



Improvements to Hydrogen Delivery Scenario Analysis Model (HDSAM) and Results

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*Amgad Elgowainy
Argonne National Laboratory*



UChicago
Argonne LLC

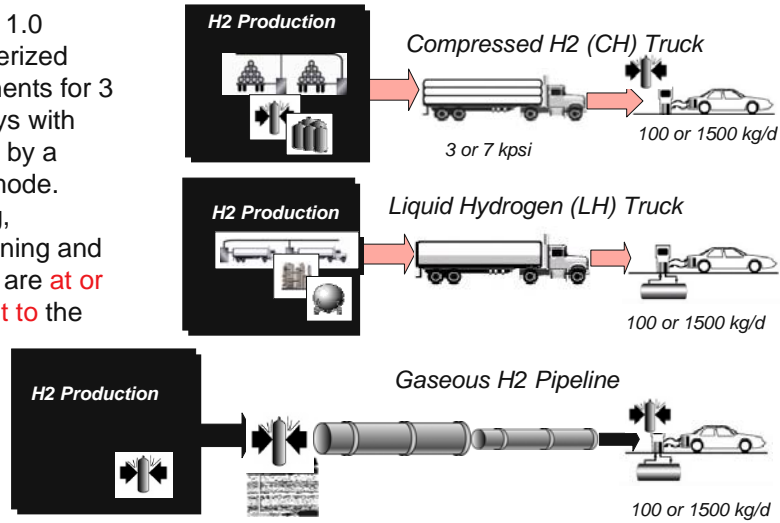


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Comparison of Delivery *Pathways*- V1.0 vs. V2.0

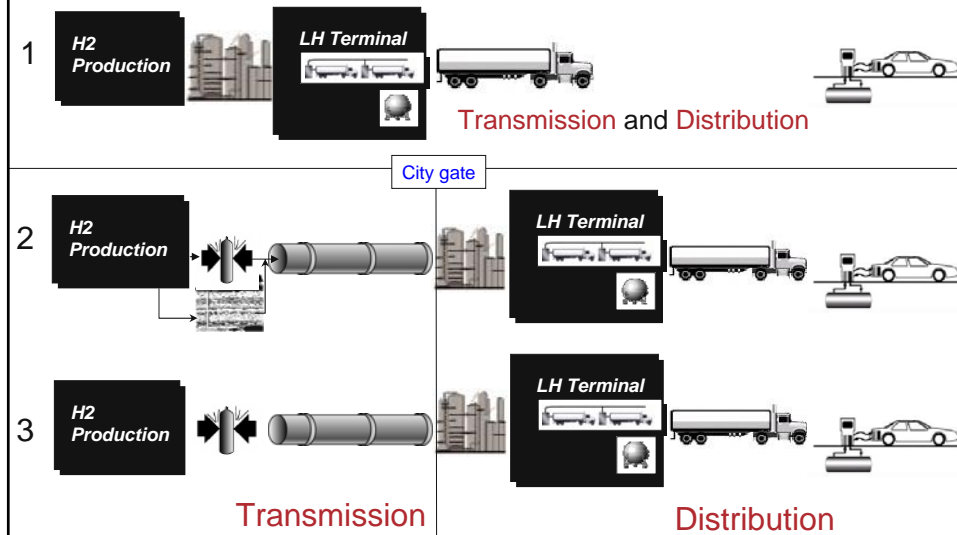
HDSAM V1.0 Estimates Delivery Cost for 3 Pathways

Version 1.0 characterized components for 3 pathways with delivery by a single mode. Loading, conditioning and storage are **at or adjacent to** the plant



