Hydrogen Fueling Infrastructure Research and Station Technology

Reference Designs for Hydrogen Fueling Stations

DOE-EERE-FCTO Webinar Series

October 13, 2015

Joe Pratt[1], Danny Terlip[2], Amgad Elgowainy[3], Chris Ainscough[2], Jennifer Kurtz[2]

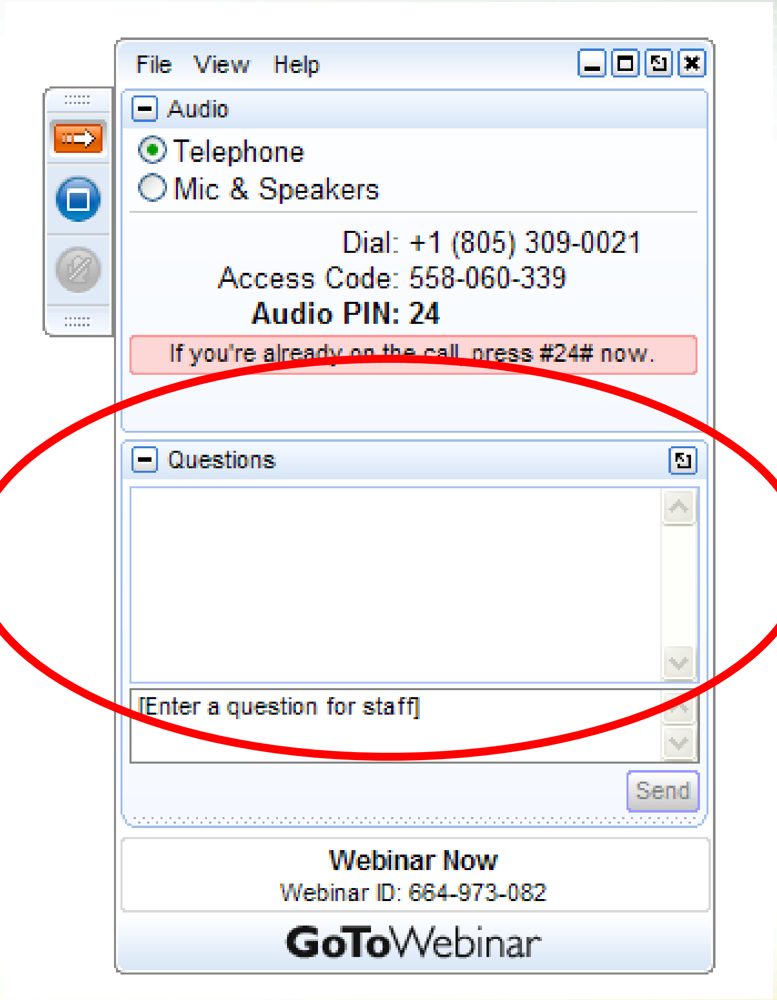
[1]Sandia National Laboratories

[2]National Renewable Energy Laboratory

[3]Argonne National Laboratory

Question and Answer

- Please type your questions into the question box



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Outline

1. Objective and Approach
2. Development of Inputs
3. Economic Screening Results
4. Market Matching and Downselect
5. Station Designs
6. Conclusions and Future Steps

H2First is a multi-lab project launched by the DOE's Energy Efficiency and Renewable Energy (EERE) Fuel Cell Technologies Office (FCTO) to support H2USA

Objective and Uniqueness

Objective: Speed acceptance of *near-term* hydrogen infrastructure build-out by exploring the advantages and disadvantages of various station designs and propose near-term optima.

- H2FIRST team updated economic modeling tools to give outputs relevant to **current station development**
- H2FIRST incorporated **codified setback distances** into station layout designs to present realistic usage implication and identify needs for improvement
- H2FIRST **looked at the whole picture**, from macro-scale FCEV and station roll-out factors to component level station designs

Summary of Results

- **Primary results**
  - Selected four high-priority, near-term station concepts based on economics, technical feasibility, and market need
  - Produced spatial layouts, bills of materials, and piping & instrumentation diagrams
- **Ancillary Results**
  - Near-term FCEV rollout scenario analysis year-by-year
  - Near-term hydrogen station rollout analysis year-by-year including number of stations, capacity, and overall utilization
  - Compilation of current costs for all station components
  - Costs of 120 station permutations: capital cost and station contribution to cost of hydrogen, including effect of different utilization scenarios

Audience

- **Station developers**: quick evaluation of potential sites and needs; lower investment risk; general cost and return estimates.
- **Local authorities**: understand devices, components in a typical station.
- **Code developers**: understand near-term needs for code refinement.
- **Other H2USA groups**: new tool and baseline for economic studies.
- **Businesses/entrepreneurs and R&D organizations**: Identification of near-term business solution and technology needs.
- **Local municipalities and the general public**: high-level understanding of typical stations lowering acceptance risk.
- **Funding agencies**: Understanding of current technological capabilities, costs, and market needs.

Approach

Utilization, capacity, size, dispenser…

1. Define parameters and ranges

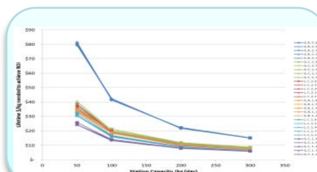
Compressor, land, O&M, 875 bar storage, …

2. Gather cost data and specify metrics. Review.

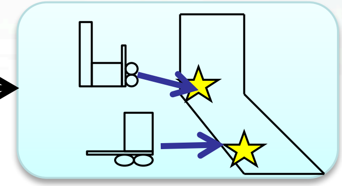
HRSAM Model Development

Station	Utilization	Capacity	Dispensers
1	20%	50	1
2	Ramp	100	1
3	Ramp	200	2
	…	…	…
N	…	…	…

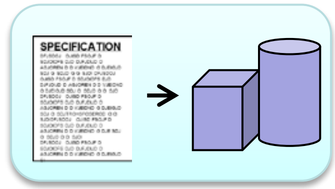
3. Specify and simulate station concepts utilizing HRSAM's optimization method.



