H2A Delivery: Forecourt Compression & Storage Optimization (Part II)

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Objectives

- **Define the attributes of a hydrogen forecourt**
  - Number of dispensers
  - Capacity of hydrogen storage
  - Size of hydrogen compressor or pump
- **Optimize storage and compression size to minimize initial capital investment**
- **Create an optimizing methodology that allows users to input a wide variety of forecourt sizes (100-5,000 kg/day)**
- **Create a more robust calculation than that used in previous H2A model**
  - All components sized with a 70% capacity factor or hard-wired
  - Only calculated costs for 2 distinct forecourt capacities (100 and 1,500 kg/day)

Gasoline Station Baseline

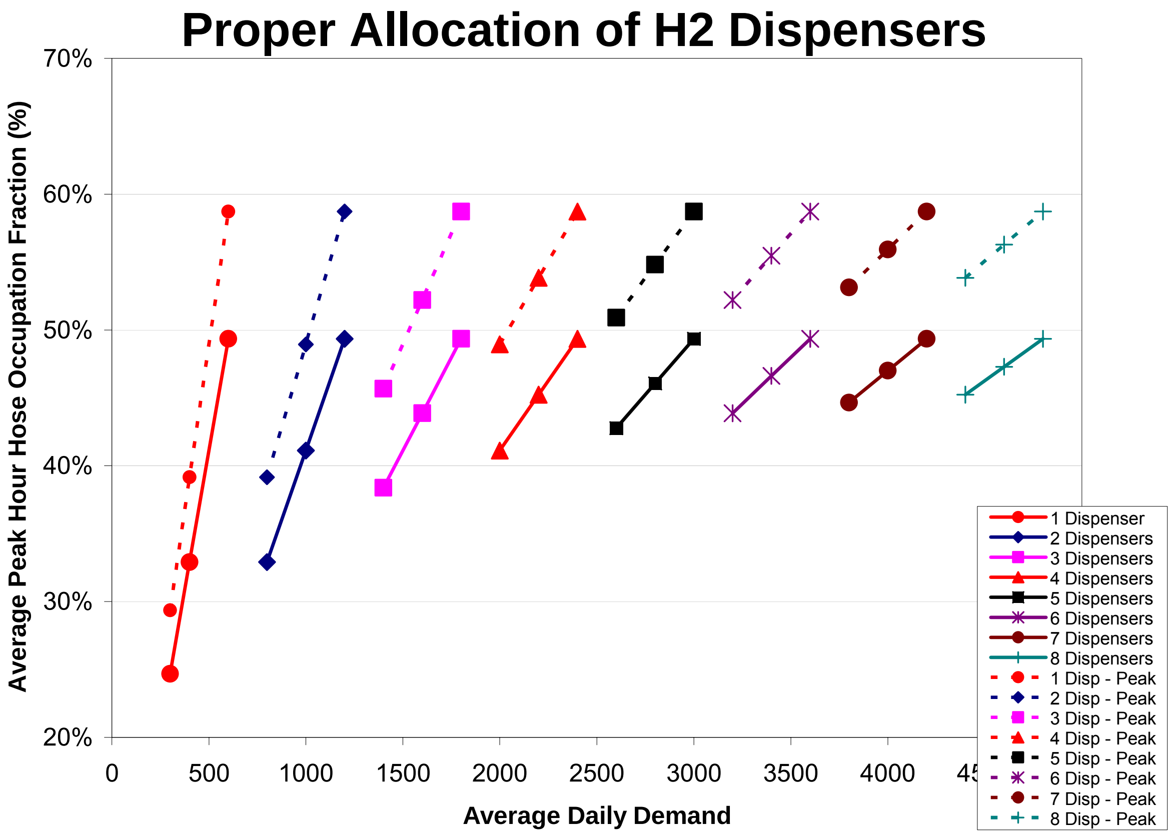
- **Number of dispensers at forecourt set in order to match the performance (fill time, relative crowding) of modern gas stations**

Fuel	Gasoline[1]
Peak Monthly Supply gge/month	300,000
Monthly Peak Factor	1.10
Friday Peak Factor	1.08
Avg. Monthly Supply* gge/month	272,727
Avg. Daily Supply gge/day	9,091
Peak Daily Supply gge/day	9,818
Peak Hourly Fraction	7.80%
Peak Hour Supply gge/hour	766
Avg. Fill Amount gal/fill	11
Peak Vehicle Fills fill/hr	70
Hose Flow Rate gal/min	5
Time Required for Fill min	2.20
Linger Time** min	3
Total Time at Pump min/fill	5.20
Total Occupied Hose Time*** min/hr	362
Available Hoses	12
Available Hose Time min/hr	720
Hose Occupied Fraction	**50.3%**

*It is assumed that the interseasonal variations will be adsorbed by the system.

