Hydrogen Fueling Infrastructure Research and Station Technology

Reference Station Design

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

June 11, 2015

*Presenter

[1]National Renewable Energy Laboratory

[2]Sandia National Laboratories

[3]Argonne National Laboratory

Project ID # PD106

Overview

Timeline

- Task Start Date: March 2014
- Task End Date: March 2015
- Percent Complete: 100%

Budget

- Total Task Budget: $280k
  - DOE Share: $280k
  - Funds Spent To-date: $280k
    - SNL: $140k
    - NREL: $140k

Barriers (*Delivery* area)

A. Lack of Hydrogen/Carrier and Infrastructure Options Analysis

K. Safety, Codes and Standards, Permitting

Partners

- National Labs: Sandia*, NREL*, Argonne
- H2USA Hydrogen Fueling Station Working Group
- California Air Resources Board
- DOE-EERE-FCTO

**Task Co-Leads*

Objective and Relevance

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

- FY15 Impacts:
  - Provide a detailed view of how these stations fit in greenfield and existing sites in relation to the NFPA 2 standard
  - Help station developers quickly evaluate the suitability of their sites for a particular station type and capacity.
  - Provide station developers and local authorities a complete picture of the devices, components, and associated costs that make up a station
  - Provide a tool that the H2USA financing and market support and acceleration working groups can use to develop station rollout scenarios
  - Promote common component sizing and interchangeability

Approach

H2FIRST Team
H2USA
ANL, DOE

Utilization, capacity, size, dispenser…

1. Define parameters and ranges

H2FIRST Team
H2USA
ANL, DOE

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

2. Specify cost data and metrics. Review.

ANL with input from H2FIRST Team and DOE*

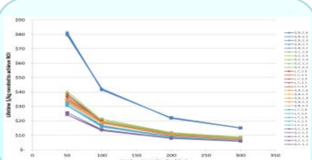
HRSAM Model Development

H2FIRST Team

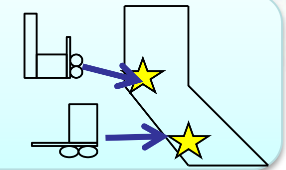
Station	Utilization	Capacity	Dispensers
1	20%	50	1
2	Ramp	100	1
3	Ramp	200	2
	…	…	…
N	…	…	…

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

H2FIRST Team with review by DOE

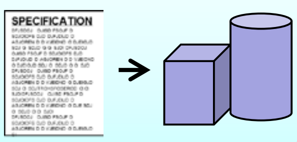


4. Station concept selection based on comparative economics and technical feasibility



H2FIRST Team with inputs from CARB & literature

5. Match station concepts to market needs



H2FIRST Team

6. Alignment of designs to actual equipment

H2FIRST Team

7. Station designs

*Leverage of other DOE-EERE funded work

Approach

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

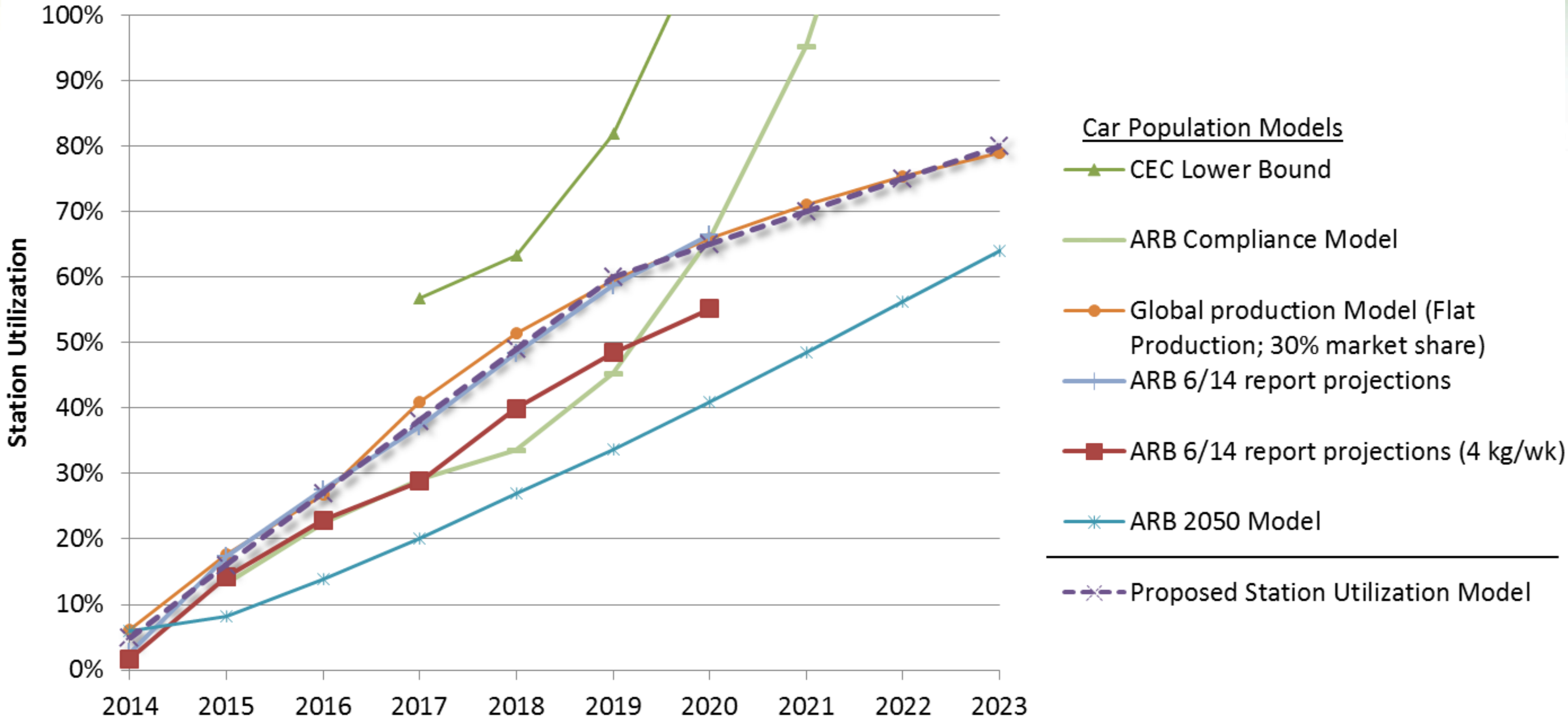
- Leveraging
  - H2FIRST team leveraged other DOE-EERE work through the use of the HRSAM economic model
  - The team also leveraged market analysis and rollout strategy work done by the State of California (ARB) and the California Fuel Cell Partnership

