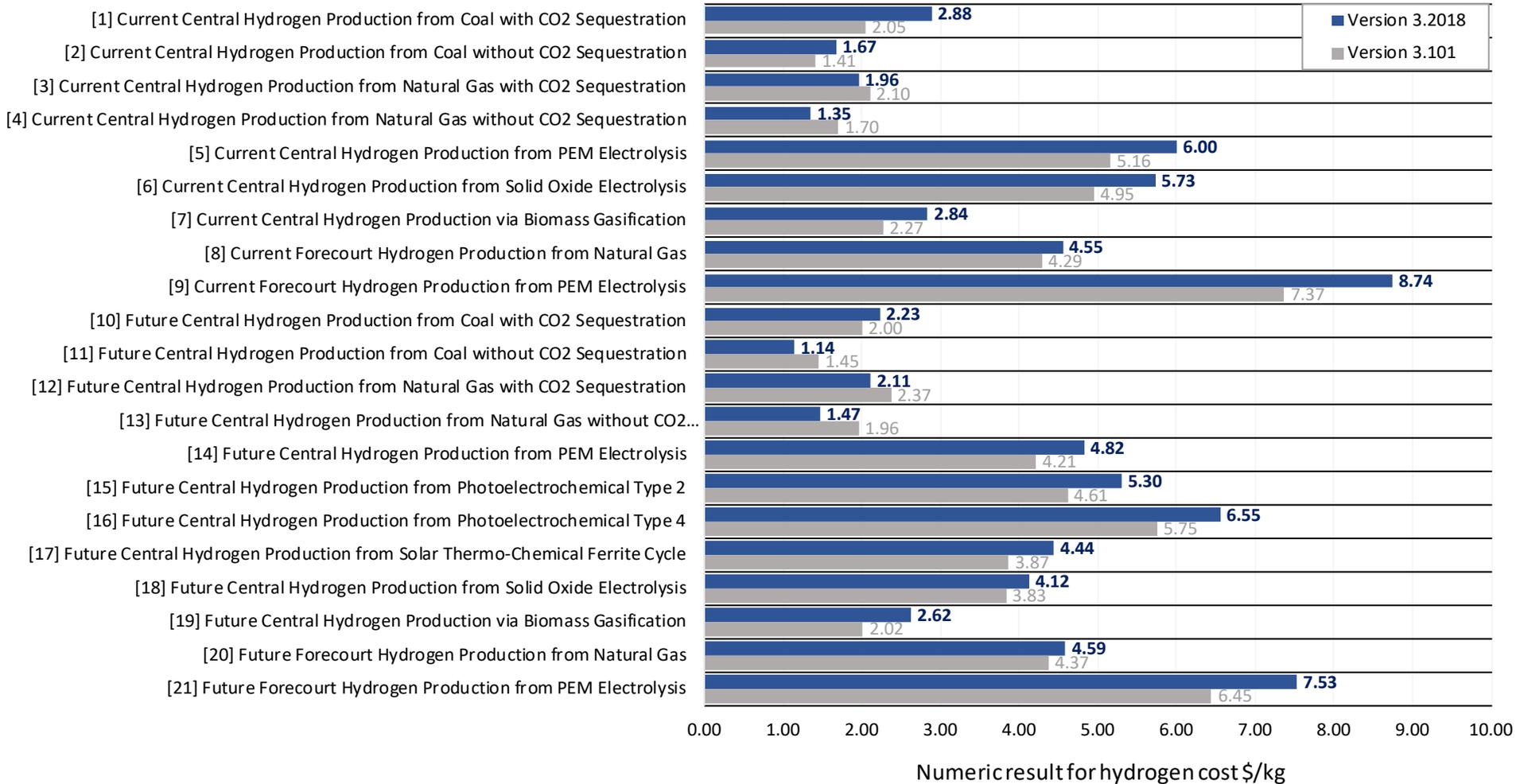
SLIDES

Case Index

Case ID Case title

- 1 Current Central Hydrogen Production from Coal with CO2 Sequestration
- 2 Current Central Hydrogen Production from Coal without CO2 Sequestration
- 3 Current Central Hydrogen Production from Natural Gas with CO2 Sequestration
- 4 Current Central Hydrogen Production from Natural Gas without CO2 Sequestration
- 5 Current Central Hydrogen Production from PEM Electrolysis
- 6 Current Central Hydrogen Production from Solid Oxide Electrolysis
- 7 Current Central Hydrogen Production via Biomass Gasification
- 8 Current **Forecourt** Hydrogen Production from Natural Gas
- 9 Current **Forecourt** Hydrogen Production from PEM Electrolysis
- 10 Future Central Hydrogen Production from Coal with CO2 Sequestration
- 11 Future Central Hydrogen Production from Coal without CO2 Sequestration
- 12 Future Central Hydrogen Production from Natural Gas with CO2 Sequestration
- 13 Future Central Hydrogen Production from Natural Gas without CO2 Sequestration
- 14 Future Central Hydrogen Production from PEM Electrolysis
- 15 Future Central Hydrogen Production from Photoelectrochemical Type 2
- 16 Future Central Hydrogen Production from Photoelectrochemical Type 4
- 17 Future Central Hydrogen Production from Solar Thermo-Chemical Ferrite Cycle
- 18 Future Central Hydrogen Production from Solid Oxide Electrolysis
- 19 Future Central Hydrogen Production via Biomass Gasification
- 20 Future **Forecourt** Hydrogen Production from Natural Gas
- 21 Future **Forecourt** Hydrogen Production from PEM Electrolysis

Summary of Update Impact



H2A Background



- Purpose
 - Analysis portfolio development
 - Provide research direction
- History
 - Began in February 2003, financial support from U.S. DOE
 - Team of analysts from labs, industry, consulting firms, and universities