**TIAX Assumption: Linger time is the time that the vehicle is occupying the hose without actively filling the vehicle.

***For all hoses

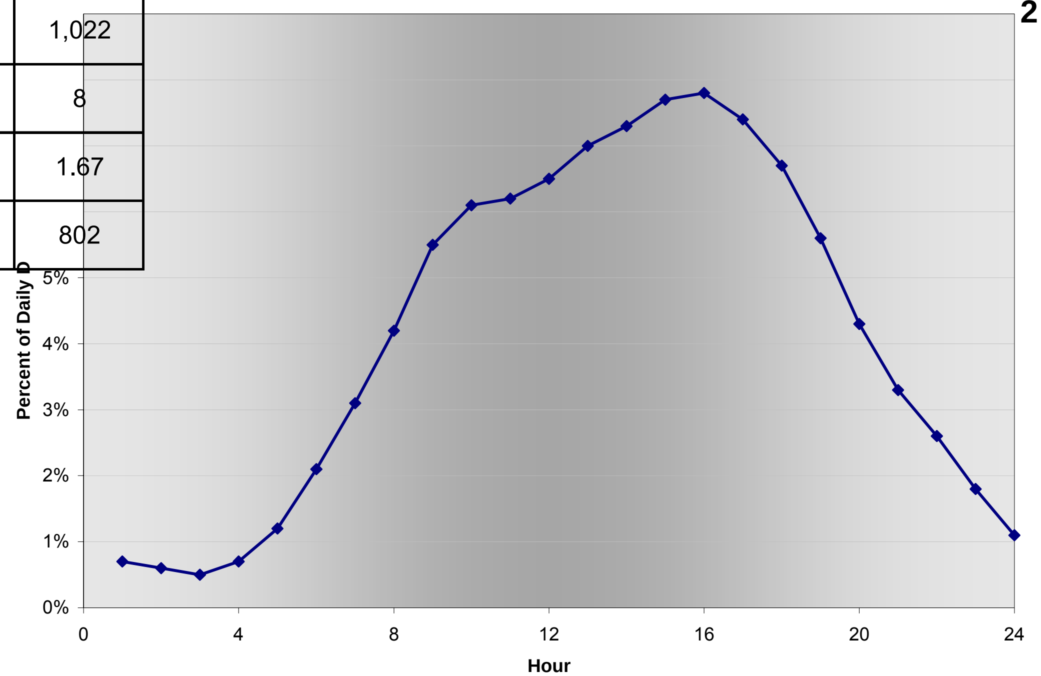


Assumes: 6 kg_{H2} vehicle tanks, 75% average fill, 3 min. linger time, 1.67 kg/min hose flow rate

