U.S. DEPARTMENT OF ENERGY FUEL CELL TECHNOLOGIES OFFICE



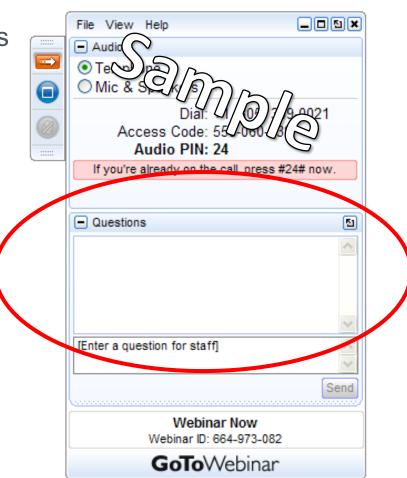


Overview of Station Analysis Tools
Developed in Support of H2USA

5/12/2015

Presenter(s):

Amgad Elgowainy, PhD Marc Melaina, PhD Please type your questions into the question box



hydrogenandfuelcells.energy.gov

Webinar Agenda

- Welcome and House Keeping 5 minutes
- Hydrogen Refueling Station Analysis Model (HRSAM) 20 minutes
 - Amgad Elgowainy
- Hydrogen Financial Analysis Scenario Tool (H2FAST) 20 minutes
 - Marc Melaina
- Questions and Answers 15 minutes

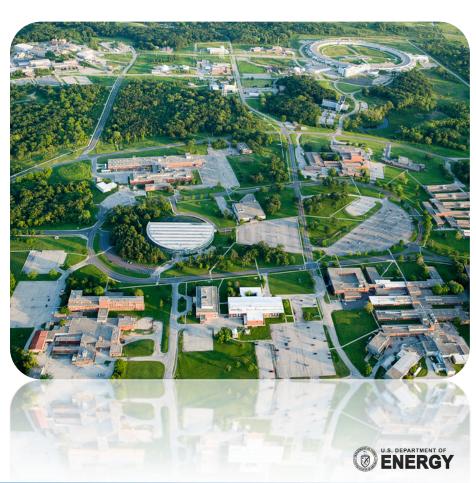


Hydrogen Refueling Station Analysis Model (HRSAM) → A near-term HRS cost model

Amgad Elgowainy

Argonne National Laboratory

May 12, 2015

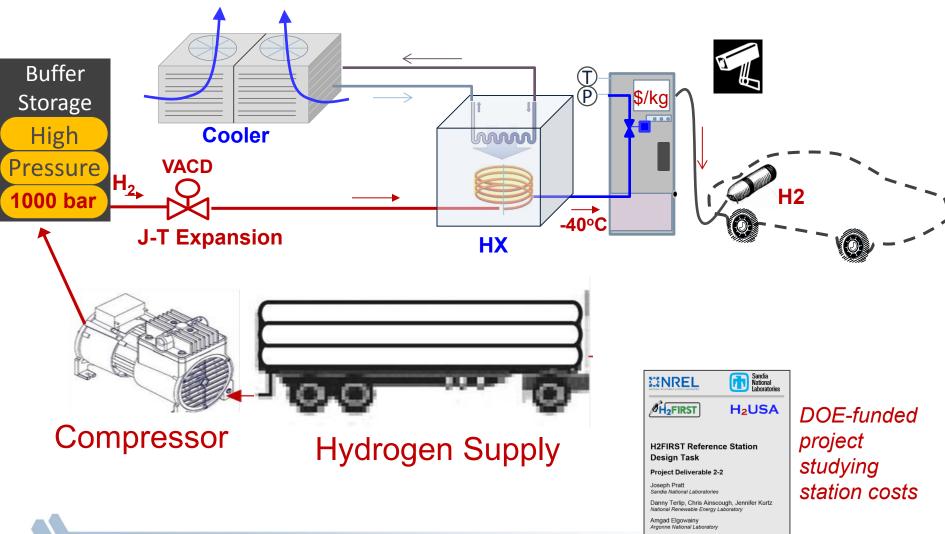


Acknowledgments

- ☐ Daryl Brown PNNL
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- ☐ George Parks Fuel Science
- ☐ Bob Boyd Boyd H2
- Lance Atkins Nissan
- Erika Sutherland FCTO

Why HRSAM?

There is a need to understand cost drivers at Hydrogen Refueling Stations (HRS) in order to reduce the cost of hydrogen fuel



Model Background and Description

HRSAM can simulate designs and costs of user-defined stations based on current market data

- ☐ HRSAM is built on the refueling module of HDSAM
 - √ 10 years of modeling and analysis experience
 - ✓ Populated with early market cost data and design practices
 - ✓ Enhanced features (e.g., impacts of HRS utilization ramp up)
- ☐ Today's component cost and performance data obtained from vendors and industry contacts
- Optimizes the size of station components and observes key specifications of SAE J2601 fueling protocol
- □ Reviewed by peers and experts from the industry and checked against cost of early stations (e.g., in CEC recent PONs)
- ☐ User-friendly, Excel-based model

Methodology: Inputs

Users can easily define key parameters to assess the impact on refueling cost

— Key station <u>design</u> parameters:

- ✓ Station size (capacity)
- ✓ Station utilization (i.e., with slow vehicle deployment rate)
- ✓ Design configuration (e.g., gaseous vs. liquid supply, cascade vs. booster fueling)
- ✓ Desired station performance (e.g., fill speed and back-to-back fill capability)

