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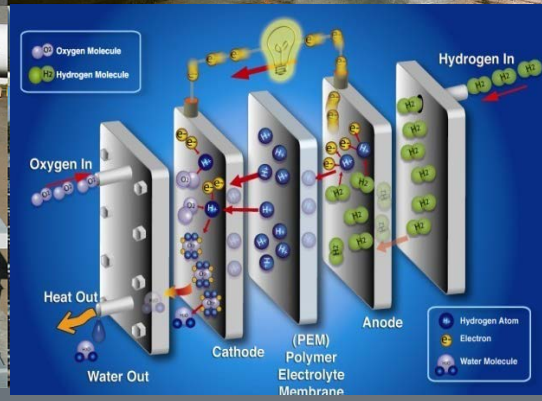


Overview of Station Analysis Tools Developed in Support of H2USA

5/12/2015

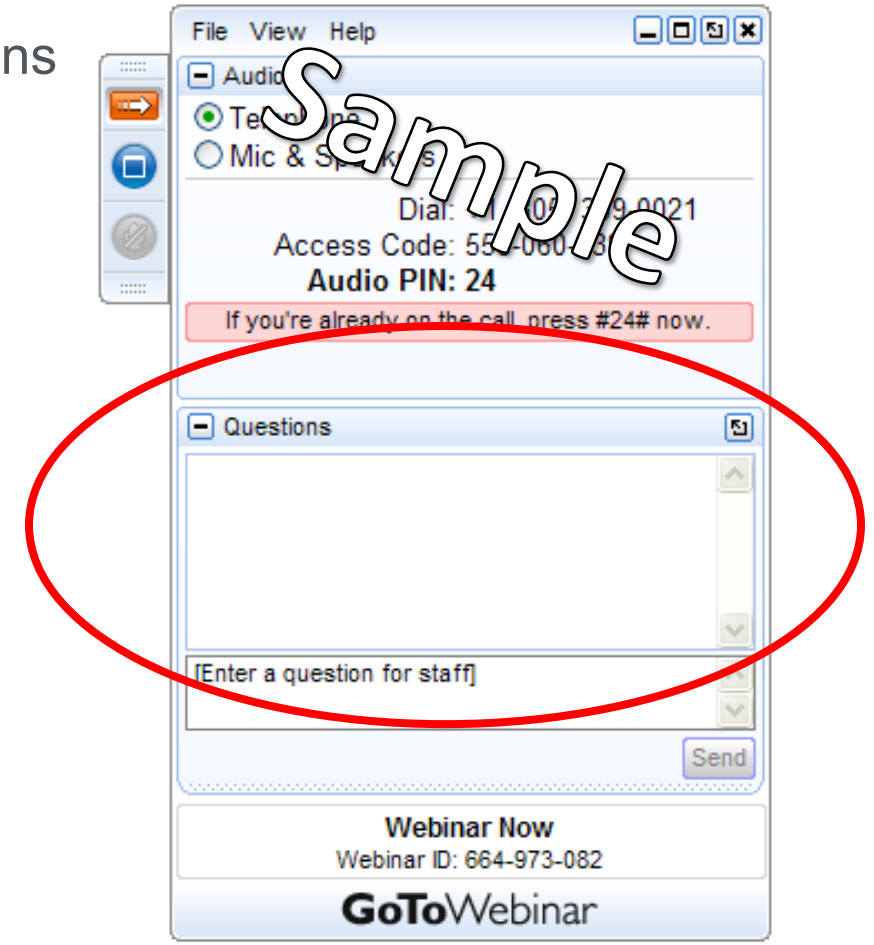
Presenter(s):

Amgad Elgowainy, PhD

Marc Melaina, PhD

Question and Answer

- 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

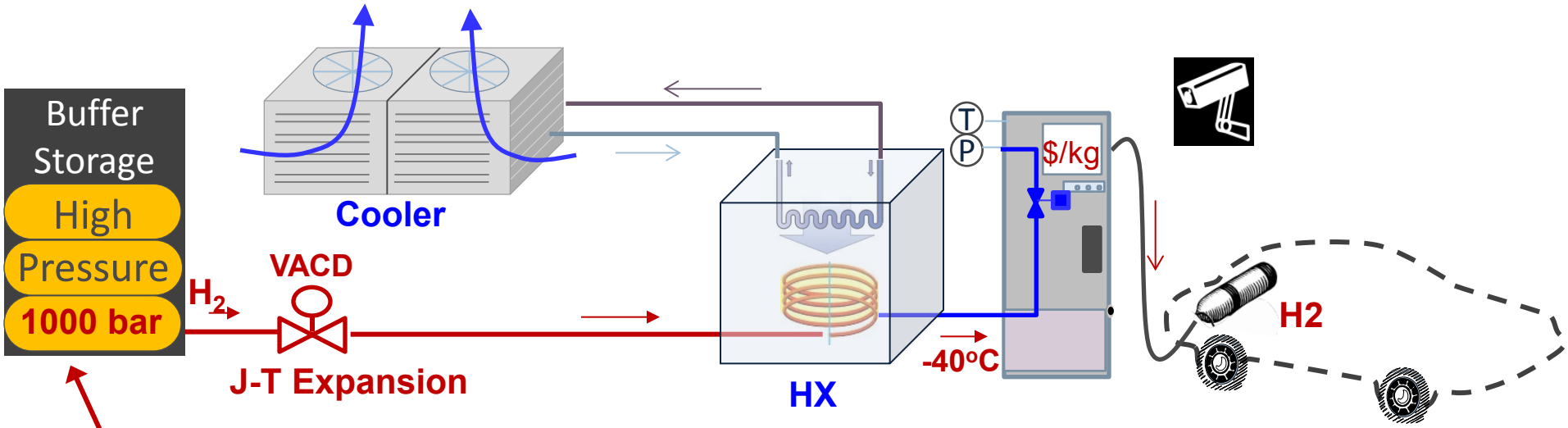
May 12, 2015

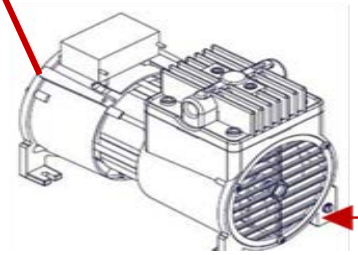
Acknowledgments

- Daryl Brown – PNNL
- Neha Rustagi – ORISE Fellow
- Joe Pratt – SNL
- Danny Turlip – NREL
- George Parks – Fuel Science
- Bob Boyd – Boyd H2
- Lance Atkins – Nissan
- Erika Sutherland – FCTO

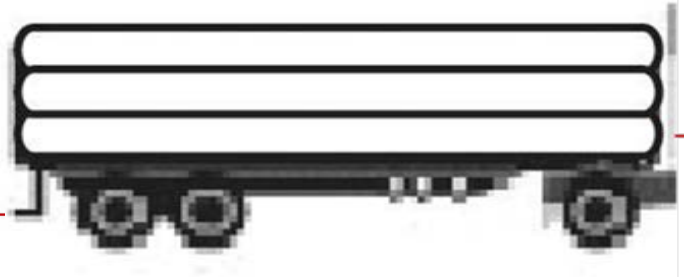
Why HRSAM?

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

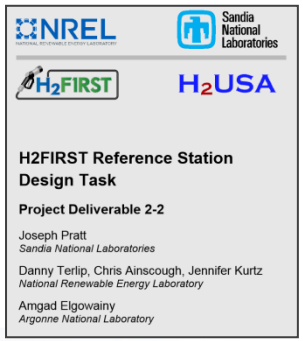




Compressor



Hydrogen Supply



DOE-funded project studying station costs

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

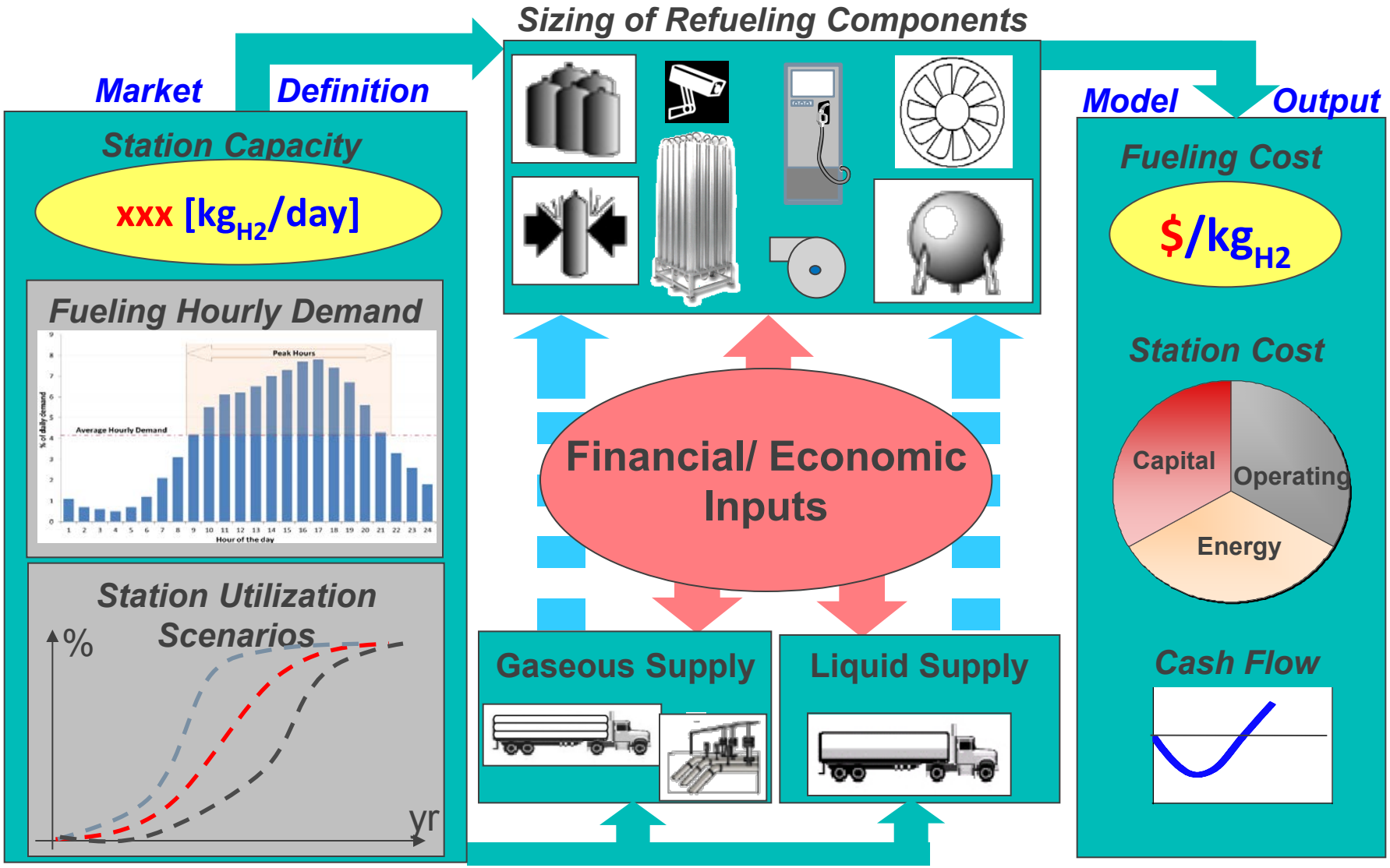
Users can easily define key parameters to assess the impact on refueling cost

— **Key station design 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 economic 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

