

Techno-economic Tools to Simulate the Costs of Hydrogen Infrastructure Technologies

Amgad Elgowainy, Energy Systems Division, Argonne National Laboratory

This presentation does not contain any proprietary, confidential, or otherwise restricted information

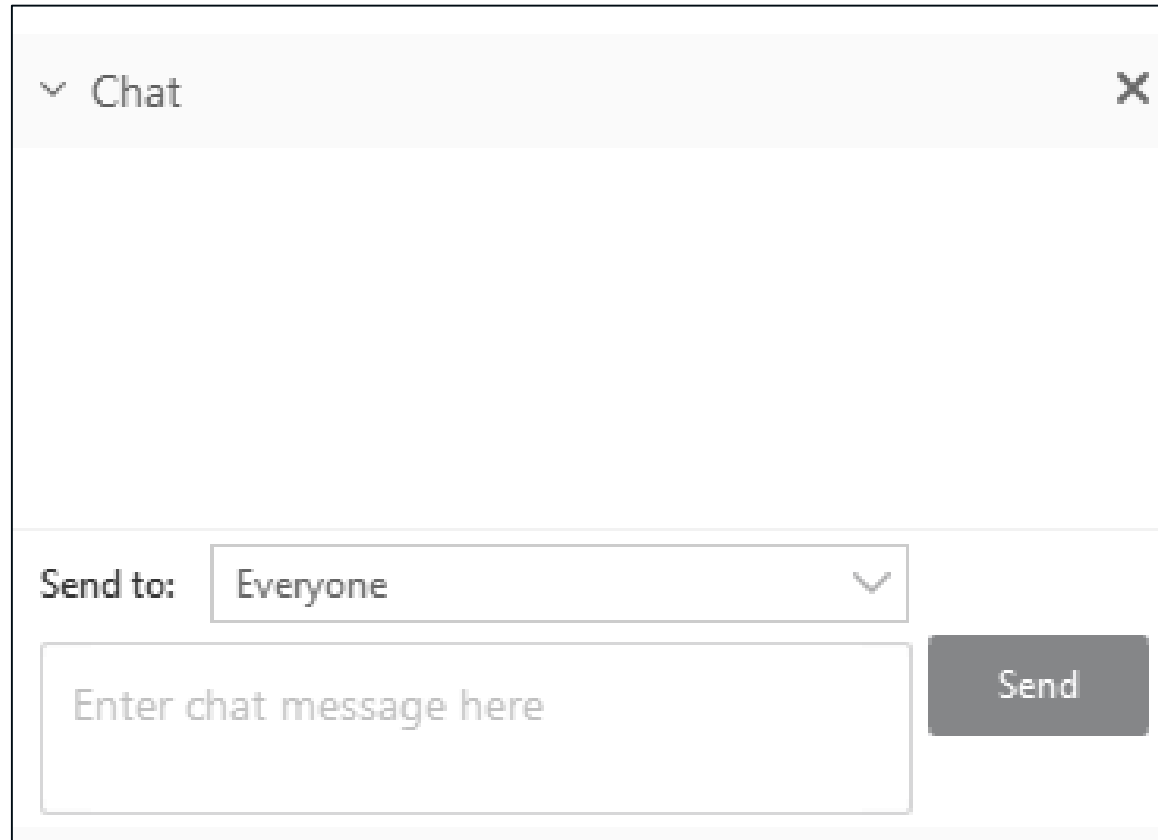
Fuel Cell Technologies Office Webinar

February 27, 2018



Question and Answer

- Please type your questions to the chat box. **Send to: (HOST)**



The image shows a chat window titled "Chat" with a close button (X) in the top right corner. Below the title bar is a large empty text area for messages. At the bottom of the window, there is a "Send to:" dropdown menu currently set to "Everyone". Below the dropdown is a text input field with the placeholder text "Enter chat message here". To the right of the input field is a dark grey "Send" button.

Hydrogen Infrastructure Modeling Goal

- Suite of tools complete **bottom-up engineering designs and cost analyses** of hydrogen infrastructure (pipelines, liquefiers, liquid tankers, tube trailers, geologic storage, gaseous fueling stations, and liquid fueling stations) based on user-defined scenarios.
- Models have been **informed and extensively vetted by industry**.
- Models are used by government agencies, academia, and industry to **estimate investments necessary** for growth of hydrogen infrastructure, and to **inform technology-specific targets that guide R&D**.
- All models are publicly available at: <https://hdsam.es.anl.gov/>

Scope of Infrastructure Models



Long-distance Transport of Hydrogen from:

- 1) Central Production Facilities to a City, and***
 - 2) City Gate to Hydrogen Fueling Stations***
- (e.g. liquid tankers, tube trailers, pipelines, geologic caverns, terminals)***



Hydrogen Fueling Stations for Fuel Cell Vehicles

User-Defined Model Inputs: Market, Technical and Economic

□ Market

- Market size (e.g., 5,000 FCEVs; 50,000 FCEVs)
- Station capacity (e.g., 300 kg/day; 1000 kg/day)
- Station utilization rate