[1] **Moore, Graham; Chevron.**

Forecourt Capacity & Demand

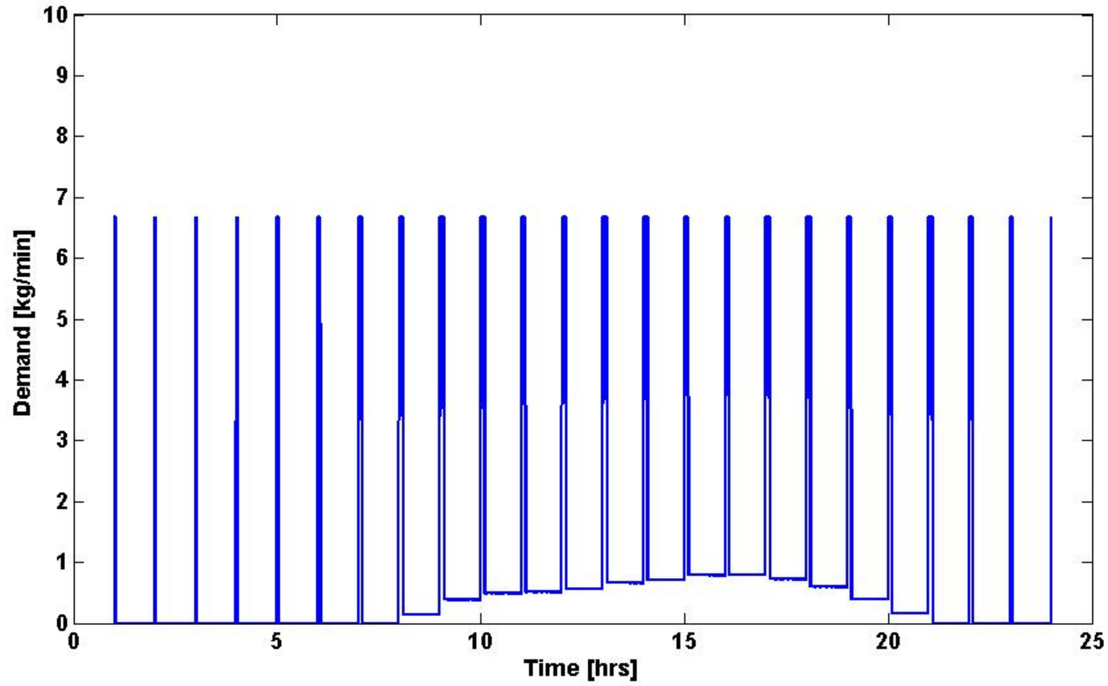
	Scenario			
	1	2	3	4
Average Demand (kg/day)	1,000	2,200	3,400	4,600
Average Vehicles (cars/day)	222	489	756	1,022
Dispensers	2	4	6	8
Hose Flow Rate (kg/min)	1.67	1.67	1.67	1.67
Peak Flow Rate (kg/hr)	200	401	601	802



- **Number of dispensers and hose flow rates determine the peak instantaneous output**
- **A known demand profile illustrates that the system must maintain high output for many consecutive hours**

[2] Moore, Graham; Chevron.