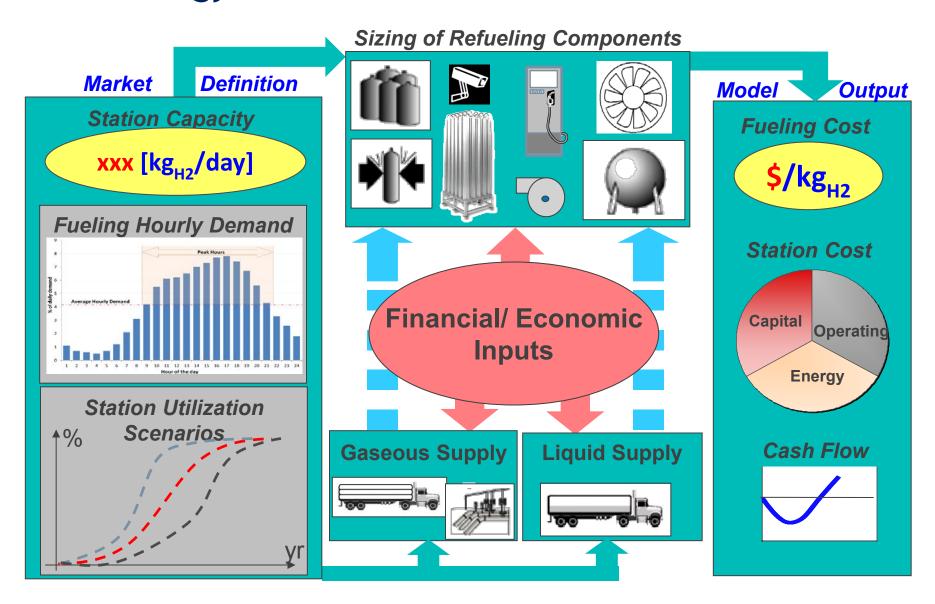
Key <u>economic</u> parameters

- ✓ Rate of return (discount rate)
- ✓ Analysis period
- ✓ Debt/equity ratio
- ✓ Components life / depreciation schedule

Other important parameters

- ✓ Setback distances affect cost of land
- ✓ Component reliability affects operating & maintenance cost
- ✓ Efficiency of equipment affects energy cost

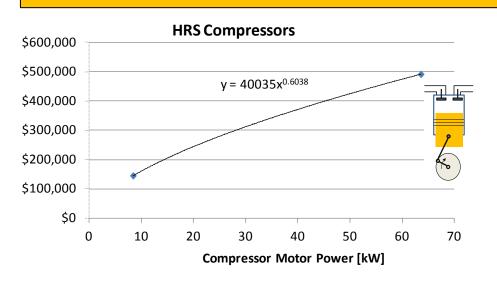
Methodology: HRSAM Model Structure

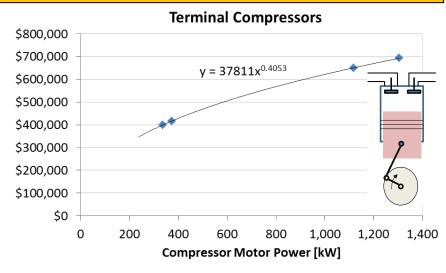


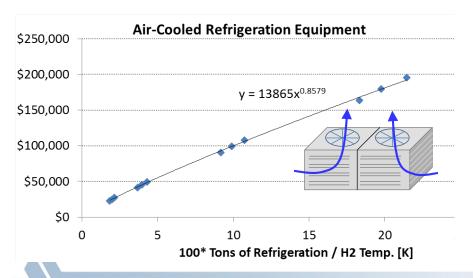
Available at: http://www.hydrogen.energy.gov/h2a_delivery.html

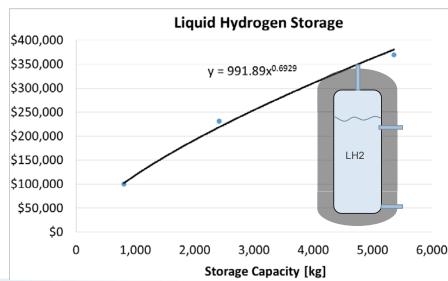
Methodology: Assumptions

HRSAM estimates the cost of station equipment based on data points taken from the existing market



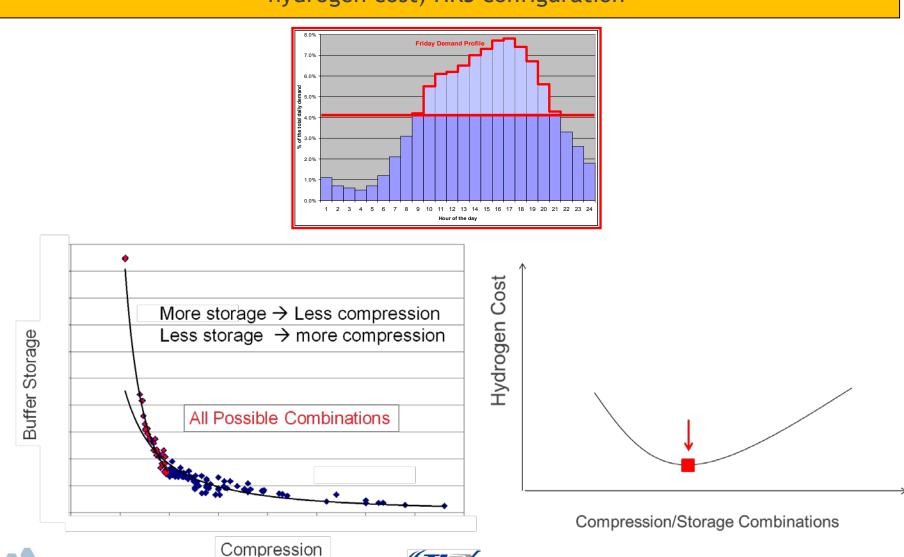






Methodology: Optimization

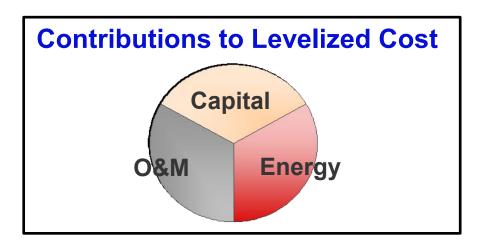
HRSAM searches for, and determines, the optimum (based on the lowest levelized hydrogen cost) HRS configuration