Accomplishments: Summary

- 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, year-by-year FCEV rollout scenario compilation and assessment
  - 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 and comparison of HRSAM- and BOM-predicted equipment and materials costs
  - Costs of 120 station permutations: capital cost and station contribution to cost of hydrogen, including effect of different utilization scenarios

Useful to: Station developers, municipalities, local authorities/code officials, finance and planning groups

Accomplishment: Determined station parameters with near-term ranges of interest



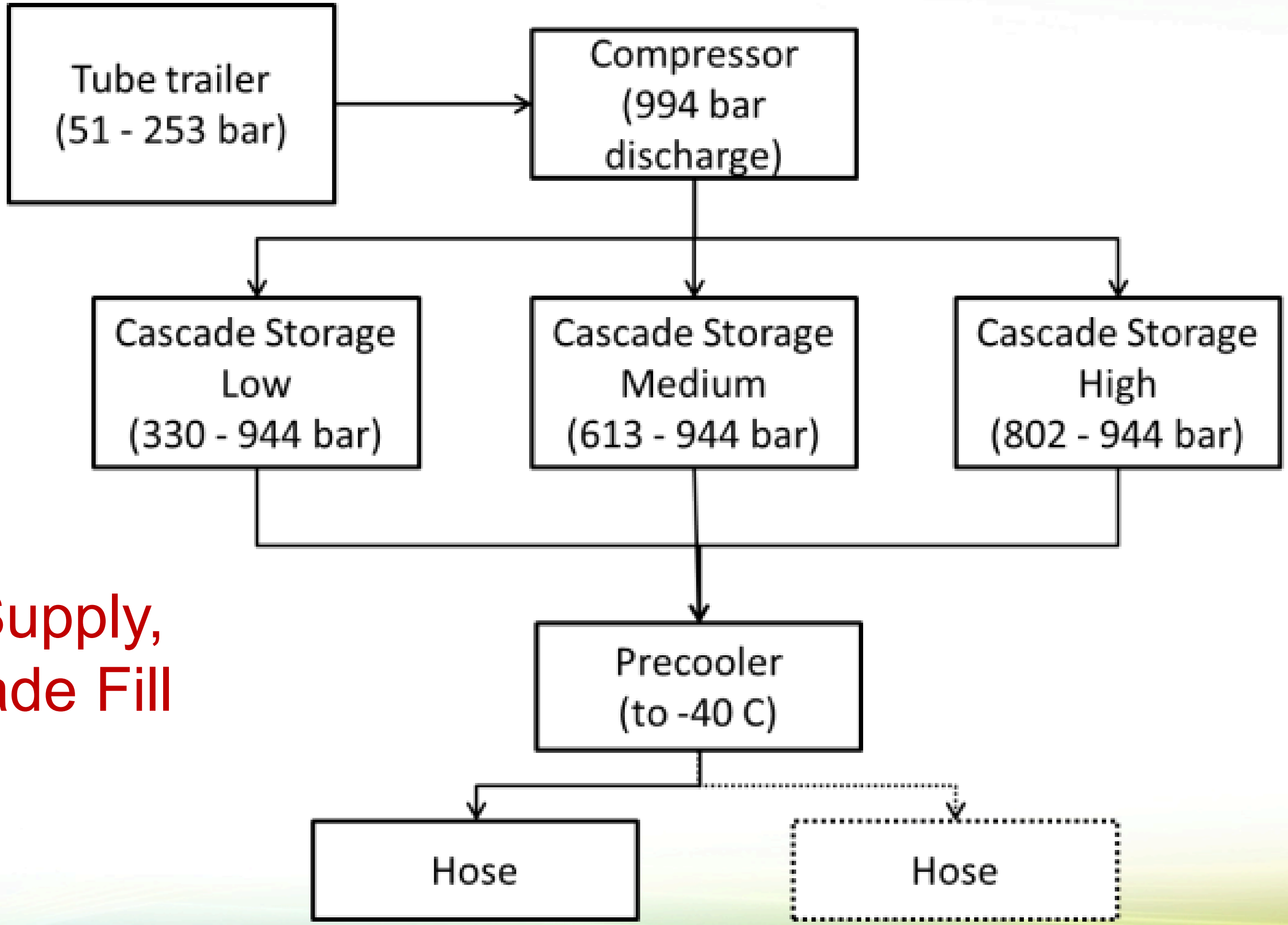
Average network utilization was estimated from station growth and vehicle roll-out scenarios and modeled to increase from 5% to 80% over the next 10 years