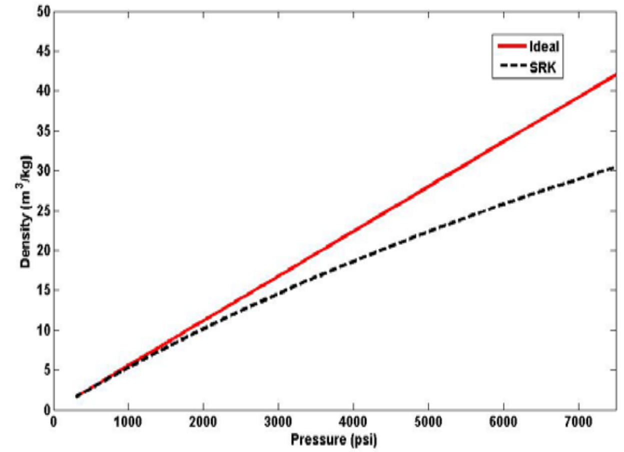
Modified Demand Profile



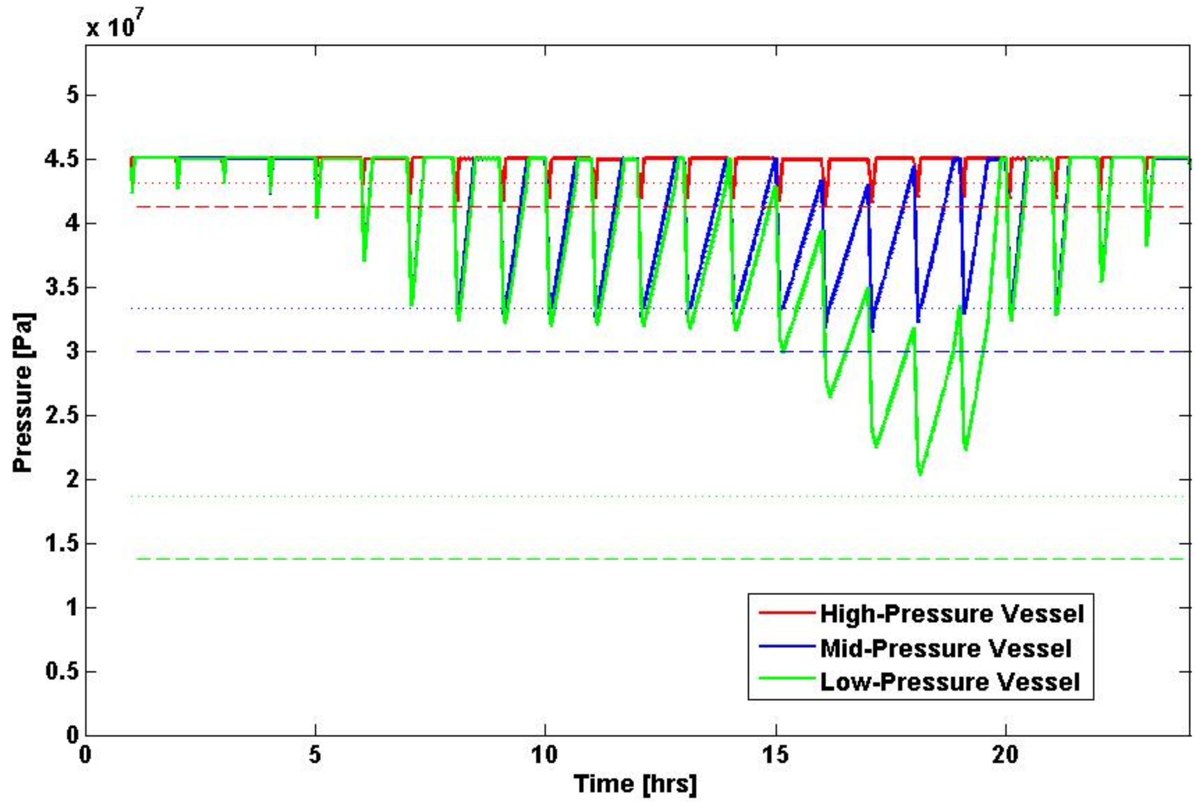
- **A modified demand profile tests the system's ability to meet peak and average demand**
  - Not meant to reflect reality, but to determine robustness
- **Peak flow rate for first 5 minutes of every hour, followed by average flow to meet remaining hourly demand**

Storage System Specifications

- **Three-tier cascade**
  - Each vessel capable of storing H_2 to 6,500 psi
- **Individual cascades supply a distinct pressure range**
  - Low-pressure cascade: < 2,000 psi
  - Medium-pressure cascade: 2,000 – 4,400 psi
  - High-pressure cascade: 4,400 – 6,000 psi
- **Logic system developed to control compressor activity**
  - High-pressure cascade takes priority due to the small ΔP between the peak storage pressure and the fueling pressure
- **Pressure calculated using the Soave-Redlich-Kwong EOS**



Modeling System Dynamics



- **Pressure in each vessel is tracked throughout the day**
- **If pressure falls below set threshold, the model determines that the storage is too small and re-runs with larger storage**

Results Interpretation

- **Model calculates the storage required for multiple different forecourt demand levels and between 10-14 compressor capacities at each demand level**
- **Compressor size and storage capacity are normalized using the minimum compressor capacity and daily forecourt demand**
- **This yields the following non-dimensional parameters:**

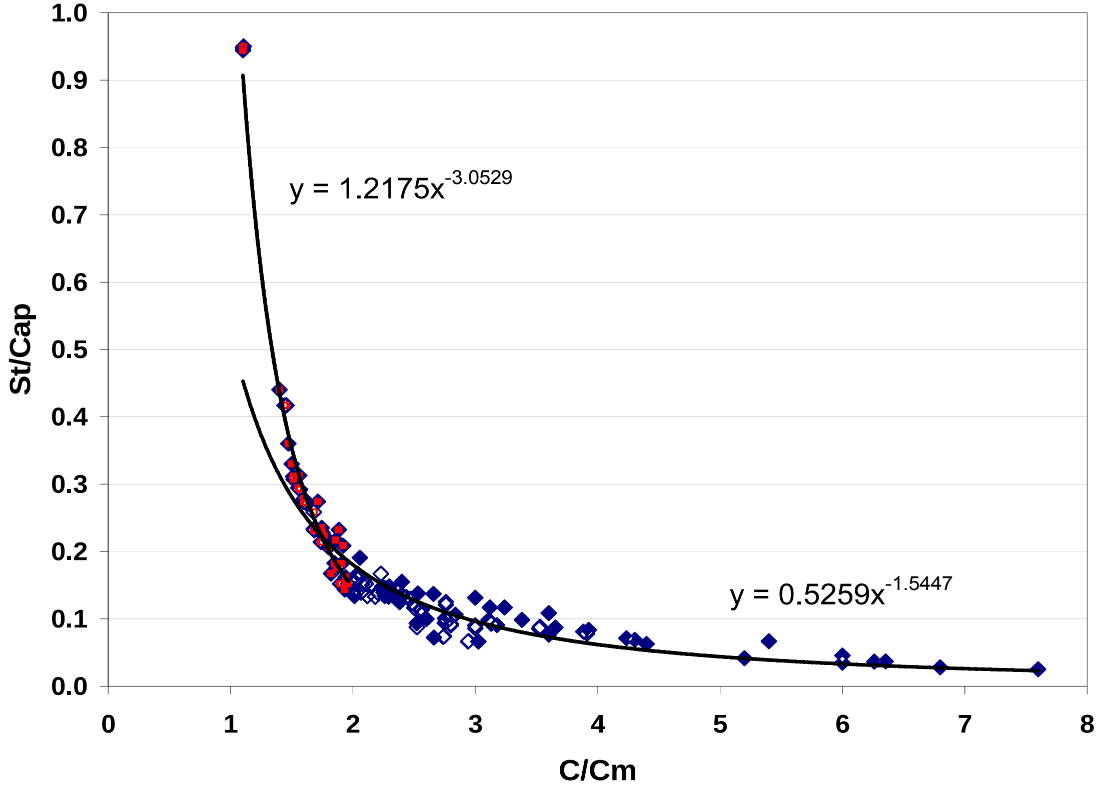
C/Cm = compressor capacity (kg/hr) / minimum capacity (kg/hr)

