H2A Production Model Updates

2011 Hydrogen Program Annual Merit Review and Peer Evaluation Meeting

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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 2011*

Complete: 80% (FY2011 work)

Budget

Total Project Funding (FY 2010 and 2011)**: $400k

- 100% DOE-funded

FY2010: $200k

FY2011: $200k

* Project continuation and direction determined annually by DOE.

** H2A update project is part of a larger H2A and FCPower model project

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

- Argonne National Laboratory
- Pacific Northwest Laboratory
- Directed Technologies, Inc. (DTI)
- TIAX LLC
- 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:

- Incorporate new knowledge
- Incorporate new Annual Energy Outlook (AEO) fuel cost projections
- Update baseline year
- Re-evaluate assumptions

Approach

1. Update the “templates” for central and forecourt cases
   - Make any needed structural changes to the models
   - Develop strategy for updating cost values
   - Update common tables
   - Review common assumptions
2. Thoroughly test the template changes and review new approaches and assumptions with stakeholders
3. Update bottom-up cost estimates for published H2A case studies based on the new templates
4. Write a “case study report” summarizing the case study results

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

Accomplishments: Update H2A Central Template

Update to 2007 Dollars

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

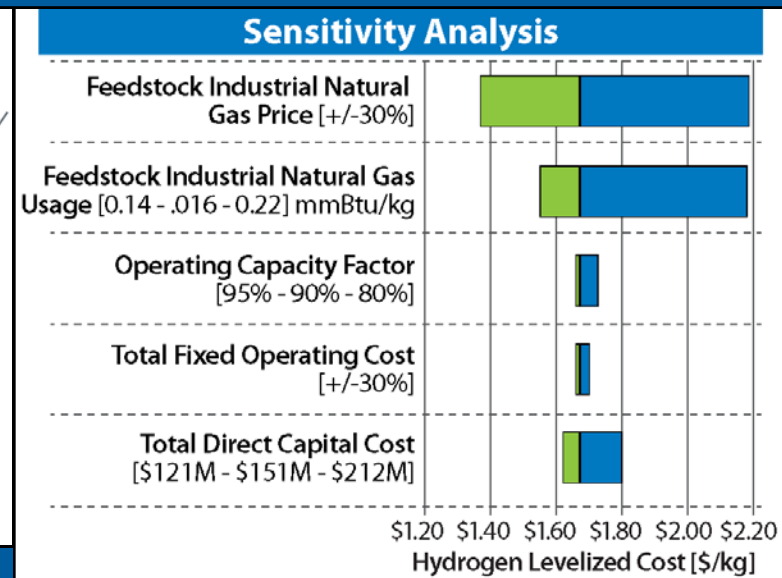
Central SMR case study will be used to develop top-down cost thresholds

RESULTS $2005

Cost Component	Cost Contribution ($/kg)	Percentage of H_2 Cost
Capital Costs	$0.25	19.2%
Decommissioning Costa	$0.00	0.0%
Fixed O&M	$0.06	4.3%
Feedstock Costs	$0.95	71.5%
Other Raw Material Costs	$0.00	0.0%
Byproduct Credits	$0.00	0.0%
Other Variable Costs (including utilities)	$0.07	4.9%
Total	**$1.32**	

RESULTS $2007

Cost Component	Cost Contribution ($/kg)	Percentage of H_2 Cost
Capital Costs	$0.31	18.6%
Decommissioning Costs	$0.00	0.0%
Fixed O&M	$0.06	3.7%
Feedstock Costs	$1.23	73.3%
Other Raw Material Costs	$0.00	0.0%
Byproduct Credits	$0.00	0.0%
Other Variable Costs (including utilities)	$0.07	4.4%
Total	**$1.68**	