 - Use of Key Industrial Collaborators (KIC)

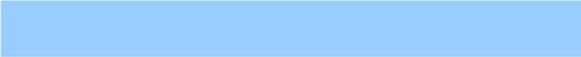
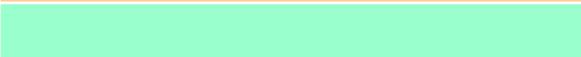
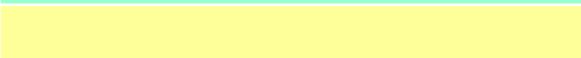
Partners, Interactions, Collaboration

- **H2A team:** DOE, NREL, Technology Insights, Parsons Engineering, Directed Technologies, Inc., TIAX, ANL, UC Davis, PNNL
- **Key Industrial Collaborators:** AEP, Air Products, Areva, BOC, BP, ChevronTexaco, Conoco Phillips, Eastman Chemical, Entergy, Exxon Mobil, FERCO, GE, Praxair, Shell, Stuart Energy, Thermochem
- **Feed to and feedback from:** OnLocation, ORNL, ANL, DOE PBA, DOE FE, DOE NE, LLNL Markal, EPA

H2A Tool Features



- Color-coded to facilitate user input

	Calculated Cells
	User Input Required
	Optional Input
	Information

- Yes/no toggle switches to allow for user input or H2A standard input
 - Inputs turn on/off based on yes/no toggle switch
- Error messages included to alert user when input errors are made
- Documentation is provided on website for model support

H2A Input Sheet Bird's-Eye View

The screenshot shows a complex spreadsheet interface for hydrogen production cost analysis. Key sections include:

- Table of Assumptions:** Lists parameters like 'Plant Size (MM scfd of Hydrogen)', 'Feedstock Cost (\$/MMBtu)', and 'Utilities Cost (\$/MMBtu)'.
- Detailed Revenue Assumptions:** Breaks down revenue from 'Hydrogen Sales', 'Sulfur Dioxide', and 'Water'.
- Process Revenue, Utilities, and Expenses:** A large table detailing the costs of various inputs like 'Natural Gas', 'Electricity', and 'Steam'.
- Capital Cost:** Lists 'Fixed Capital Costs' and 'Working Capital Costs'.
- Fixed Operating Costs:** Details 'Maintenance', 'Labor', and 'Overhead' costs.
- Variable Operating Costs:** Details 'Feedstock', 'Utilities', and 'Waste' costs.

