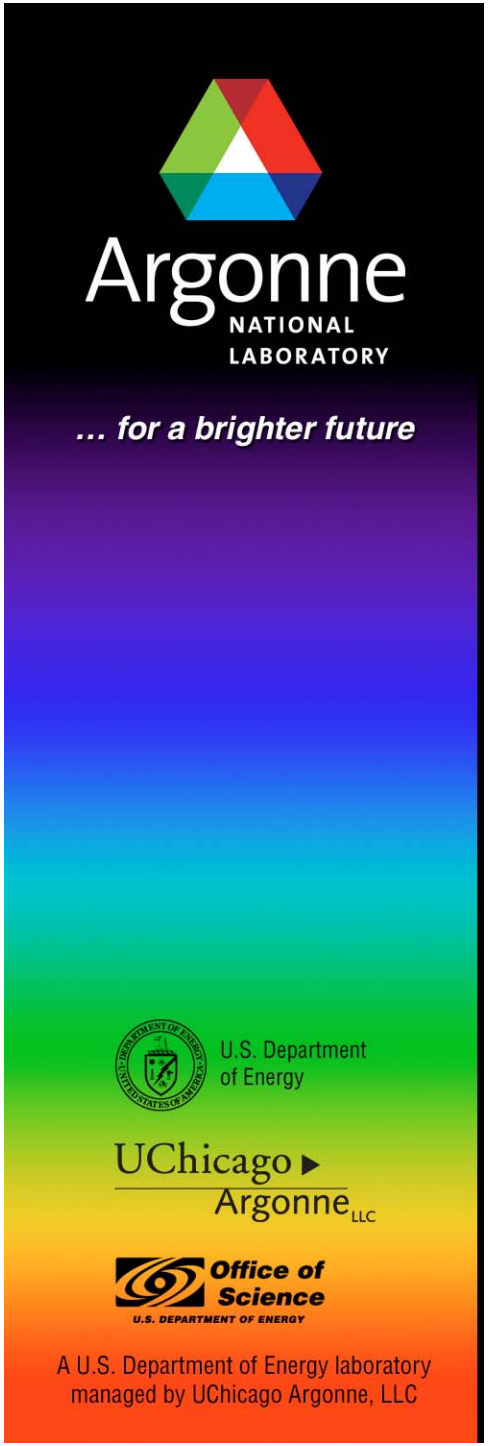

Technical and Economic Analysis of Hydrogen Refueling Stations

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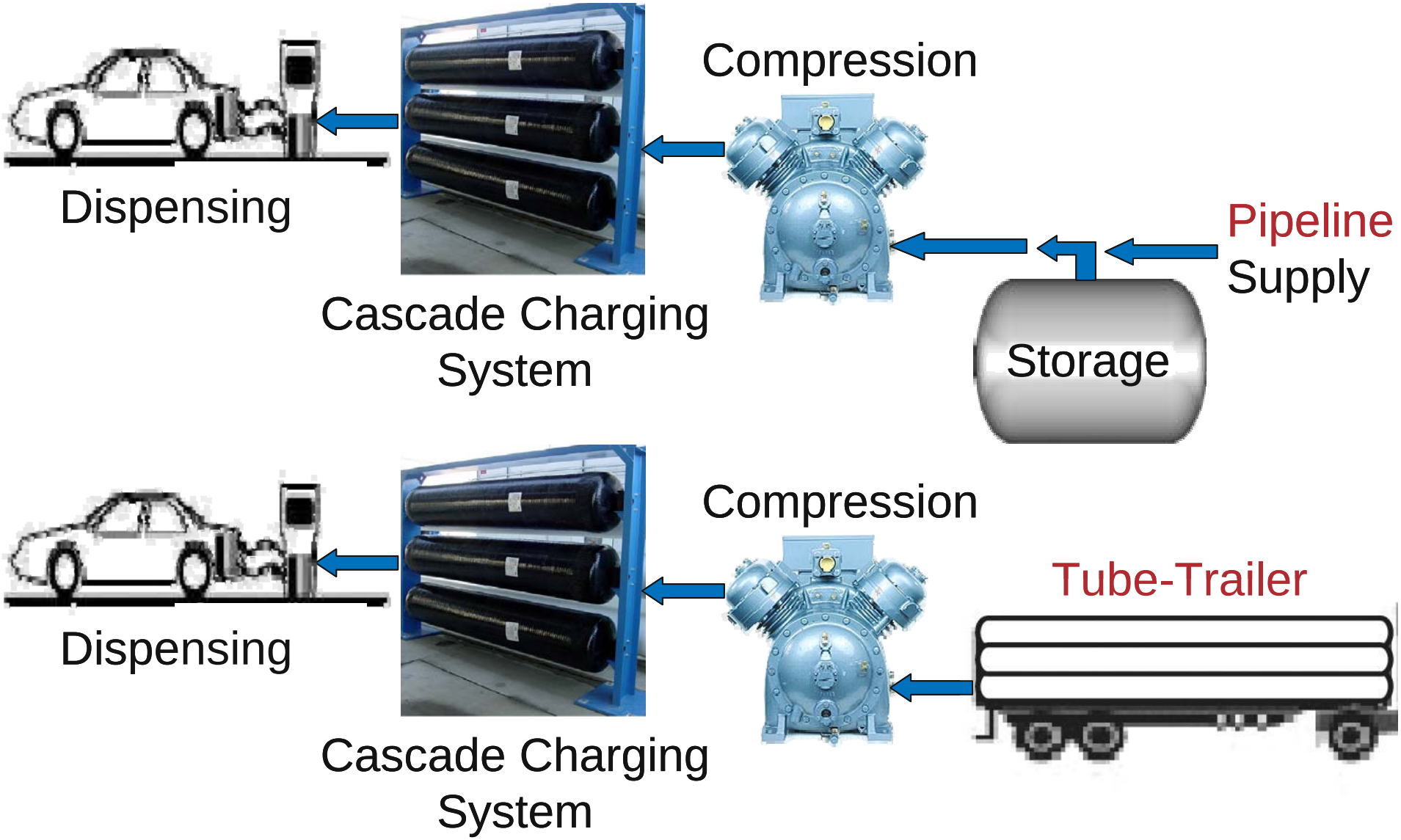
National Hydrogen Association
Sacramento, CA
April 1, 2008