where, minimum capacity (kg/hr) = daily demand (kg) / 24 (hrs)

St/Cap = total storage (kg) / daily demand (kg)

- **The non-dimensional parameters are compared to determine if a consistent relationship exists between forecourt sizes**

Non-Dimensional Results



- **Results show a clear, consistent relationship between compressor and storage sizes for all forecourt capacities**
- **Valid for all types of forecourt – tube trailer, pipeline & liquid**
- **Indicates that a simple relationship for optimization is likely**

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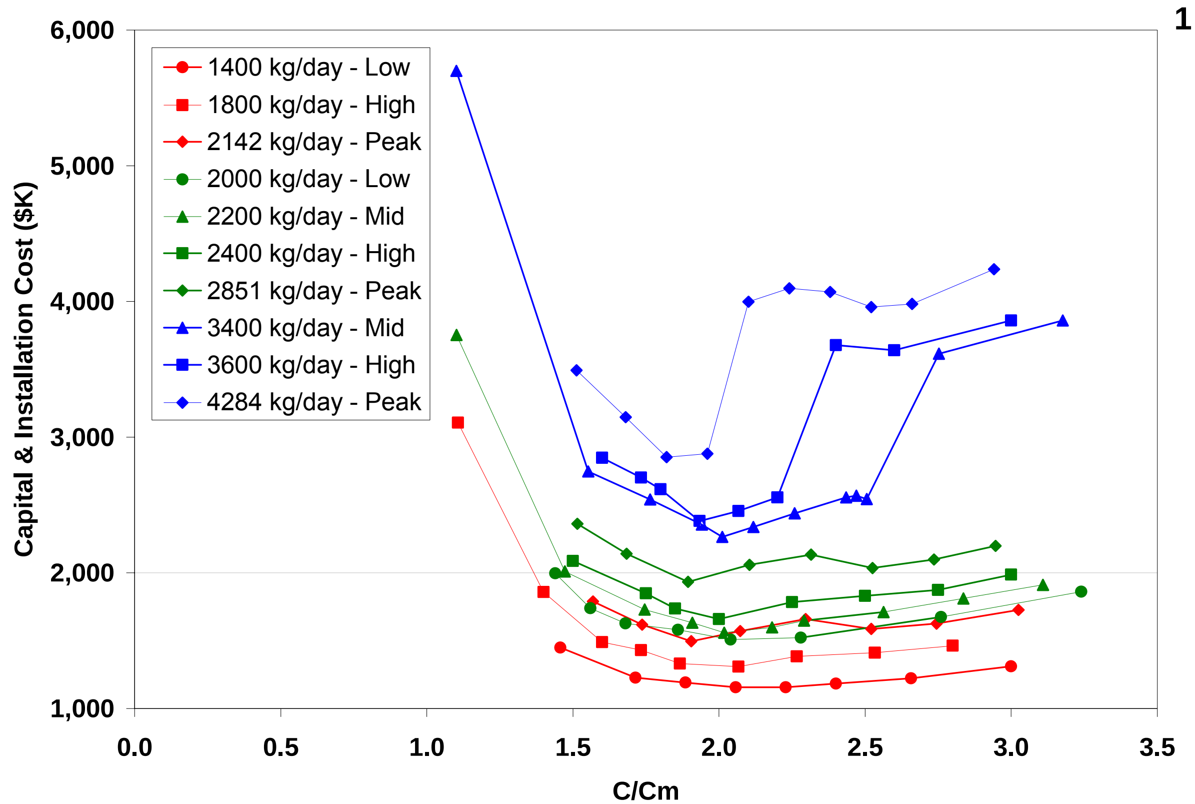
Capital Cost Variability