Levelized cost of hydrogen (\$/kg)
 Valuation of co-products
 Cost attribution by category

Plant start-up information

Financial assumptions

Feedstock, utilities, byproducts

Capital cost & commissioning

Fixed operating costs

Variable operating costs

Example Specification (capital & commissioning)

Capital Costs		Notes	
H2A Total Direct Capital Cost	\$1,254,786,607	View/Edit	Click to enter details on the Cost Detail Sheet
H2A Carbon Sequestration Total Direct Capital Cost	\$46,547,136	Unlink	Click to enter details on the Carbon Sequestration calculation sheet.
Indirect Depreciable Capital Costs			
	Enter values in basis year (2007) dollars	Combined Plant Scaling and Escalation Factor	Reference Year (2016) Dollars
Site Preparation (\$) (may change to construction costs)	\$31,298,611	1.14	\$35,825,517
Engineering & design (\$)	\$116,819,606	1.14	\$133,715,926
Process contingency (\$)	\$61,446,000	1.14	\$70,333,303
Project contingency (\$)	\$196,602,817	1.14	\$225,038,662
Other (Depreciable) capital (\$)		1.14	\$0
One-time Licensing Fees (\$)		1.14	\$0
Up-Front Permitting Costs (\$) (legal and contractors fees included here)	\$0	1.14	\$0
Total Depreciable Capital Costs			\$1,766,247,151
Non-Depreciable Capital Costs			
	Enter values in basis year (2007) dollars	Combined Plant Scaling and Escalation Factor	Reference Year (2016) Dollars
Cost of land (\$/acre)	\$5,000	1.14	\$5,723.18
Land required (acres)	180	1	180
Land Cost (\$)			\$1,030,172
Other non depreciable capital costs		1.14	\$0
Total Non-Depreciable Capital Costs			\$1,030,172.40
Total Capital Costs	\$1,767,277,323		

Example Specification (feedstock, utilities, byproducts)

Energy Feedstocks, Utilities, and Byproducts

Select the Price Table to Use

AEO_2017_Reference_Case

Select the Use

utility

Select the Feed Type

Industrial Electricity

utility

Enter usage in kWh

Industrial Electricity

Price Conversion Factor (GJ/kWh) 0.0036

Price in Startup Year (\$2016)/kWh Use H2A Default \$0.07

Usage (kWh/kg H2) 1.36

Cost in Startup Year \$19,382,174

Lookup Prices yes

OR

Enter Cost Manually

To use a new feedstock, utility or byproduct, select the price table and product from the dropdown lists and enter the usage (or byproduct) amount. Click the "Add" button to add the product to the "In Use" list. Important; only materials on the "In Use" list will be used in H2A calculations. To delete materials from the list, click the "Delete" button below

Add

Delete

Energy feedstocks, utilities, and byproducts currently in use

RT_TOP

feedstock	Price Conversion Factor (GJ/kg)	Price in Startup Year (\$2016)/kg	Usage (kg/kg H2)	Cost in Startup Year	Lookup Prices
Electric Utility Steam Coal	0.022735035	0.04756253	9.697	\$46,800,469	yes

RT_TOP

utility	Price Conversion Factor (GJ/kWh)	Price in Startup Year (\$2016)/kWh	Usage (kWh/kg H2)	Cost in Startup Year	Lookup Prices
Industrial Electricity	0.0036	0.069980611	1.362208694	\$19,382,174	yes