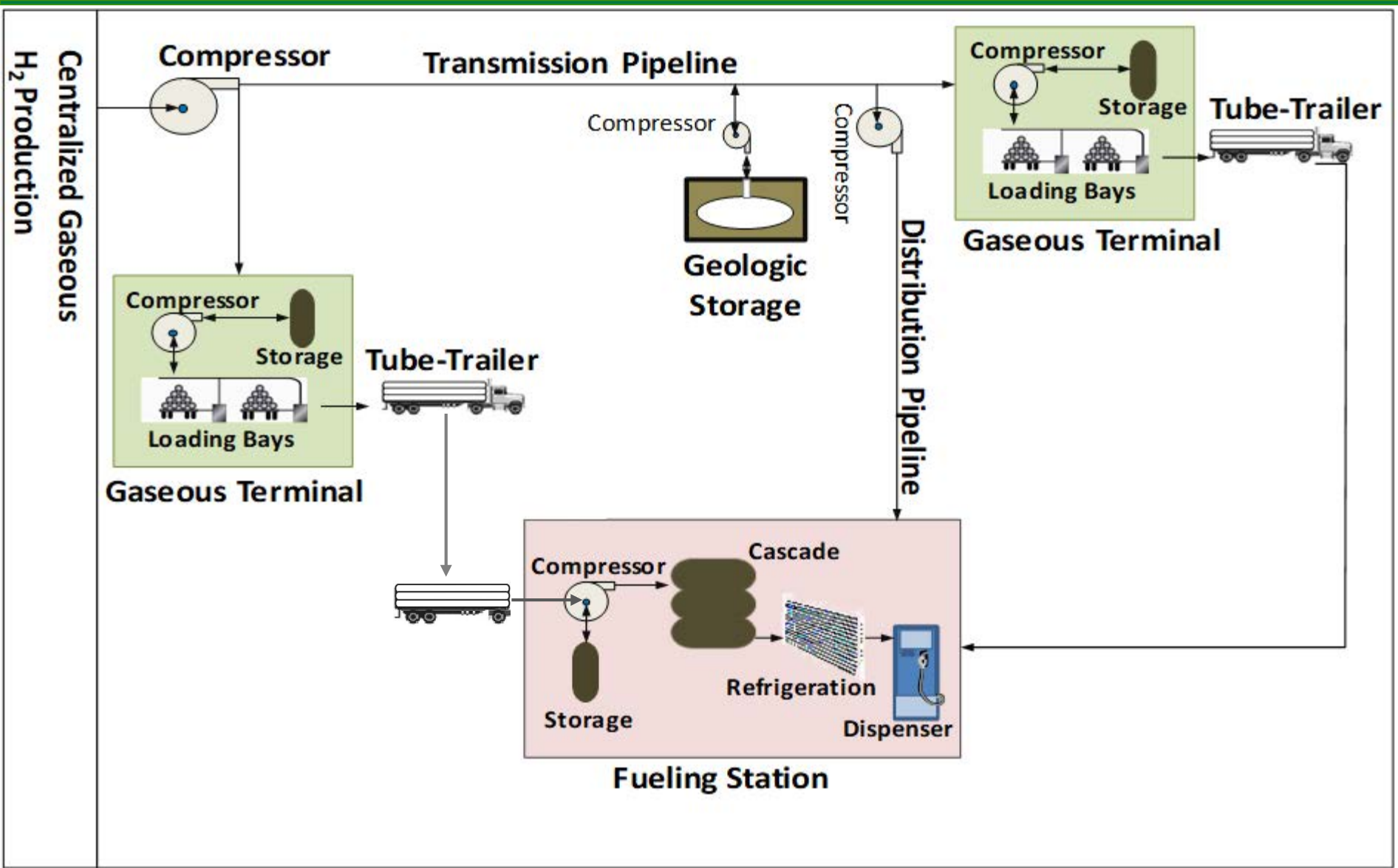
□ Technical

- Mode of hydrogen delivery (e.g., gaseous, liquid)
- Delivery distances distance (e.g., 30 miles, 300 miles, etc)
- Fill amount at fueling stations (e.g., 4 kg, 5 kg, etc)
- Fueling speed (e.g., 1 kg/min, 1.6 kg/min, etc)
- Hourly fueling demand