Accomplishment: 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

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

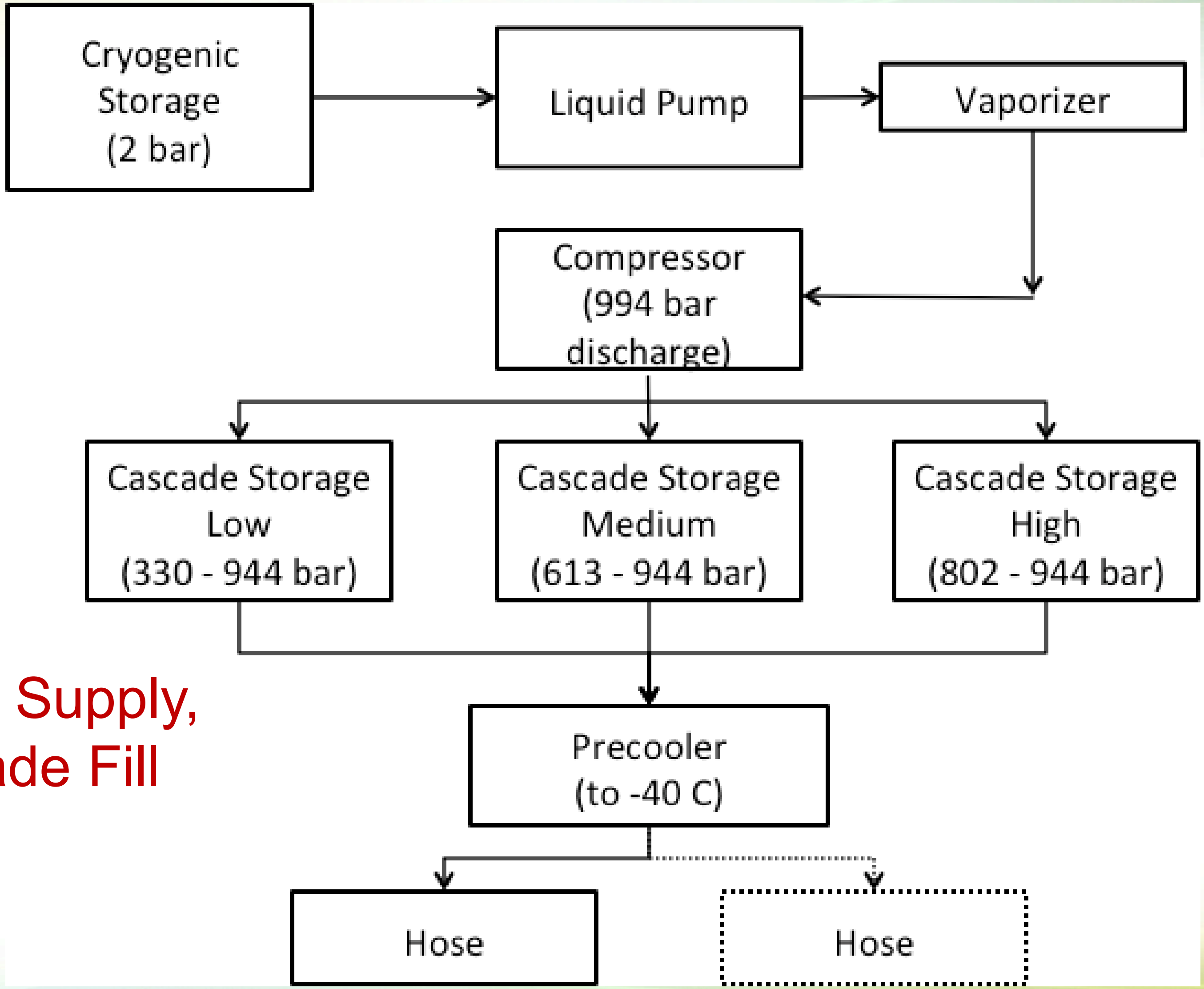
Common station designs



Gas Supply,
Cascade Fill

Three basic station designs were considered in the economic analysis

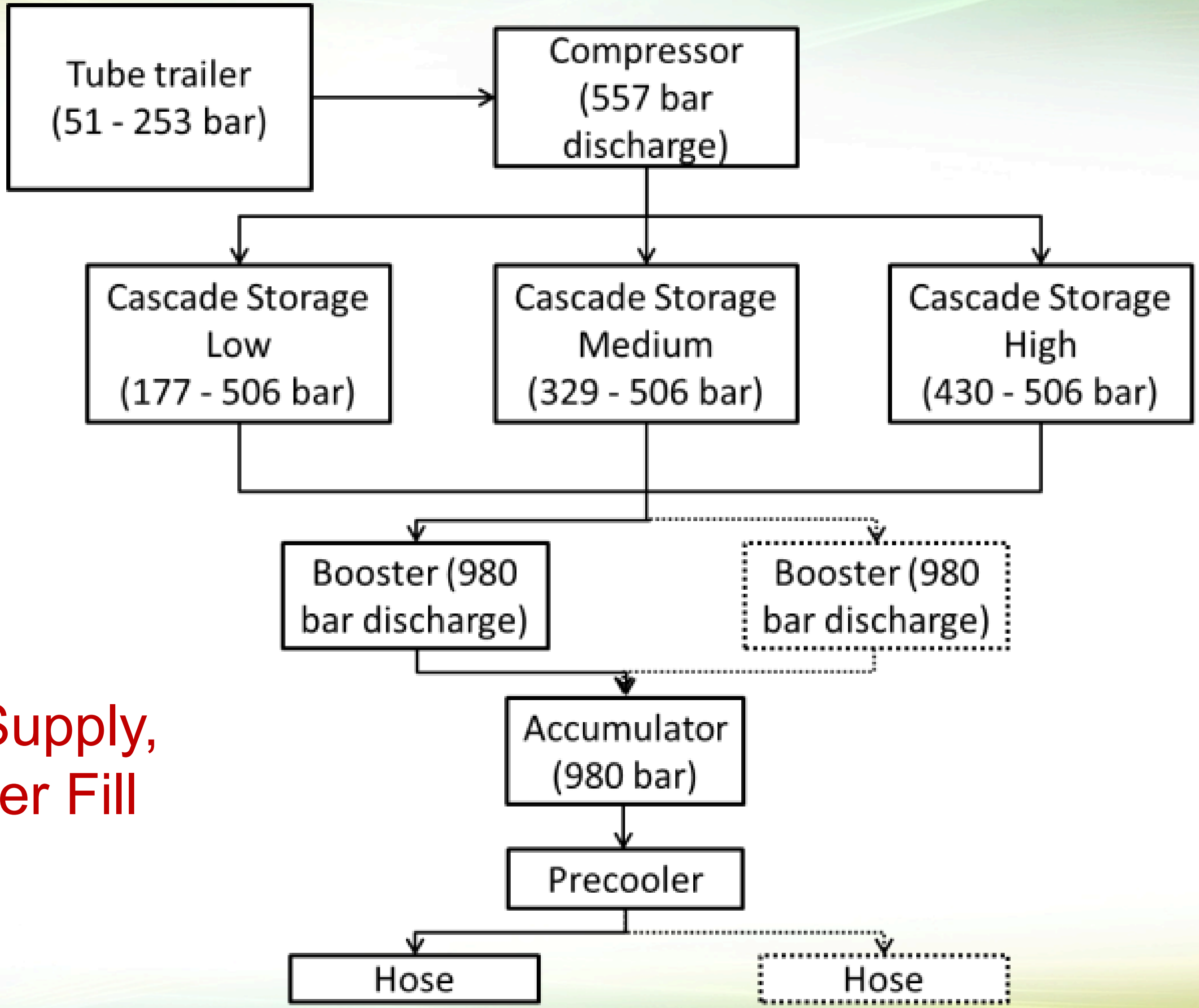
Common station designs



Liquid Supply, Cascade Fill