4. Station concept selection based on comparative economics and technical feasibility



5. Match station concepts to market needs

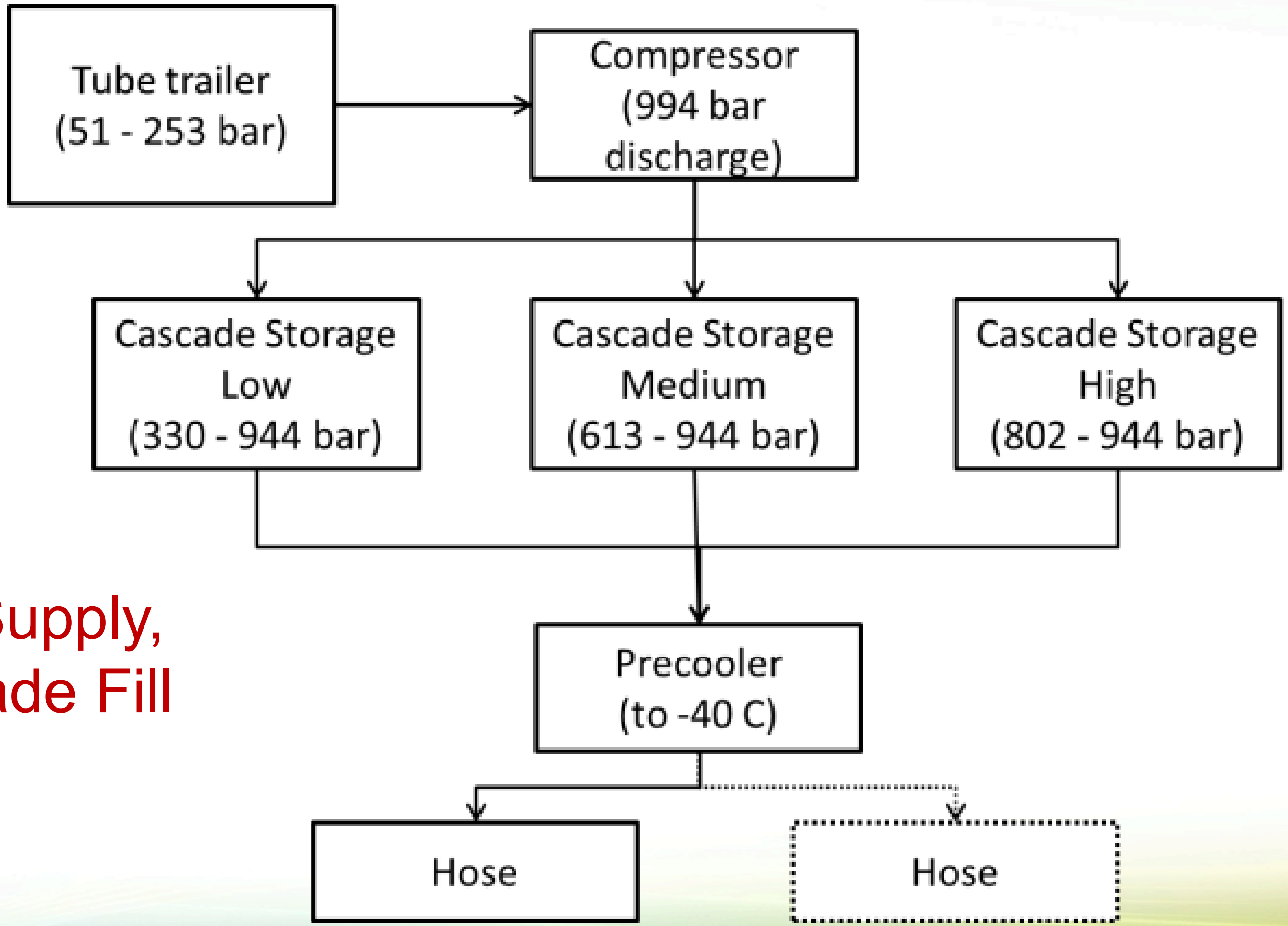


6. Alignment of designs to actual equipment

7. Station designs

DEVELOPMENT OF INPUTS

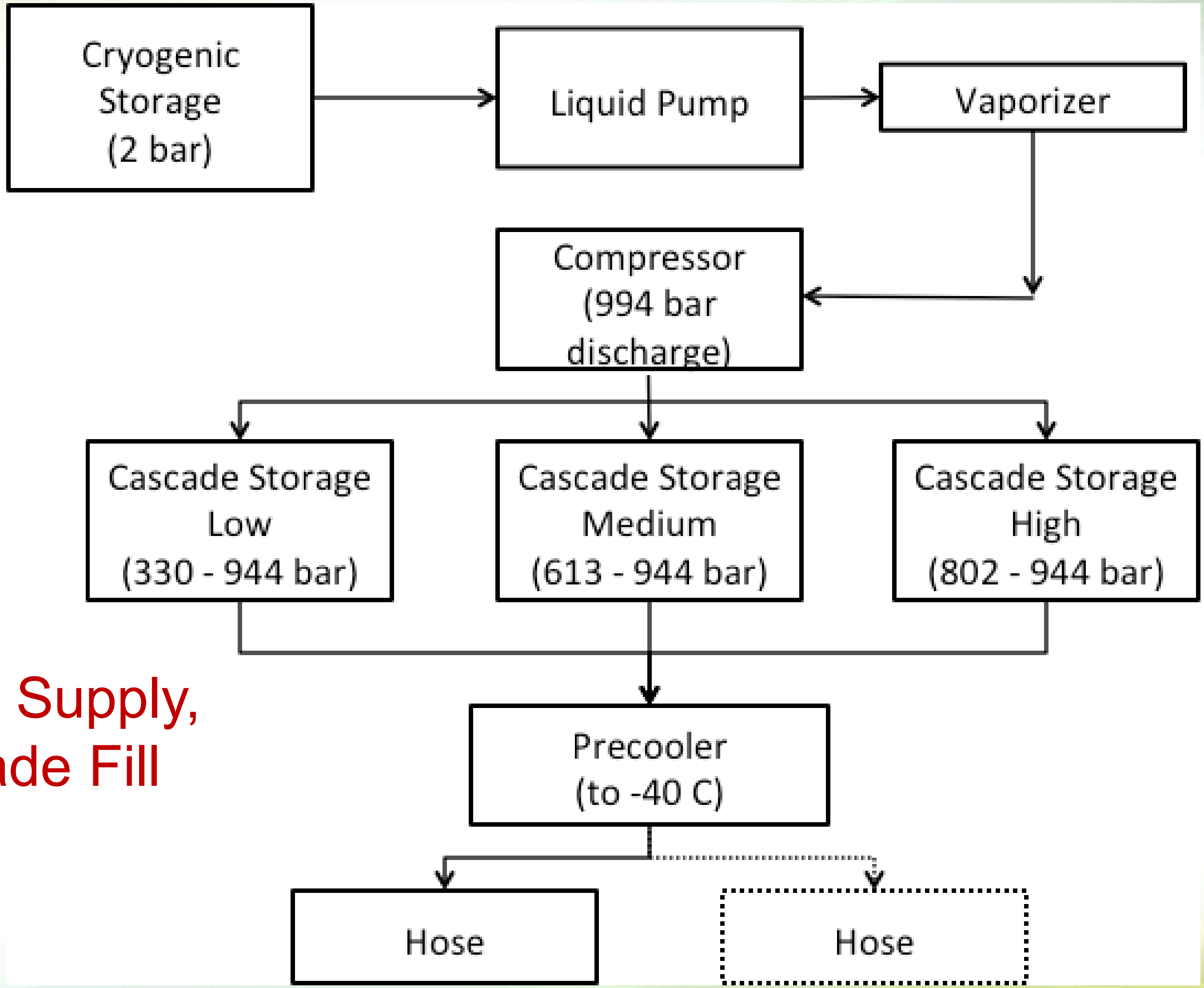
Common station designs



Gas Supply,
Cascade Fill

Three basic station designs were considered in the economic analysis

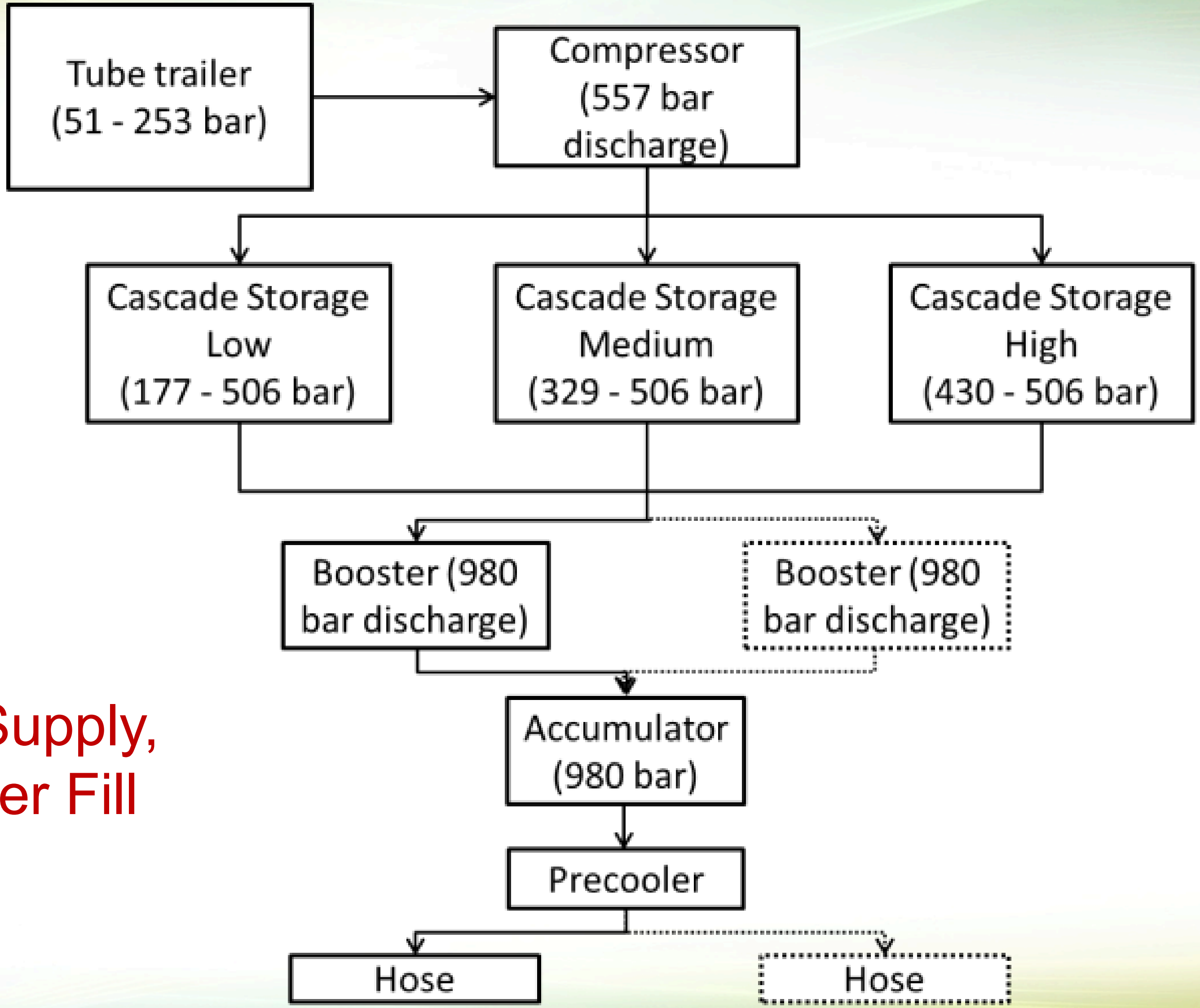
Common station designs



Liquid Supply,
Cascade Fill

Three basic station designs were considered in the economic analysis

Common station designs



Gas Supply, Booster Fill

Three basic station designs were considered in the economic analysis