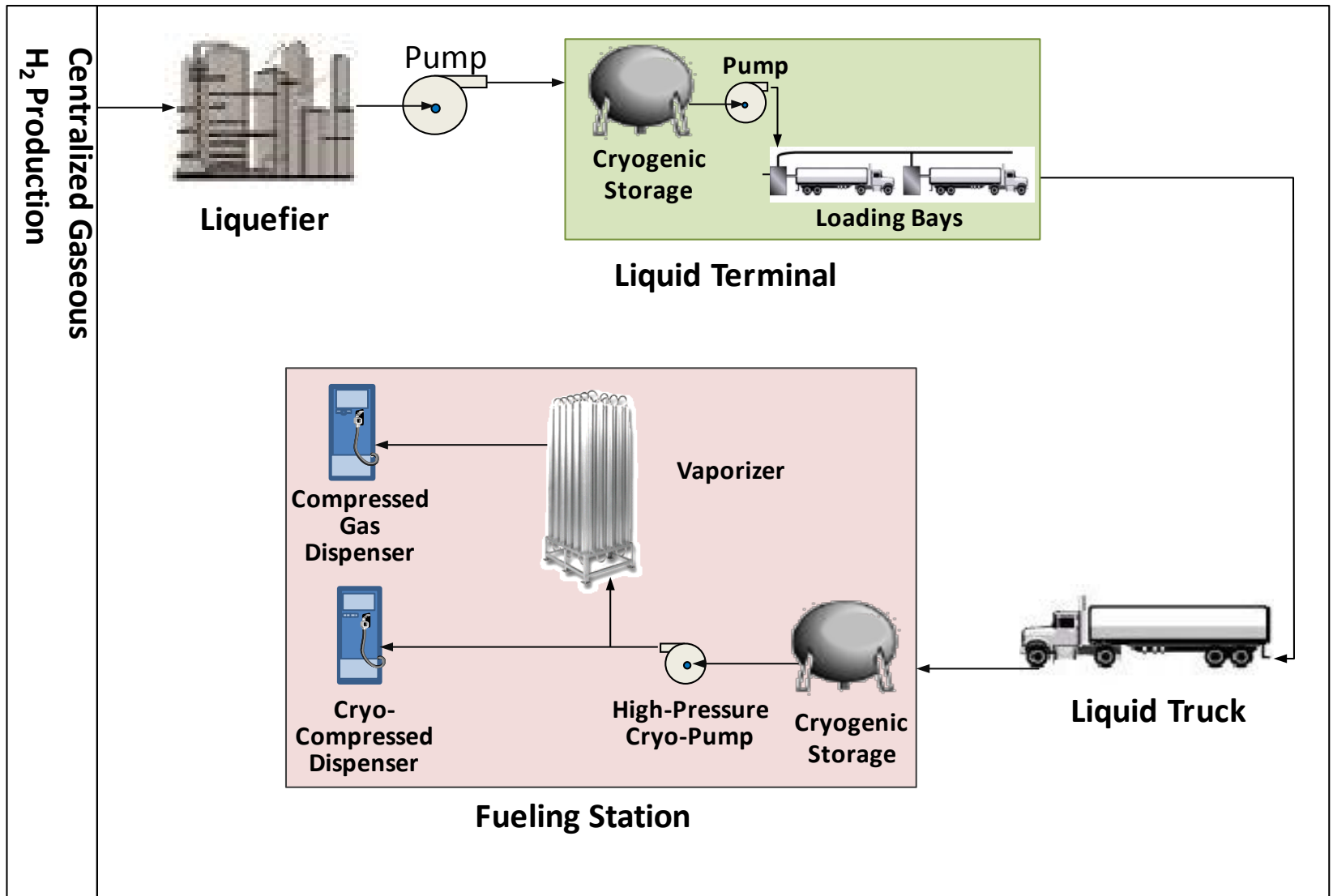
□ Economic

- Rate of return on investment
- Analysis period (10 years, 20 years, etc)
- Production volumes (i.e. economies of scale)

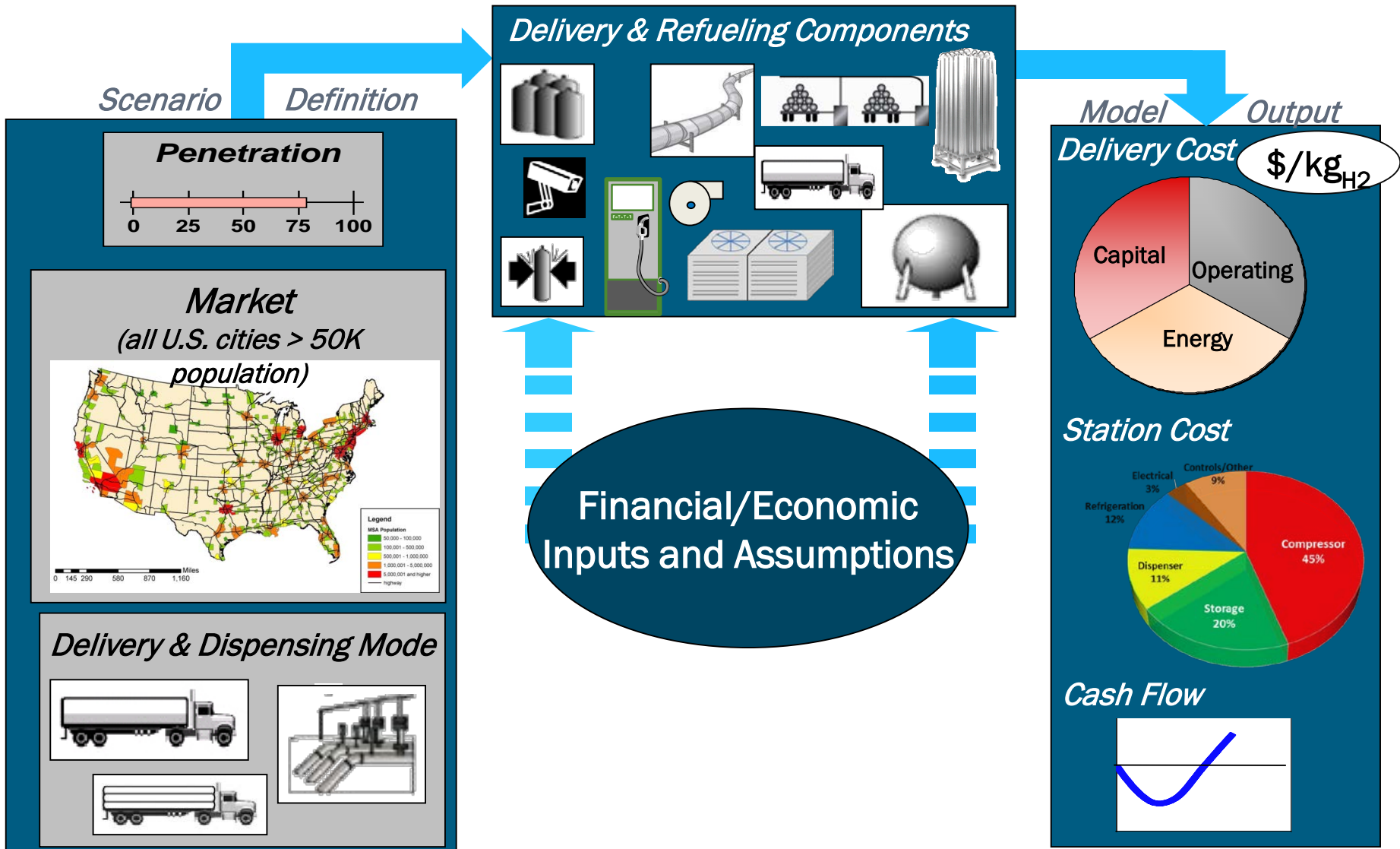
Technologies Used to Deliver Gaseous Hydrogen