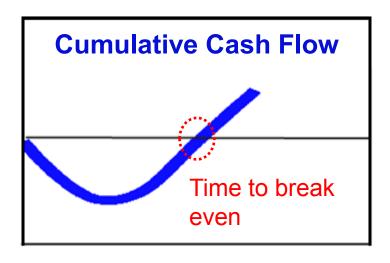


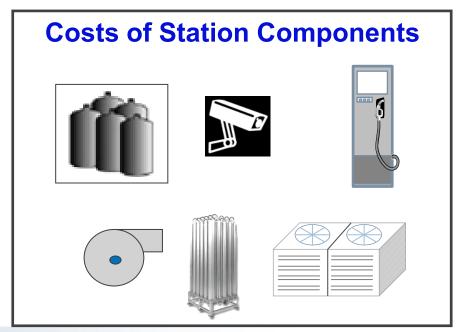
Methodology: Model Outputs

HRSAM characterizes the economics of a user-defined station

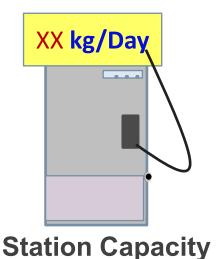


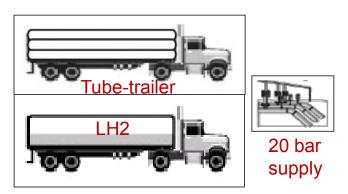




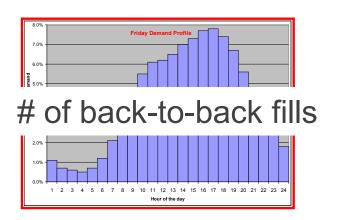


Several parameters have been identified that are of particular relevance to stakeholders and also have significant effect on station economics