General Information																						
Calendar year (end of year)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034		
Analysis year (end of year)	-	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Average utilization	-	-	-	-	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
Take or pay contract volume (kg/year)	-	-	-	-	5590002	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Average daily sales (kg/day)	-	-	-	-	170704	341448	341448	341448	341448	341448	341448	341448	341448	341448	341448	341448	341448	341448	341448	341448		
Annual hydrogen sales (kg/year)	-	-	-	-	6231435	124628630	124628630	124628630	124628630	124628630	124628630	124628630	124628630	124628630	124628630	124628630	124628630	124628630	124628630	124628630		
Evaluation of prices																						
Sales price of hydrogen (\$/kg)	\$	-	\$ 1.18	\$ 1.20	\$ 1.22	\$ 1.25	\$ 1.27	\$ 1.30	\$ 1.32	\$ 1.35	\$ 1.37	\$ 1.40	\$ 1.42	\$ 1.45	\$ 1.48	\$ 1.51	\$ 1.53	\$ 1.56	\$ 1.59	\$ 1.62	\$ 1.65	
Value of coproduct 1 (\$/units of coproduct 1)	\$	-	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.11	\$ 0.11	\$ 0.11	\$ 0.11	\$ 0.11	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.13	\$ 0.13	\$ 0.13	\$ 0.14	\$ 0.14	\$ 0.14	\$ 0.14	
Value of coproduct 2 (\$/units of coproduct 2)	\$	-	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.11	\$ 0.11	\$ 0.11	\$ 0.11	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.13	\$ 0.13	\$ 0.13	\$ 0.14	\$ 0.14	\$ 0.14	\$ 0.14	
Value of coproduct 3 (\$/units of coproduct 3)	\$	-	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.11	\$ 0.11	\$ 0.11	\$ 0.11	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.13	\$ 0.13	\$ 0.13	\$ 0.14	\$ 0.14	\$ 0.14	\$ 0.14	
Value of coproduct 4 (\$/units of coproduct 4)	\$	-	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.11	\$ 0.11	\$ 0.11	\$ 0.11	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.13	\$ 0.13	\$ 0.13	\$ 0.14	\$ 0.14	\$ 0.14	\$ 0.14	
Value of coproduct 5 (\$/units of coproduct 5)	\$	-	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.11	\$ 0.11	\$ 0.11	\$ 0.11	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.13	\$ 0.13	\$ 0.13	\$ 0.14	\$ 0.14	\$ 0.14	\$ 0.14	
Value of coproduct 6 (\$/units of coproduct 6)	\$	-	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.11	\$ 0.11	\$ 0.11	\$ 0.11	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.13	\$ 0.13	\$ 0.13	\$ 0.14	\$ 0.14	\$ 0.14	\$ 0.14	
Value of coproduct 7 (\$/units of coproduct 7)	\$	-	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.11	\$ 0.11	\$ 0.11	\$ 0.11	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.13	\$ 0.13	\$ 0.13	\$ 0.14	\$ 0.14	\$ 0.14	\$ 0.14	
Value of coproduct 8 (\$/units of coproduct 8)	\$	-	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.11	\$ 0.11	\$ 0.11	\$ 0.11	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.13	\$ 0.13	\$ 0.13	\$ 0.14	\$ 0.14	\$ 0.14	\$ 0.14	
Value of coproduct 9 (\$/units of coproduct 9)	\$	-	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.11	\$ 0.11	\$ 0.11	\$ 0.11	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.13	\$ 0.13	\$ 0.13	\$ 0.14	\$ 0.14	\$ 0.14	\$ 0.14	