Three basic station designs were considered in the economic analysis

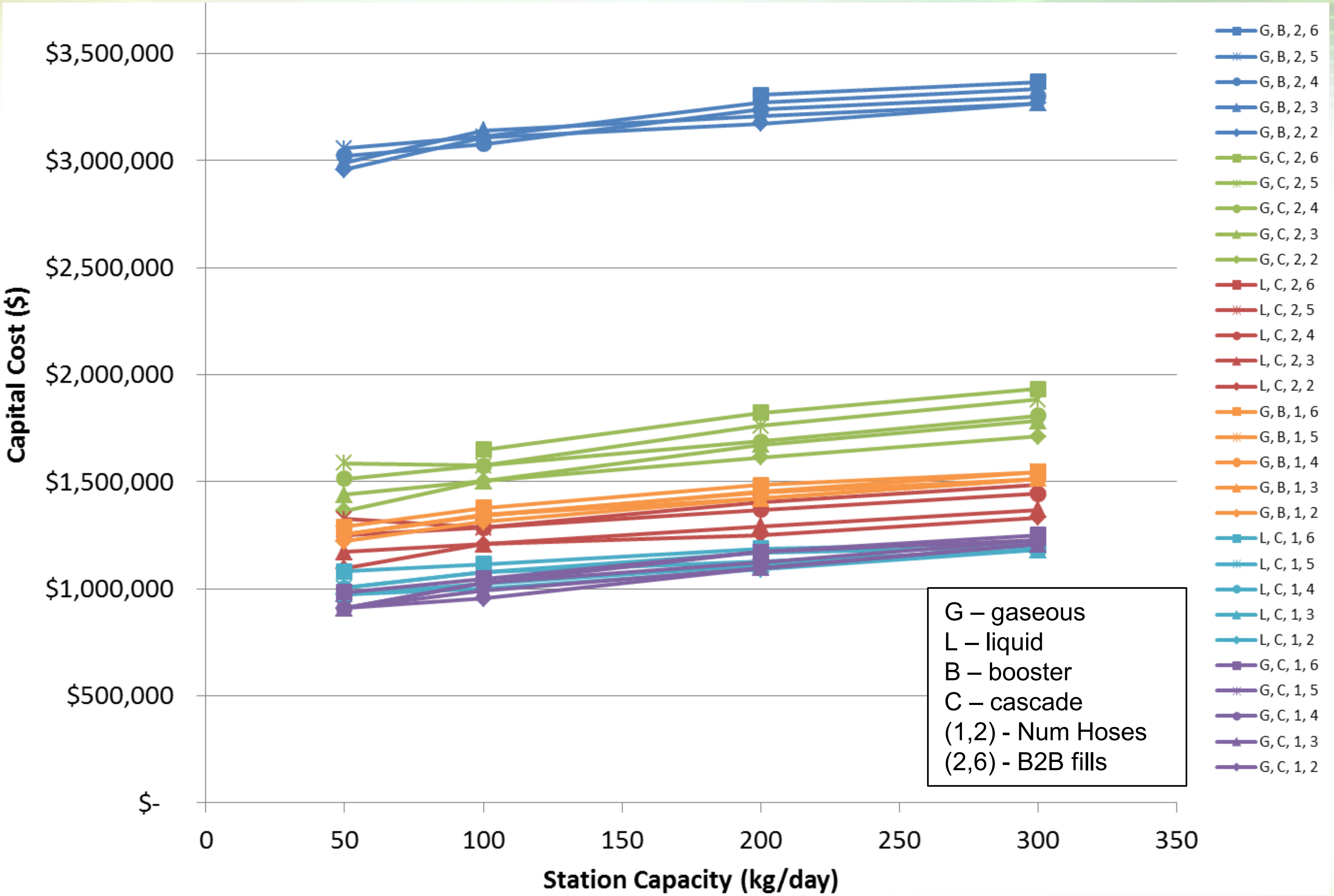
Common station designs



Gas Supply, Booster Fill

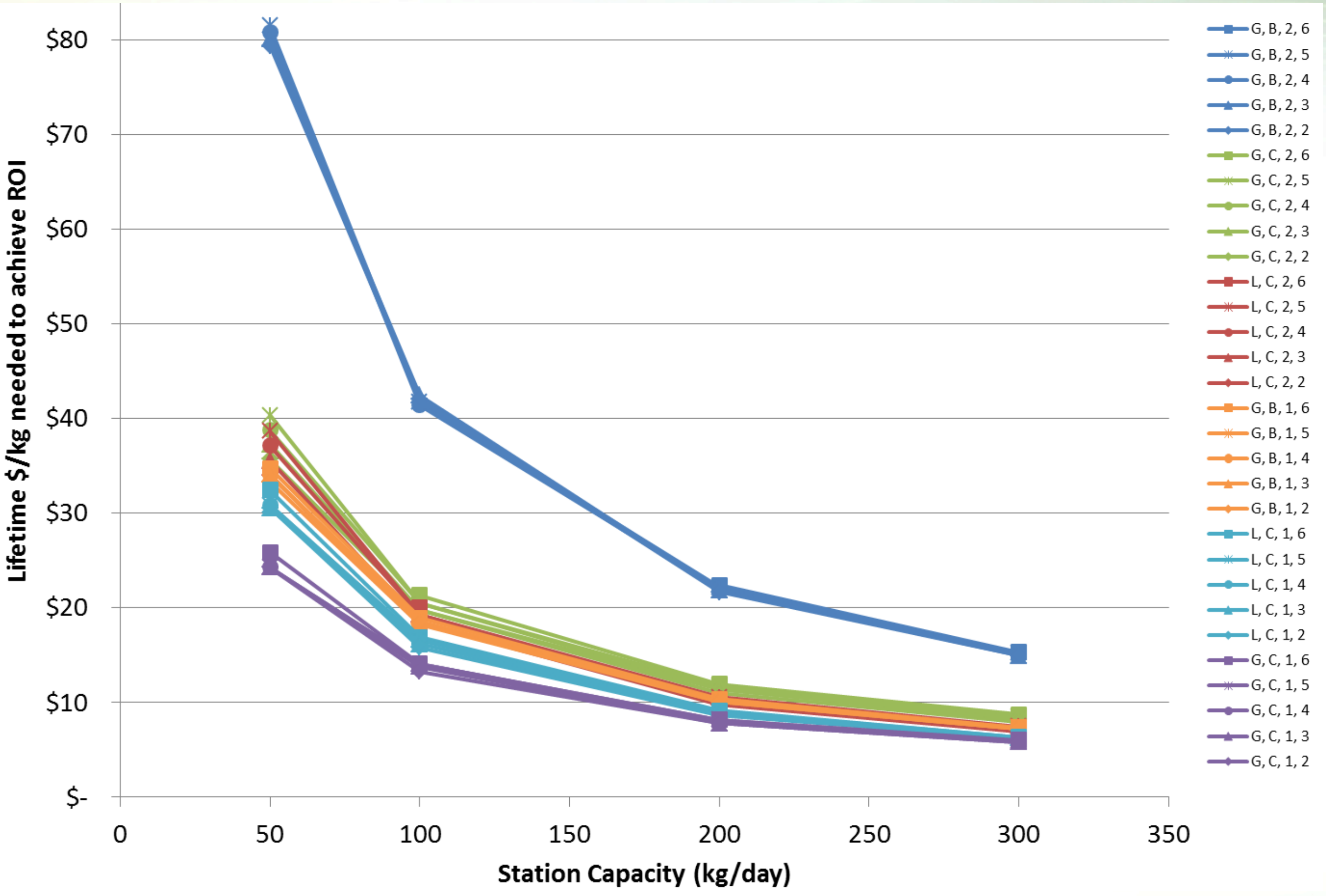
Three basic station designs were considered in the economic analysis

Accomplishment: Station capital cost



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

Accomplishment: Station contribution to the cost of hydrogen