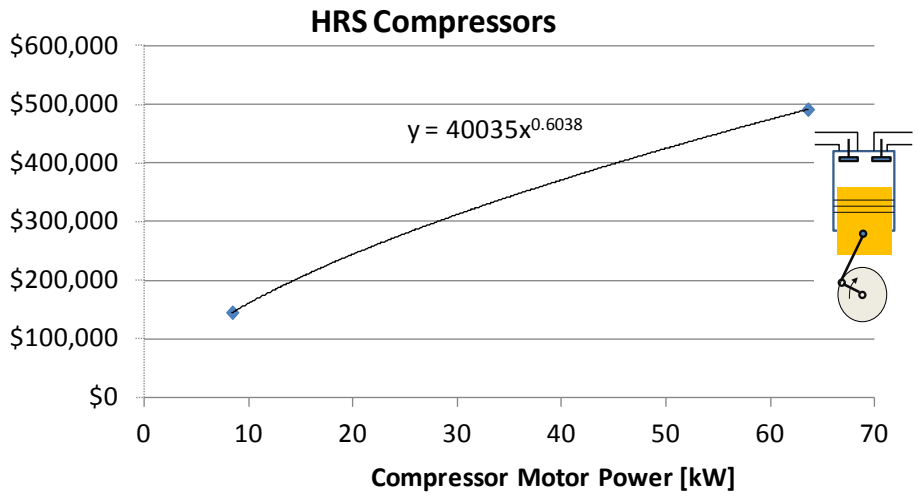
Methodology: HRSAM Model Structure

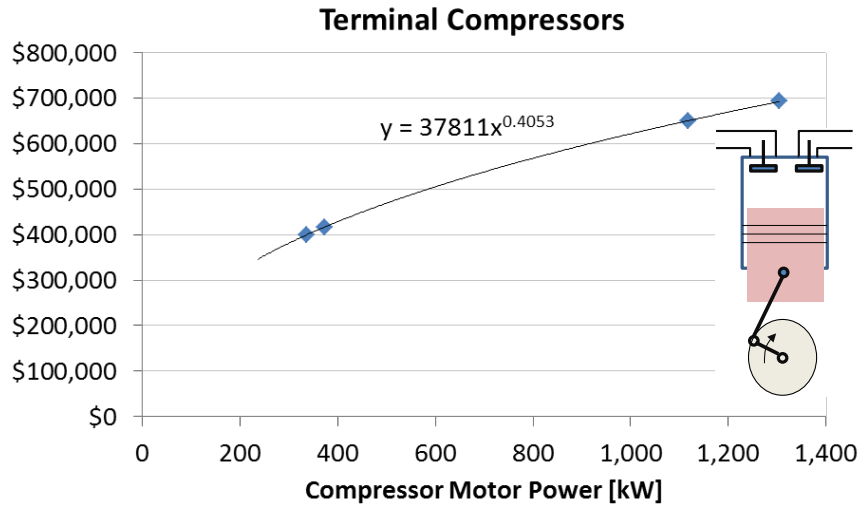


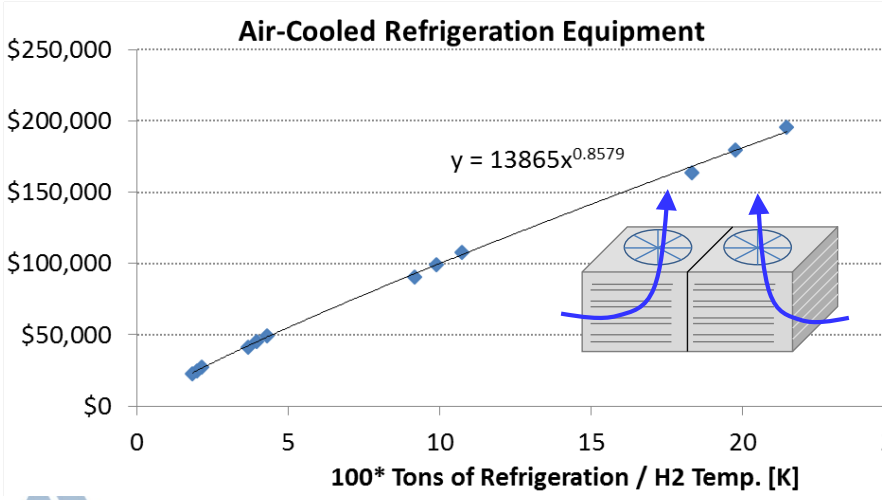
Available at: http://www.hydrogen.energy.gov/h2a_delivery.html