Cost of ind.rnat gas (\$/mmBtu)	\$	-	\$ 3.50	\$ 4.16	\$ 4.63	\$ 5.18	\$ 5.73	\$ 6.26	\$ 6.80	\$ 7.34	\$ 7.87	\$ 8.40	\$ 8.93	\$ 9.46	\$ 10.00	\$ 10.53	\$ 11.06	\$ 11.59	\$ 12.12	\$ 12.65	\$ 13.18	
Cost of ind.electr (\$/kWh)	\$	-	\$ 0.07	\$ 0.07	\$ 0.07	\$ 0.07	\$ 0.08	\$ 0.08	\$ 0.08	\$ 0.09	\$ 0.09	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.11	\$ 0.11	\$ 0.11	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.13	
Cost of ind.electr (\$/MMWh)	\$	-	\$ 7.00	\$ 7.00	\$ 7.00	\$ 7.00	\$ 7.00	\$ 7.00	\$ 7.00	\$ 7.00	\$ 7.00	\$ 7.00	\$ 7.00	\$ 7.00	\$ 7.00	\$ 7.00	\$ 7.00	\$ 7.00	\$ 7.00	\$ 7.00	\$ 7.00	
Cost of biomass (\$/kg)	\$	-	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	
Cost of process water (\$/gal)	\$	-	\$ 0.01	\$ 0.01	\$ 0.01	\$ 0.01	\$ 0.01	\$ 0.01	\$ 0.01	\$ 0.01	\$ 0.01	\$ 0.01	\$ 0.01	\$ 0.01	\$ 0.01	\$ 0.01	\$ 0.01	\$ 0.01	\$ 0.01	\$ 0.01	\$ 0.01	
Cost of cooling water (\$/gal)	\$	-	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.00	
Cost of comm.electr gas (\$/units of feedstock 6)	\$	-	\$ 7.19	\$ 7.19	\$ 7.19	\$ 7.19	\$ 7.19	\$ 7.19	\$ 7.19	\$ 7.19	\$ 7.19	\$ 7.19	\$ 7.19	\$ 7.19	\$ 7.19	\$ 7.19	\$ 7.19	\$ 7.19	\$ 7.19	\$ 7.19	\$ 7.19	
Cost of comm.electr gas (\$/units of feedstock 7)	\$	-	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	
Cost of feedstock 8 (\$/units of feedstock 8)	\$	-	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	
Cost of feedstock 9 (\$/units of feedstock 9)	\$	-	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	\$ 0.10	
Labor + CGA (\$/h)	\$	-	\$ 69.29	\$ 69.29	\$ 69.29	\$ 69.29	\$ 69.29	\$ 69.29	\$ 69.29	\$ 69.29	\$ 69.29	\$ 69.29	\$ 69.29	\$ 69.29	\$ 69.29	\$ 69.29	\$ 69.29	\$ 69.29	\$ 69.29	\$ 69.29	\$ 69.29	
Total annual maintenance	\$	-	\$ 1,049.00	\$ 1,049.00	\$ 1,049.00	\$ 1,049.00	\$ 1,049.00	\$ 1,049.00	\$ 1,049.00	\$ 1,049.00	\$ 1,049.00	\$ 1,049.00	\$ 1,049.00	\$ 1,049.00	\$ 1,049.00	\$ 1,049.00	\$ 1,049.00	\$ 1,049.00	\$ 1,049.00	\$ 1,049.00	\$ 1,049.00	
Replacement costs (\$/year)	\$	-	\$ 1,239.78	\$ 1,239.78	\$ 1,239.78	\$ 1,239.78	\$ 1,239.78	\$ 1,239.78	\$ 1,239.78	\$ 1,239.78	\$ 1,239.78	\$ 1,239.78	\$ 1,239.78	\$ 1,239.78	\$ 1,239.78	\$ 1,239.78	\$ 1,239.78	\$ 1,239.78	\$ 1,239.78	\$ 1,239.78	\$ 1,239.78	
Other variable costs (\$/year)	\$	-	\$ 2,123.00	\$ 2,123.00	\$ 2,123.00	\$ 2,123.00	\$ 2,123.00	\$ 2,123.00	\$ 2,123.00	\$ 2,123.00	\$ 2,123.00	\$ 2,123.00	\$ 2,123.00	\$ 2,123.00	\$ 2,123.00	\$ 2,123.00	\$ 2,123.00	\$ 2,123.00	\$ 2,123.00	\$ 2,123.00	\$ 2,123.00	
INCOME STATEMENT																						
Revenues (annual)																						
hydrogen sales	\$	-	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	
Total revenue	\$	-	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	
198,584,973	\$	-	\$ 202,358,087	\$ 202,358,087	\$ 202,358,087	\$ 202,358,087	\$ 202,358,087	\$ 202,358,087	\$ 202,358,087	\$ 202,358,087	\$ 202,358,087	\$ 202,358,087	\$ 202,358,087	\$ 202,358,087	\$ 202,358,087	\$ 202,358,087	\$ 202,358,087	\$ 202,358,087	\$ 202,358,087	\$ 202,358,087	\$ 202,358,087	
Operating expenses																						
Cost of ind.rnat gas	\$	-	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	