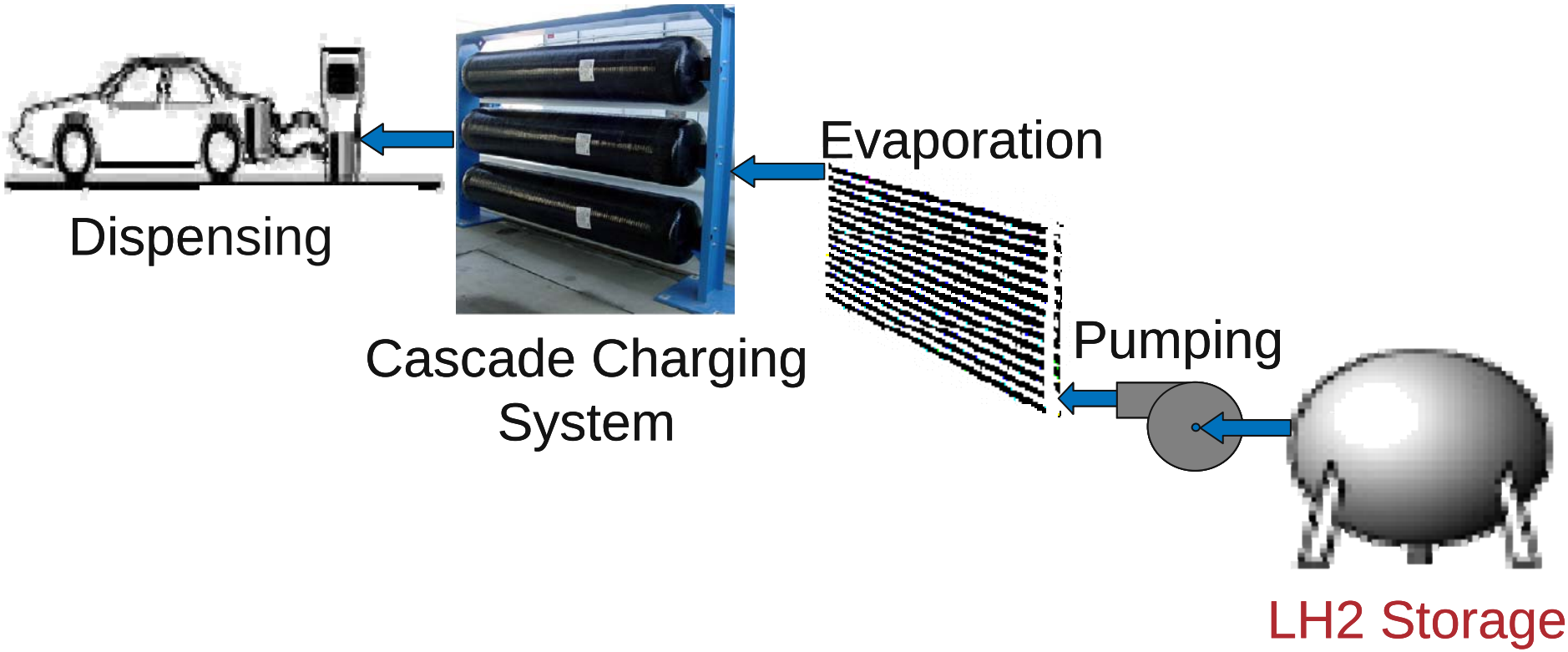
Presentation Overview

- Refueling Station Configuration Options
- Station Storage Requirements
- Design and Cost Assumptions
- Optimization
- Results
- Summary and Conclusions