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

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

Accomplishments: Assessed market needs

H2FIRST

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

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

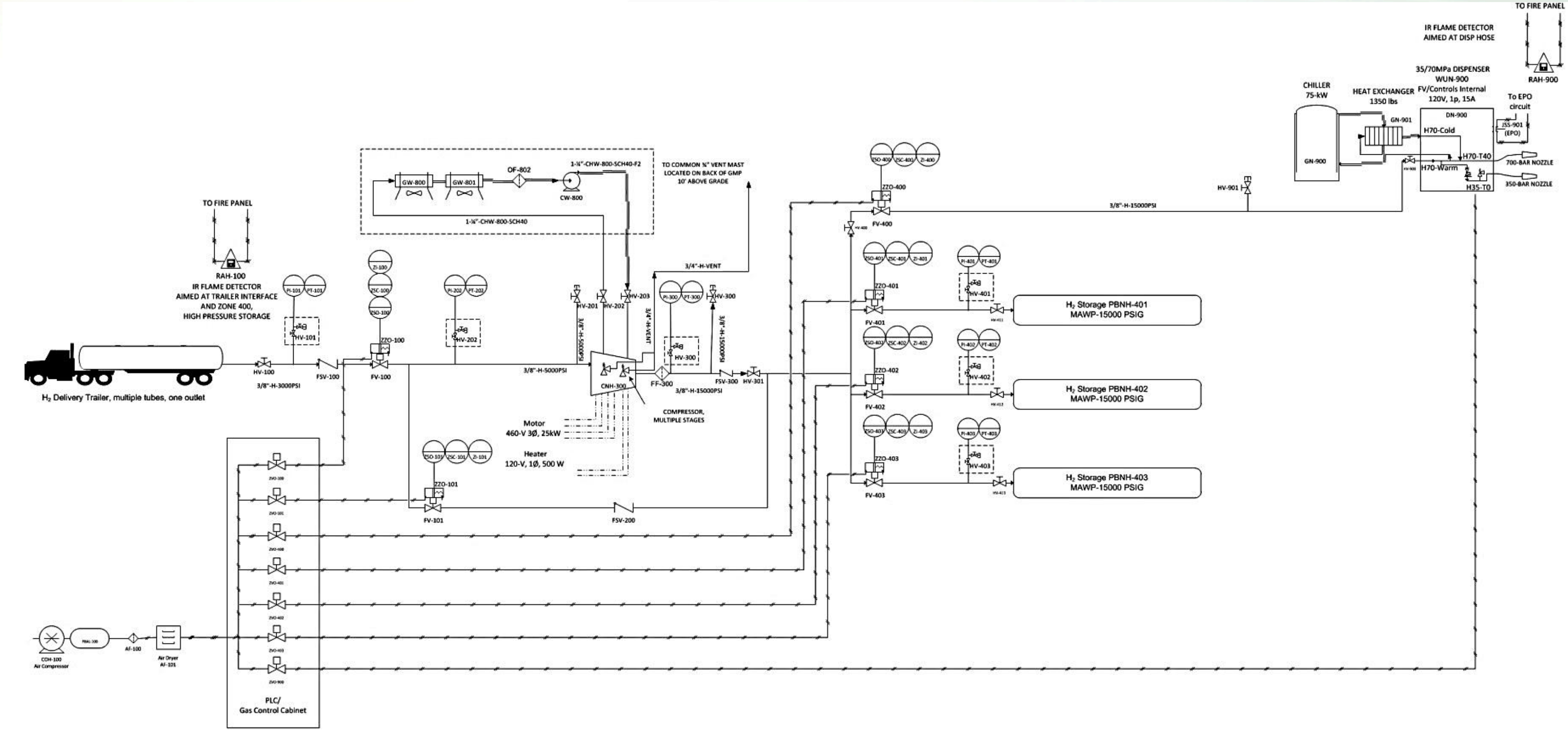
Accomplishments: Matched economically best-performing station design possibilities with market needs