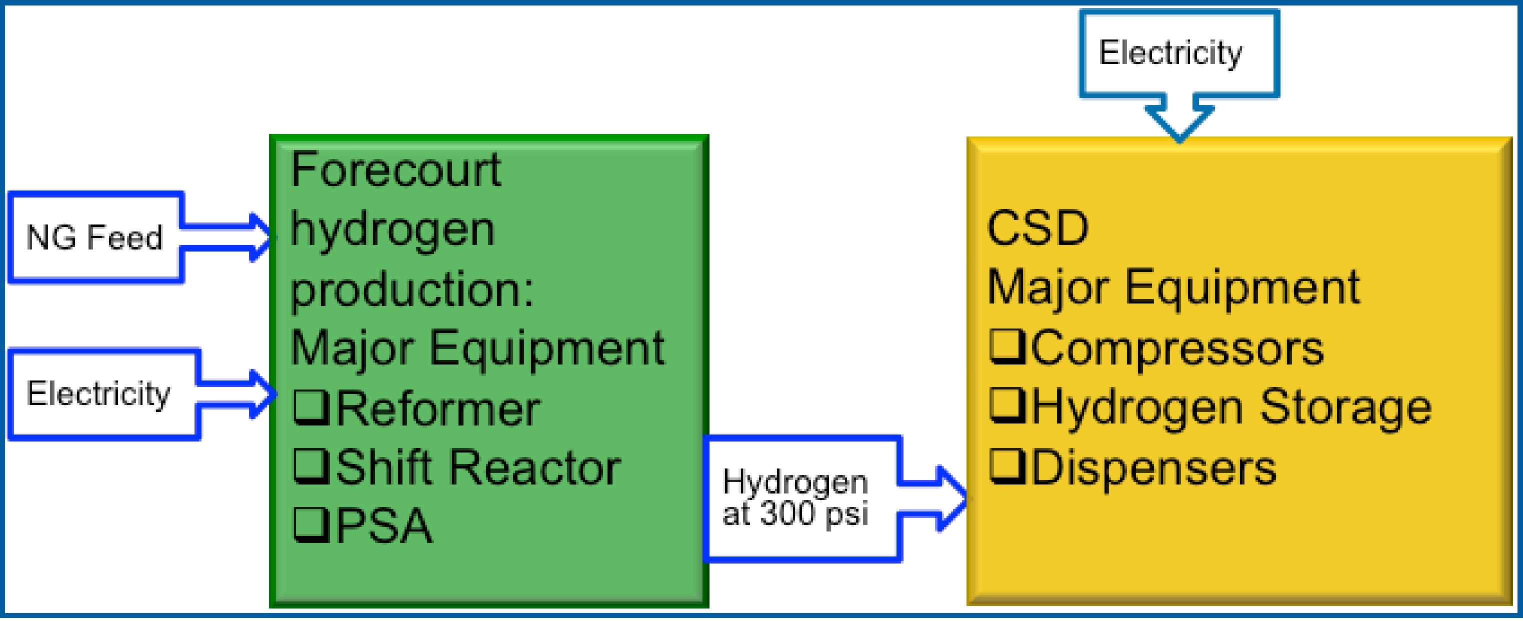


Changes to Assumptions for Central Steam Methane Reforming (SMR) Plant

- 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
- Natural gas price increased from $7.00/mmBtu ($2005) to $8.33/mmBtu ($2007)

Accomplishments: Update H2A Forecourt Template

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

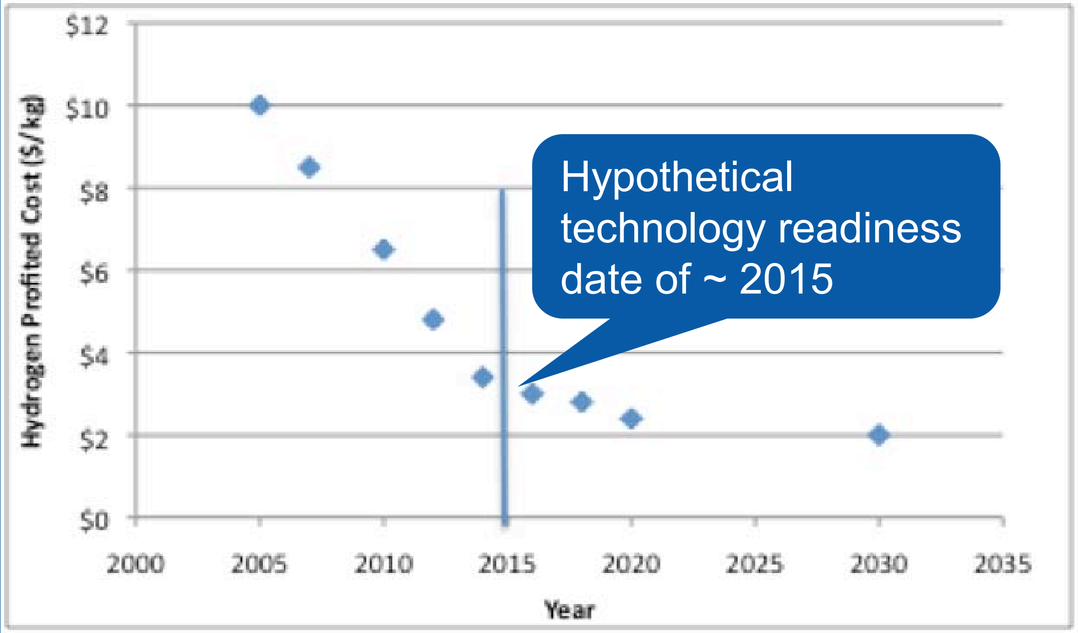
Make adjustments for forecourt operation