Gaseous Refueling Station Configuration Options

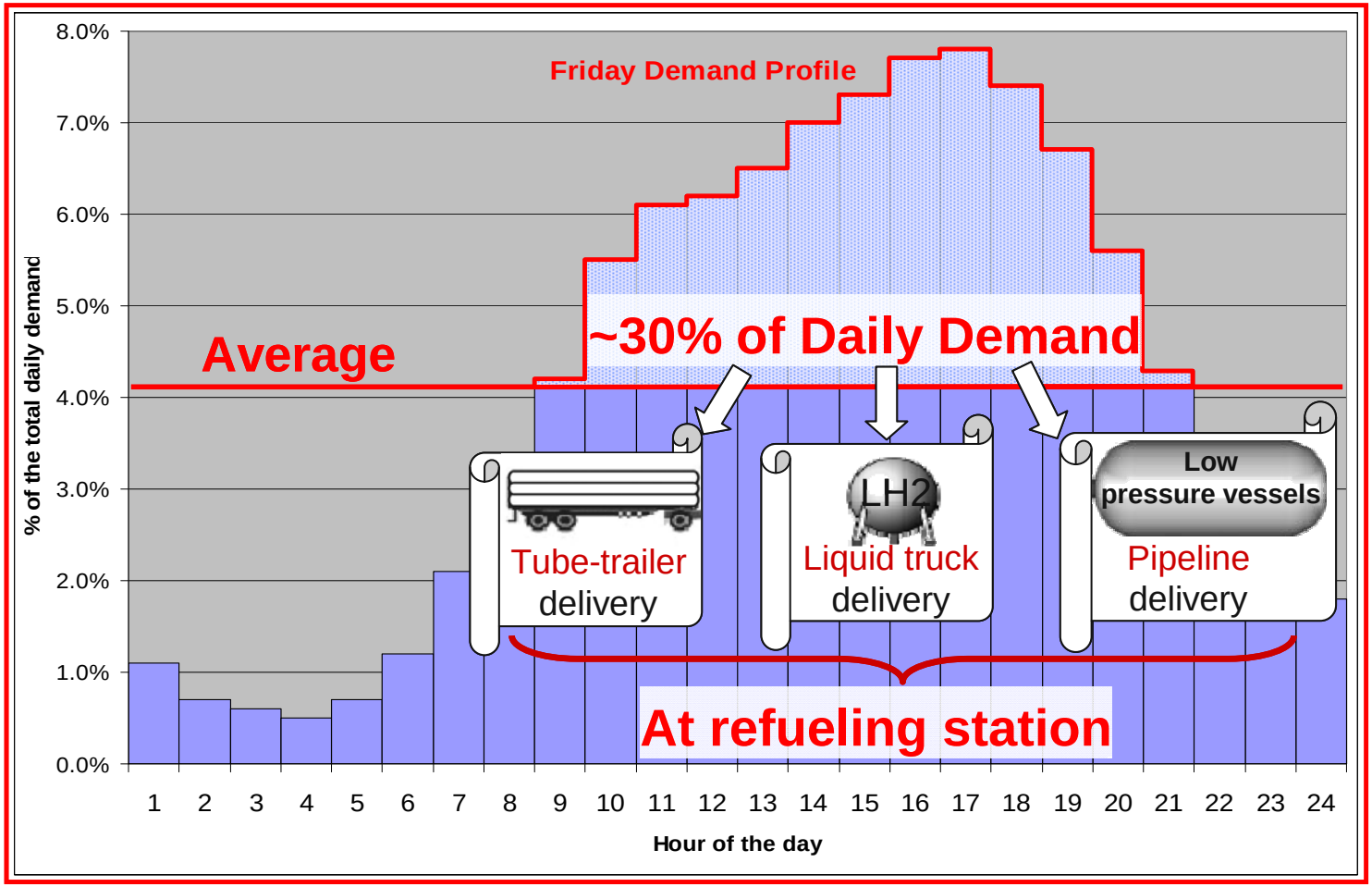


Liquid Refueling Station Configuration for Liquid H2 Delivery by Trucks



Station MINIMUM Storage Requirement

-Refueling station storage requires a minimum of 1/3 of the station daily demand



STATION DESIGN AND COST ASSUMPTIONS

Cascade Charging System (NOT Effective for Storage)