H2FIRST

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

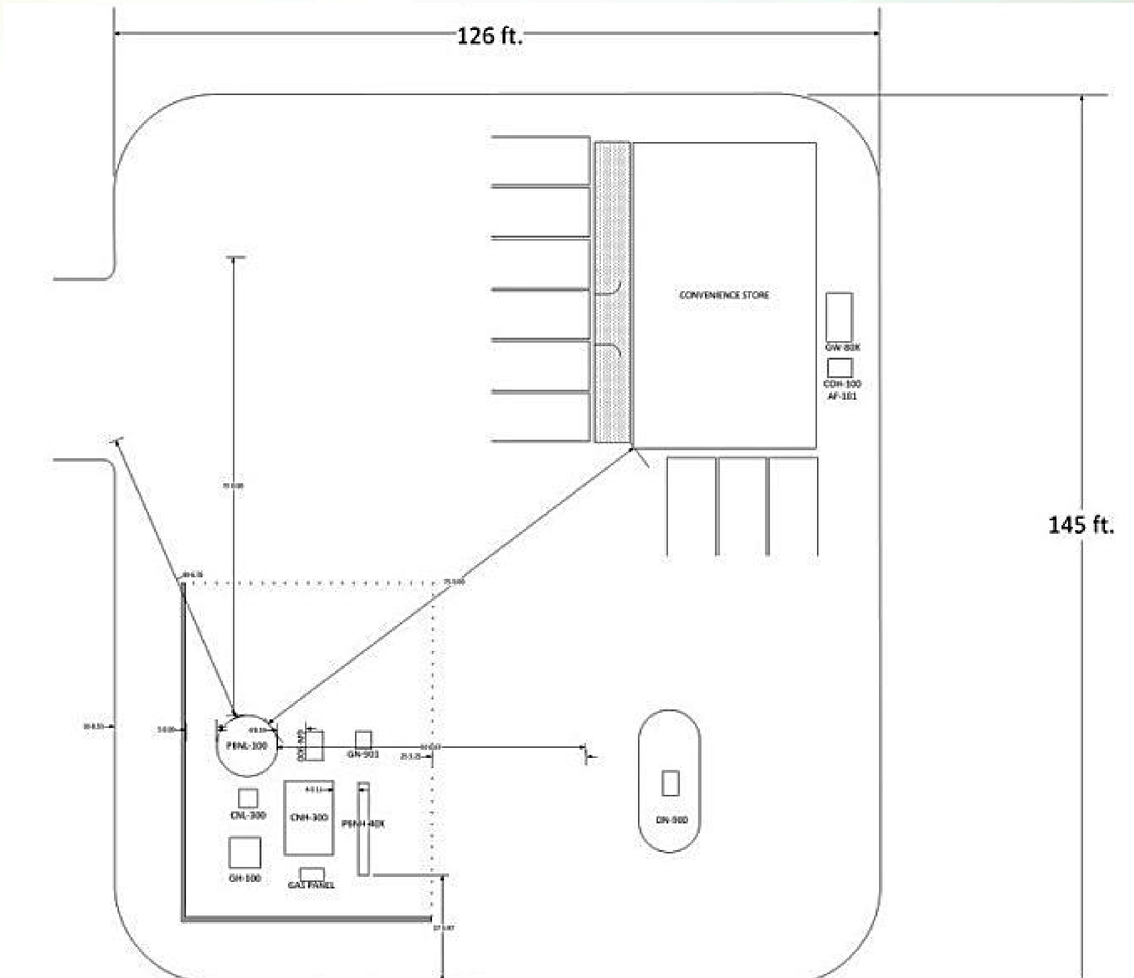
The top-performing station types that best-matched market needs were selected for detailed conceptual design.