Technologies Used to Deliver Liquid Hydrogen



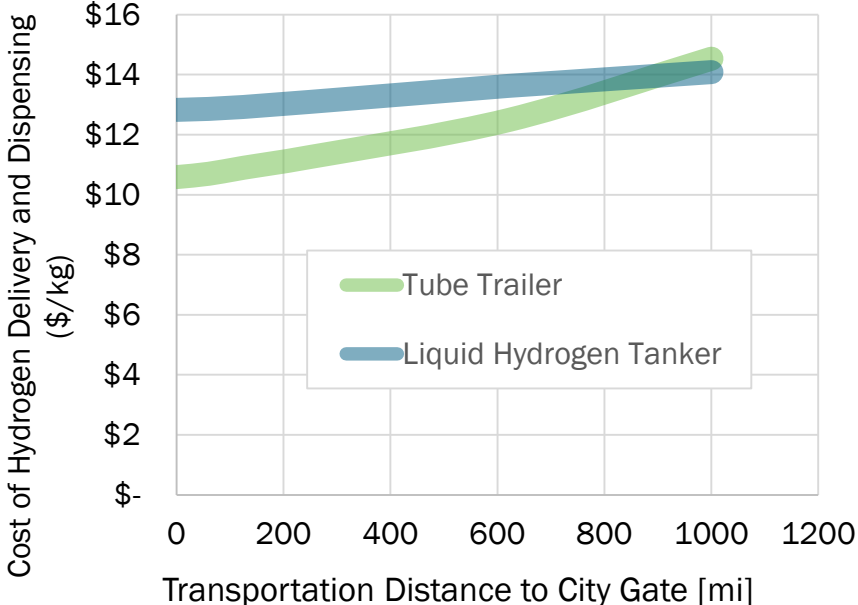
Hydrogen Delivery Scenario Analysis Model (HDSAM)



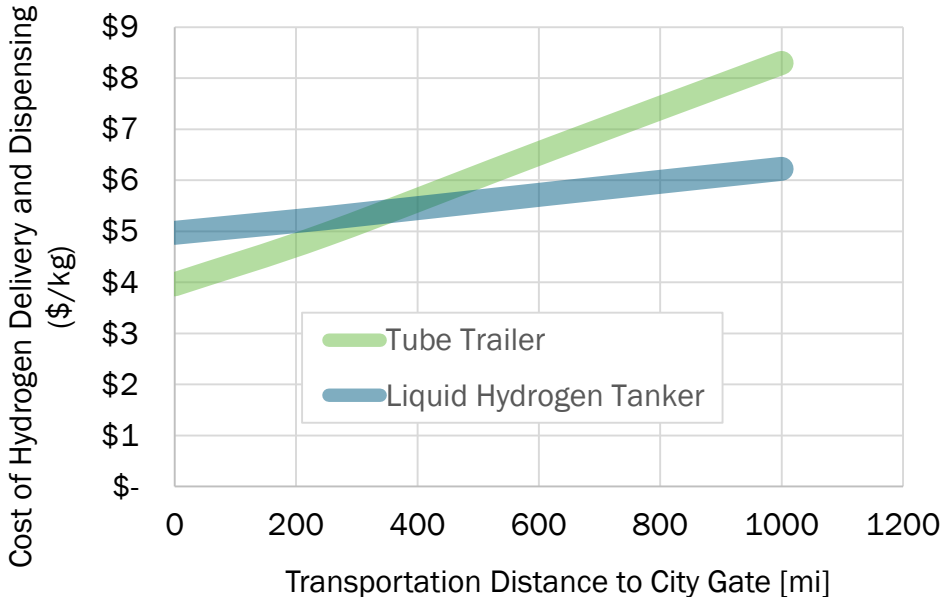
<https://hdsam.es.anl.gov/index.php?content=hdsam>