Determined station parameters with near-term ranges of interest

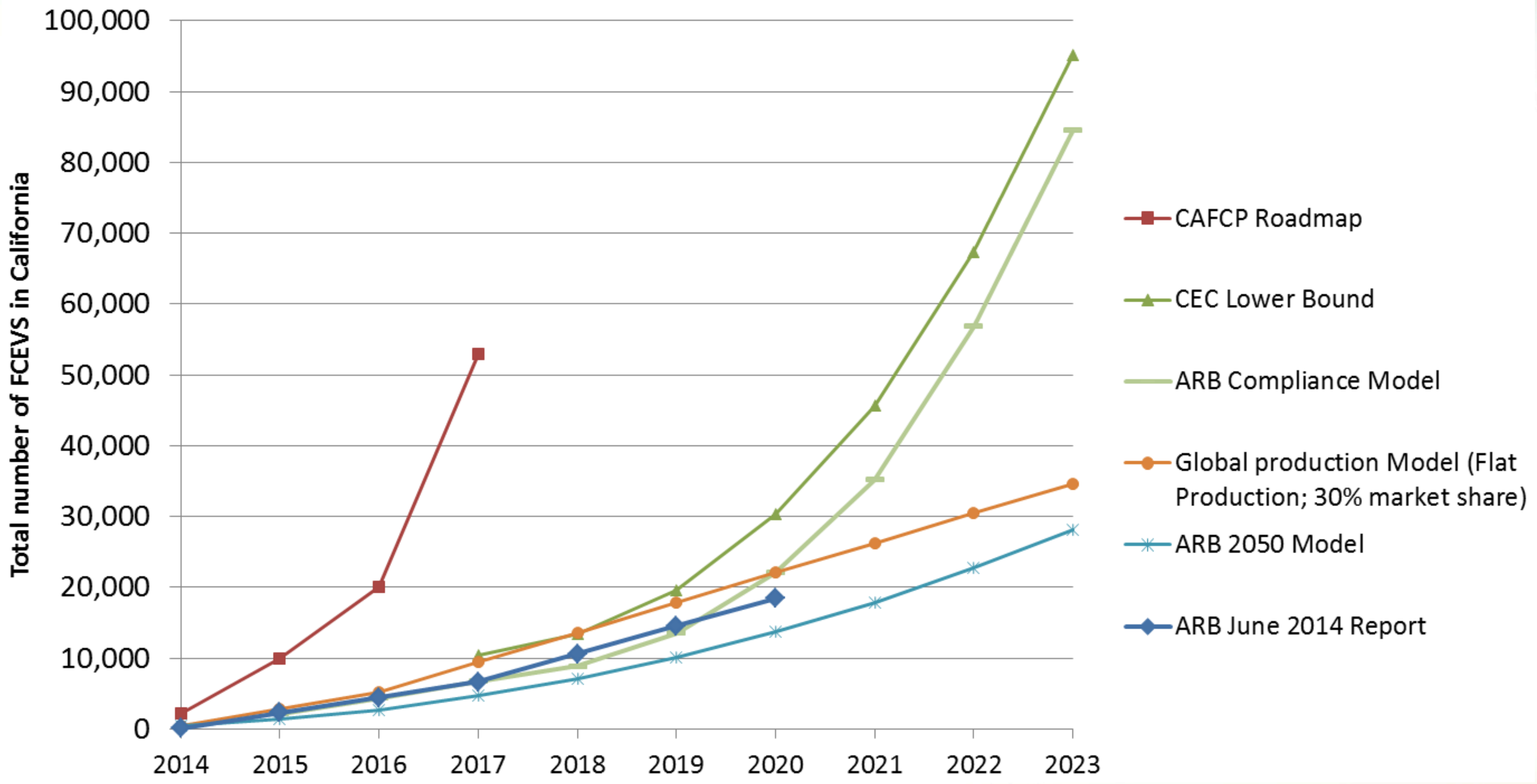
Performance Parameter	Values Used for Screening
Design capacity (kg/day)	50, 100, 200, 300
Peak performance	2, 3, 4, 5, 6 consecutive fills per hose
Number of hoses	1, 2
Fill configuration	Cascade, booster compressor
Hydrogen delivery method	Gas (tube trailer), liquid trailer

Another critical parameter needed: Utilization

$$\textit{Utilization} = \frac{\text{Actual hydrogen dispensed}}{\text{Designed hydrogen dispensing capability}}$$

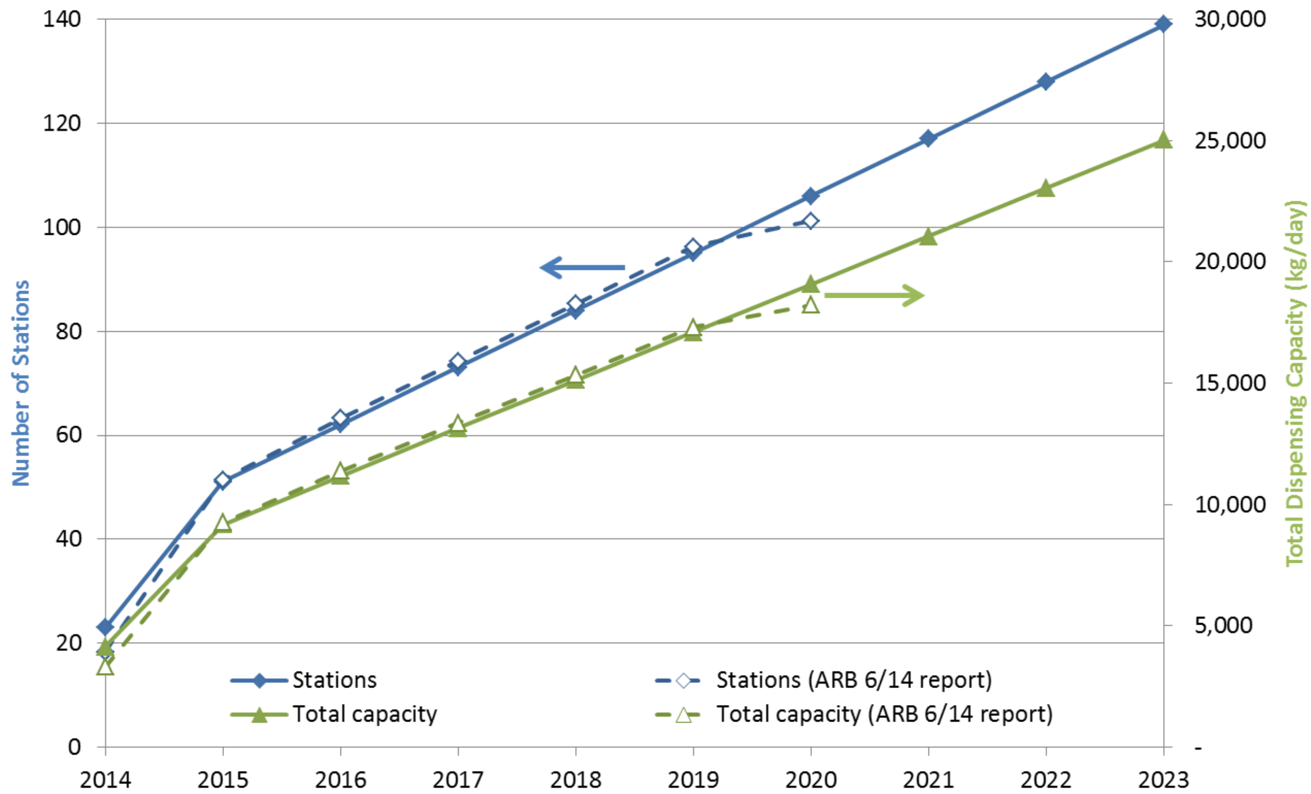
The values for the five performance parameters were chosen with industry input to reflect near-term station requirements and most common characteristics.