Produced Piping and Instrumentation Diagrams (P&IDs)…



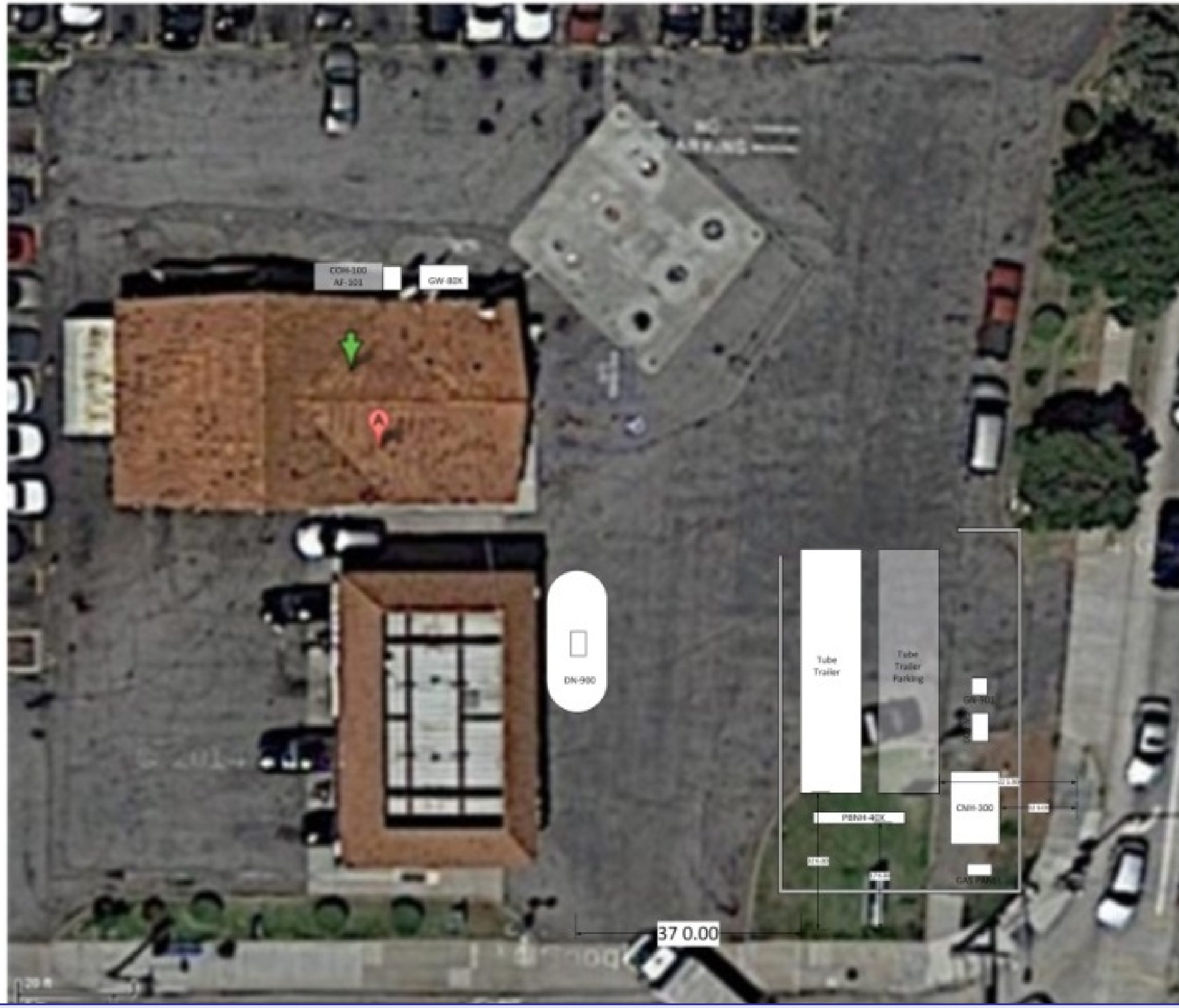
The P&IDs illustrate typical system designs for gaseous and liquid delivery stations.

…physical layouts considering NFPA-2 setback distance requirements, for greenfield…



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

…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.

H2FIRST

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.

Accomplishments: Supported HRSAM-predicted equipment costs through comparison to costs estimated from BOMs

Profile	Delivery	Capacity (kg/day)	Consec. Fills	Hoses	HRSAM Equip. Costs		BOM Equip. Costs
High Use Commuter	Gaseous	300	6	1	**$753,491**	↔	**$767,000**
High Use Commuter	Liquid	300	5	2	**$933,350**	↔	**$998,000**
Low Use Commuter	Gaseous	200	3	1	**$660,486**	↔	**$742,000**
Intermittent	Gaseous	100	2	1	**$573,605**	↔	**$717,000**

HRSAM uses major equipment costs as representative of all material and equipment costs. In the range studied, these were close to the BOM estimates which consider all station equipment and materials individually.

Collaborations

H2FIRST itself is a **SNL-NREL** co-led, collaborative project.

Other collaborators:

- **ANL** modified HDSAM to HRSAM
- **H2USA** (primarily HFSWG)
  - HRSAM development
  - Reviewed final report
  - Reviewed parameters and ranges of interest
- **FCTO** team assisted with:
  - HRSAM development
  - Parameter definition
  - Vehicle and station roll-out and utilization scenarios
- **California ARB** participated in informal discussions on vehicle and station roll-out scenarios

Remaining Barriers and Challenges for Near-Term Infrastructure Rollout

- **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.

Potential Future *Reference Station* Work

- Assess technological and economic changes
- Re-evaluate parameter ranges of interest to near-term stations
- Re-assess economic potential of new station concepts, for example:
  - On-site generation
  - Light/heavy duty mixed stations
- Assist with assessing economic impact of different business practices
- Produce new station designs that reflect these changes

Technology Transfer Activities

- HRSAM is intended to be publically released.
- No other technologies were developed through this project.