- **Cost minimums exist within the range of compressors tested**
- **Optimal configuration varies as a result of discrete variations in storage size, varying demand for comparable stations and the effects of the logic system used determine cascade filling**

[3] Results shown assume costs for a gas compressor, liquid pumps will change optimum

Compressor & Cascade Parameters

- **Capital cost (as a function of C/Cm) and the relationship between compressor and storage size yield optimal parameters (for tube trailers and pipeline forecourts):**

C/Cm ≈ 2.0

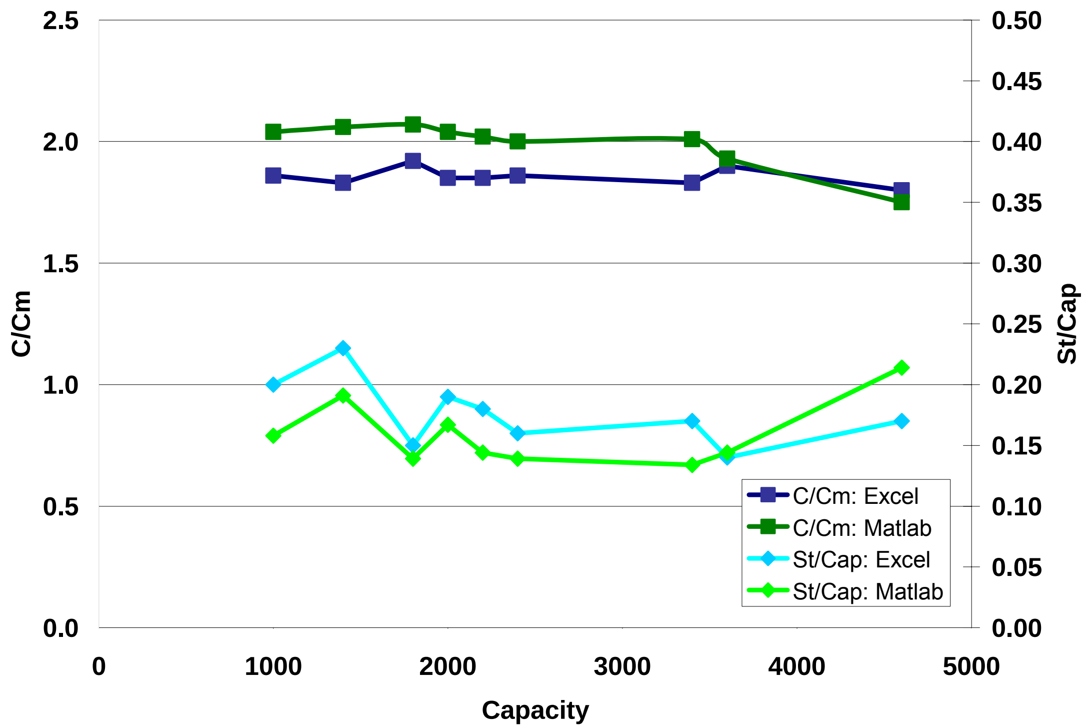
St/Cap ≈ 0.18

- **The larger end of the compressor range was chosen as the optimal parameter**
  - For larger capacity stations the cost increase for an undersized compressor is particularly pronounced
- **Result Comparison: 1,000 kg/day**
  - New - Compressor: 100 kg/hr; Cascade Storage: 215 kg
  - Old – Compressor: 62 kg/hr; Cascade Storage: 358* kg

*** New calculations indicate that this is ½ of the required storage to meet new demand profile**

Model Implementation

- **MATLAB model and results used as the foundation for an Excel tool that performs these optimizations within the H2A framework**



- **Models are highly correlated, with the differences resulting primarily from small variations in assumptions**

Low-Pressure Storage

- **Low-pressure storage is required at forecourts serviced by pipelines**
  - Upstream infrastructure cannot meet instantaneous demand
- **Net flow to/from storage tank defines the required capacity**