Characterized FCEV rollout scenarios (for California)



Estimated number of stations and network capacity

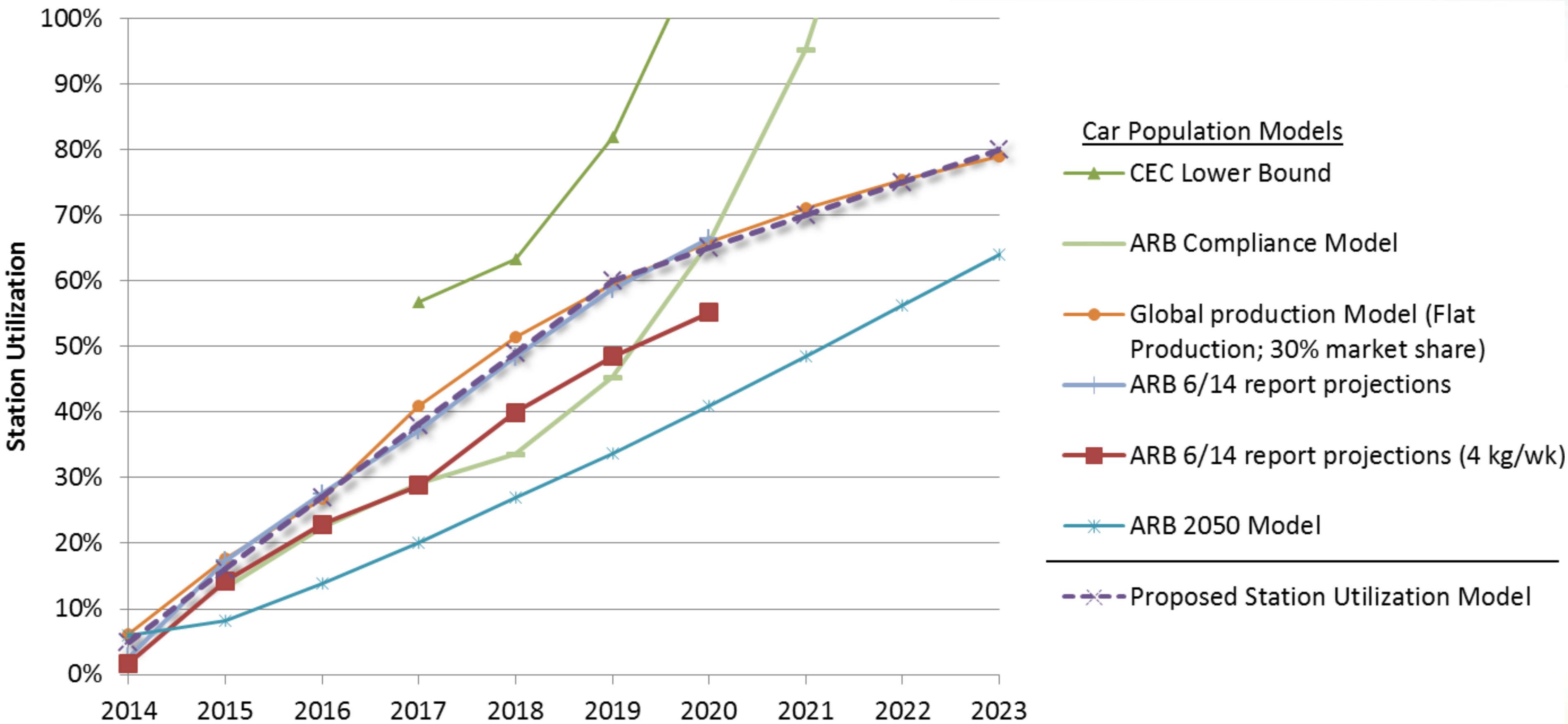
Year	CaFCP (2014)	ARB (2014)
2014	23	
2015	51	51
2016	59	
2017	67	73
2018	77	
2019	87	
2020	99	100
2021	111	
2022	123	



180 kg/day average capacity

Estimated near-term station utilization

$$\textit{Utilization} = \frac{\text{Actual hydrogen dispensed}}{\text{Designed hydrogen dispensing capability}}$$



Note: Increasing average utilization by ~30% reduces hydrogen cost by ~30%

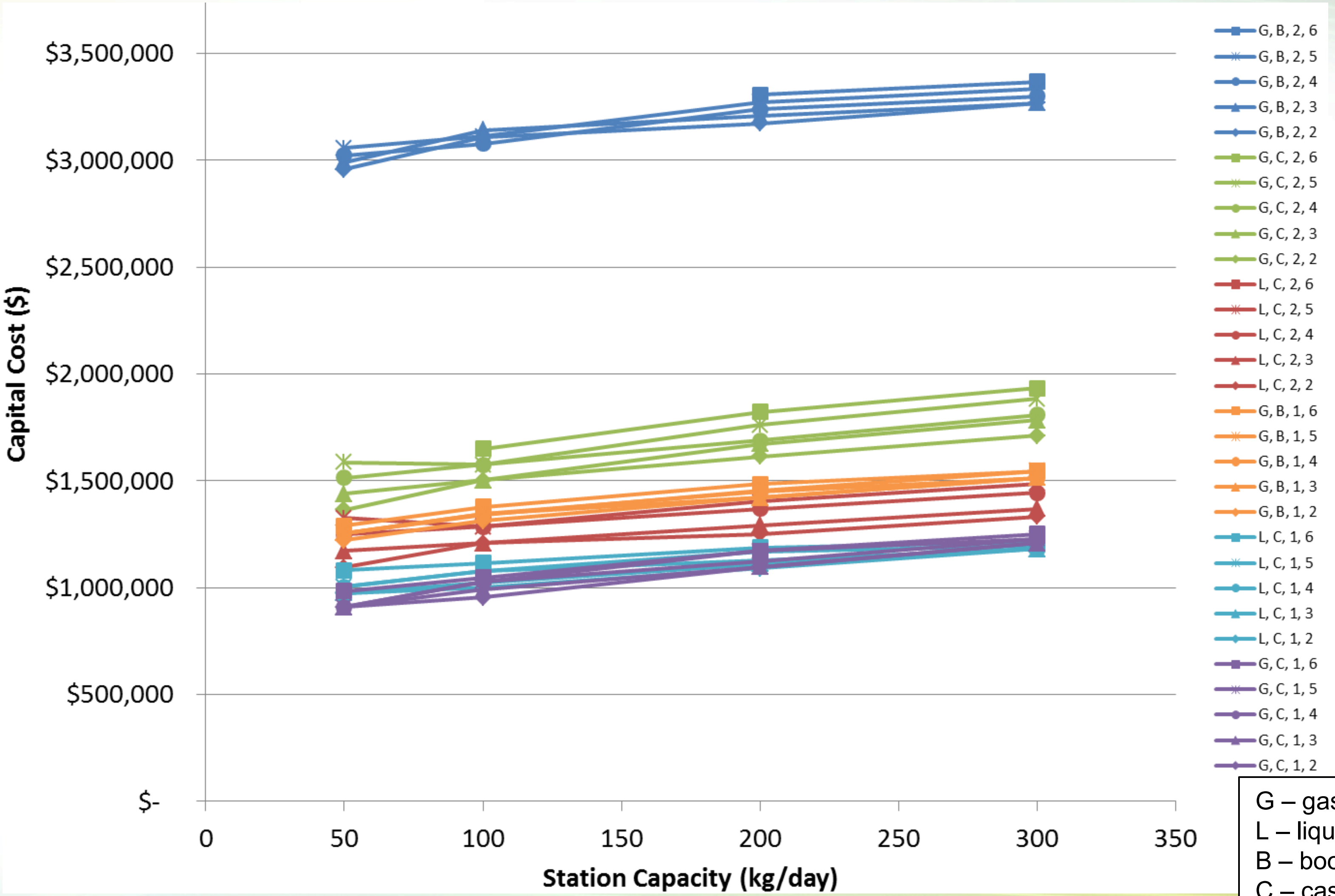
Updated input cost parameters to current off-the-shelf estimates

- Chiller cost
- Low-to-high pressure compressor cost (for cascade fill systems)
- Low-to-medium pressure compressor cost (for booster fill systems)
- Medium-to-high pressure compressor (for booster fill systems)
- Dispenser
- High-pressure storage (for cascade fill systems)
- Medium-pressure storage (for booster fill or 350-bar dispensing systems)
- Accumulator (small high-pressure storage for booster fill systems)
- Low-pressure storage (for 20-bar supply systems)
- Installation factor—equipment

Note: Cost data is primarily based on literature and NREL station experience. Better accuracy is desired in future iterations - CEC data will help address.