Hydrogen Delivery via Liquid Tankers vs. Tube Trailers

Early Market
12,000 FCEVs
300 kg/day station

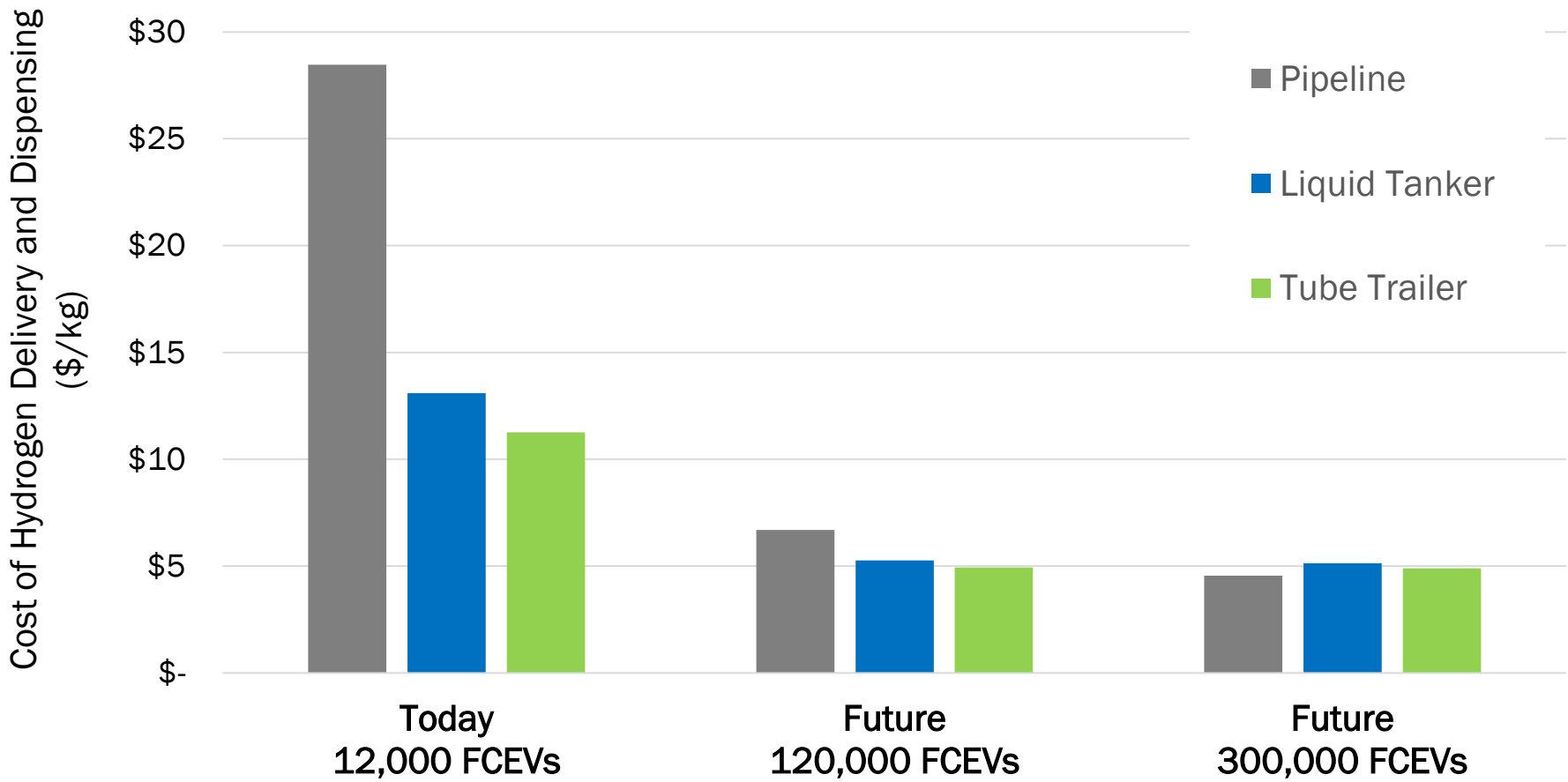


Future Market
120,000 FCEVs
1000 kg/day station



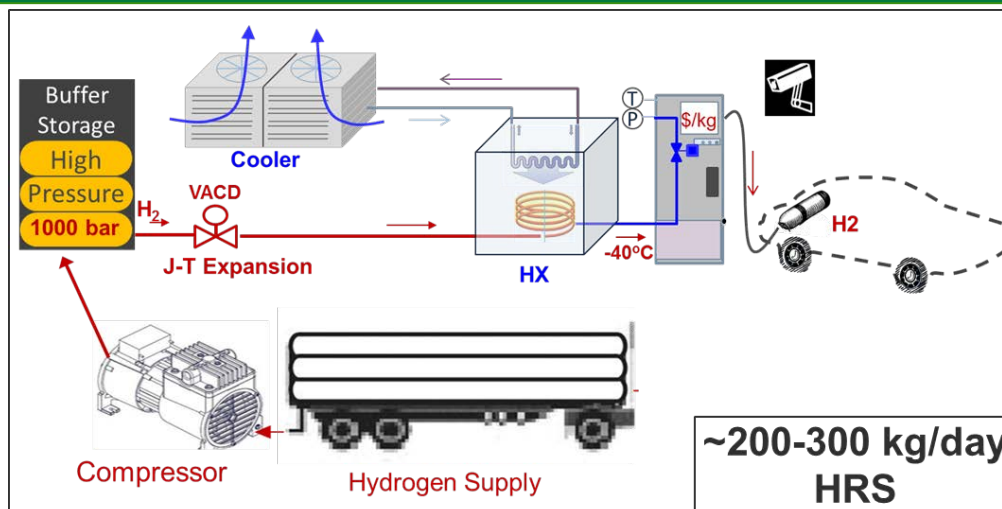
Liquid delivery is lower cost than tube-trailer gaseous delivery when market demands are high and transportation distances are long.

Adapting Delivery Modes for Market Demands



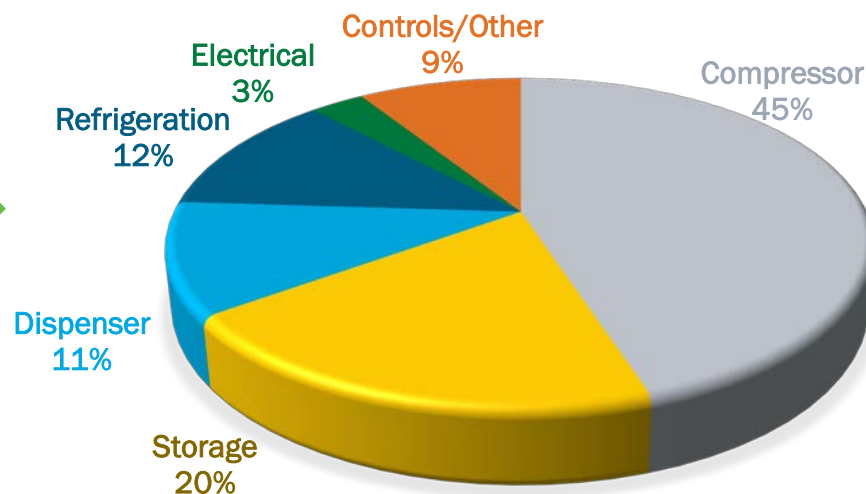
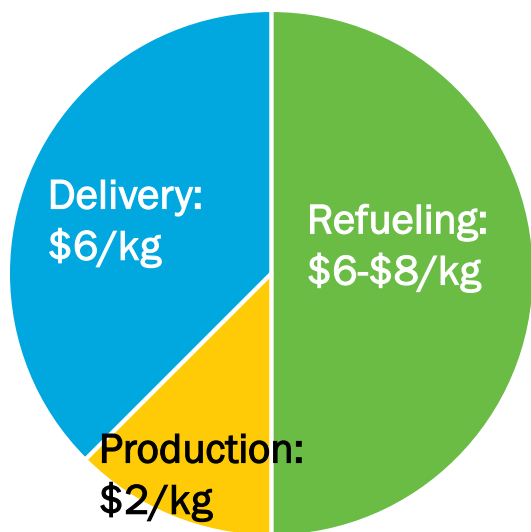
- Trucking is lowest cost option with small market demand (near-term)
- Pipeline is lowest cost option with large market demand (long-term)

Cost Drivers of Hydrogen Fueling Stations



Current Retail Price of Hydrogen Fuel:
\$13-\$16/kg

Capital Costs of Hydrogen Fueling Stations
(Simulated)