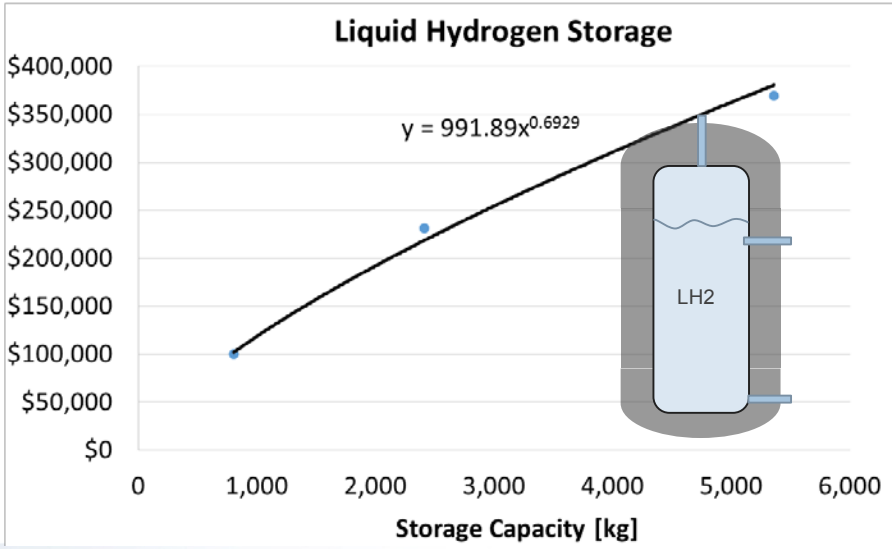
Methodology: Assumptions

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



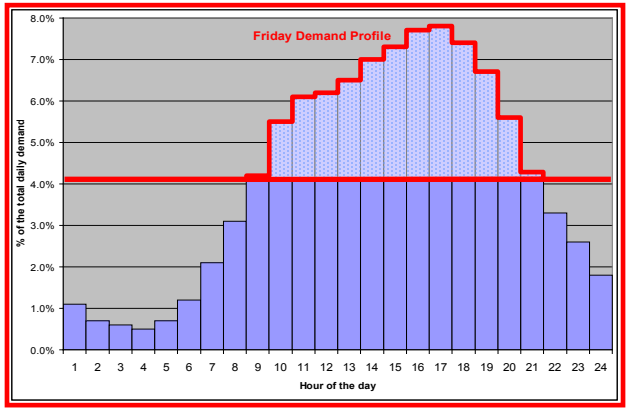


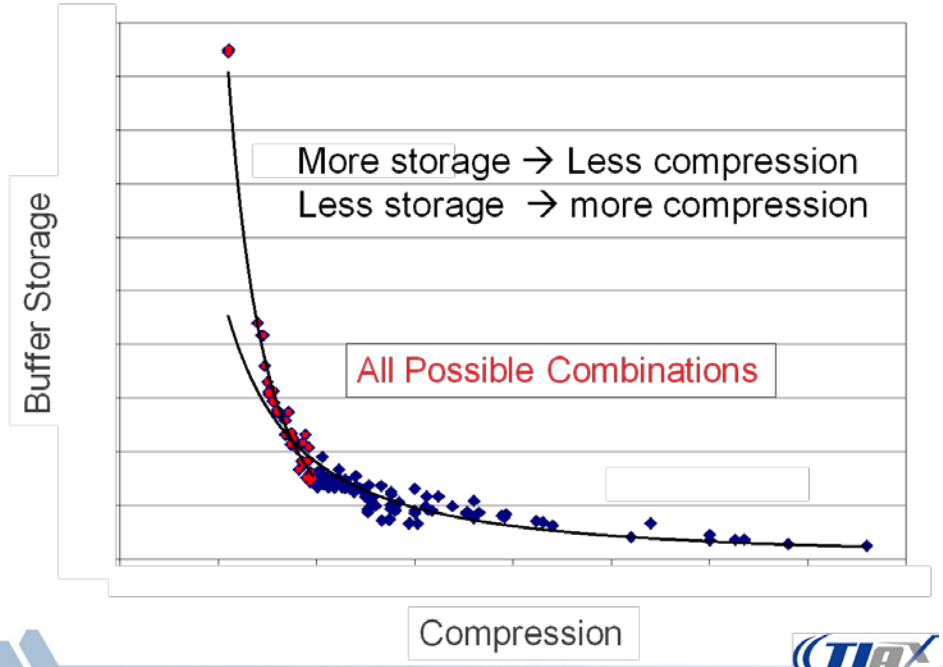


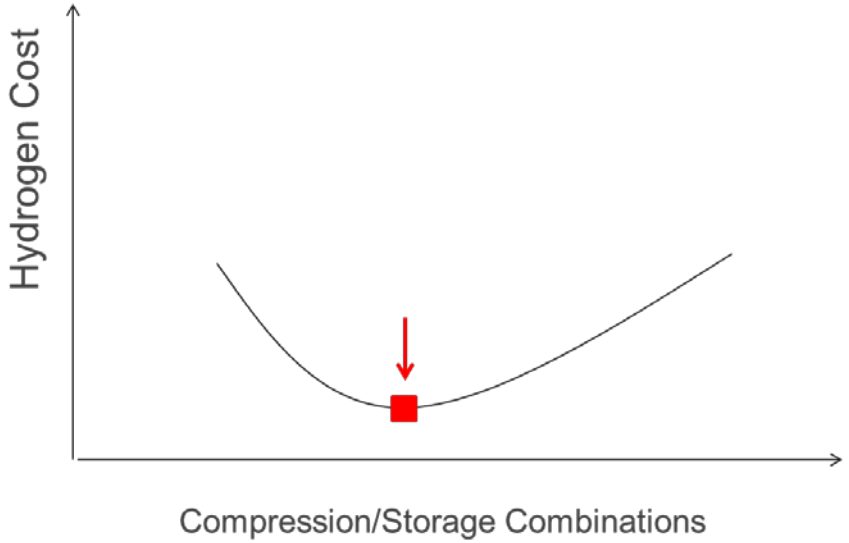


Methodology: Optimization

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







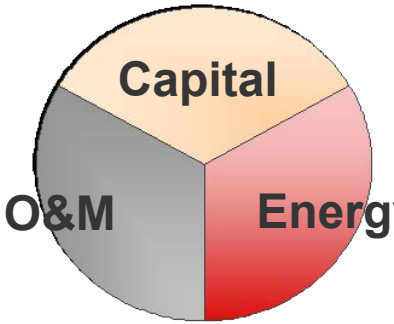
Methodology: Model Outputs

HRSAM characterizes the economics of a user-defined station

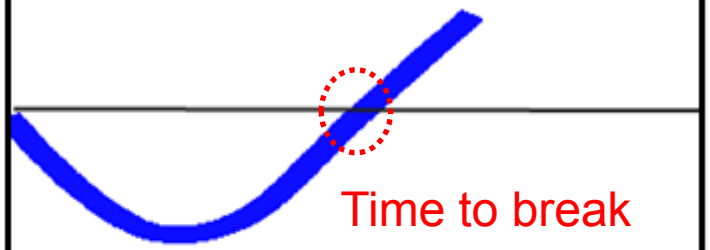
Station Levelized Cost

$/kg H2

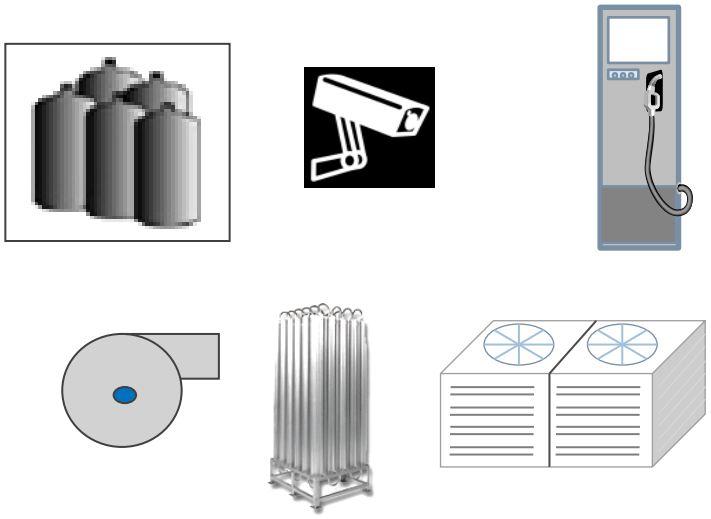
Contributions to Levelized Cost



Cumulative Cash Flow

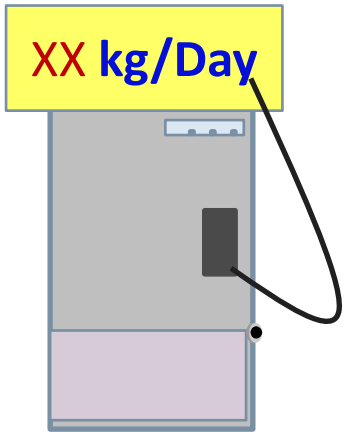


Costs of Station Components

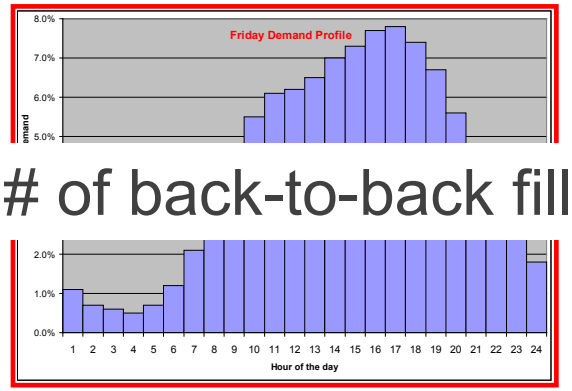


Analyses from HRSAM

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



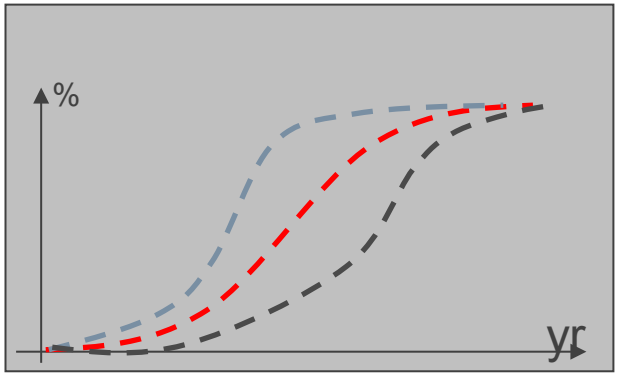
Station Capacity



# of back-to-back fills

Refueling Demand

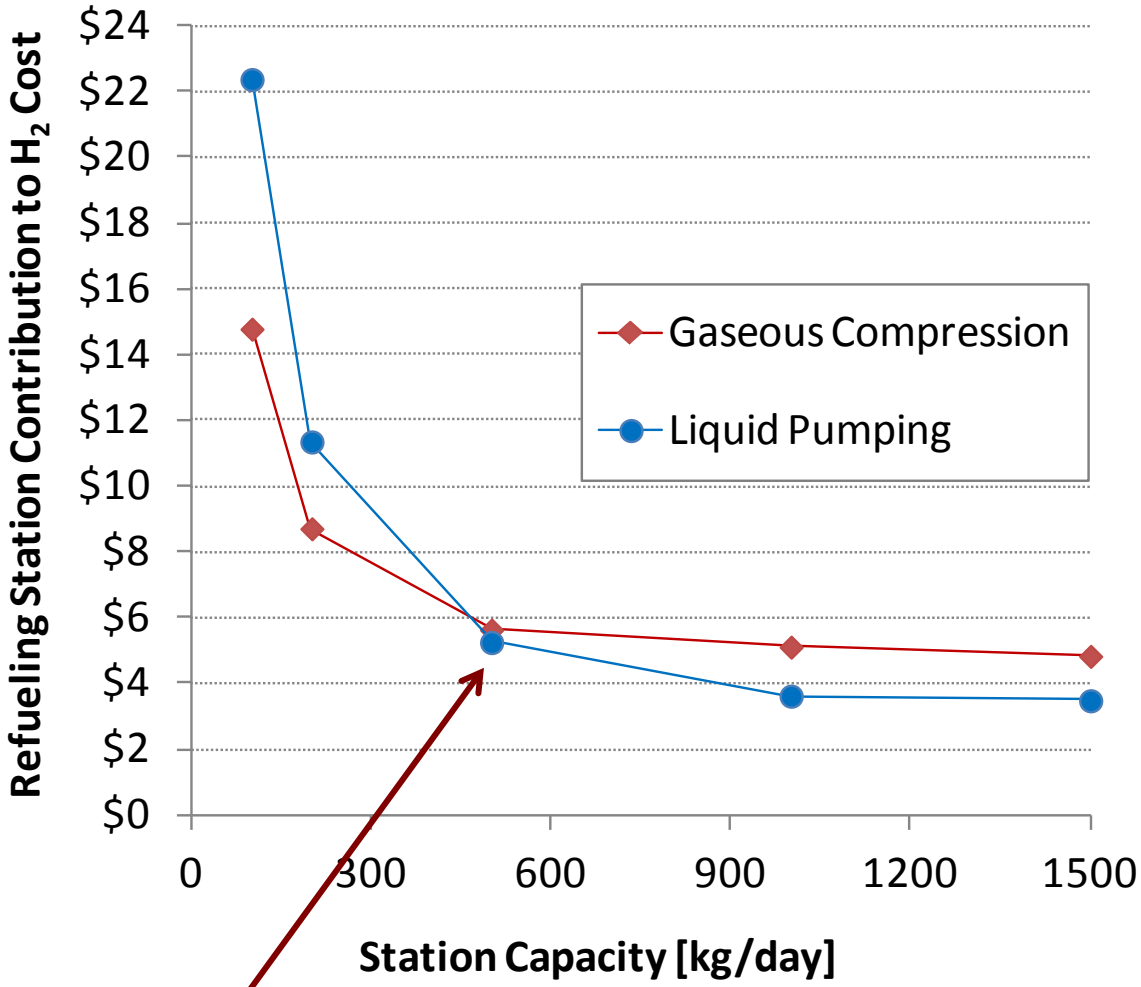
H2 Supply



Station Utilization

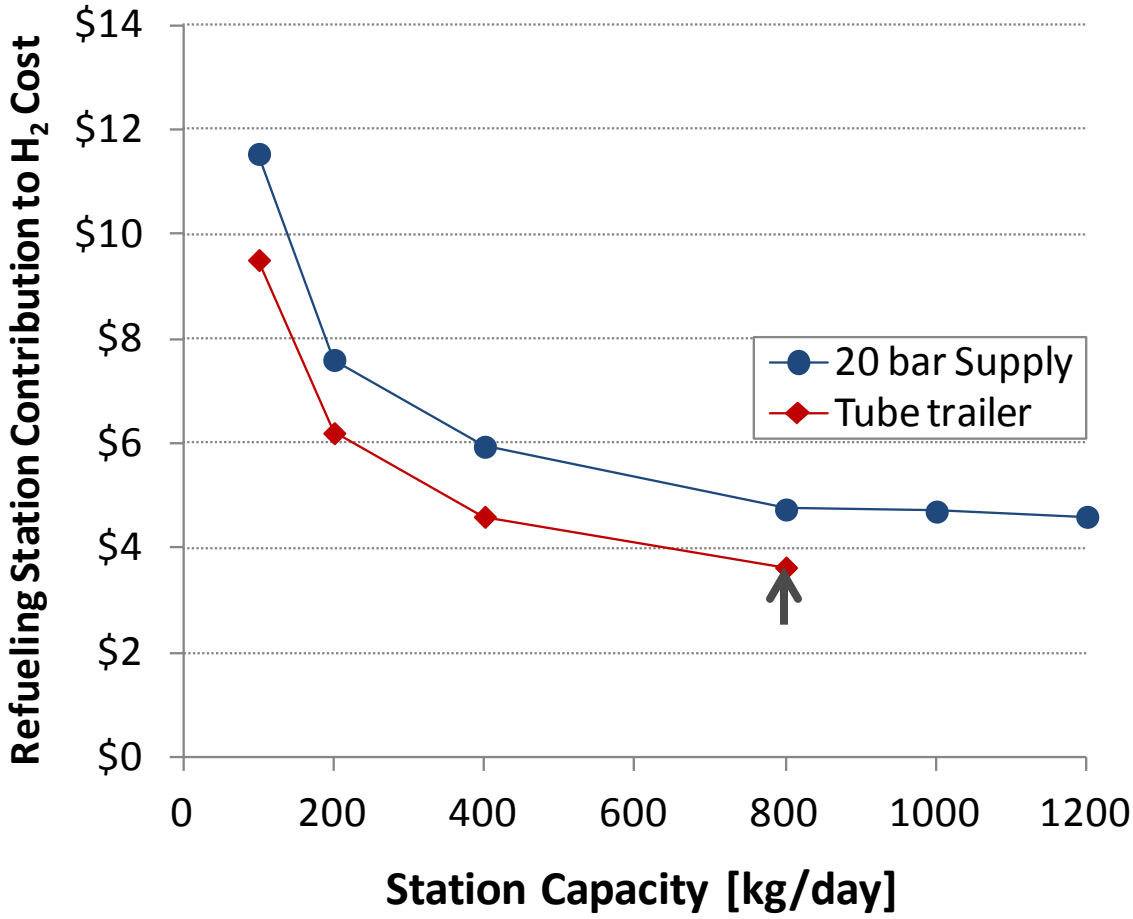
Analyses from HRSAM

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



Analyses from HRSAM

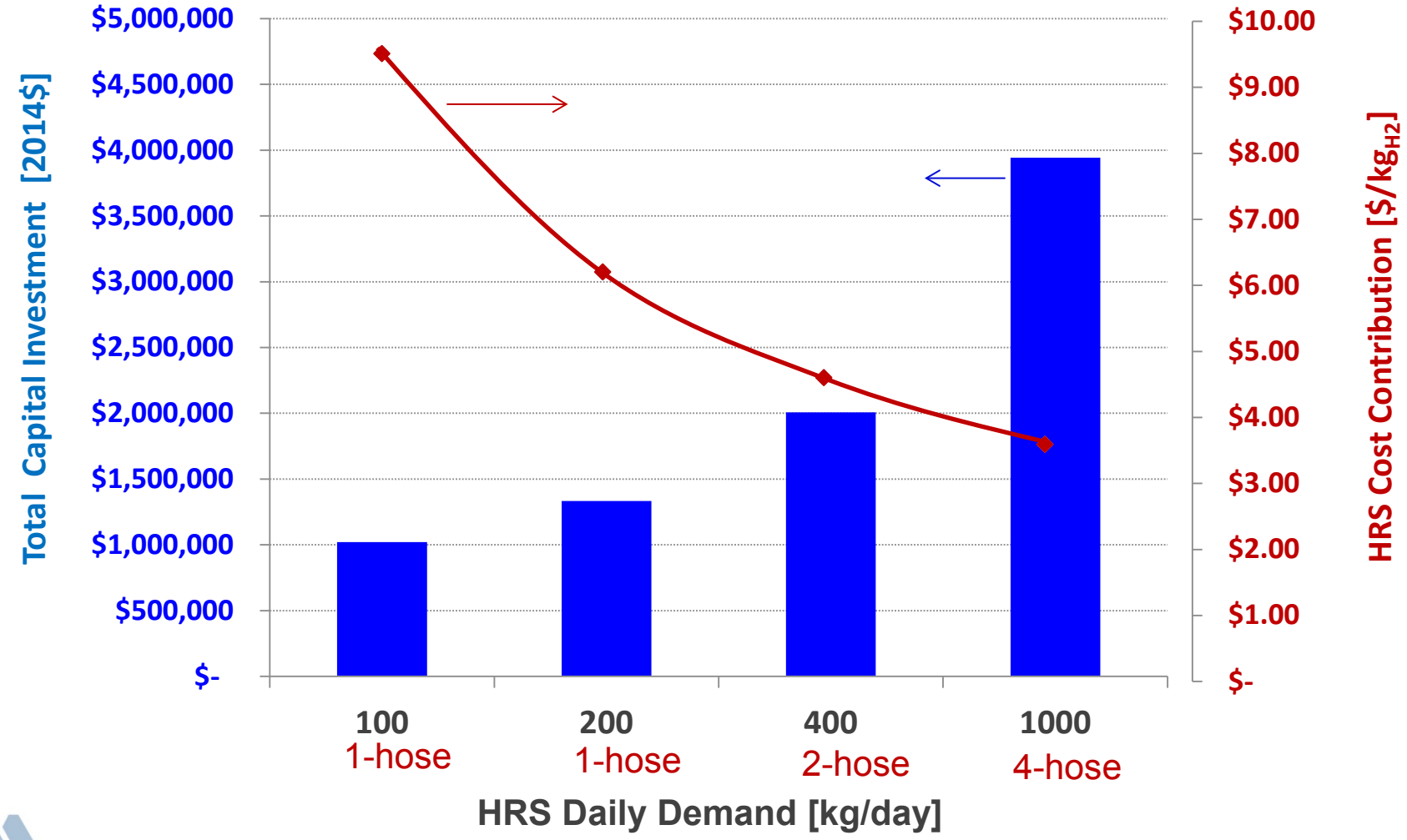
Tube-trailers can reduce station cost due to pre-compression at terminal