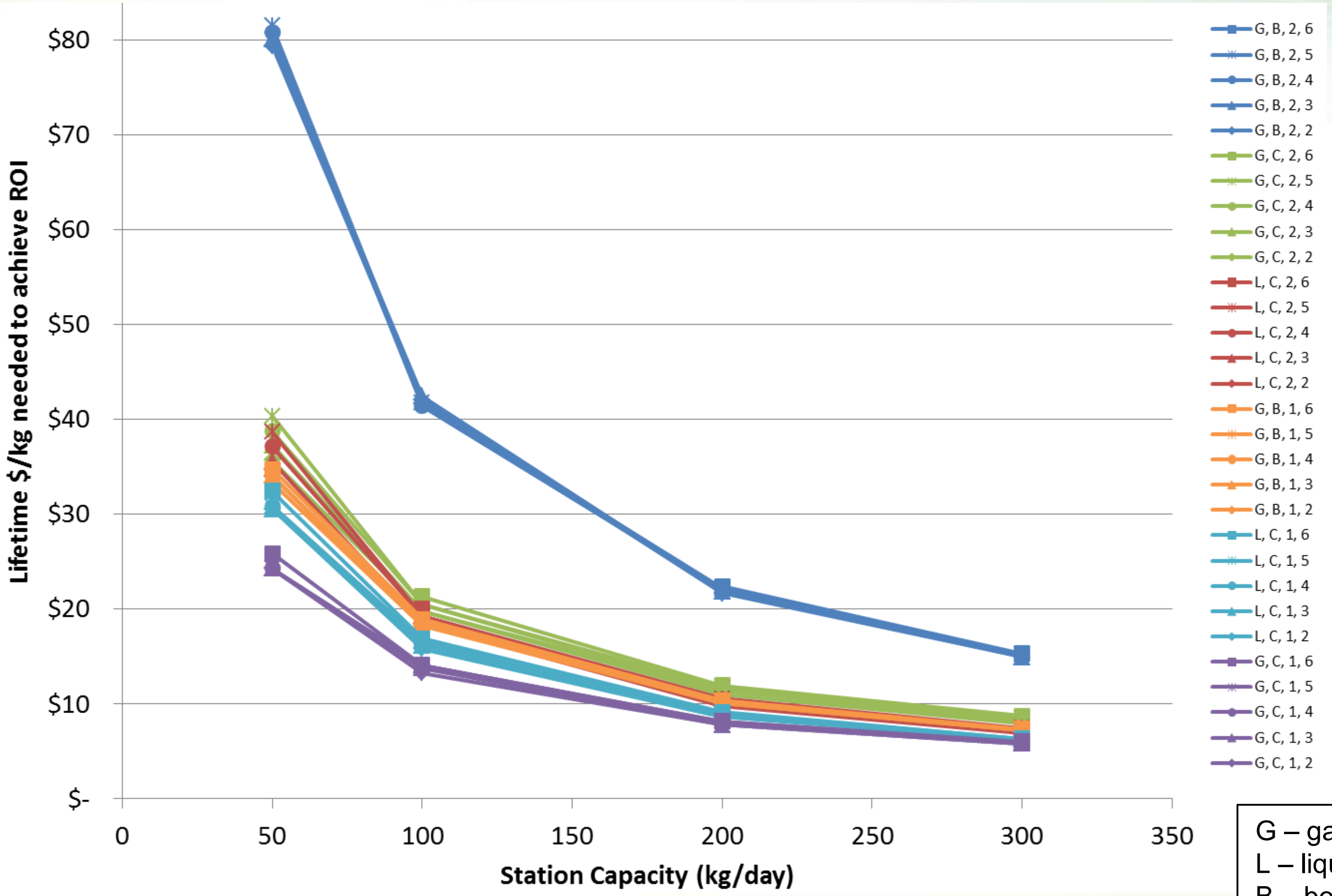
ECONOMIC SCREENING RESULTS

HRSAM estimates of station capital costs typically vary from $1M to $2M



G – gaseous
L – liquid
B – booster
C – cascade
(1,2) - Num Hoses
(2,6) - B2B fills

Cost of hydrogen typically varies from $40/kg to a low of $6/kg



G – gaseous
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(1,2) - Num Hoses
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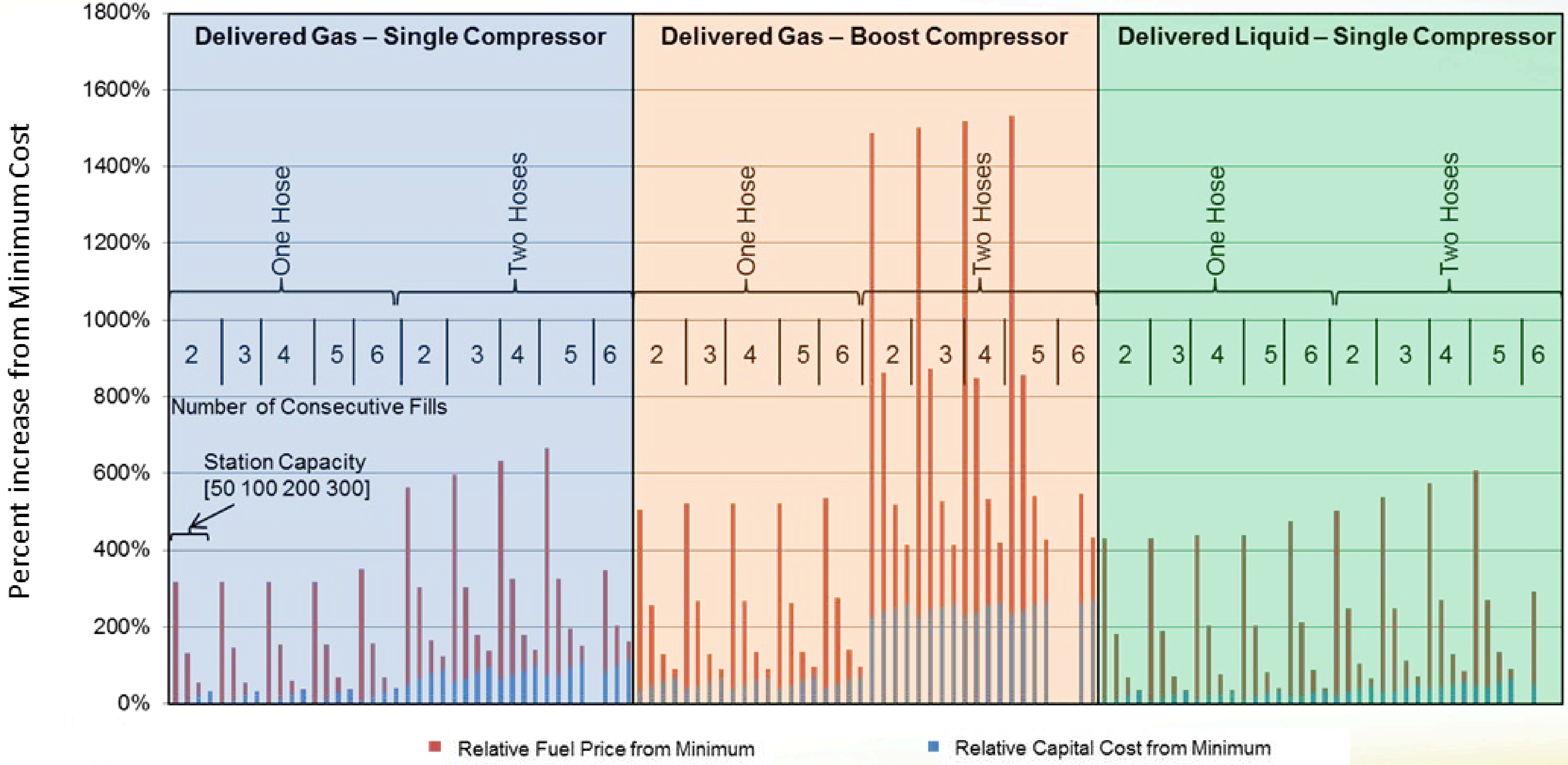
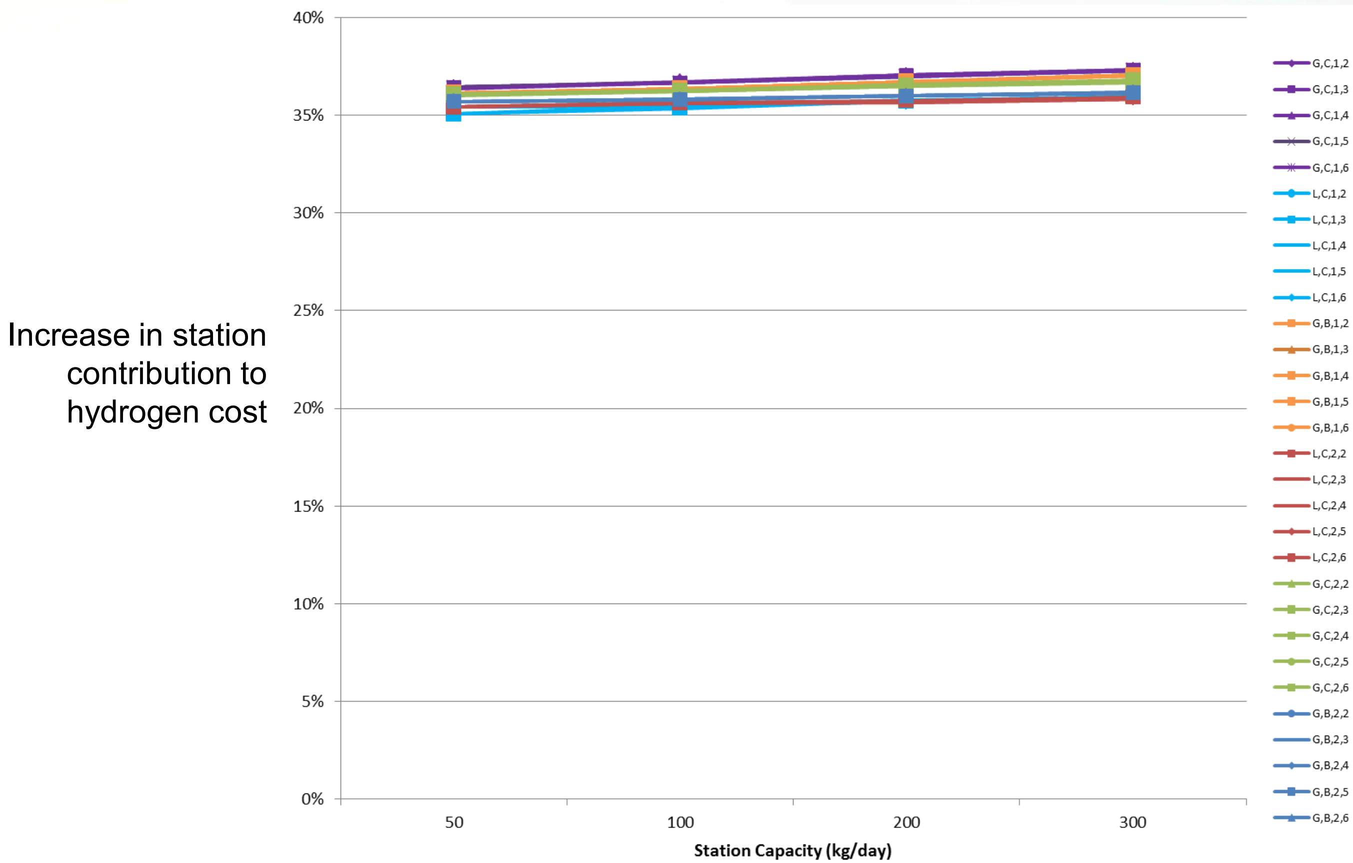
Full cost comparison of station types