- ASTM SA372, Grade J, Class 70 low alloy steel
- Vessels are 16 inches diameter, 30 feet long
  - *6500 psia vessel holds 67 kg*
  - **$926/kg of hydrogen (uninstalled)**

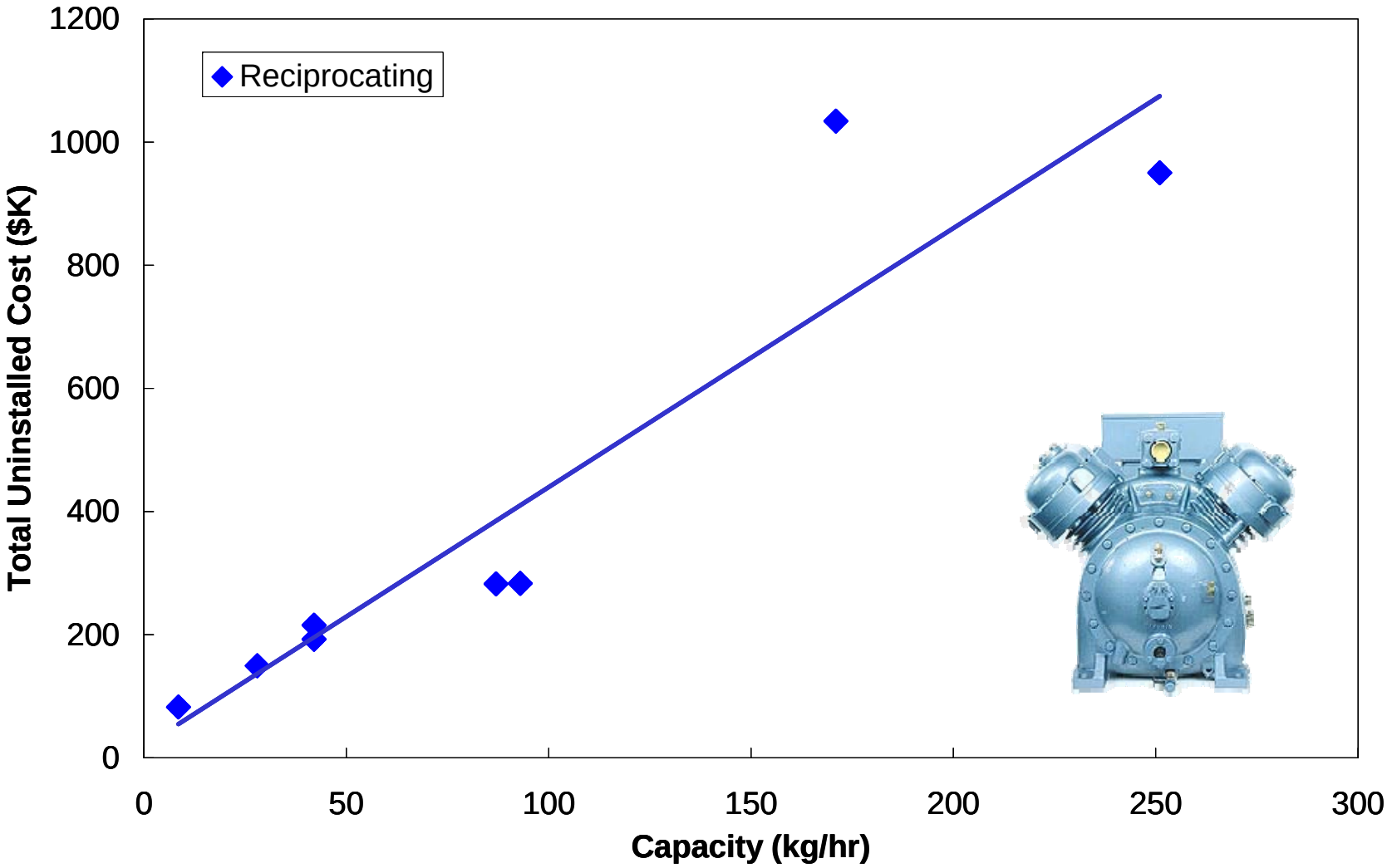
- Recommended inputs to H2A model
  - *$1204/kg of hydrogen, including shipping, auxiliaries, and installation*
  - *No economies of scale*