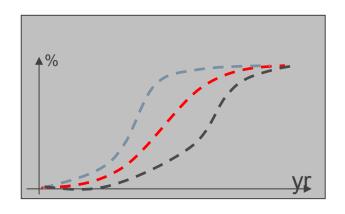




H2 Supply

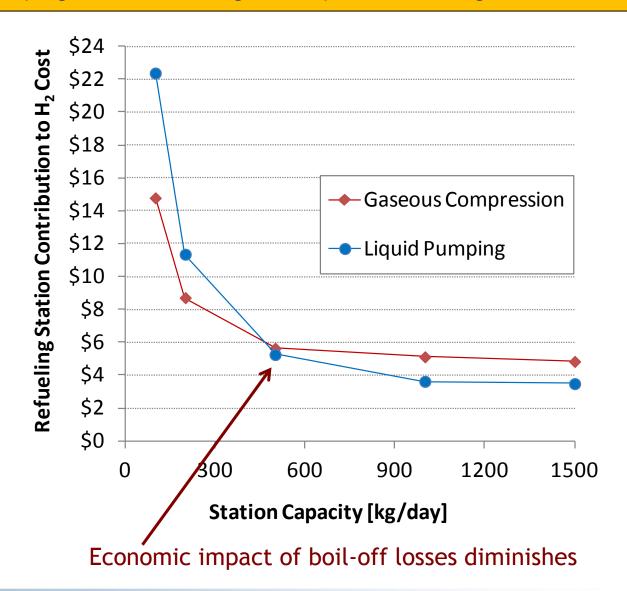


Refueling Demand

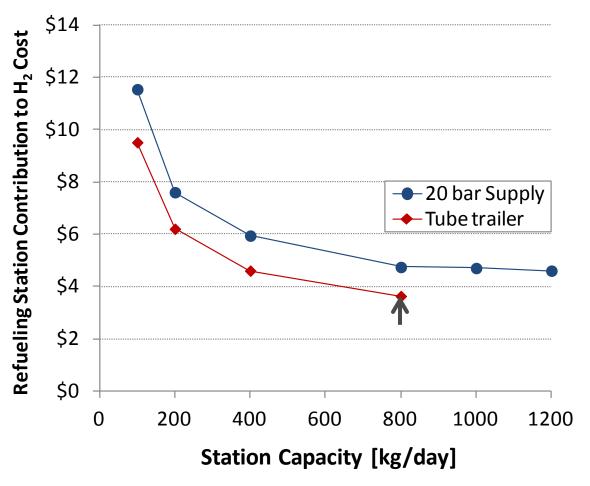


Station Utilization

Liquid pumping is favorable to gas compression at large LH2 station capacities

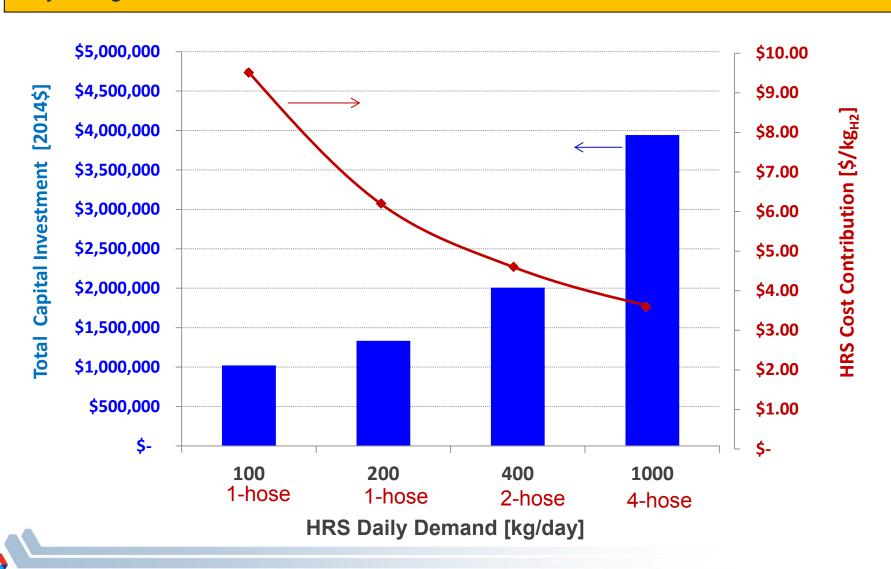


Tube-trailers can reduce station cost due to pre-compression at terminal

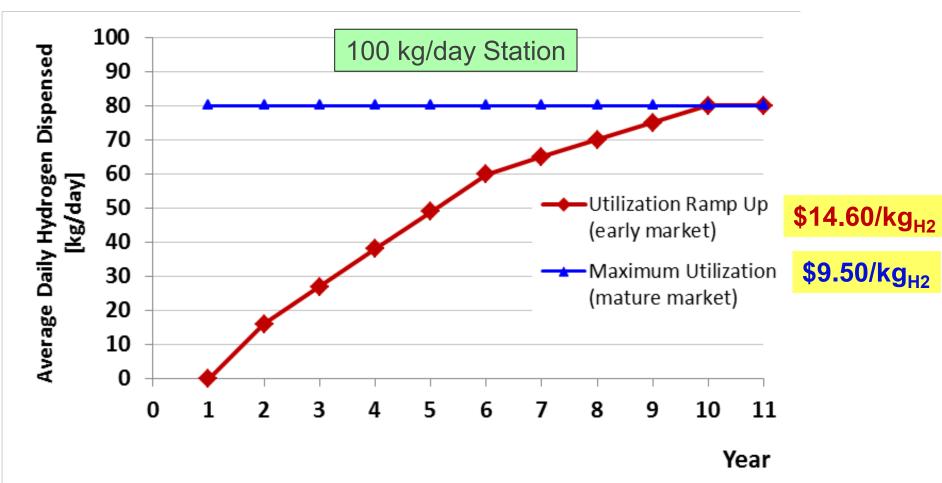


- ☐ Tube-trailers are limited to station capacities smaller than delivered payload due to the practical limitations on frequency of delivery (< one delivery per day)
 - ✓ Tube-trailers can carry up to 1000 kg payload at 500 bar

Large stations are not suitable for early FCEV markets because they are viable only at high utilization rates



Station utilization ramp up is the single most influential factor on the H₂ cost in early markets



☐ FCEV deployment rate is critical to market success

Thank You!

aelgowainy@anl.gov

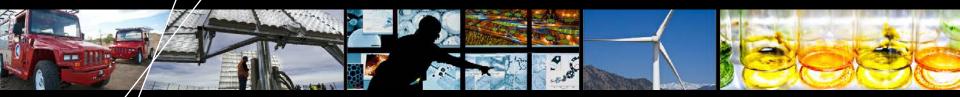
Link to HRSAM (and HDSAM) models:

http://www.hydrogen.energy.gov/h2a_delivery.html





Overview of the Hydrogen Financial Analysis Scenario Tool (H2FAST)



H2USA Modeling Overview

Marc Melaina, Brian Bush, Michael Penev

12 May 2015

Presentation Outline

- Introduction: what is H2FAST and what questions can it answer?
- Review each version of H2FAST
 - o H2FAST Web Tool
 - H2FAST Excel Tool
 - H2FAST Business Case Scenario tool (beta)
- Summary

The H2FAST framework has been implemented within multiple tools

Consistent financial calculations are deployed across the H2FAST web and spreadsheet tools and SERA scenarios

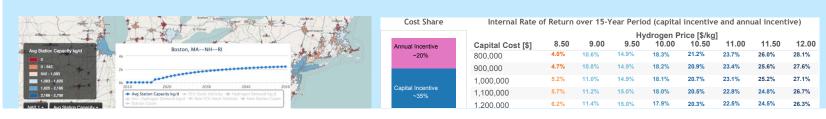


Tool interface designs have been tailored to distinct end-user groups

H2FAST-Excel allows for more detailed inputs and elaborate outputs



Business Case Scenario tool explores the full range of SERA outputs



What types of questions can H2FAST help to answer?

H2FAST: Web

- How will a \$1 million capital incentive change the outlook for our station project?
- What if we gain \$10,000 per year (~\$30/day) in additional convenience store sales due to hydrogen customers?

H2FAST: Excel

- What if our demand ramp-up rate is sluggish the first couple years, but then increases rapidly in the 4th year?
- What if we put \$5 million into a project with 7 stations?

H2FAST: BCS-Vis

- What kind of investments and incentives would be needed for a network of stations covering an entire metropolitan area or region?
- How can we prioritize investments in one region or city compared to another?