Increase in hydrogen cost from changing from a ramped profile (5%-80% over 10 years) to a flat 20% utilization for all 10 years.



No station design is better than another in withstanding a lower-than-expected utilization

G – gaseous
L – liquid
B – booster
C – cascade
(1,2) - Num Hoses
(2,6) - B2B fills

MARKET MATCHING AND DOWNSELECT

Three station classifications with corresponding near-term performance requirements were identified.

Example: Market needs from ARB 2014 report

Classification	Daily Throughput	Hourly Peak Throughput	Dispensers	Technical Capabilities
High Use Commuter	High	High	More than 2	Back-to-back, simultaneous fills
Low Use Commuter	Low–intermediate	Low	2	Simultaneous fills
Intermittent	Low, intermittent	Low	1–2	Limited fuel capabilities

The top-performing station types that best-matched market needs were selected for detailed conceptual design.

Profile	Site Type	Delivery	Capacity (kg/day)	Consecutive Fills	Hoses	Station Contribution to Hydrogen Cost ($/kg)	Capital Cost (2009$)
High Use Commuter	Gas station or greenfield	Gaseous	300	6	1	$6.03	$1,251,270
High Use Commuter	Greenfield	Liquid	300	5	2	$7.46	$1,486,557
Low Use Commuter	Gas station or greenfield	Gaseous	200	3	1	$5.83	$1,207,663
Intermittent	Gas station or greenfield	Gaseous	100	2	1	$13.28	$954,799