Low Pressure Gaseous Storage

- Gas storage vessel design
  - SA516, Grade 70; 2,500 psia; 2.5 in. wall thickness
  - 4.1 ft. diameter, 24.9 ft. long, 91 kg hydrogen capacity
  - $2.30/lb of steel; $900/kg of hydrogen (uninstalled)

- Recommended inputs to H2A model
  - $1170/kg of hydrogen, including shipping, auxiliaries, and installation
  - No economies of scale

Compressor Cost

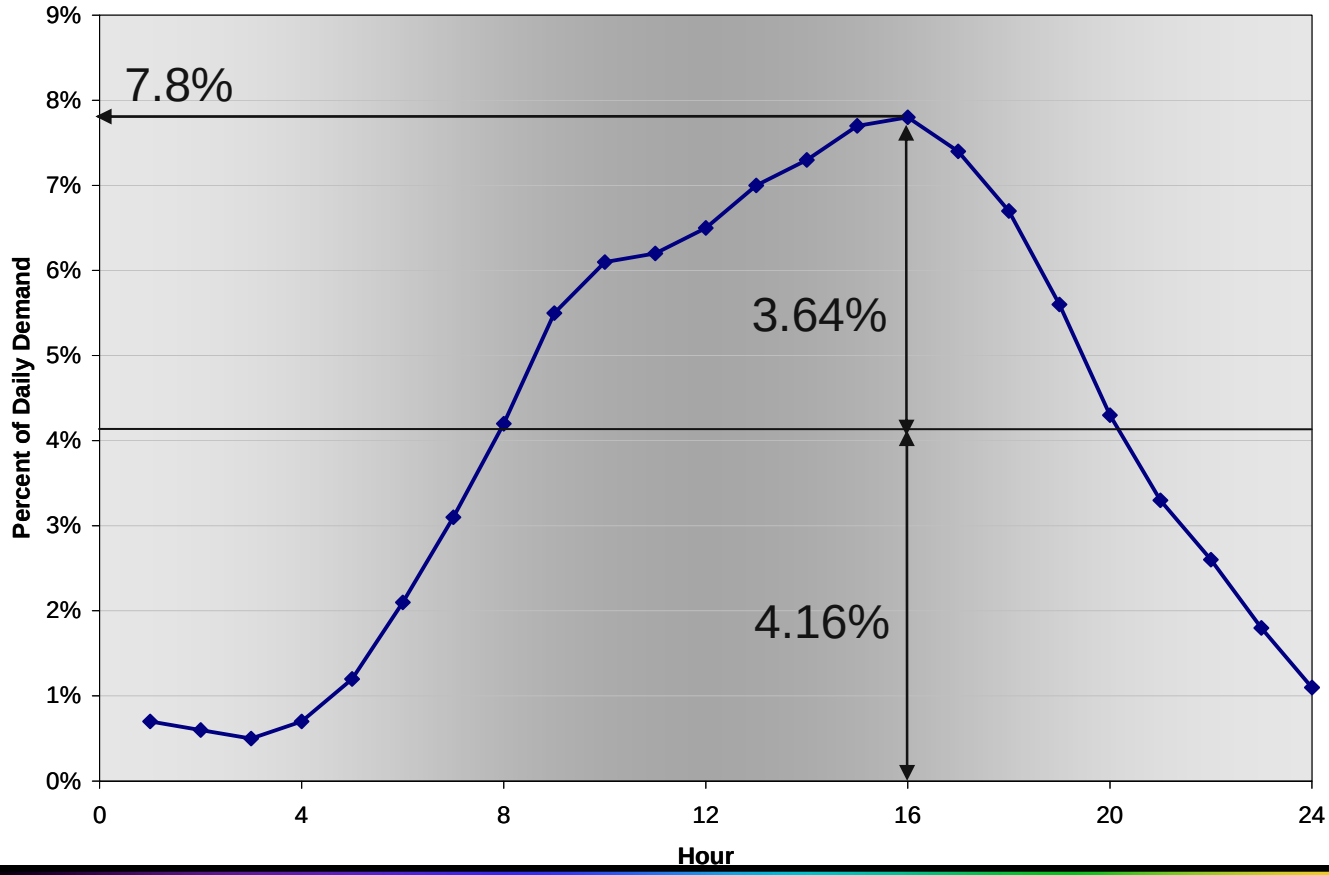


Refueling Station Optimization: Balance between Cascade & Compressor Capacities

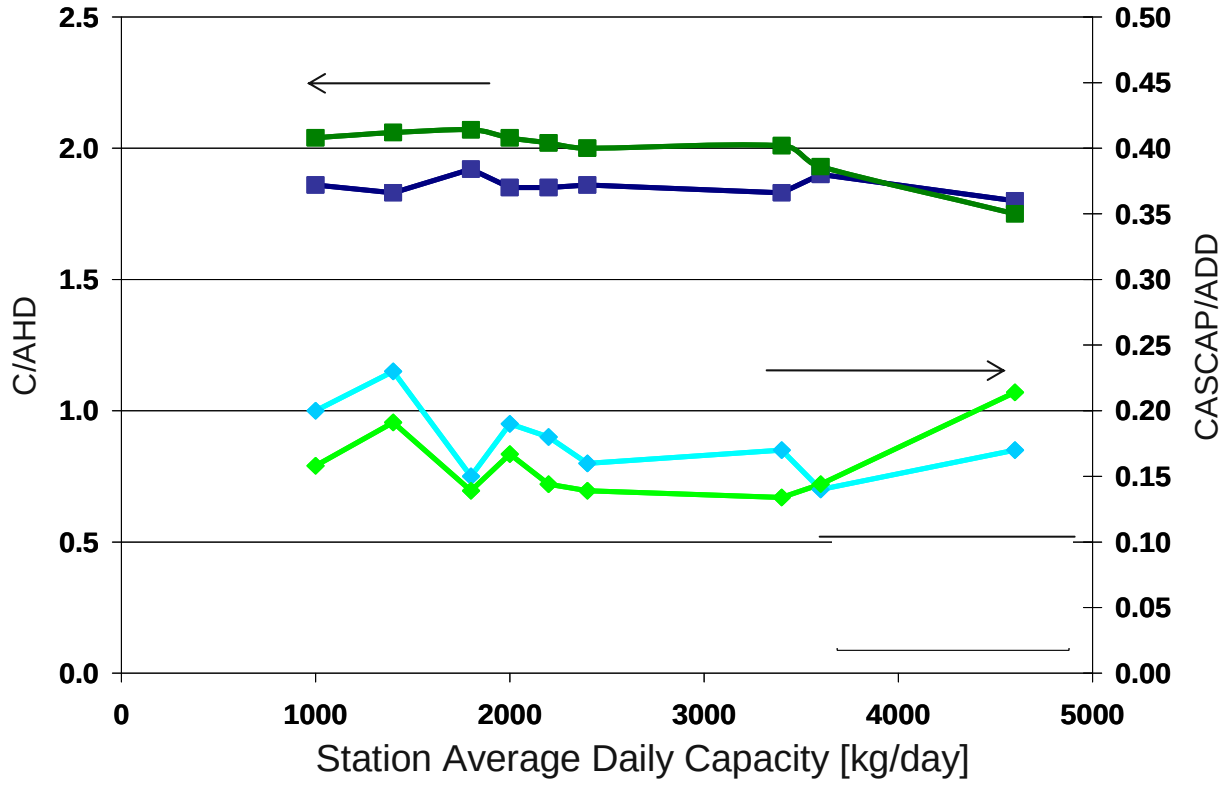
Optimum:

Compressor Capacity / Ave. Station Hourly Demand Rate ~ 2.0

Cascade Capacity / Ave. Station Daily Demand ~ 0.15



Validation: Independent Models Produced Same Result Despite Small Variations in Assumptions