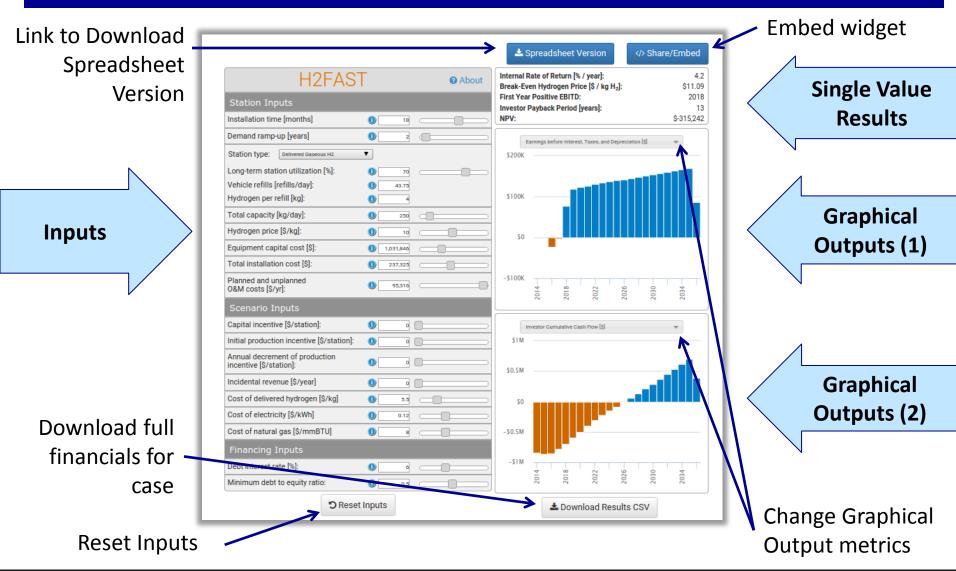




H2FAST Web Tool

H2FAST: A simple, user-friendly online tool

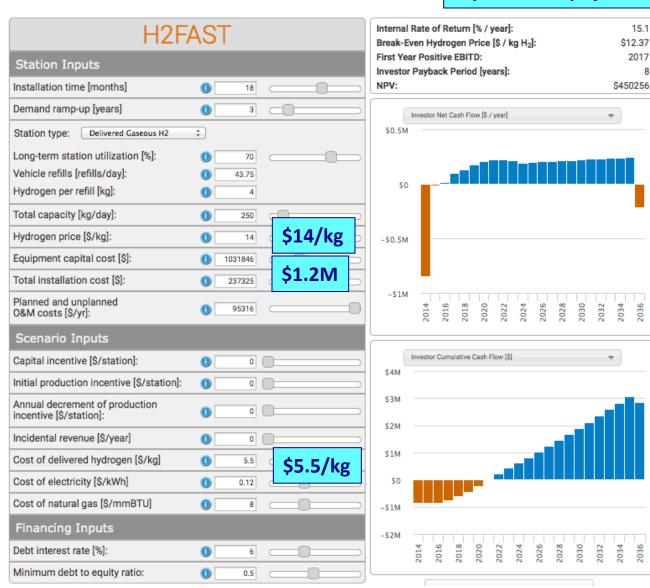
Visual results are provided instantly as inputs are changed by users



Example Case A: \$1.2 M station, no subsidy, \$14/kg price at the pump

15% IRR, 8 yr investor payback

- A nominal gaseous tank truck delivery station: 250 kg/day
- \$1.2 million in capital and installation
- Hydrogen
 delivered for
 \$5.50/kg and sold
 for \$14/kg
- Top graph shows net investor cash flow; Bottom graph shows cumulative
- Result: \$12.4/kg as breakeven price for a 10% IRR

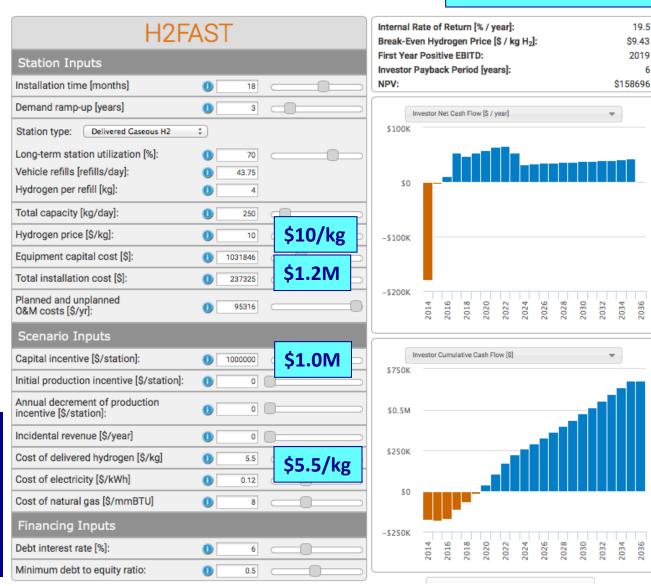


Example Case B: Assume a \$1.0 M Capital Incentive and \$10/kg price

19.5% IRR, 6 yr investor payback

- Assume \$1 M capital incentive in the first year
- Change pump price to \$10 per kg
- Increase in IRR and investor payback period
- Result: \$9.4/kg as breakeven price for a 10% IRR