STATION DESIGNS

Produced Piping and Instrumentation Diagrams (P&IDs)…

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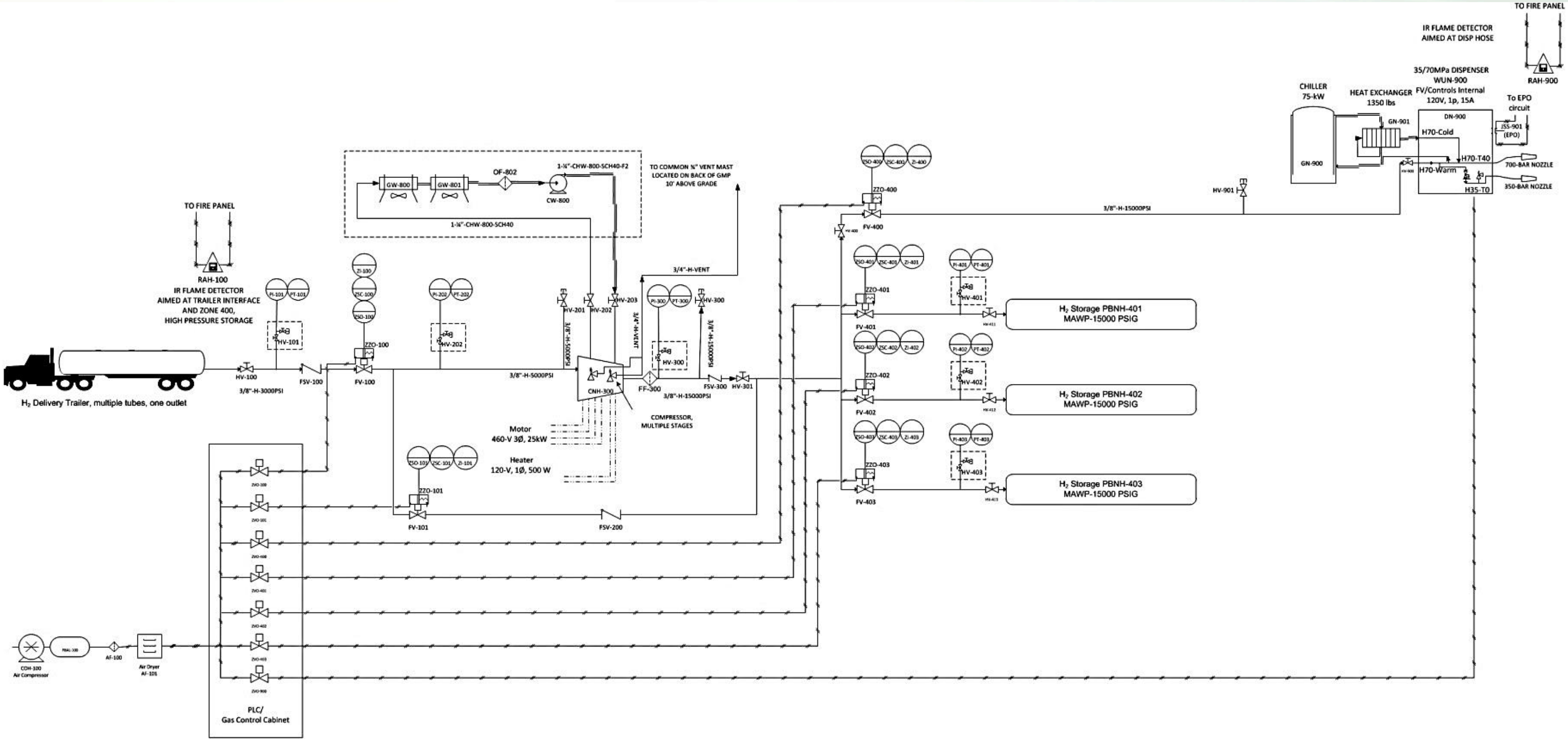
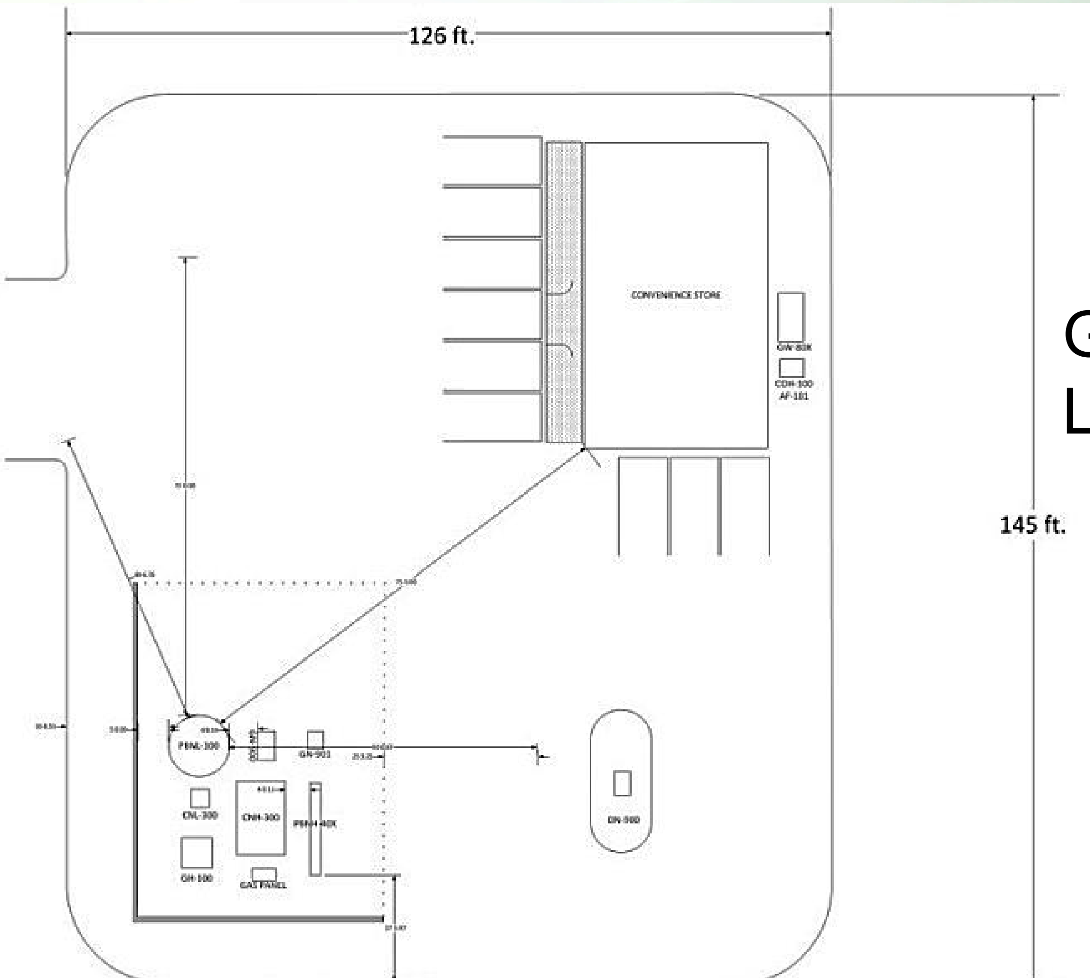


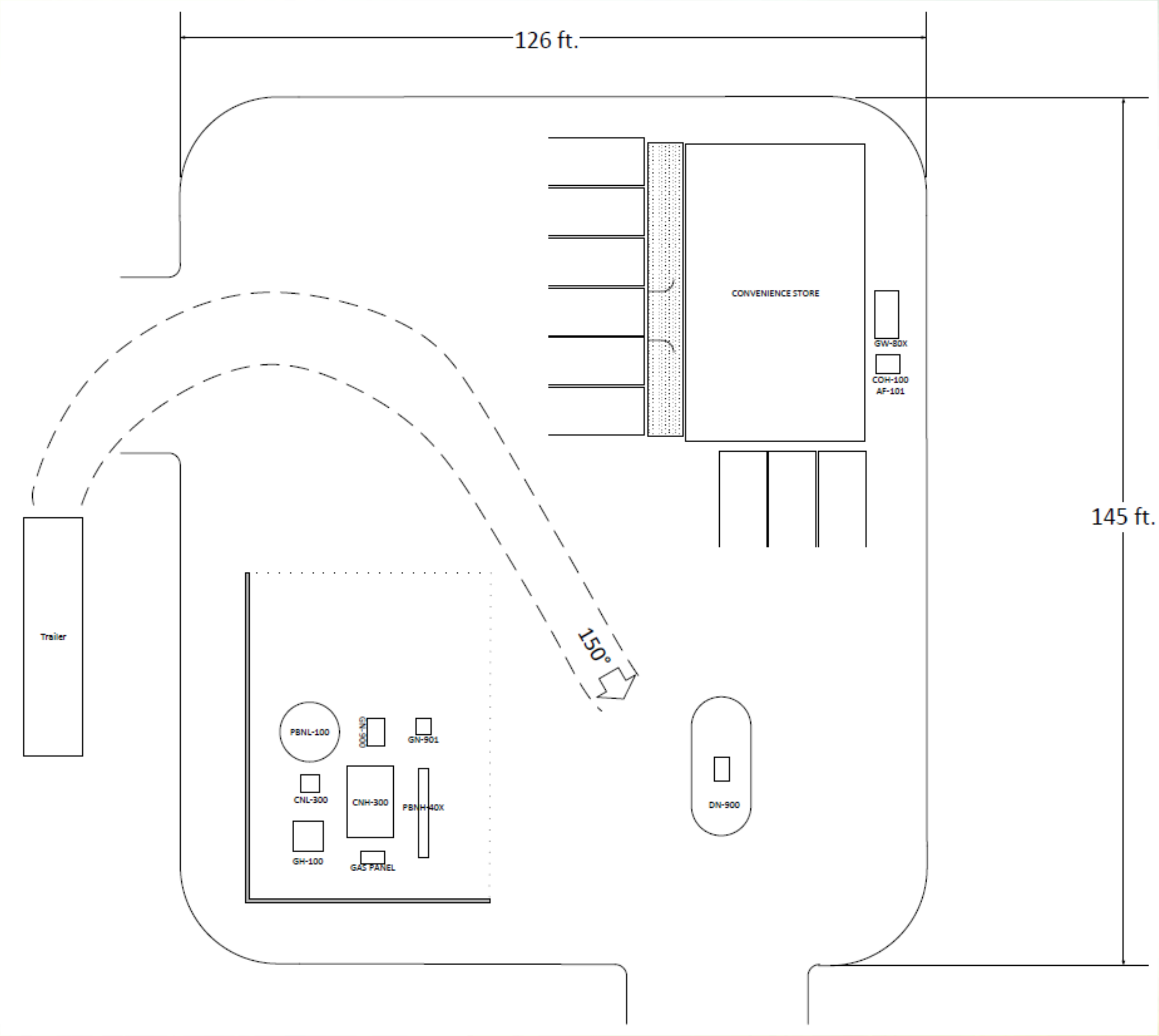
The P&IDs illustrate typical system designs for gaseous and liquid delivery stations.