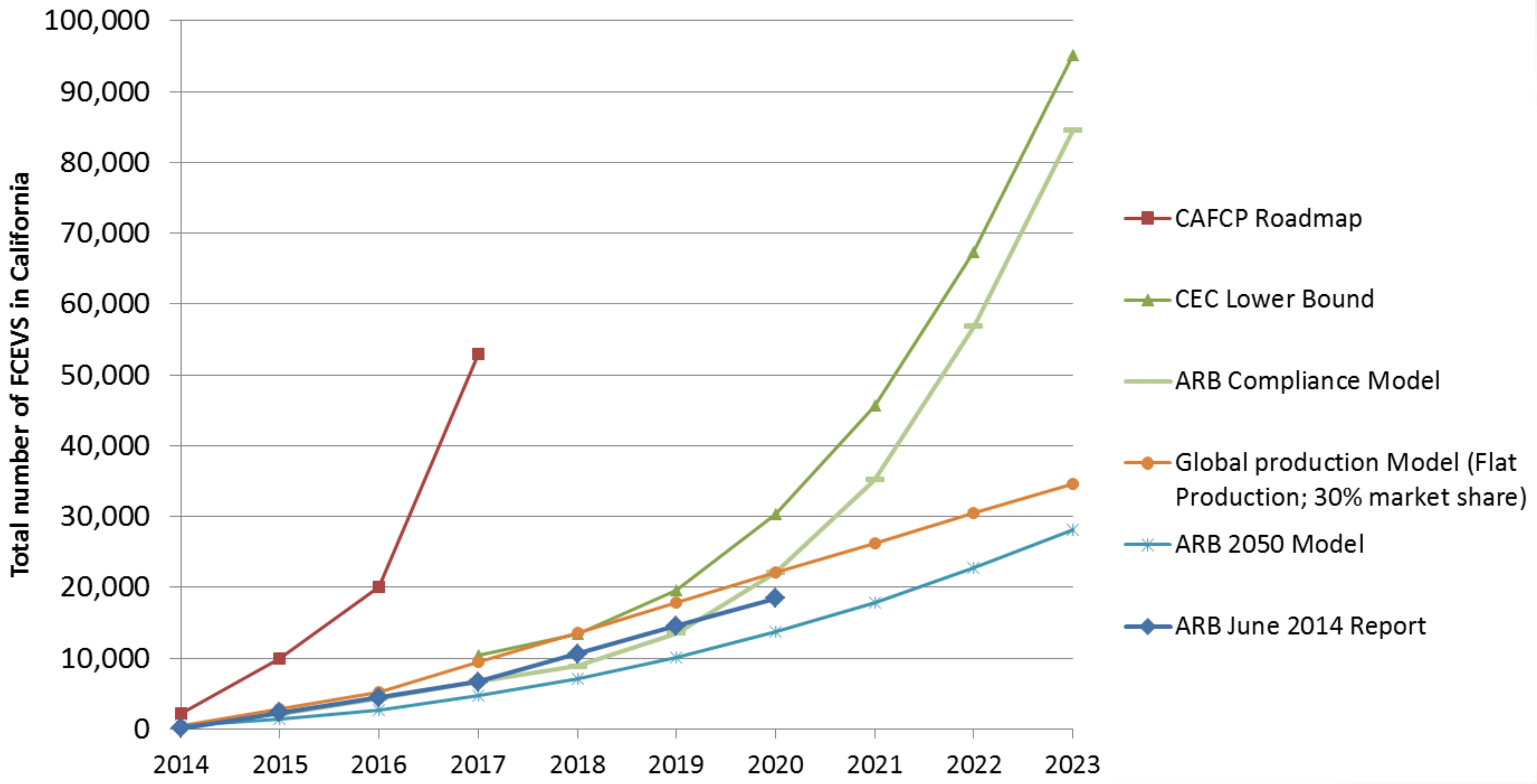
Summary

H2FIRST

- The Reference Station Design Task has produced results that include:
  - Vehicle roll-out scenario compilation and assessment
  - 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

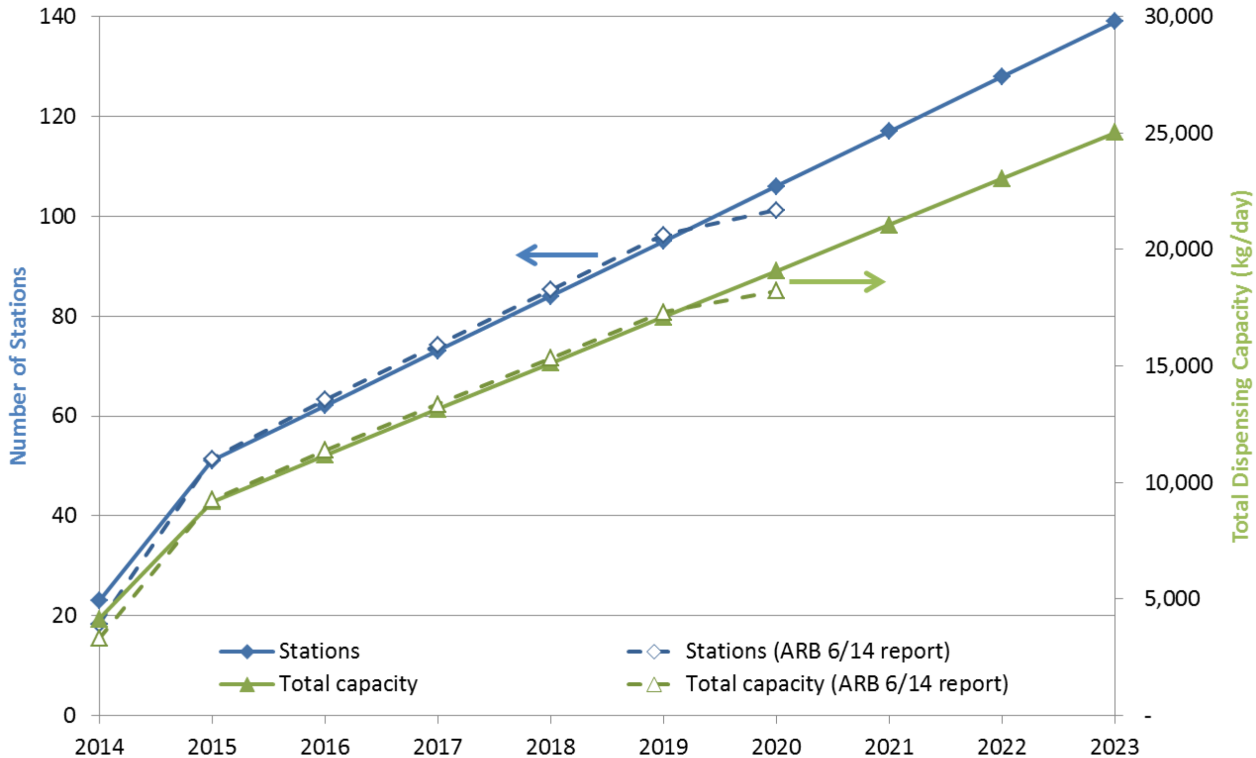
Technical Back-up Slides

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

Full cost comparison of station types