- *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*

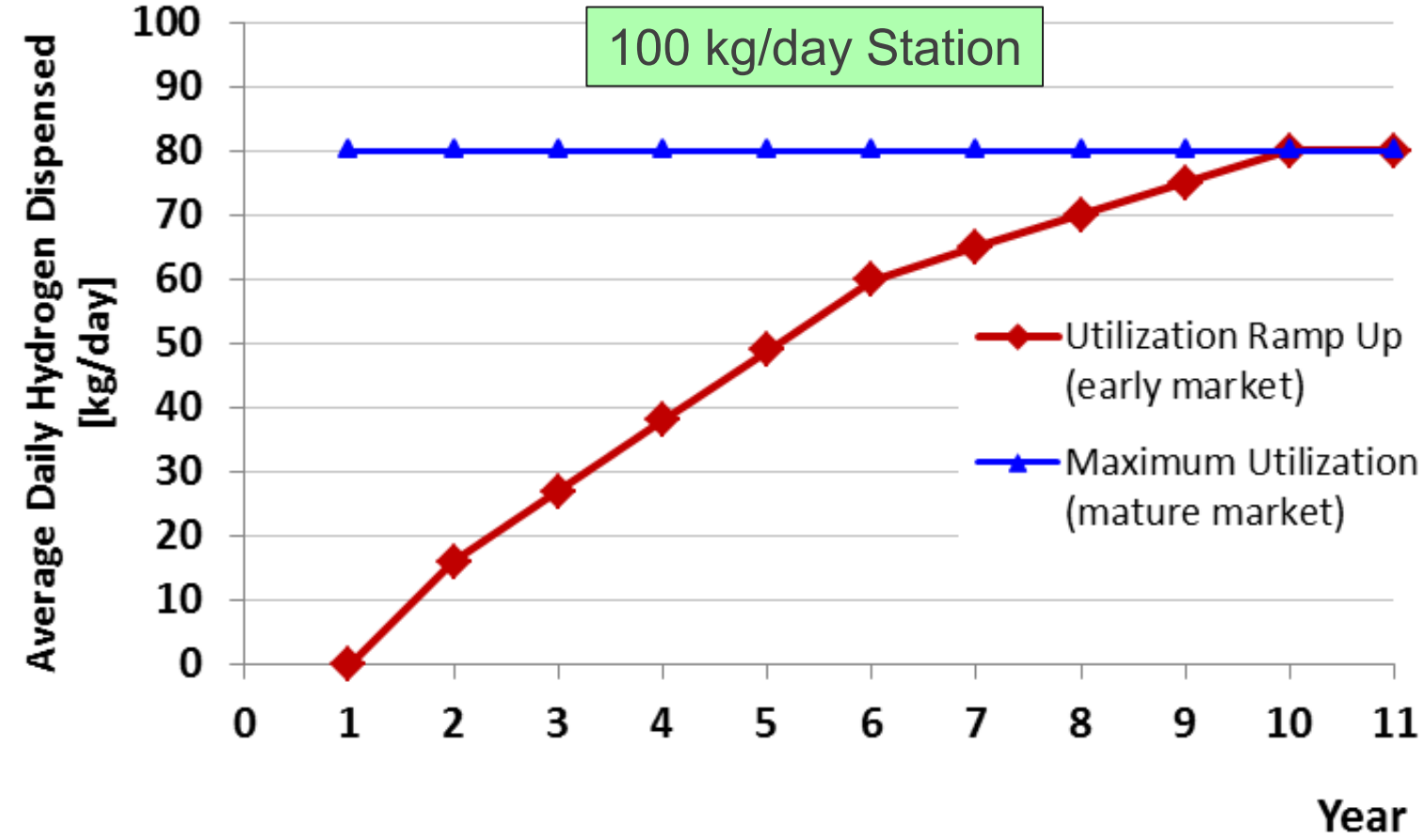
Analyses from HRSAM

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



Analyses from HRSAM

Station utilization ramp up is the single most influential factor on the H_2 cost in early markets



$14.60/kg$_{H2}$

$9.50/kg$_{H2}$

❑ *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

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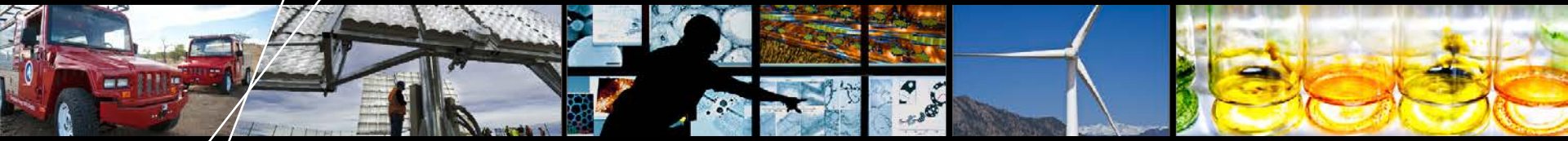
Overview of the Hydrogen Financial Analysis Scenario Tool (H2FAST)



H2USA Modeling Overview

Marc Melaina, Brian Bush, Michael Penev

12 May 2015

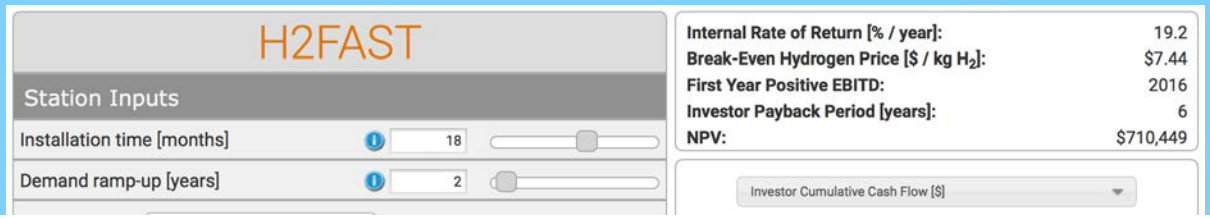
Presentation Outline

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

The H2FAST framework has been implemented within multiple tools

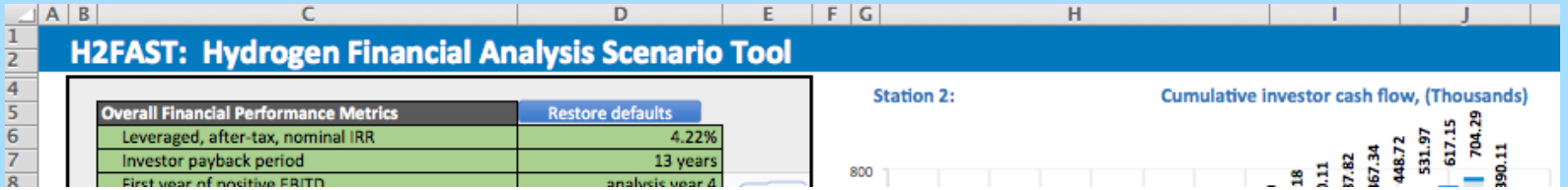
Consistent financial calculations are deployed across the H2FAST web and spreadsheet tools and SERA scenarios

H2FAST-Web is a simple, easy to use online calculator

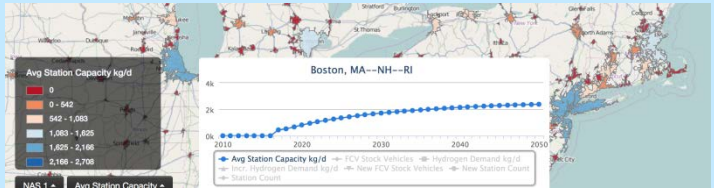


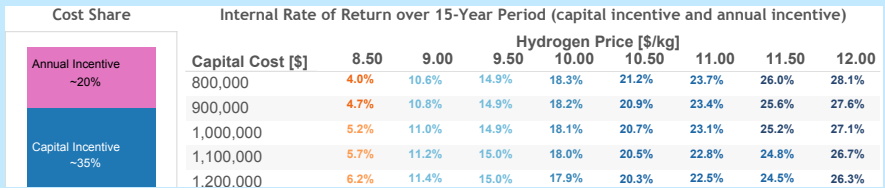
Tool interface designs have been tailored to distinct end-user groups

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?

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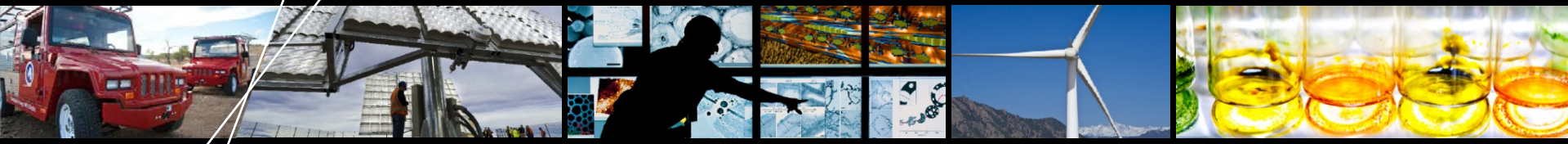


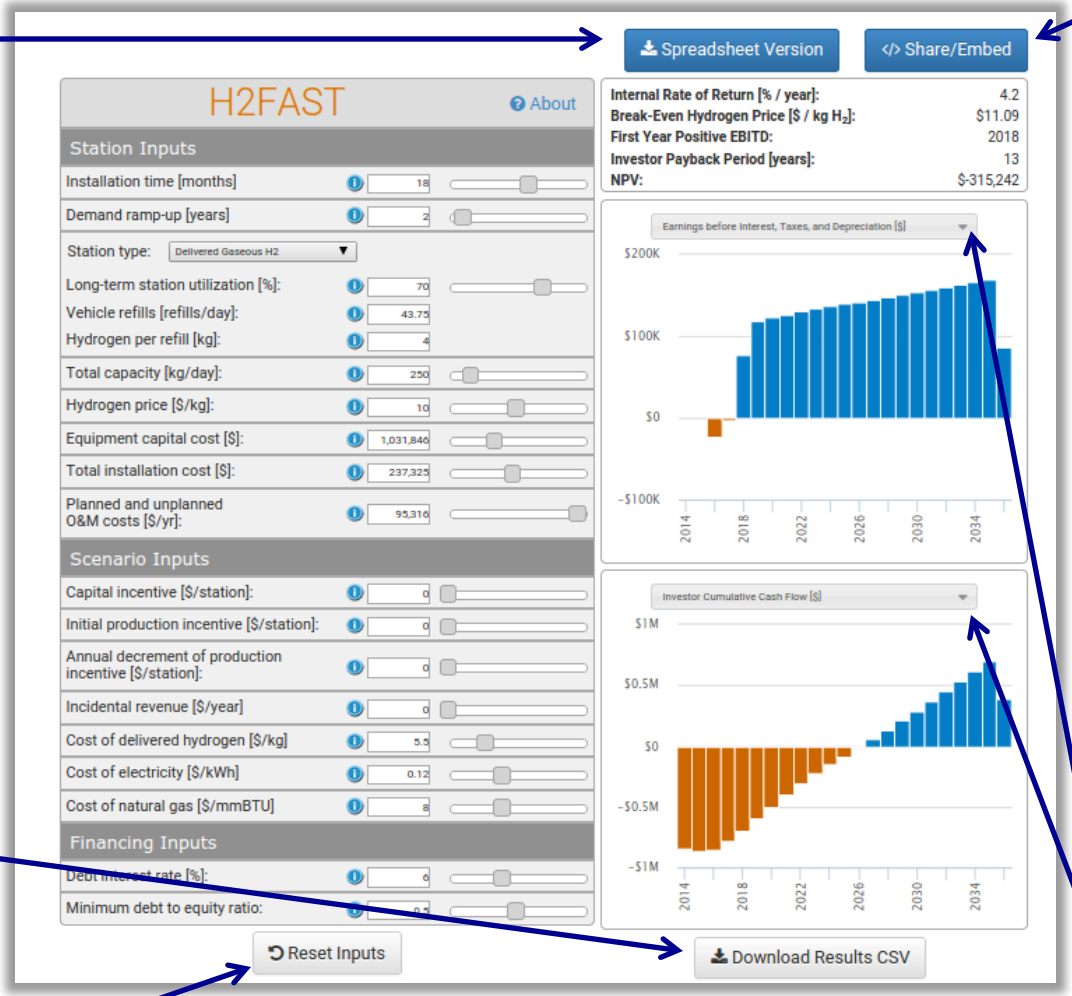
H2FAST Web Tool

H2FAST: A simple, user-friendly online tool

Visual results are provided instantly as inputs are changed by users

Link to Download Spreadsheet Version

Embed widget



Inputs

Single Value Results

Graphical Outputs (1)