H2FAST provides rapid assessments of the influence of incentives

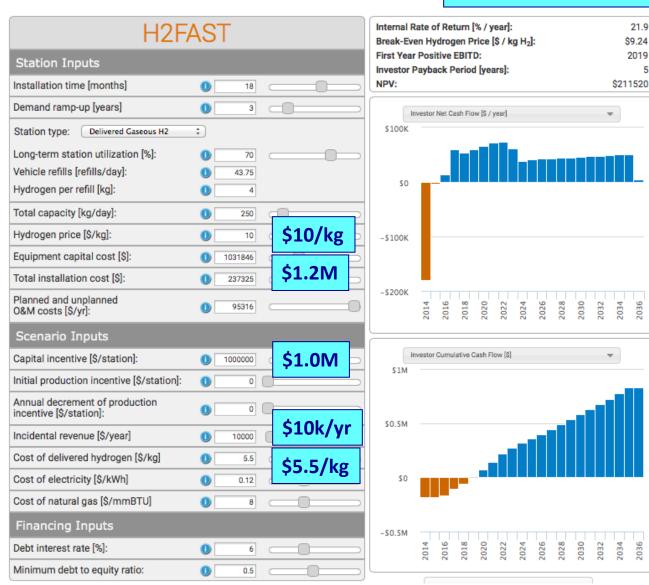


Example Case C: \$1.0 M Incentive, \$10/kg price, \$10k incidental revenue

22% IRR, 5 yr investor payback

- \$1 M capital incentive
- \$10 per kg price
- Add an incidental revenue stream of \$10k per year (~\$30/day)
- Increase in IRR and investor payback period
- Result: \$9.2/kg as breakeven price for a 10% IRR

Many financing options can be explored quickly







H2FAST Excel Tool

H2FAST Spreadsheet: Summary of Capabilities

The spreadsheet version allows for greater control of inputs and more elaborate exploration of outputs

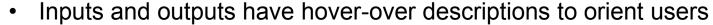
Inputs and User Interface

- Enter information for up to 10 stations and assess finances individually or as a cluster
- Side-by-side comparison of station projects
- There are two modes for users to provide inputs:
 - Basic mode:

20 parameters

Advanced mode:

51 parameters

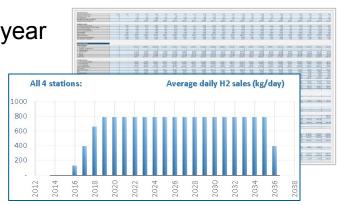


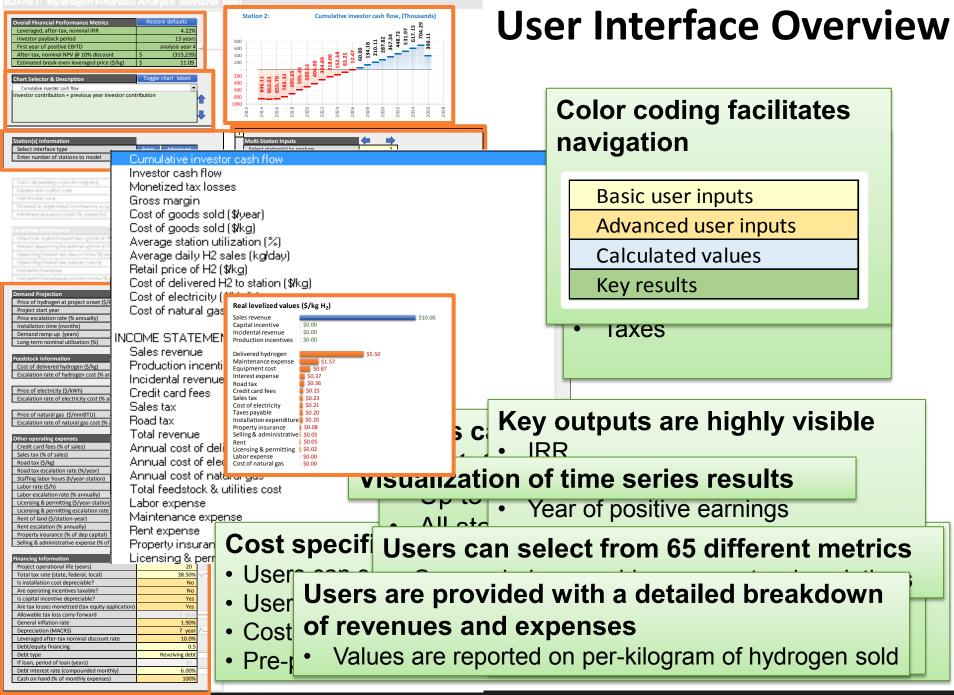
Outputs

Detailed report tables are provided for each project year

- Scenario parameters (e.g. volumes of sales)
- Income statement
- Cash flow statement
- Balance sheet
- Select ratio analyses







Report Tables

All typical US GAAP report values are displayed for each analysis year

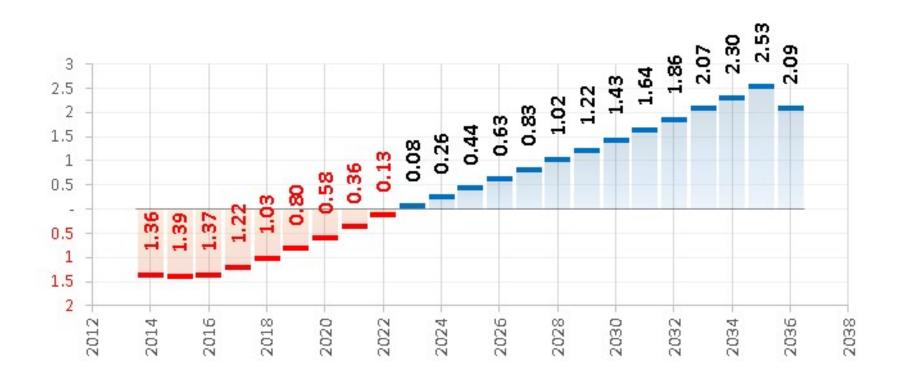
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Assets Assets													4										
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Gamustose PFXI Cumulathe debrealation	AJISTANA C	5,001,576	58:15% 509:512	5001 S25 1.727 111	5 (84 69)	5,881,535	5,651,535 5,651,738	4,072,764	NUMBER 1494-20	-5,851,576 	777.46	His COL	4(8:1) t	CReese St	3,857,935 4,757,945	3,85°,305 4,757,345	5,451,516 4,757,346	5,011,516 4,717,140	5301.536 6.777.346	5101 SIS 4 717 346	5/81,5/5 6757 346	4,957,545	5,851,505 3,757,525
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total fabilities	1,850,500	1950519	19:0512	196057	1/6/(5/7	1,635.2	1,46,401	1,694,61	189020	1896512	1262512	1,960,512	1,950,512	1,550,512	1,550,010	1,59,51	189,512	1,940,512	1960512	1 950 502	1,00,000	1,463,517	
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Time Series Examples