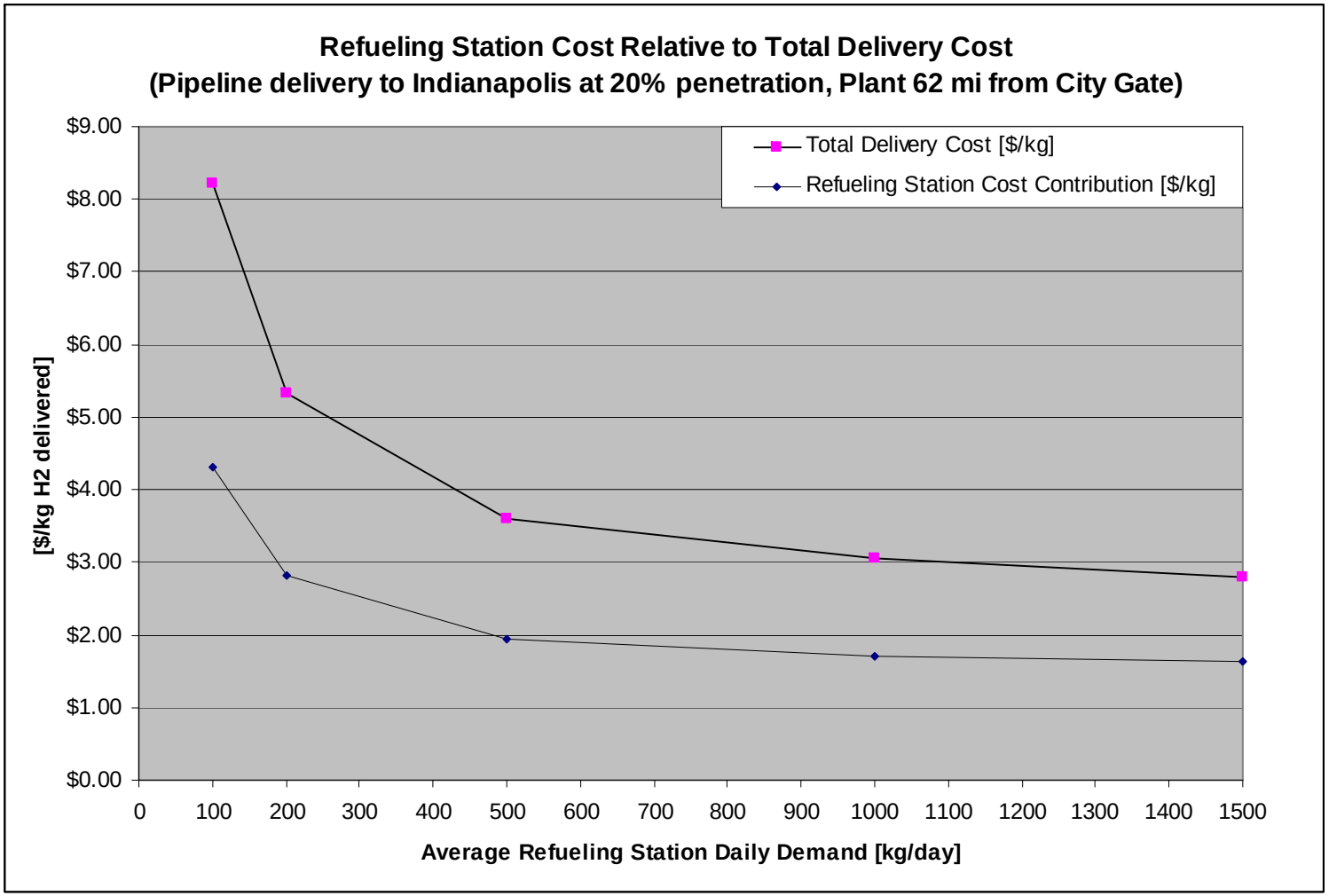


C = Compressor capacity
AHD = Average Hourly Demand
CASCAP = Cascade capacity
ADD = Average Daily Demand