Graphical Outputs (2)

Download full financials for case

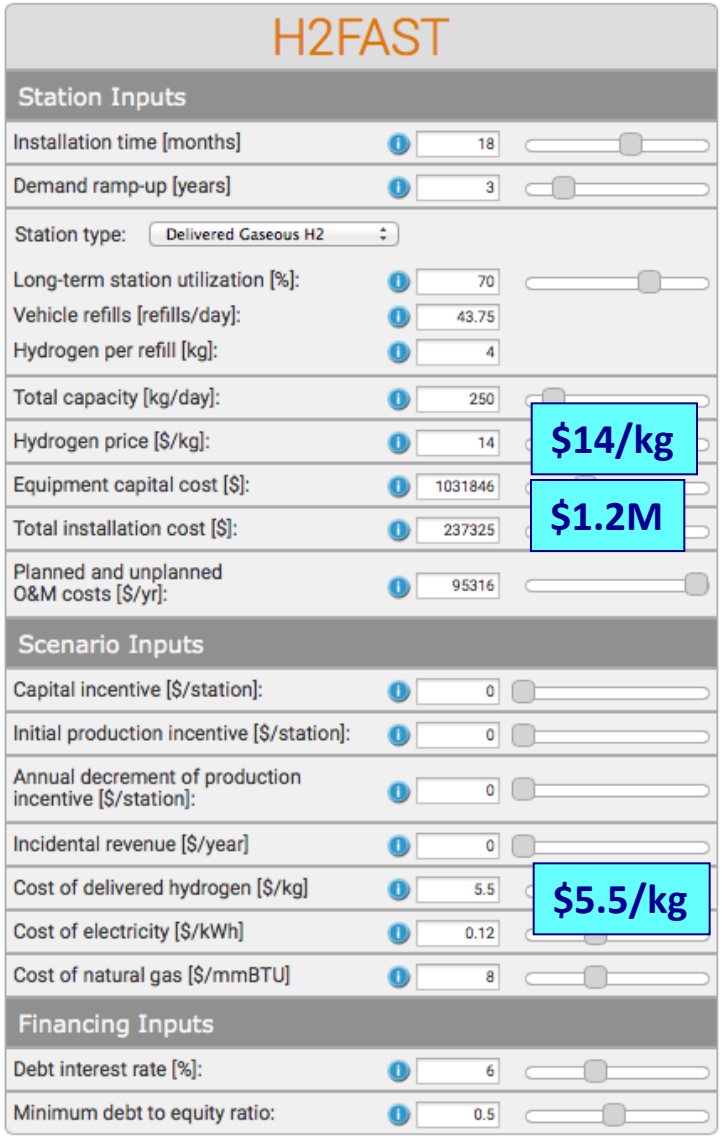
Reset Inputs

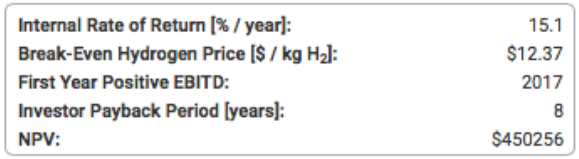
Change Graphical Output metrics

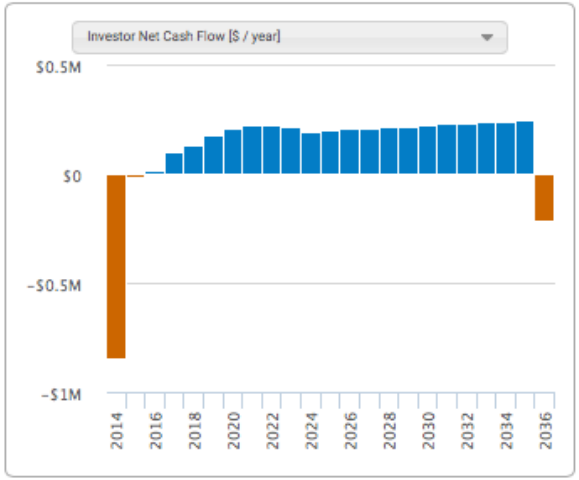
Example Case A: $1.2 M station, no subsidy, $14/kg price at the pump

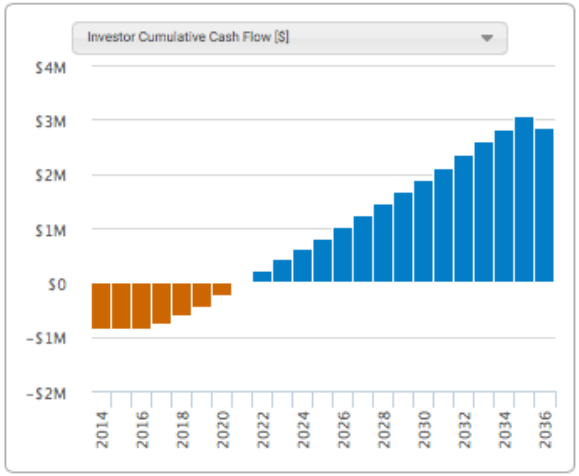
15% IRR, 8 yr investor payback

- 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







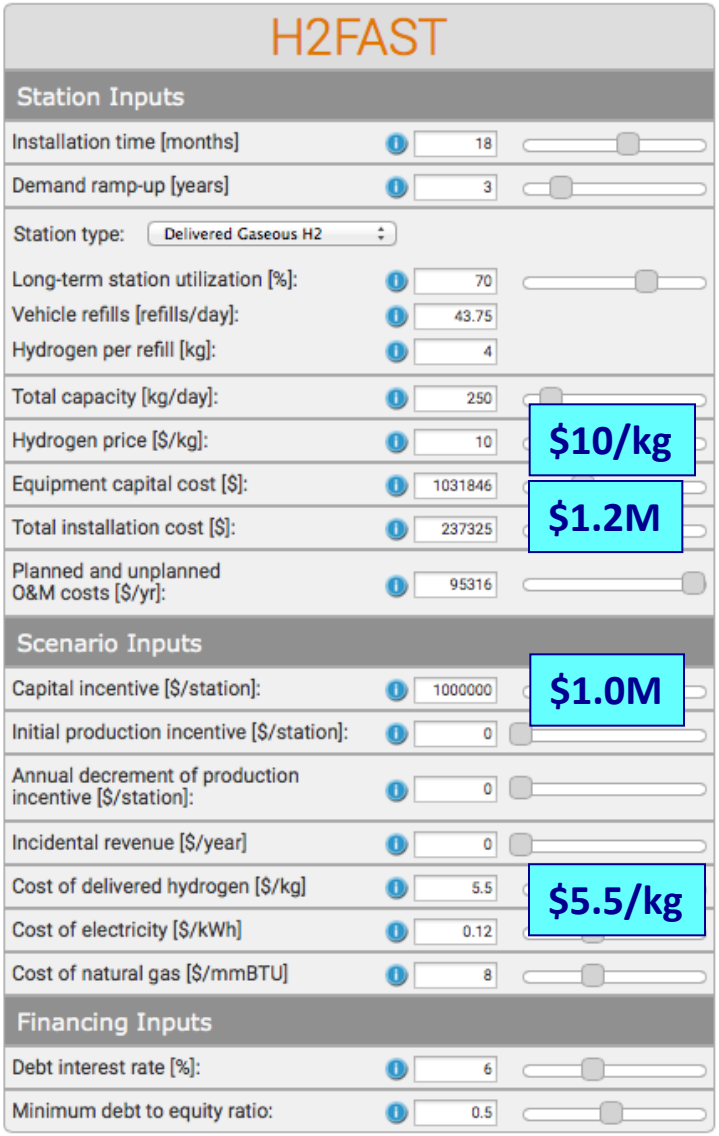


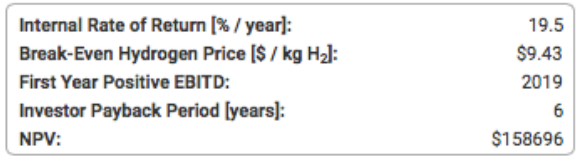
Example Case B: Assume a $1.0 M Capital Incentive and $10/kg price

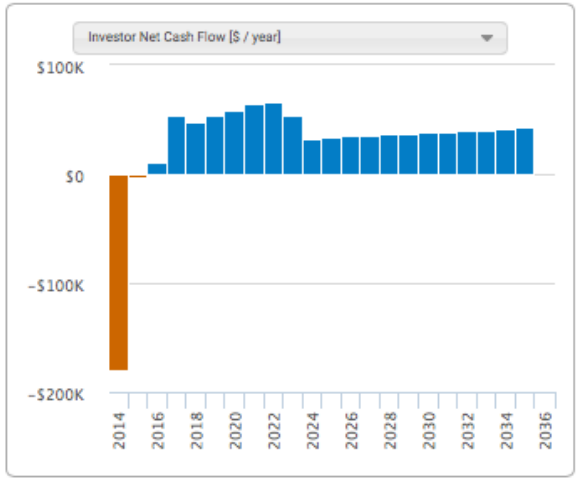
19.5% IRR, 6 yr investor payback

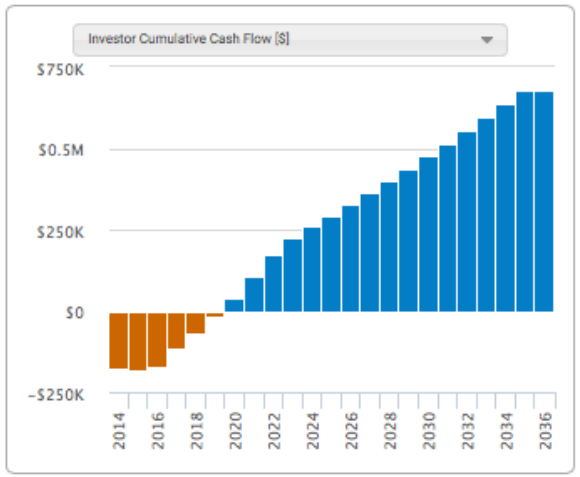
- Assume $1 M capital incentive in the first year
- Change pump price to $10 per kg
- Increase in IRR and investor payback period
- Result: $9.4/kg as breakeven price for a 10% IRR