Range of tables satisfied most end user inquiries

Station 3:

Cumulative investor cash flow, (Millions)



- User can select from 65 common reportable time series
- Detailed description is available for each time series
- Labels can be turned on and off to show numeric values

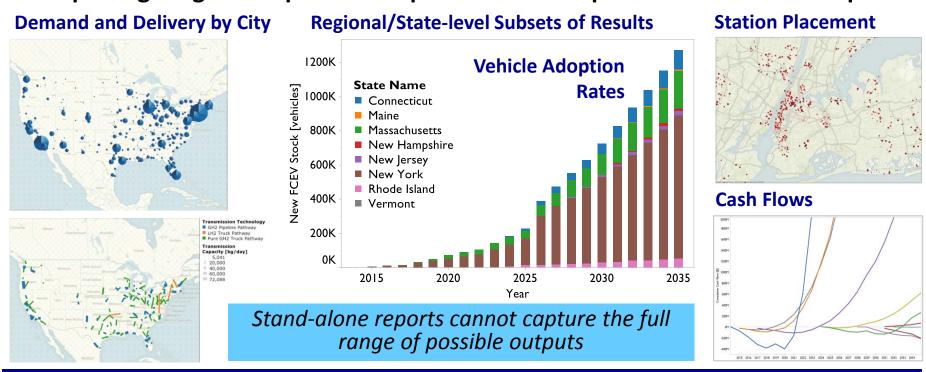




H2FAST Business Case Scenario - Visualization Tool

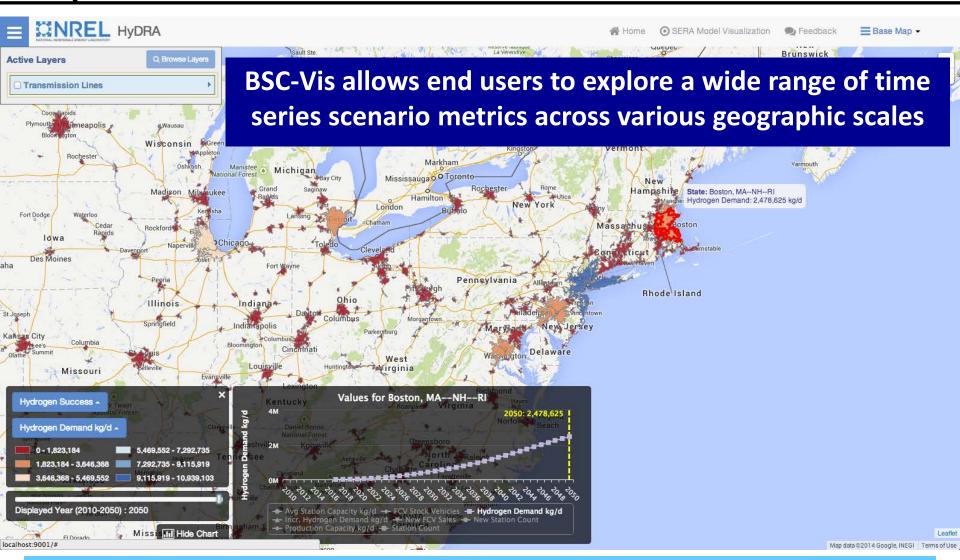
Multivariate visualization provides access to large scenario data results

- The SERA model can generate a large volume of scenario results
- The H2FAST framework can be applied across the entire hydrogen supply chain system and a broad range of scenario parameters
- Some engaged audiences, such as H2USA WG members, are interested in exploring ranges of inputs assumptions and multiple sets of scenario outputs



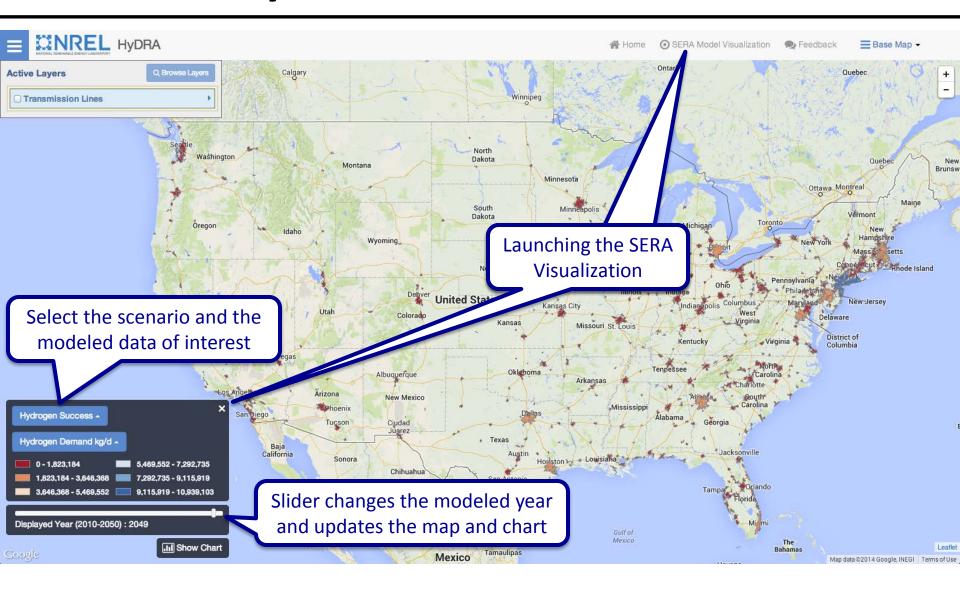
The Business Case Scenario Visualization tool (BCS-Vis) is being developed to allow end-users to explore a wide range of inputs and outputs