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

Accomplishments: 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: Forecourt Production Model Template Revised Indirect Capital Cost Assumptions

Site Prep Costs

Using AACE* cost categories for a “>150psi, >400F Gas Process”:

Foundation: (% of process cost)

Materials: 5%

Labor: 6.65%

Miscellaneous (% of process cost)

Materials: 4%

Labor: 3.2%

On notional \$1M process plant this equals \$1M x 18.85% = \$188.5K

Installation Costs (% of total direct uninstalled capital)

Sales tax:	**5%**	Typical state sales tax
Shipping:	**1%**	Based on actual low-rider coast-to-coast transport of single large load
Insurance:	**1%**	Shipping insurance estimate
Setting:	**10%**	One half of AACE generic recommended value due to N^{th} plant considerations

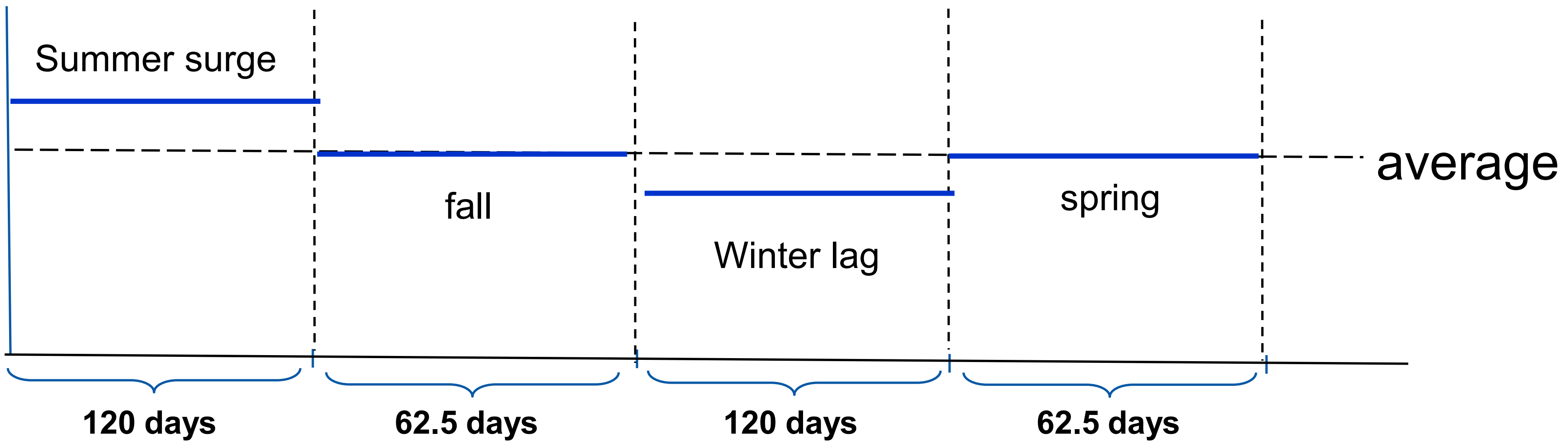
Total Installation: 17% of total direct uninstalled capital

** The Association for the Advancement of Cost Engineering*

Site preparation and installation costs increased for forecourt stations based on AACE guidelines and N^{th} plant assumptions