H2FAST provides rapid assessments of the influence of incentives







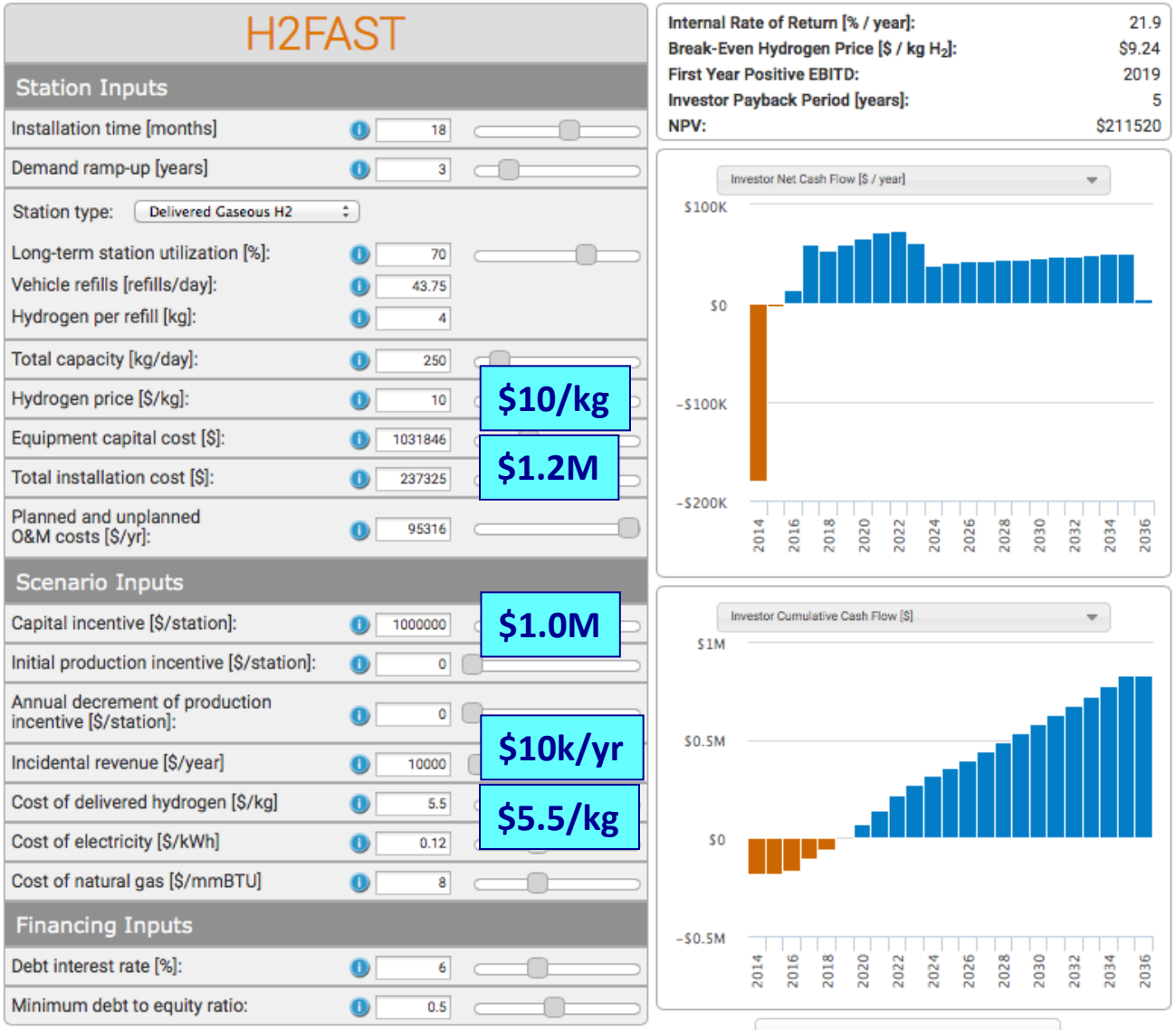


Example Case C: $1.0 M Incentive, $10/kg price, $10k incidental revenue

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



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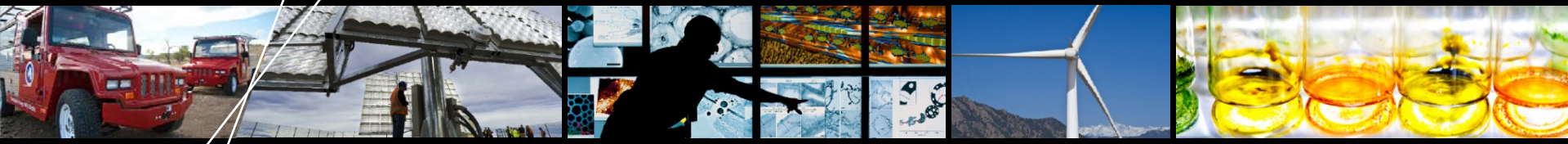


H2FAST Excel Tool

H2FAST Spreadsheet: Summary of Capabilities

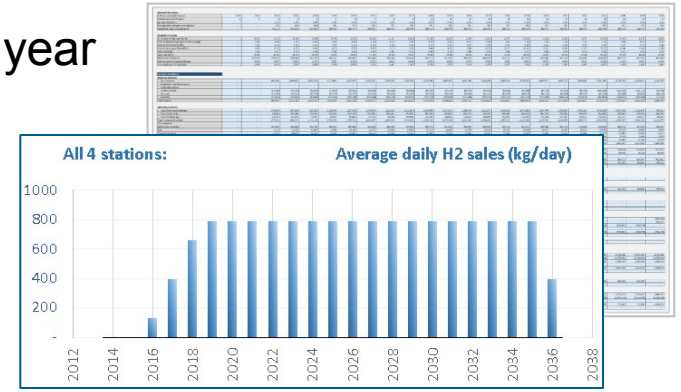
The spreadsheet version allows for greater control of inputs and more elaborate exploration of outputs

Inputs and User Interface

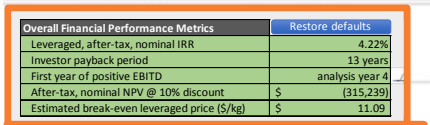
- Enter information for up to 10 stations and assess finances individually or as a cluster
- Side-by-side comparison of station projects
- There are two modes for users to provide inputs:
  - Basic mode: 20 parameters
  - Advanced mode: 51 parameters
- Inputs and outputs have hover-over descriptions to orient users

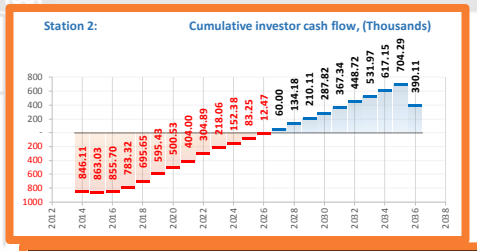
Outputs

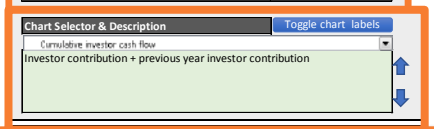
- Detailed report tables are provided for each project year
  - Scenario parameters (e.g. volumes of sales)
  - Income statement
  - Cash flow statement
  - Balance sheet
  - Select ratio analyses

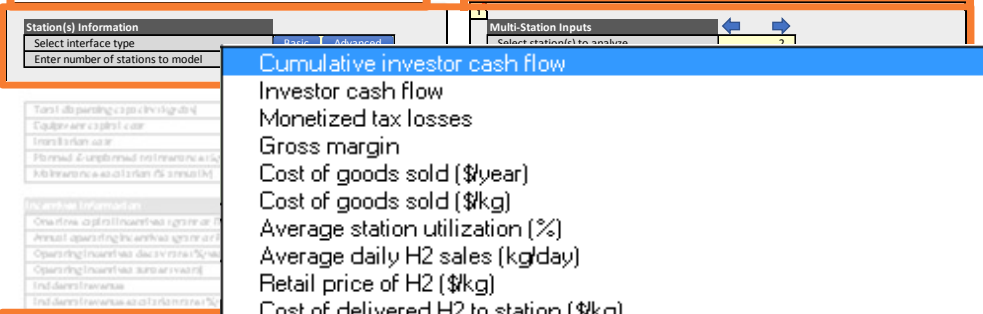


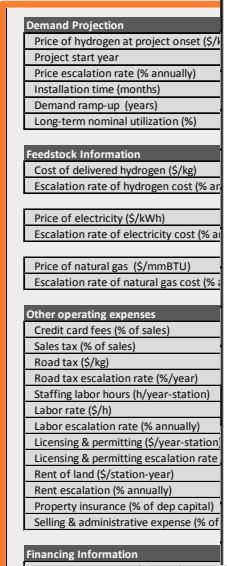
User Interface Overview

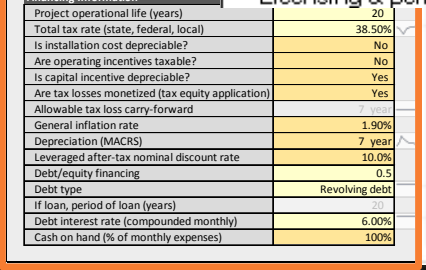












Color coding facilitates navigation

- Basic user inputs
- Advanced user inputs
- Calculated values
- Key results

- Taxes

Key outputs are highly visible

- IRR
- Year of positive earnings

Visualization of time series results

Cost specifi

- User
- User
- Cost
- Pre-p

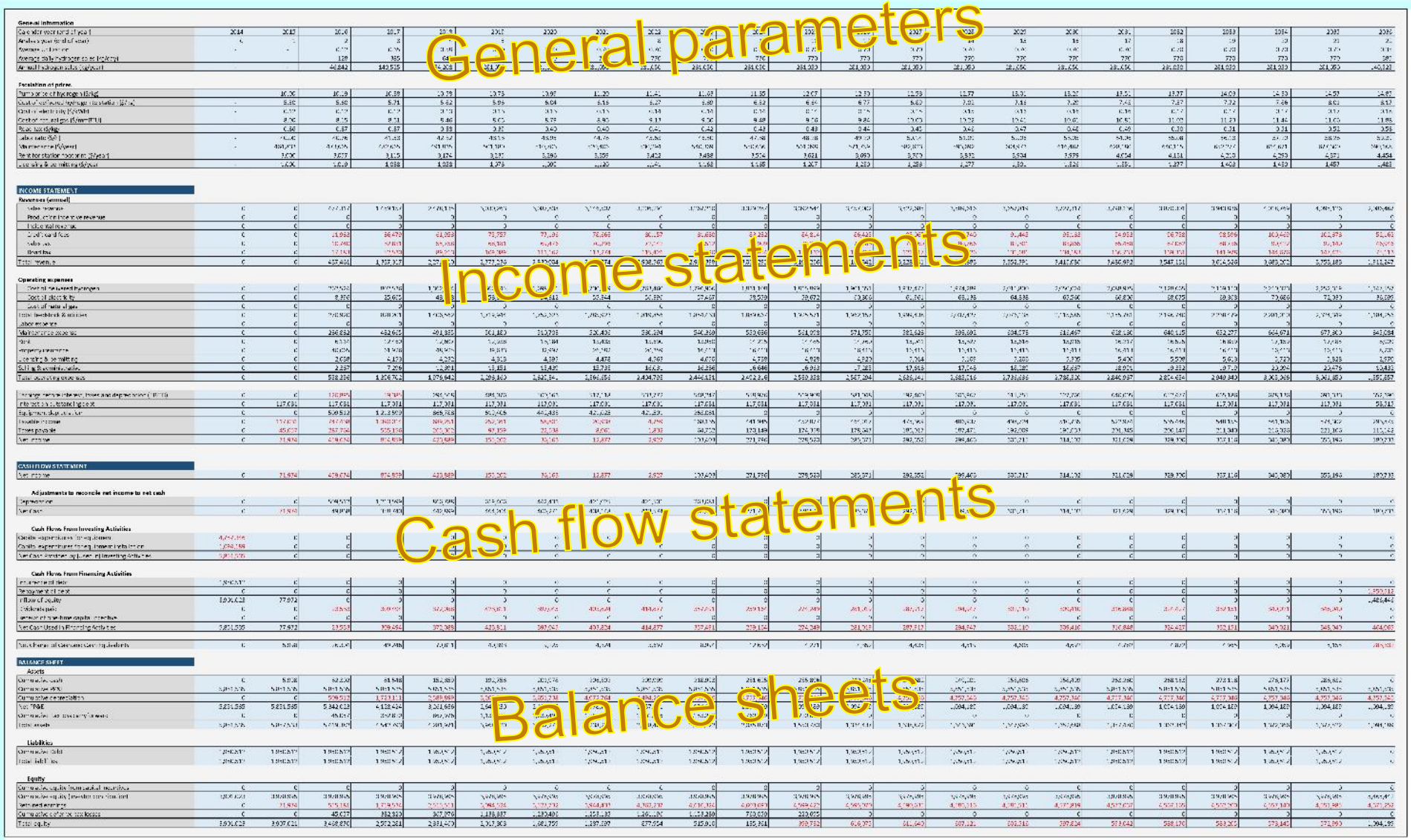
Users can select from 65 different metrics