Business Case Scenario tool explores the full range of SERA outputs

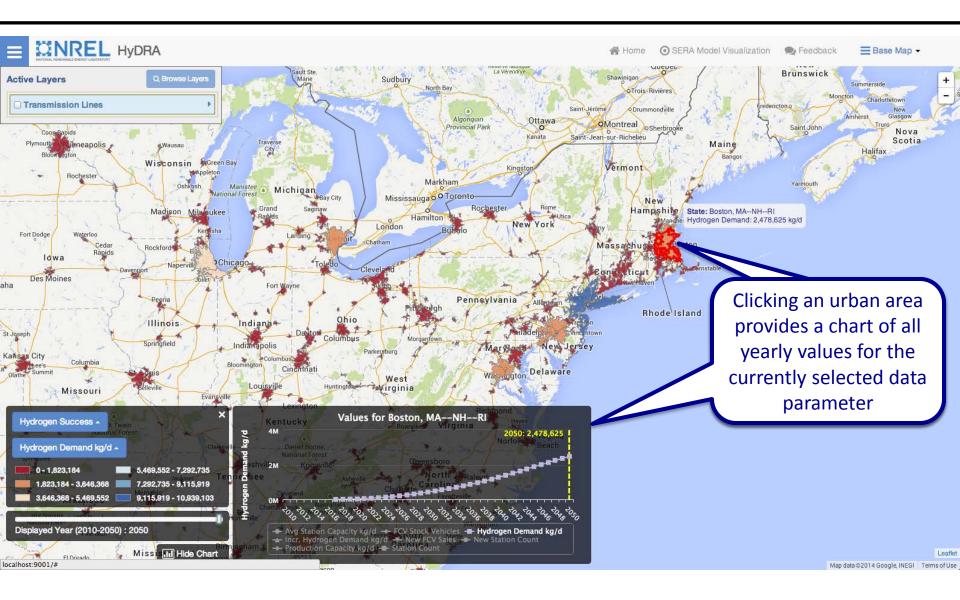


4-min video demonstrates the multivariate visualization tool: http://youtu.be/J7y51c-dldo

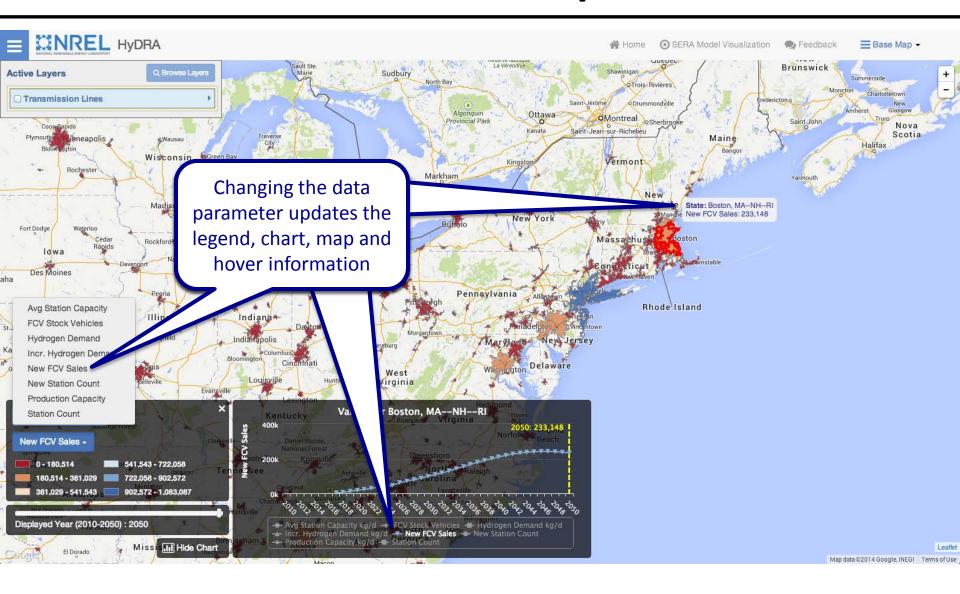
Selection of years



Selection of urban areas



Selection of metrics and output variables



Summary

- The H2FAST Web and Spreadsheet tools are an effective means of informing investment decisions on hydrogen station projects
 - Developed for end-users requiring a simple, first-cut analysis (web version) as well as more detailed and elaborate analyses (spreadsheet version)
- The H2FAST framework can also be applied to the entire hydrogen fuel supply chain to evaluate the financial implications of infrastructure development at the city, region, or national levels
 - This framework is currently being used internally to inform H2USA IFWG members in scenario exploration
 - A beta version of a visualization tool has been developed to allow access to these multivariate results to a broader audience



Thanks!



Contact email: Marc.Melaina@nrel.gov



Thank You

Please let us know if you have any questions or comments!

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