…physical layouts considering NFPA-2 setback distance requirements…

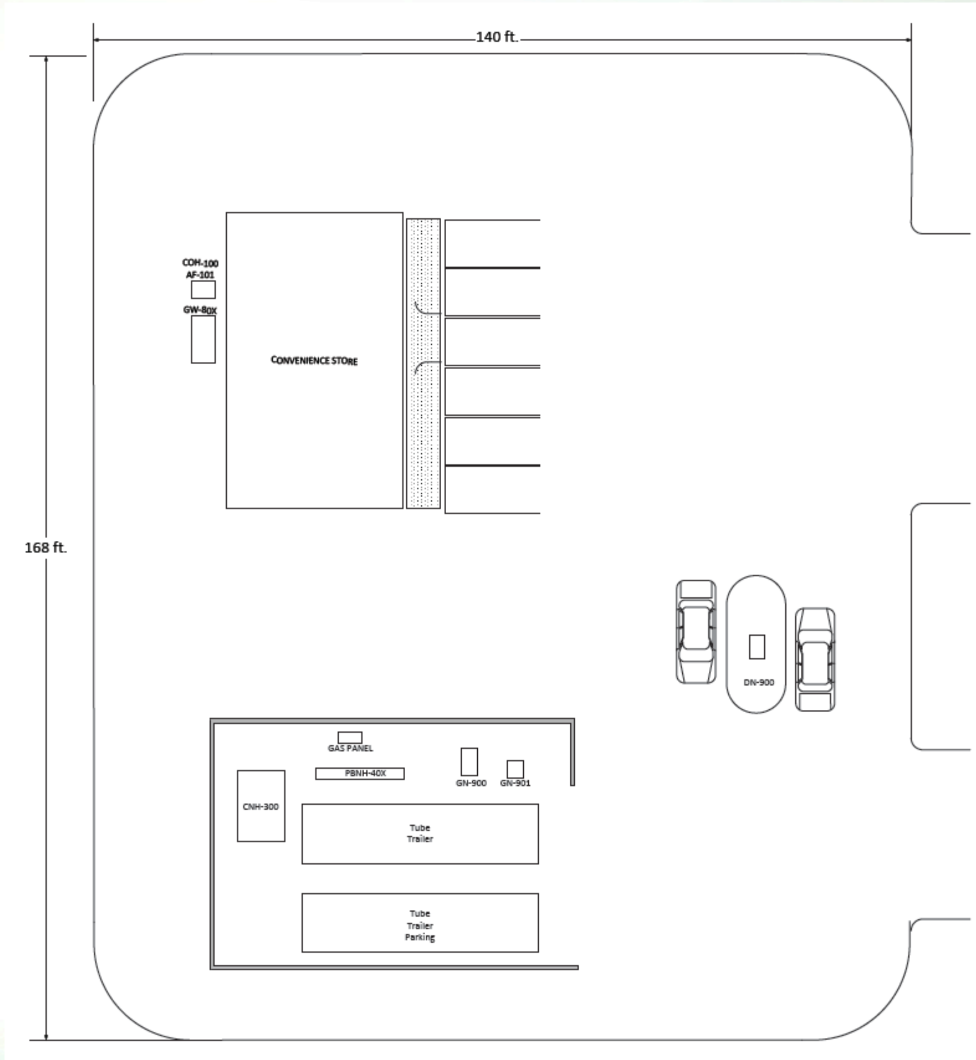


Greenfield
Liquid

The layouts show the amount of space required to install these stations to code.



Greenfield Liquid (delivery truck flow)



Greenfield Gaseous

…and at existing gasoline stations…

The layouts also show how a station can be sited at an existing gasoline station.

…and Bills of Materials (BOMs) with off-the-shelf components and costs.

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Table 14. Bill of Materials for the 100 kg/day Gaseous Station

Description	Tag Number	Quantity	Approx Cost	Ext Cost
Hydrogen tank 401	PBNH-401	1	$40,000	$40,000
Hydrogen tank 402	PBNH-402	1	$40,000	$40,000
Hydrogen tank 403	PBNH-403	1	$40,000	$40,000
Pressure transmitter w/ indicator	PT-101	1	$1,000	$1,000
Pressure transmitter w/ indicator	PT-202	1	$1,000	$1,000
Pressure transmitter w/ indicator	PT-300	1	$1,000	$1,000
Pressure transmitter w/ indicator	PT-401	1	$1,000	$1,000
Pressure transmitter w/ indicator	PT-402	1	$1,000	$1,000
Pressure transmitter w/ indicator	PT-403	1	$1,000	$1,000
Block and bleed valve	HV-101	1	$500	$500
Block and bleed valve	HV-202	1	$500	$500
Block and bleed valve	HV-300	1	$500	$500
Block and bleed valve	HV-401	1	$500	$500
Block and bleed valve	HV-402	1	$500	$500
Block and bleed valve	HV-403	1	$500	$500

The BOMs list typical components needed for stations along with present-day costs.

CONCLUSIONS AND FUTURE STEPS

Remaining Barriers and Challenges for Near-Term Infrastructure Rollout

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- **Component level R&D** for chillers, cryogenic pumps and evaporators, high-capacity delivery trailers, and underground storage tanks

- **System innovation** to reduce chilling needs, address liquid boil-off issues with low-utilization stations, and optimize storage-compressor interactions
- **Revision of liquid hydrogen setback distances** by providing the scientific basis needed to assess and potentially reduce these current codified setback distances
- **Modeling and/or demonstration of business practice methods** such as fleets, consumer driven economics, big stations vs. many stations, and integration of mobile fueling trucks.

Next Step: Reference Station Phase II

Four new station types:

- Conventional design with on-site generation
  - Electrolysis
  - SMR
- Containerized stations
  - Delivered hydrogen gas
  - On-site electrolysis

Deliverables

- Economic analysis including apples-to-apples comparisons to Phase 1 station results
- Station designs for each of the four new selected stations including greenfield and gasoline station co-location.

Summary

- The Reference Station Design Task has produced results that include:
  - Vehicle roll-out scenarios
  - Detailed engineering and design of near-term station concepts
  - Economic and market assessments
  - Identification of areas for future efforts
- Stakeholders that benefit from this work are varied and include:
  - Planning groups including H2USA and state/local agencies
  - Technology developers and R&D organizations/agencies
  - Local municipalities and the general public
  - Station developers
  - Code authorities

For more information on the Reference Station task:

- **Visit the Reference Station website** for the final report and to download high-resolution images of the P&IDs
  - http://www.energy.gov/eere/fuelcells/downloads/h2first-reference-station-design-task-project-deliverable-2-2
- **Contact the Reference Station team**:
  - Joe Pratt, Sandia
    - (925) 294-2133
    - jwpratt@sandia.gov
  - Danny Terlip, NREL
    - (303) 275-4180
    - Danny.Terlip@nrel.gov

Question and Answer

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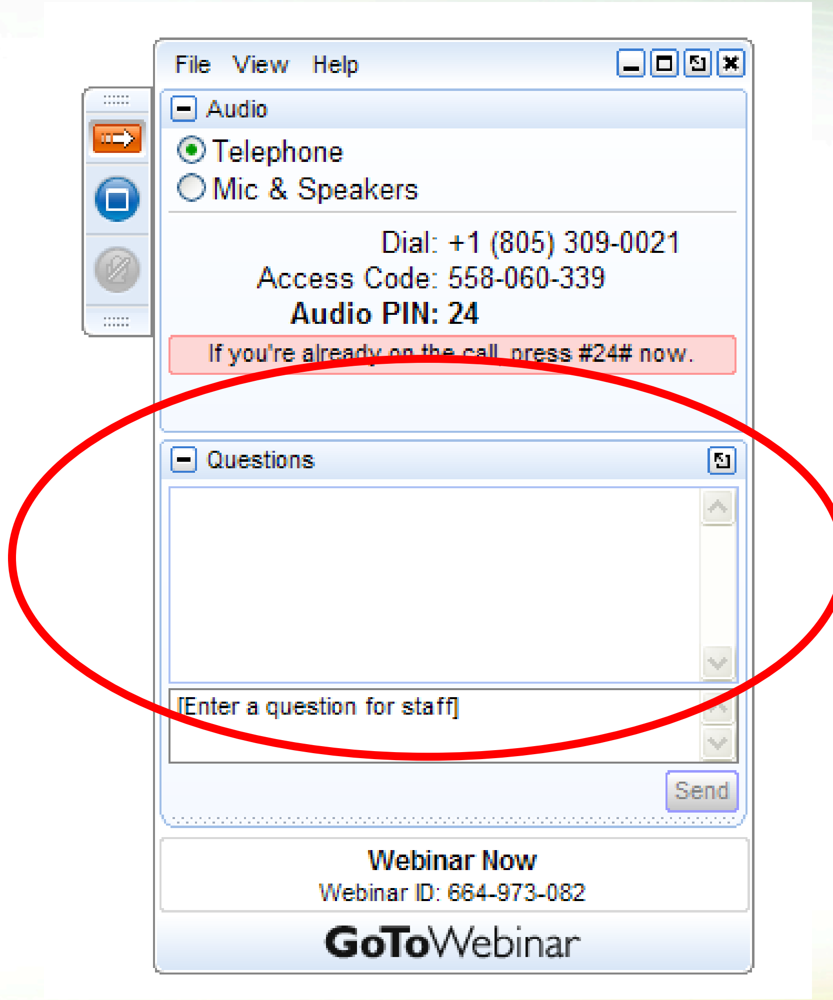

Additional Information

- More information located at EERE website!
  - http://www.energy.gov/eere/fuelcells/h2first
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Thank You!