Users are provided with a detailed breakdown of revenues and expenses

- Values are reported on per-kilogram of hydrogen sold

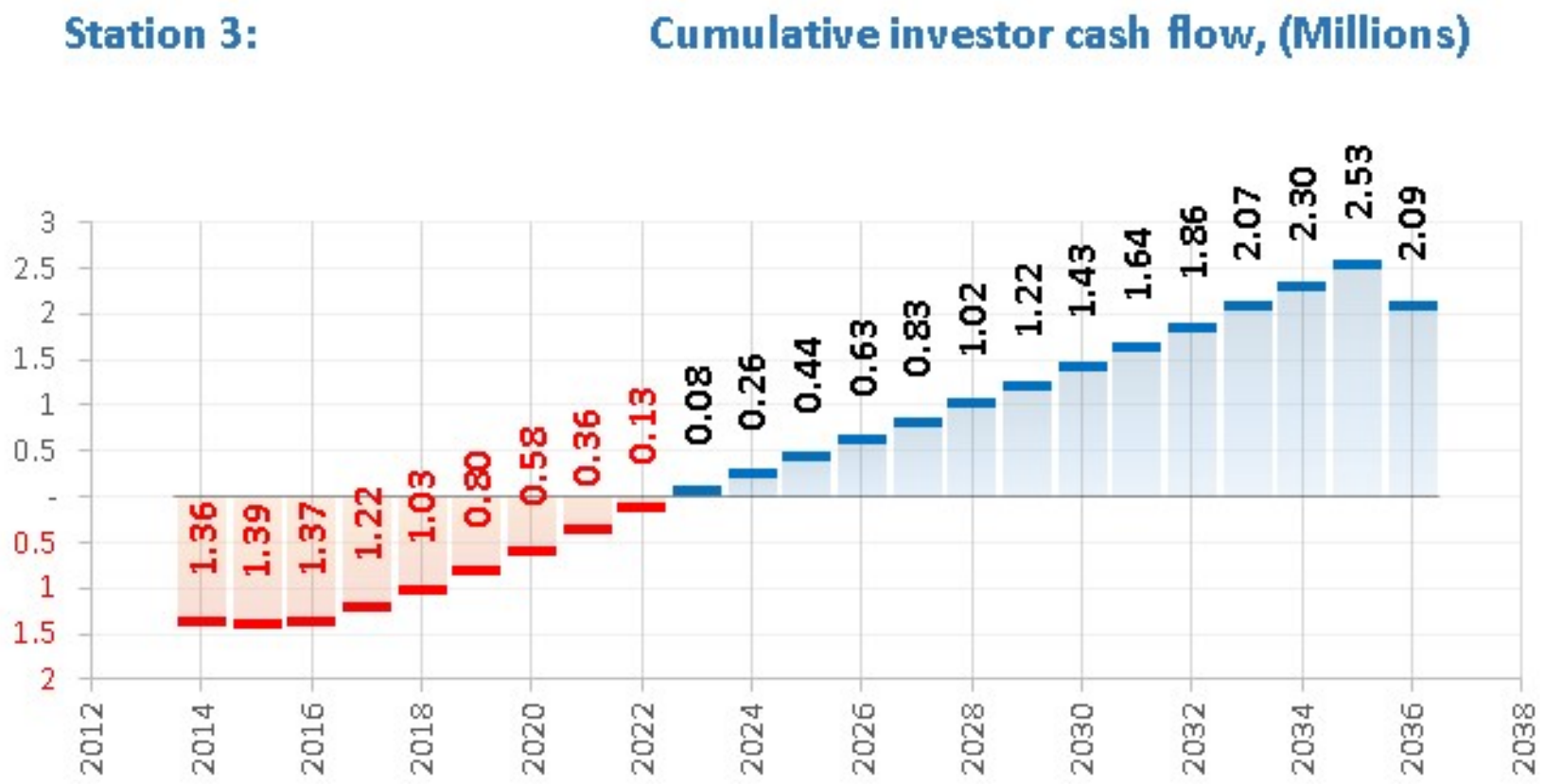
Report Tables

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



Time Series Examples

Range of tables satisfied most end user inquiries



- 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

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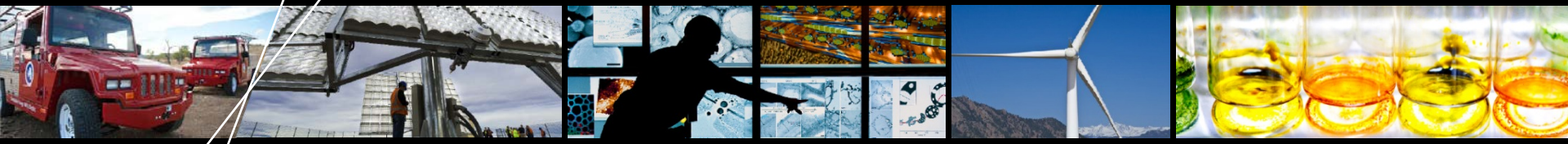


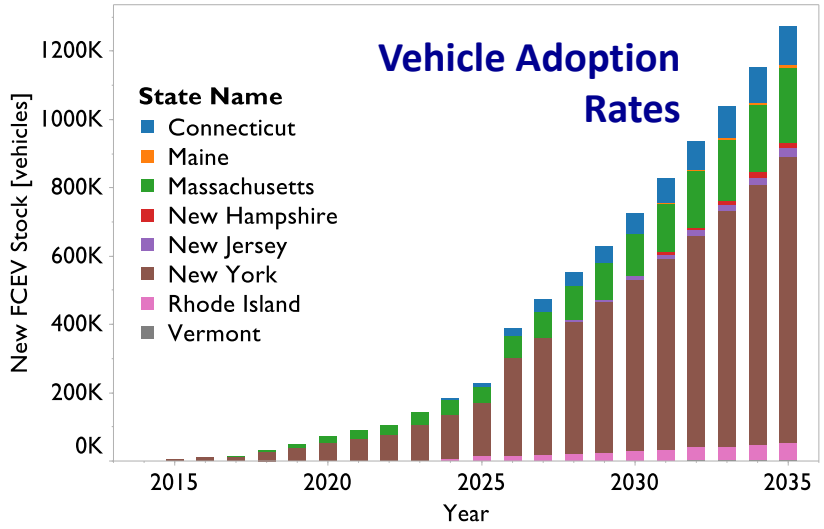
H2FAST Business Case Scenario – Visualization Tool