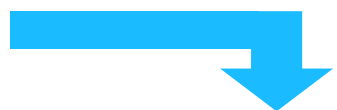


Hydrogen Refueling Models (HRSAM and HDRSAM)

Market Definition



Sizing of Refueling Components



Station Capacity

Mode of Hydrogen Supply

Fueling Hourly Demand

Station Utilization Scenarios

Financial/Economic Inputs and Assumptions

Model Output

Fueling Cost

$\$/\text{kg}_{\text{H}_2}$

Station Cost

Cash Flow

Hydrogen Refueling Station Models

Objective: Evaluate impacts of key market, technical, and economic parameters on refueling cost [$\$/\text{kg}_{\text{H}_2}$] of light-duty and heavy-duty fuel cell vehicles



HRSAM



HDRSAM

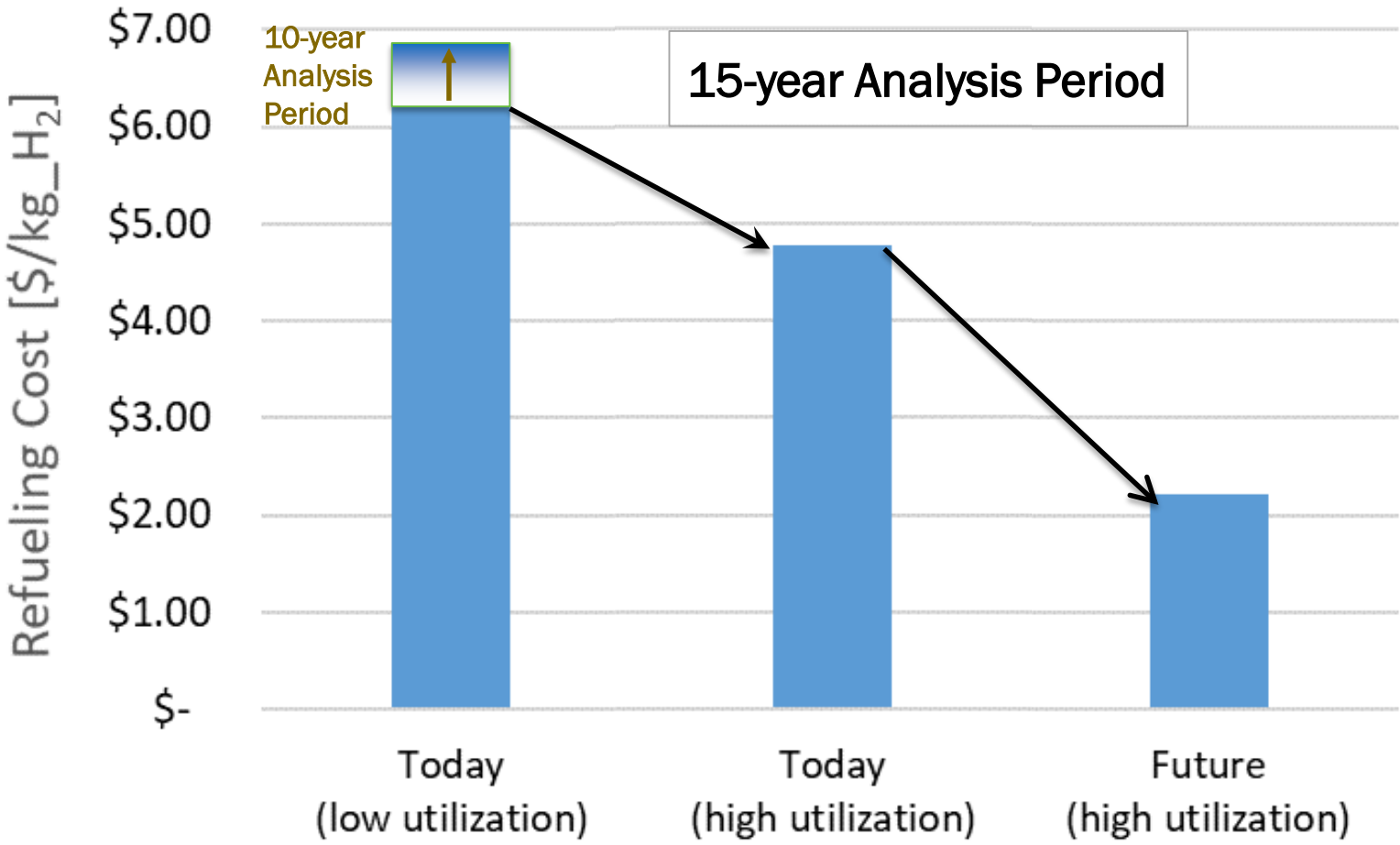
Available at: <http://hdsam.es.anl.gov/>

HRSAM

HRSAM Model is available at the link below:

<https://hdsam.es.anl.gov/index.php?content=hrsam>

Impact of station utilization and capacity on refueling cost



Today (low volume)
Early market (12,000 FCEVs)
300 kg/day station

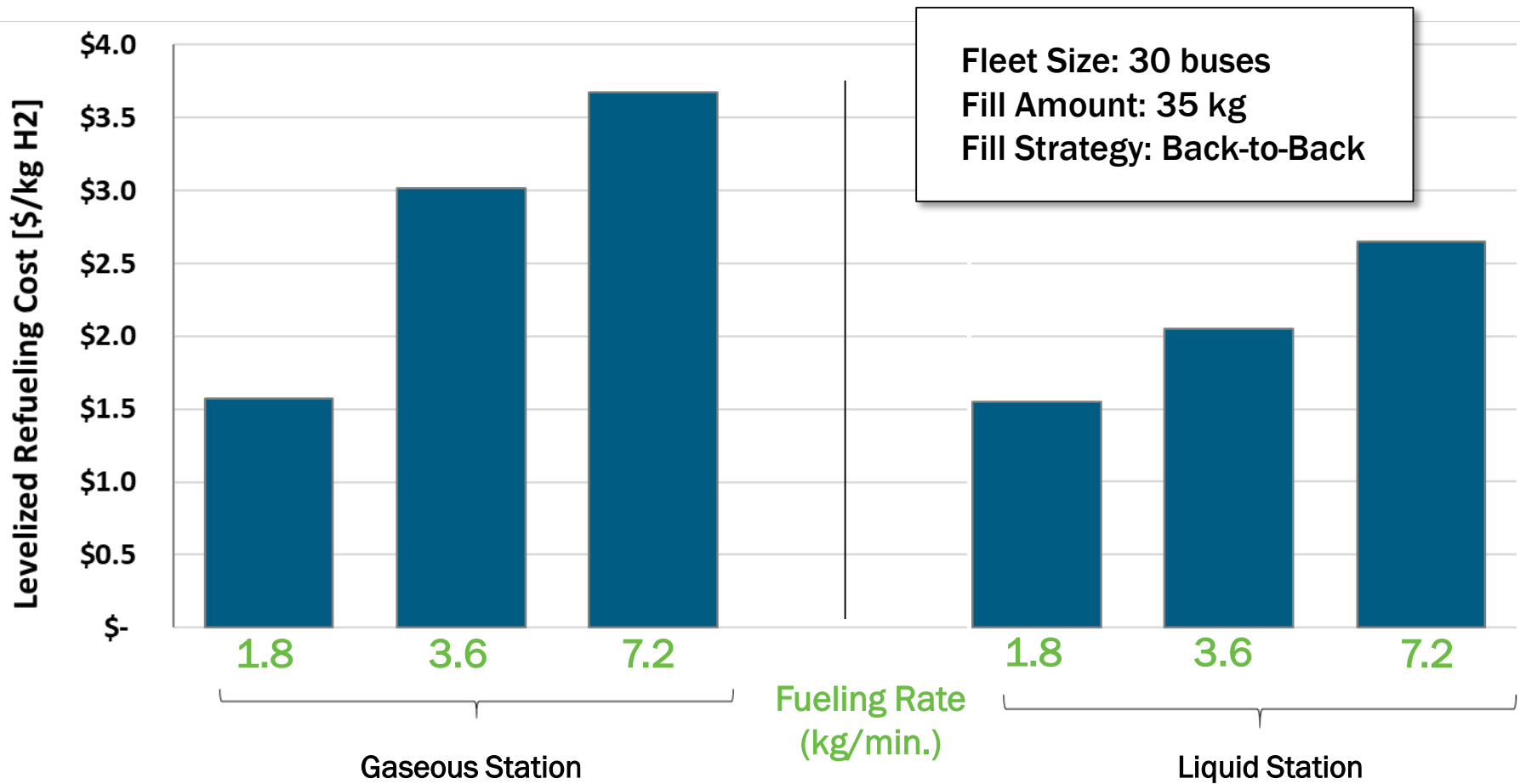
Future (high volume)
Mature market (120,000 FCEVs)
1000 kg/day station

HDRSAM

HDRSAM Tool is available at the link below:

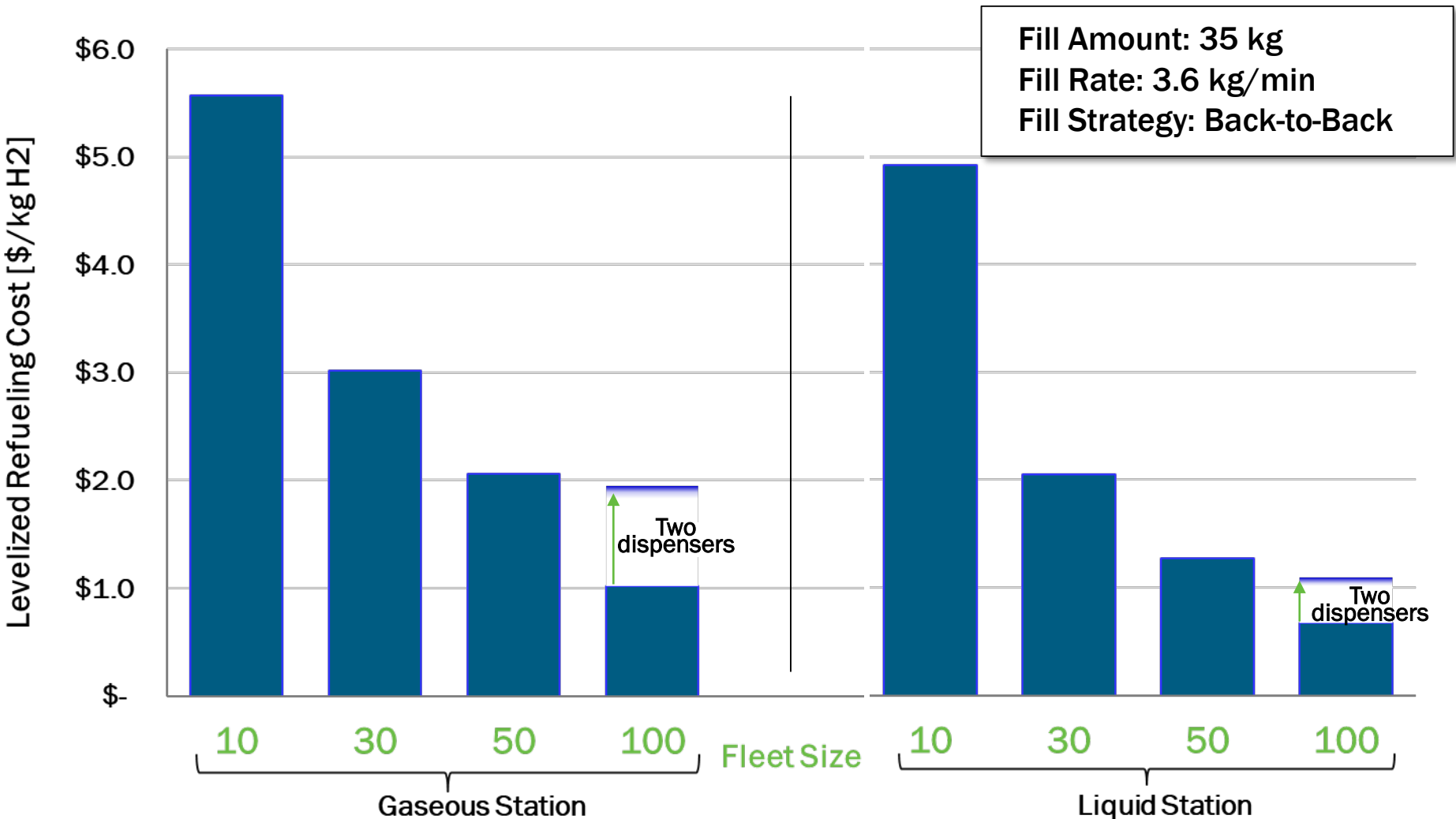
<https://hdsam.es.anl.gov/index.php?content=hdrsam>