RESULTS

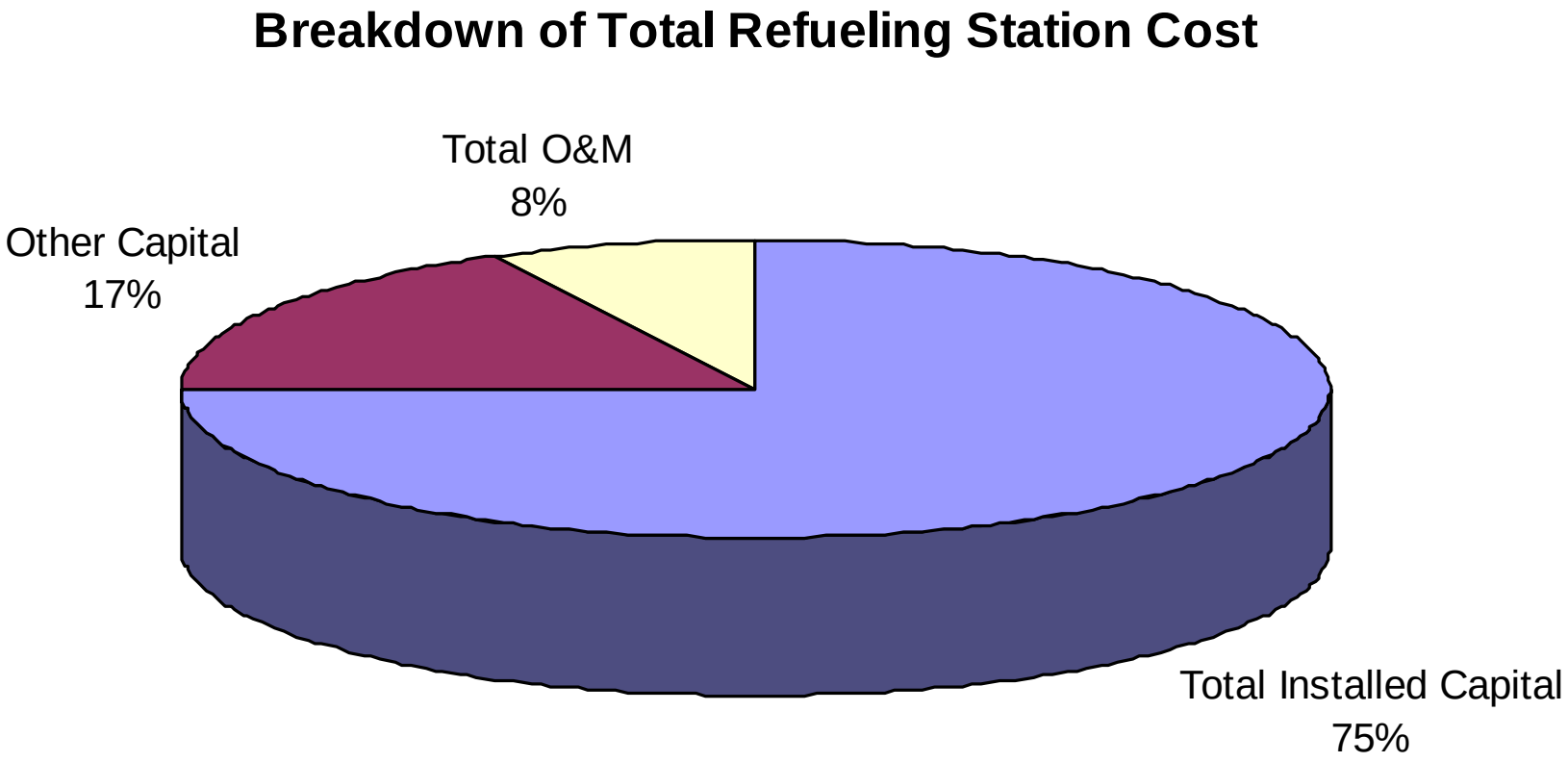
GH2 Refueling Station Cost Analysis

– Refueling station cost is a major contributor to the total delivery cost



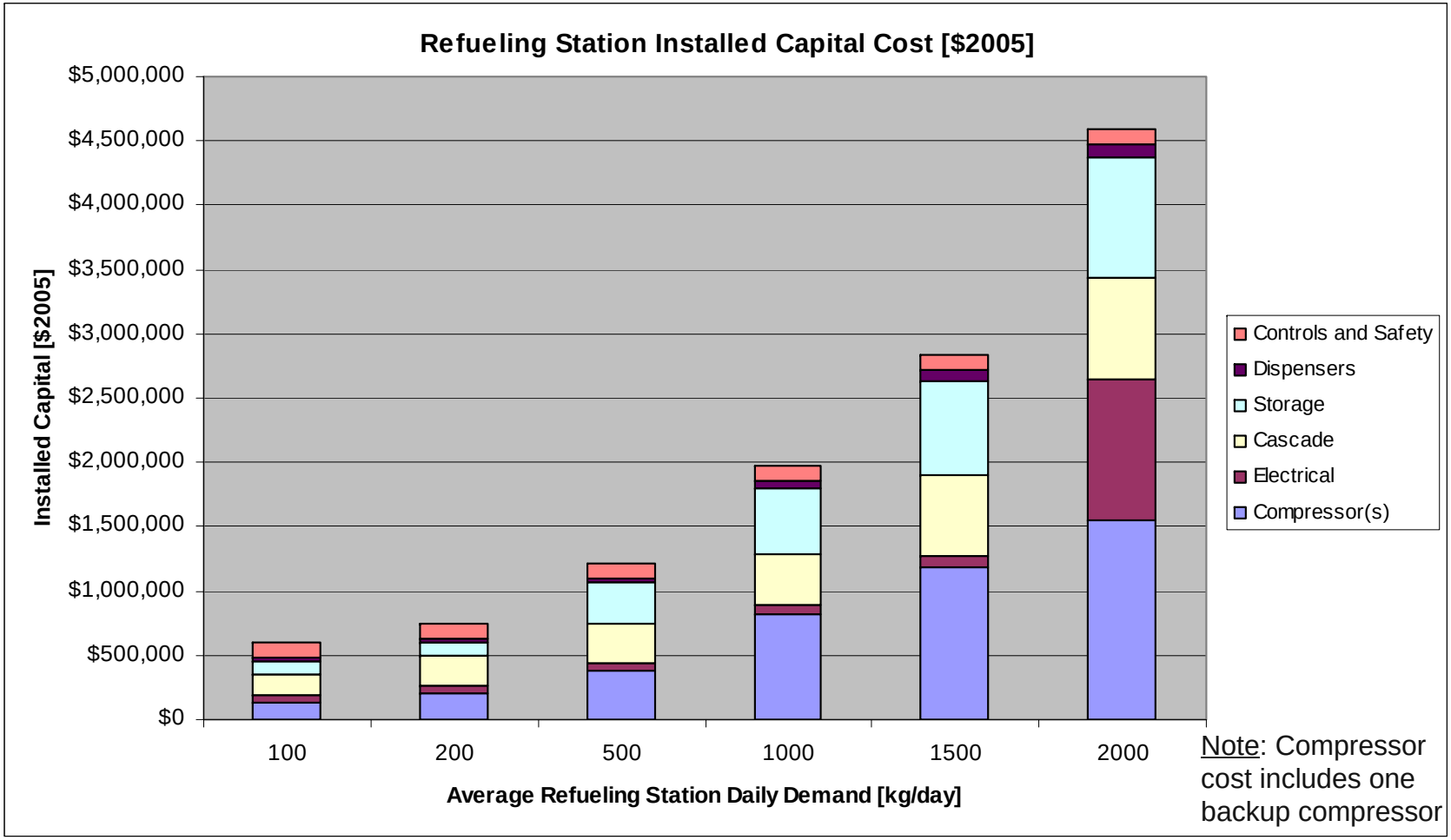
GH2 Refueling Station Cost Analysis

– Installed capital cost represents the majority of the refueling station cost



GH2 Refueling Station Cost Analysis

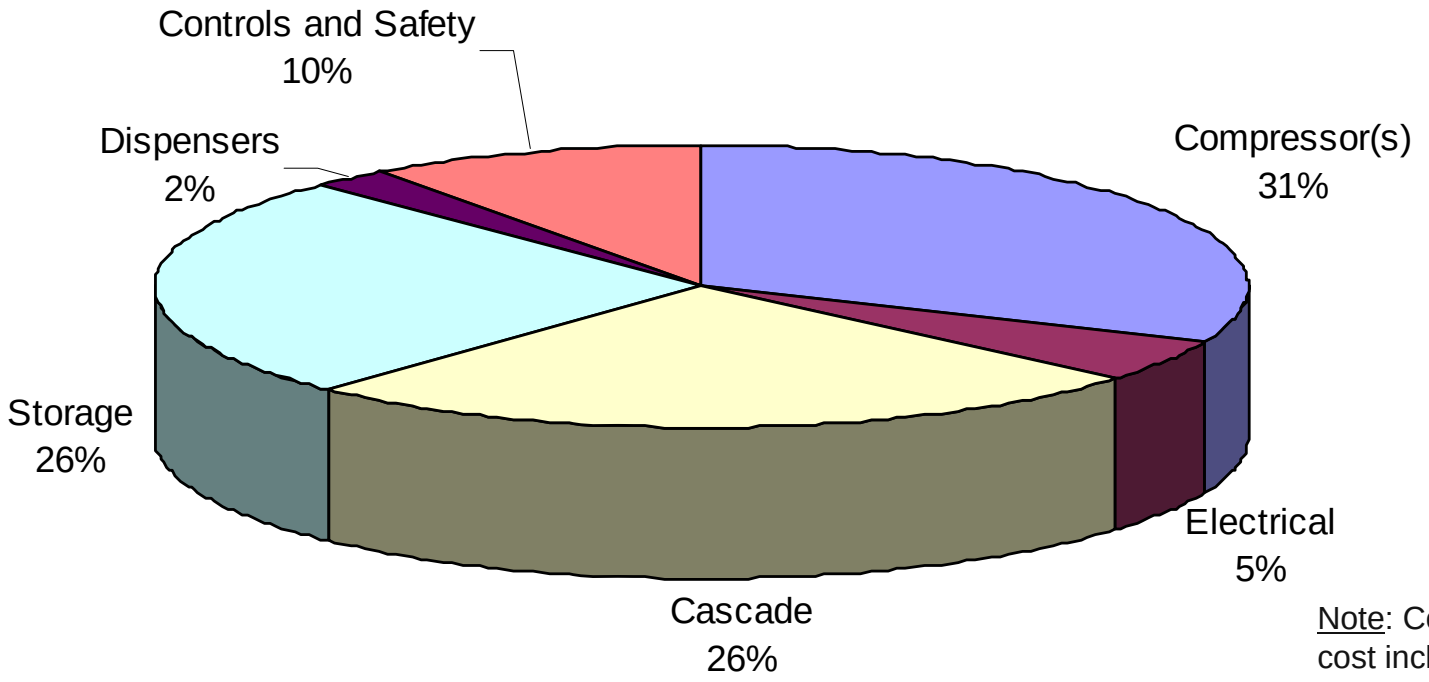
– Compressors, Cascade System, and GH2 storage are the major component contributing to the total capital cost



GH2 Refueling Station Cost Analysis

– Compressors, Cascade System, and GH2 storage are the major components contributing to total capital cost

% Cost Contribution of Refueling Station Components to Total Installed Capital [500 kg/day Station]



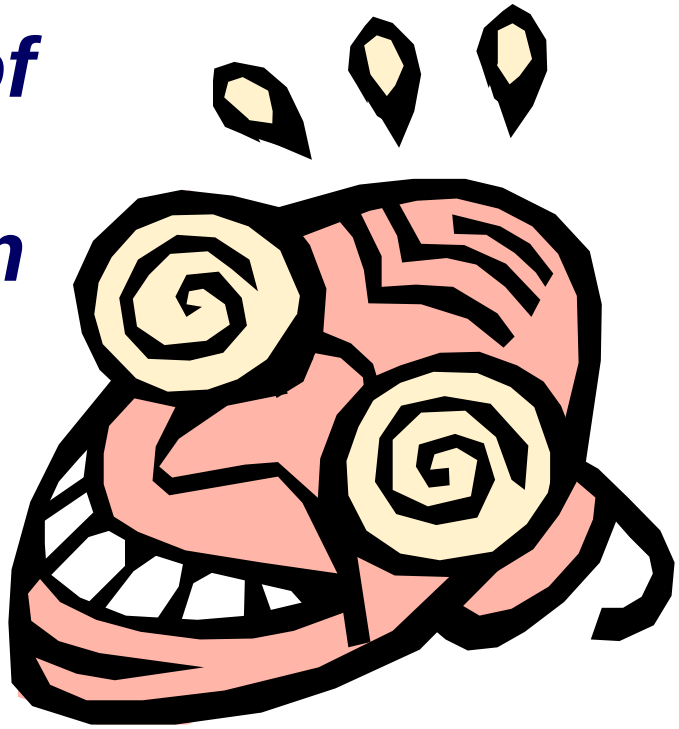
Note: Compressor cost include one backup compressor

Summary and Conclusions

- *A methodology was developed to design and optimize gaseous and liquid hydrogen refueling stations*
- *Refueling station compressors and cascade system were sized to minimize total station cost*
- *Refueling station storage requires a minimum of 1/3 of the station daily demand*
- *Compressors, cascade system, and GH2 storage are the major components contributing to the total capital cost of hydrogen delivery*
- *The total cost of the refueling station is a major contributor to the total delivery infrastructure cost*

Version 2.0 of the H2A Delivery Models will be Published SOON!

Thanks to other members of H2A/Nexant project team, USDOE Delivery Tech Team and OFCHIT



Questions??

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