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

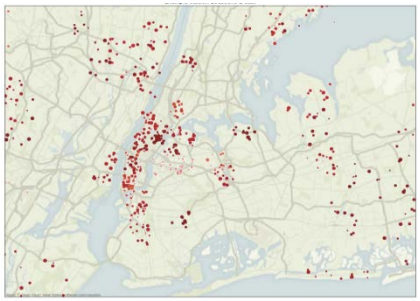
Demand and Delivery by City

Regional/State-level Subsets of Results

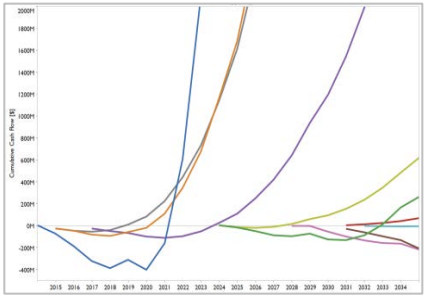


Stand-alone reports cannot capture the full range of possible outputs

Station Placement

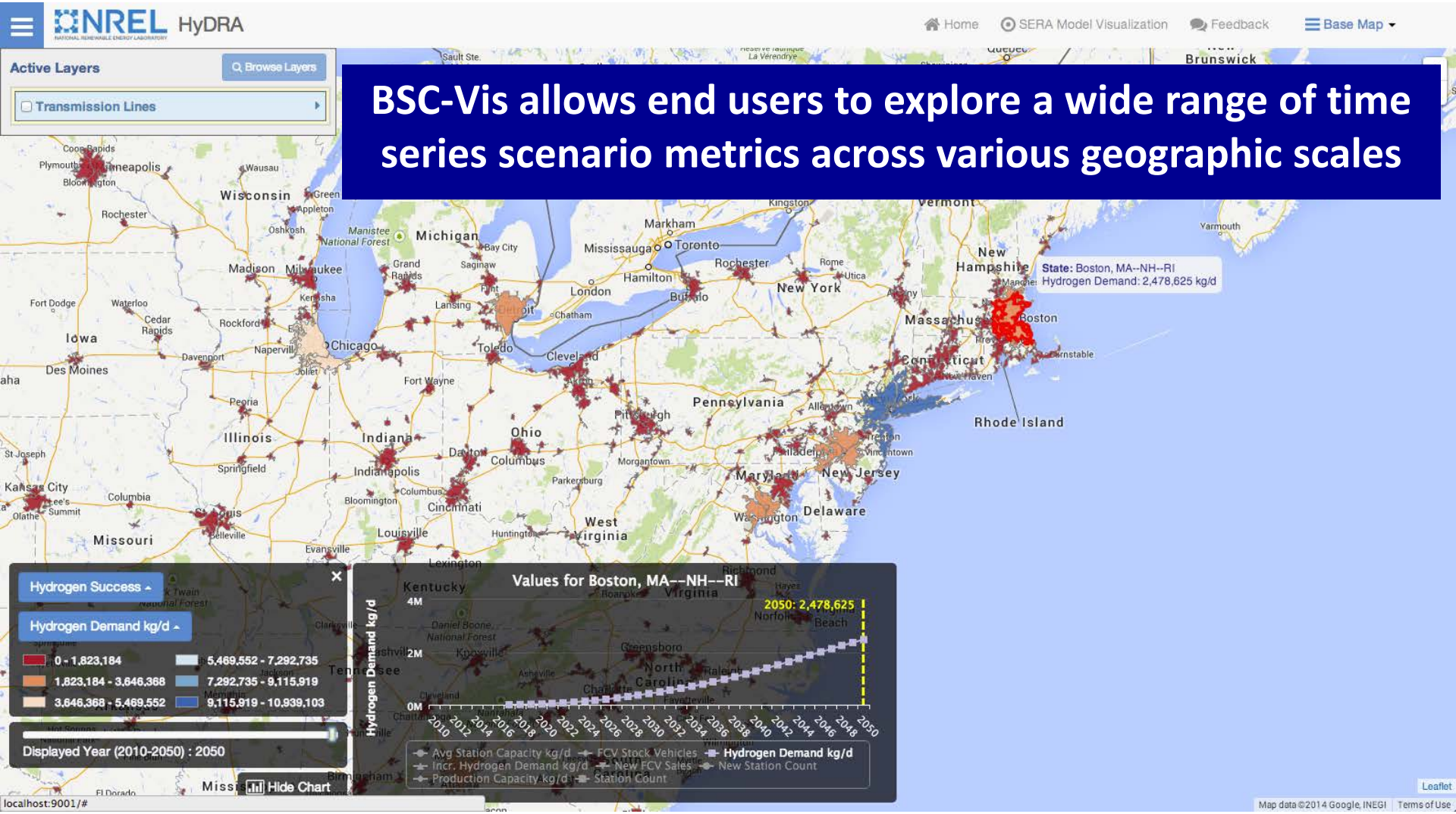


Cash Flows



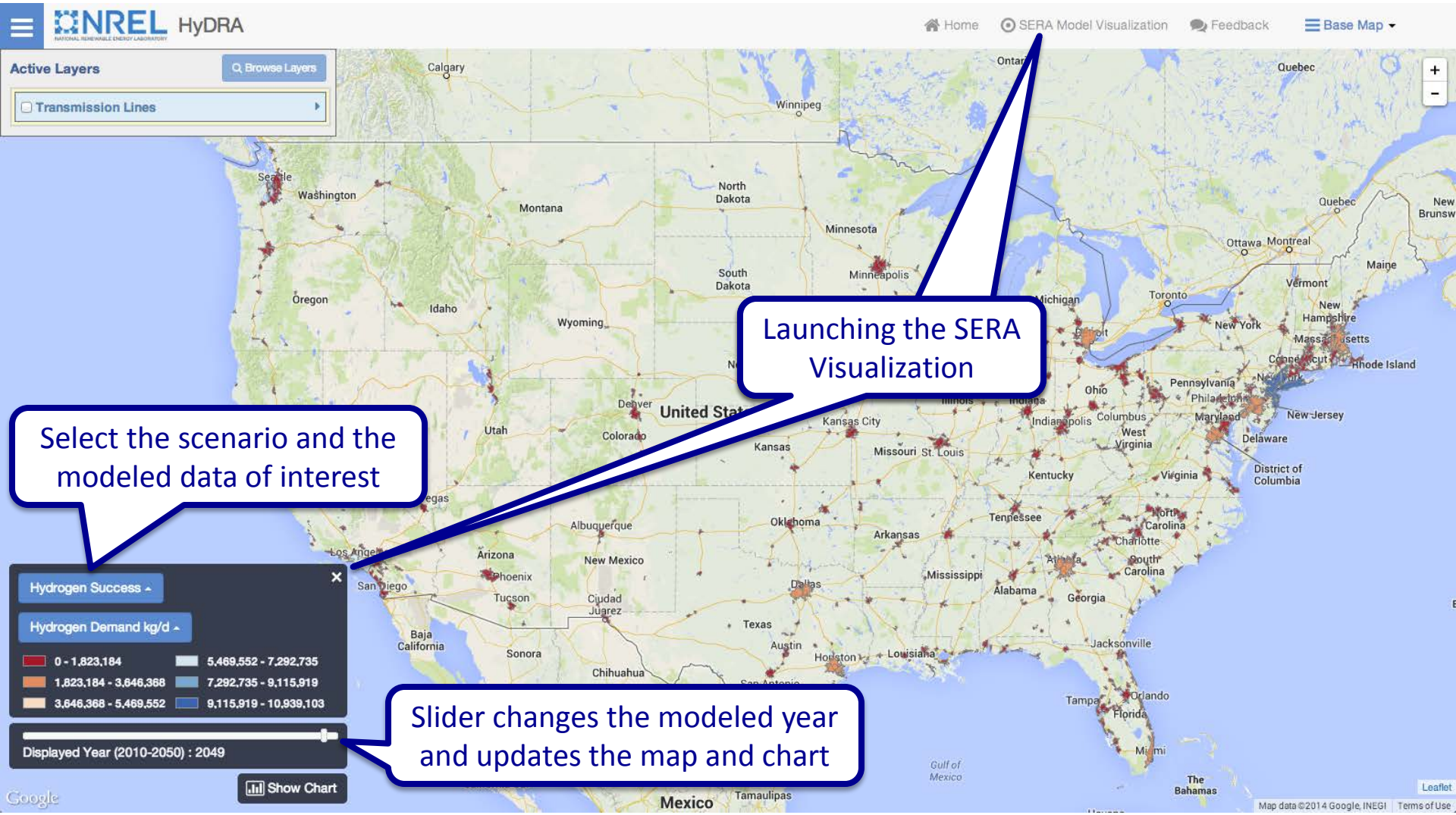
The Business Case Scenario Visualization tool (BCS-Vis) is being developed to allow end-users to explore a wide range of inputs and outputs

Business Case Scenario tool explores the full range of SERA outputs

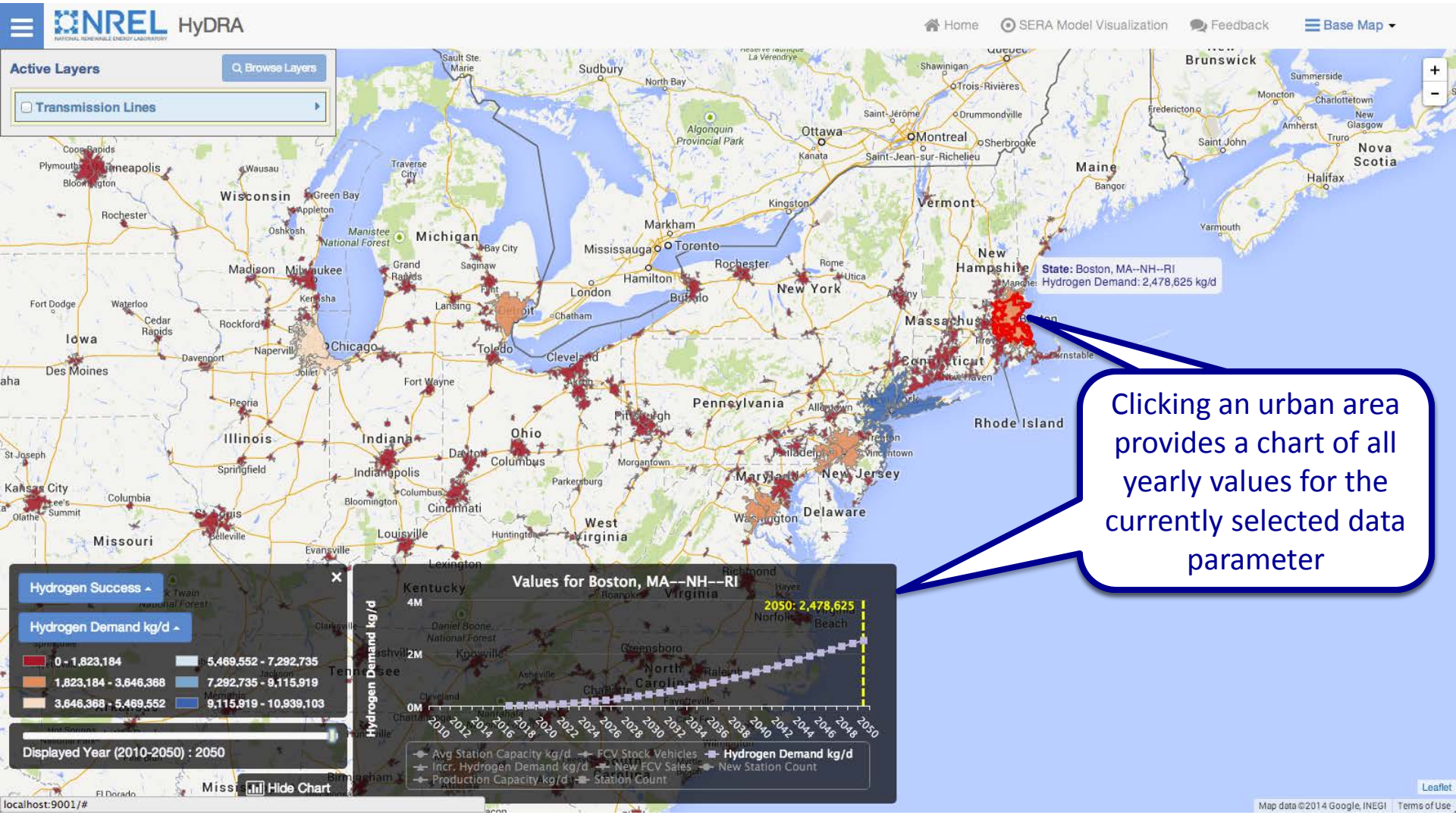


4-min video demonstrates the multivariate visualization tool: http://youtu.be/J7y51c-dldo

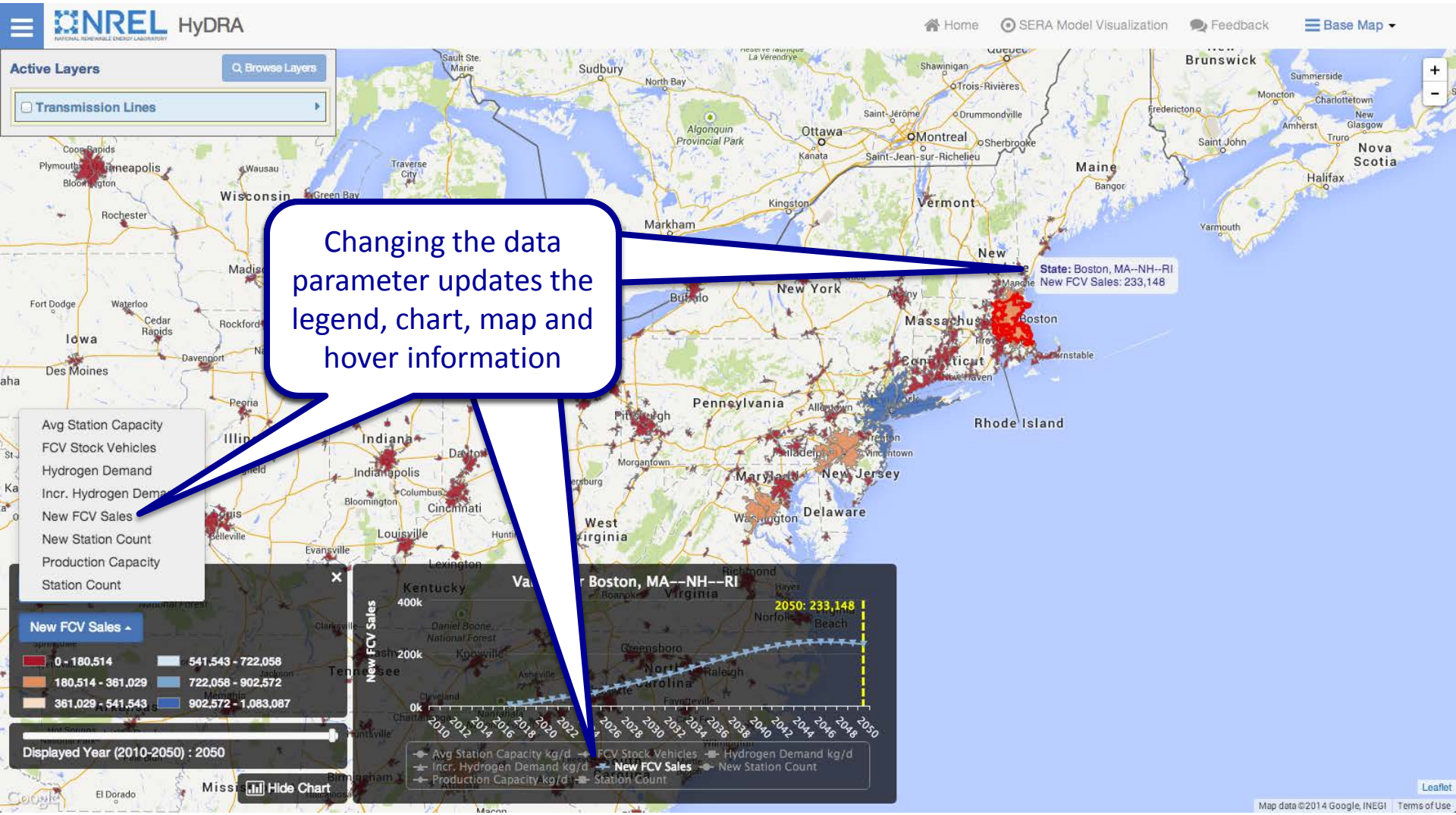
Selection of years



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

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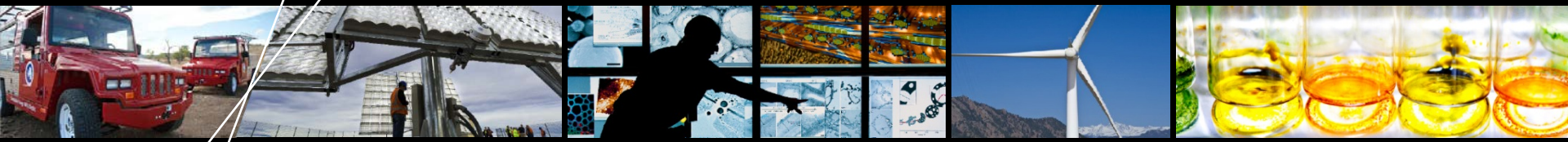
Thanks!



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Questions and Answers

QUESTIONS?

Thank You

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

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