Accomplishments: Forecourt CSD Model Template Proposed Revised Strategy for Summer Surge Refueling

H2A default seasonal dispensing profile



Onsite storage to accommodate the full summer surge period is not feasible

The reformer must be large enough to meet summer demand– it will be run at less than full capacity for the rest of the year

Onsite storage is still needed;

- To meet daily and weekly variation in demand
- To meet demand during reformer outages

Accomplishment: Calculate the size of the dispensing equipment and storage

Maximum dispensed = hydrogen demand on a Friday in the summer

Example:

- *Summer surge = 10% above yearly average*
- *Friday peak = 8% above weekly average*
  - ➢ *Friday in the summer = yearly average * (1.1)*(1.08)*

For 1,200 kg/day yearly average dispensed, this amount is:
*1,200 * 1.1 * 1.08 = 1,426kg*

The summer Friday maximum also determines the amount of storage needed to cover outages; i.e., hydrogen storage must cover a 14-hour reformer outage during peak hours on a Friday in the summer

- ➢ kg dispensed during 14h peak period = 1220kg

The dispensing equipment must also be sized for the summer Friday maximum.

Accomplishment/Proposed Future Work: Update Current H2A bottom-up Cost Estimates Based on New Templates

Pathway (Technology Readiness Date)

Central Biomass (2020)
Current and Future Central Hydrogen Production via Biomass Gasification

Central Electrolysis (2020)
Current and Future Central Hydrogen Production from Grid Electrolysis

Central Coal (2020)
Current and Future Central Hydrogen Production from Coal without CO2 Sequestration
Current and Future Central Hydrogen Production from Coal with CO2 Sequestration

Central Natural Gas (2015)
Current and Future Central Hydrogen Production from Natural Gas without CO2 Sequestration
Current and Future Central Hydrogen Production from Natural Gas with CO2 Sequestration

Central Nuclear (2025)
Future Central Hydrogen Production from Nuclear Energy via High Temperature Electrolysis

Forecourt (Distributed) Electrolysis (2015)
Current and Future Forecourt Hydrogen Production from Grid Electrolysis (1,500 kg per day)

Forecourt (Distributed) Natural Gas (2015)
Current and Future Forecourt Hydrogen Production from Natural Gas (1,500 kg per day)

Forecourt (Distributed) Ethanol (2020) – *under consideration*
Current and Future Forecourt Hydrogen Production from Ethanol (1,500 kg per day)

Accomplishment/Proposed Future Work: Summary Report for each H2A Case Study

The *case study report will document changes from H2A version 2 to H2A version 3 for each H2A model.*

Updated capital and non-feedstock operating costs for H2A central SMR case

Production Process Costs	(H2A Version 2)	(H2A Version 3)	Change
Direct capital	$134,844,000	$151,318,000	+12%
Indirect capital	$45,650,000	$63,553,000	+12%
Fixed operating	$6,917,000	$7,649,000	+11%
Variable O&M, excluding fuel	$2,123,000	$2,304,000	+9%
Materials for repairs	$810,097	$860,493	+6%
Labor*	$2,046,600	$2,033,911	-1%

Updated process energy costs for H2A central SMR case

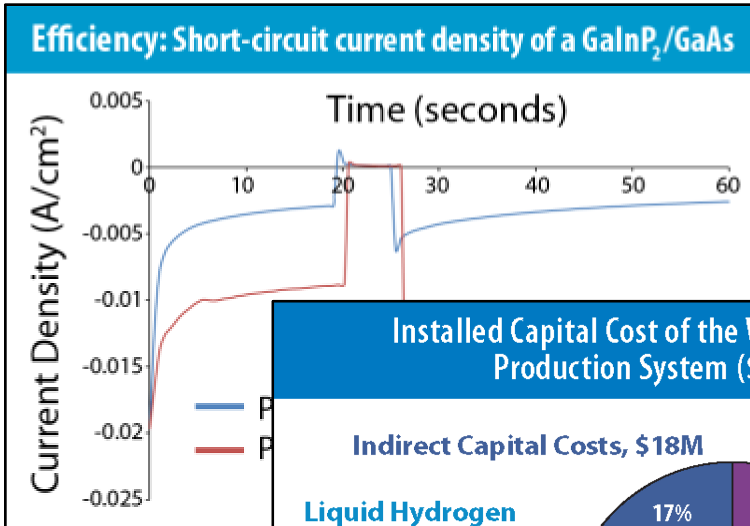
Production Process Energy	H2A Version 2	H2A Version 3	Change
Industrial natural gas price ($/mmBtu)	$7.00	$8.33	+19%
Natural gas cost in startup year	$136,232,000	$161,868,000	+19%
Contribution to hydrogen LCOE ($/kg)	$0.95	$1.23	+29%
Proportion of total LCOE	72%	73%	+1%