Impact of fueling rate on refueling cost



- Comparable cost for slow fills with gaseous and liquid stations
- Faster fills require higher capacity equipment and result in higher cost
- Liquid stations can handle faster fills with less cost increase

Impact of fleet size (demand) on refueling cost



- Fleet sizes have a strong impact: cost can drop to ~\$1/kg_{H₂} with large fleet size
- Liquid station, in general, provides a lower refueling cost option

Contributors to the development of the Hydrogen Delivery and Refueling Models over the past decade

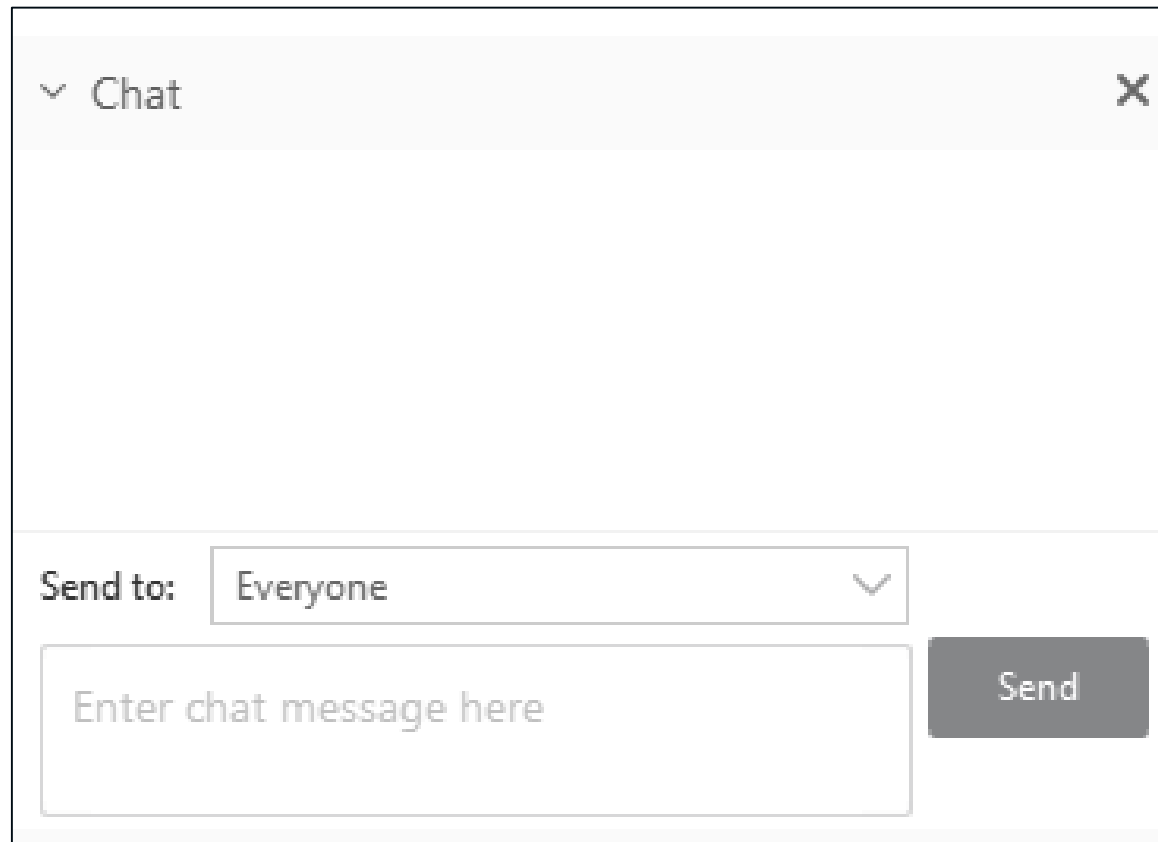
- Amgad Elgowainy (ANL)
- Krishna Reddi (ANL)
- Marianne Mintz (ANL)
- Jerry Gillette (ANL)
- Daryl Brown (previously at PNNL)
- Matt Ringer (NREL)
- Neha Rustagi (DOE)

Acknowledgments

- The hydrogen delivery and refueling models have been supported by DOE's Office of Energy Efficiency and Renewable Energy's Fuel Cell Technologies Office since 2005 under the Hydrogen Delivery Program. The model developers are very thankful to the support from previous managers **Mark Paster**, **Monterey Gardiner**, **Scott Weil** and **Erika Gupta**, and from current Delivery Program manager ***Neha Rustagi***.

Question and Answer

- Please type your questions to the chat box. **Send to: (HOST)**



Chat

Send to: Everyone

Enter chat message here

Send

Thank you

Amgad Elgowainy
aelgowainy@anl.gov

Eric Parker
DOEFuelCellWebinars@ee.doe.gov

Neha Rustagi
Neha.Rustagi@ee.doe.gov

hydrogenandfuelcells.energy.gov