Cost of ind.electr	\$	-	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	
Cost of process water	\$	-	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	
Cost of cooling water	\$	-	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	
Total feedstock 2 & utilities	\$	-	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	
Labor	\$	-	\$ 3,089,829	\$ 3,089,829	\$ 3,089,829	\$ 3,089,829	\$ 3,089,829	\$ 3,089,829	\$ 3,089,829	\$ 3,089,829	\$ 3,089,829	\$ 3,089,829	\$ 3,089,829	\$ 3,089,829	\$ 3,089,829	\$ 3,089,829	\$ 3,089,829	\$ 3,089,829	\$ 3,089,829	\$ 3,089,829	\$ 3,089,829	
Total annual maintenance	\$	-	\$ 1,099,943	\$ 1,099,943	\$ 1,099,943	\$ 1,099,943	\$ 1,099,943	\$ 1,099,943	\$ 1,099,943	\$ 1,099,943	\$ 1,099,943	\$ 1,099,943	\$ 1,099,943	\$ 1,099,943	\$ 1,099,943	\$ 1,099,943	\$ 1,099,943	\$ 1,099,943	\$ 1,099,943	\$ 1,099,943	\$ 1,099,943	
Property insurance	\$	-	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	
Replacement costs	\$	-	\$ 4,740,766	\$ 4,740,766	\$ 4,740,766	\$ 4,740,766	\$ 4,740,766	\$ 4,740,766	\$ 4,740,766	\$ 4,740,766	\$ 4,740,766	\$ 4,740,766	\$ 4,740,766	\$ 4,740,766	\$ 4,740,766	\$ 4,740,766	\$ 4,740,766	\$ 4,740,766	\$ 4,740,766	\$ 4,740,766	\$ 4,740,766	
Other variable costs	\$	-	\$ 2,123,000	\$ 2,123,000	\$ 2,123,000	\$ 2,123,000	\$ 2,123,000	\$ 2,123,000	\$ 2,123,000	\$ 2,123,000	\$ 2,123,000	\$ 2,123,000	\$ 2,123,000	\$ 2,123,000	\$ 2,123,000	\$ 2,123,000	\$ 2,123,000	\$ 2,123,000	\$ 2,123,000	\$ 2,123,000	\$ 2,123,000	
Total operating expenses	\$	-	\$ 67,064,819	\$ 132,660,910	\$ 132,660,910	\$ 132,660,910	\$ 132,660,910	\$ 132,660,910	\$ 132,660,910	\$ 132,660,910	\$ 132,660,910	\$ 132,660,910	\$ 132,660,910	\$ 132,660,910	\$ 132,660,910	\$ 132,660,910	\$ 132,660,910	\$ 132,660,910	\$ 132,660,910	\$ 132,660,910	\$ 132,660,910	
Earnings before interest, taxes and depreciation (EBITD)	\$	-	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	
Income on outstanding debt	\$	-	\$ 5,516,656	\$ 5,516,656	\$ 5,516,656	\$ 5,516,656	\$ 5,516,656	\$ 5,516,656	\$ 5,516,656	\$ 5,516,656	\$ 5,516,656	\$ 5,516,656	\$ 5,516,656	\$ 5,516,656	\$ 5,516,656	\$ 5,516,656	\$ 5,516,656	\$ 5,516,656	\$ 5,516,656	\$ 5,516,656	\$ 5,516,656	
Equipment depreciation	\$	-	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Taxable income	\$	-	\$ (5,516,656)	\$ (5,516,656)	\$ (5,516,656)	\$ (5,516,656)	\$ (5,516,656)	\$ (5,516,656)	\$ (5,516,656)	\$ (5,516,656)	\$ (5,516,656)	\$ (5,516,656)	\$ (5,516,656)	\$ (5,516,656)	\$ (5,516,656)	\$ (5,516,656)	\$ (5,516,656)	\$ (5,516,656)	\$ (5,516,656)	\$ (5,516,656)	\$ (5,516,656)	
Calculated current year taxes before deferralment	\$	-	\$ (1,419,987)	\$ (1,419,987)	\$ (1,419,987)	\$ (1,419,987)	\$ (1,419,987)	\$ (1,419,987)	\$ (1,419,987)	\$ (1,419,987)	\$ (1,419,987)	\$ (1,419,987)	\$ (1,419,987)	\$ (1,419,987)	\$ (1,419,987)	\$ (1,419,987)	\$ (1,419,987)	\$ (1,419,987)	\$ (1,419,987)	\$ (1,419,987)	\$ (1,419,987)	
Remaining deferred taxes from 1 years ago	\$	-	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	
Remaining deferred taxes from 2 years ago</																						

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