O&M = Operation and maintenance
LCOE = Levelized cost of electricity

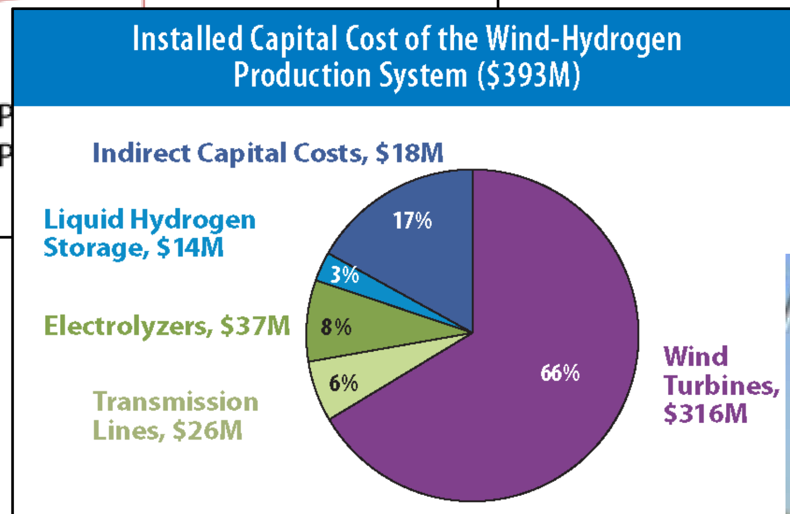
Accomplishment/Proposed Future Work: New Bottom-up Analysis for Early Development Technologies

Pathway (TR)
Photoelectrochemical (PEC) hydrogen production (2025)
Solar thermo-chemical (Ferrite cycle) (2025)
Central wind electrolysis(2020)
Biological production of hydrogen (2025)
Reforming of bio-derived liquids (pyrolysis oil) (2020)

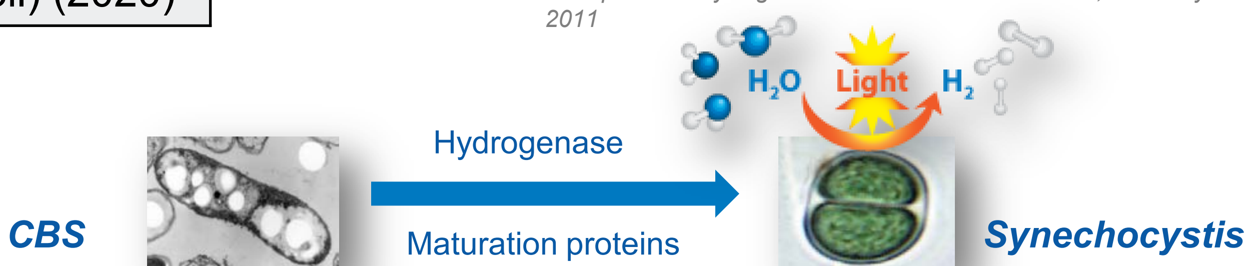
Data provided by Todd Deutsch, last updated February 2011



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

Summary

Relevance	• The H2A model is a technology neutral cost calculator for hydrogen production technologies • Periodic updates are needed to maintain the model's usefulness
Approach	• Develop and thoroughly review templates • Update and customize existing case studies • Develop new case studies for emerging technologies
Accomplishments	• Update of existing case studies including updated costs, review of assumptions, new 700 bar dispensing • Development of new case studies for emerging technologies
Collaborations and Reviewers	• Argonne National Laboratory • Pacific Northwest Laboratory • DTI • TIAX • Hydrogen Production Tech Team • Delivery Tech Team
Proposed Future Work	• Complete updates to existing case studies and publish the new case studies and summary case study reports