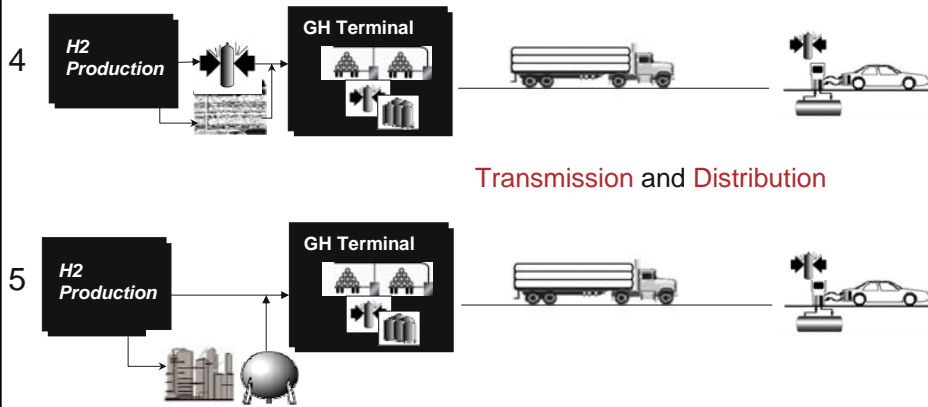
HDSAM V2.0 Simulates Nine Pathways

I. Liquid H2 Distribution:



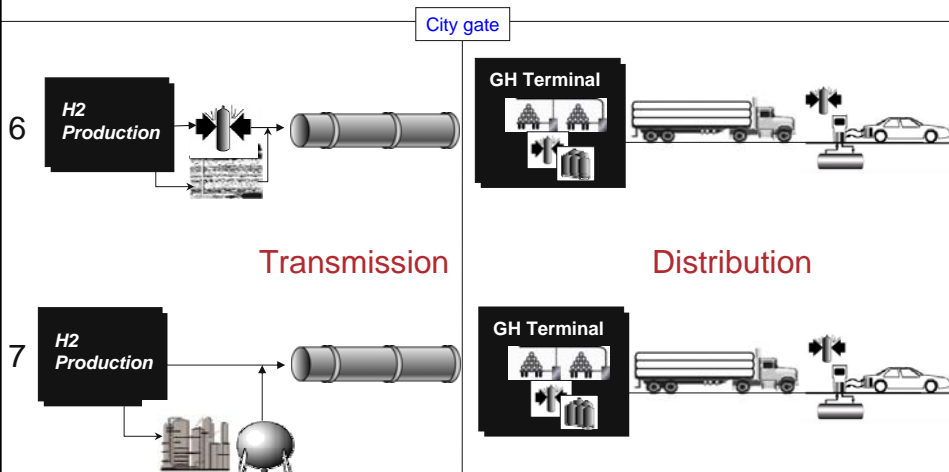
HDSAM V2.0 Simulates Nine Pathways (cont'd)

II. Compressed H2 Distribution:



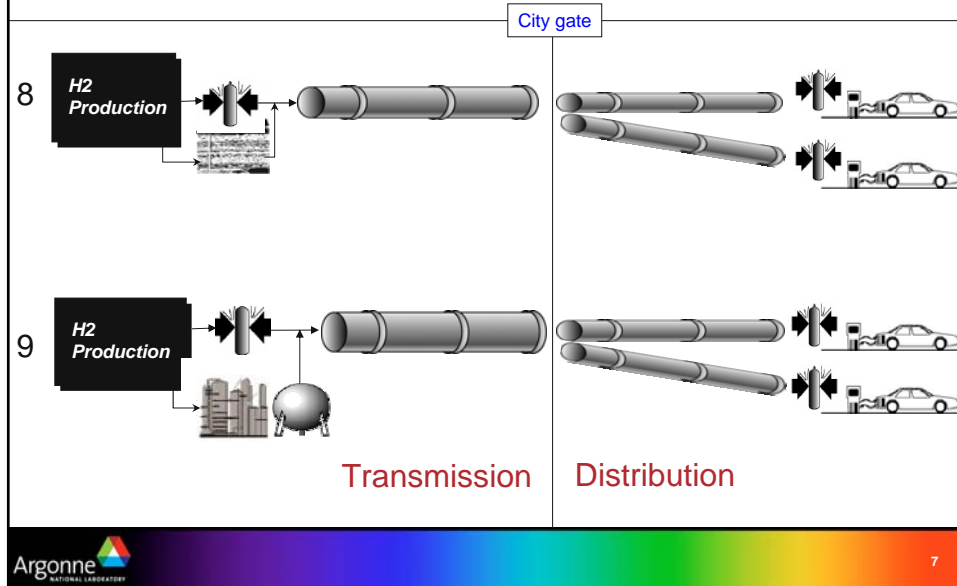
HDSAM V2.0 Simulates Nine Pathways (cont'd)

II. Compressed H2 Distribution (cont'd):



HDSAM V2.0 Simulates Nine Pathways (cont'd)

III. Pipeline Delivery:



Progress in HDSAM V2.0

■ Better representation of pathways

- Components sized to meet respective demand profile (eliminates capacity factor previously set for the entire pathway)
- Pathway storage optimization (plant outage, summer peak, Friday peak, hourly peak, HOF peak)
- Variable size forecourt (50 – 6000 kg/day)
- Additional pathways (mixed-mode deliveries, plant outage/summer peak handling)

■ Better modeling

- Forecourt (e.g., cascade vs. low-pressure storage, compressor/electrical, evaporator/pump, boil-off recovery)
- Forecourt optimization (both GH₂ and LH₂, based on total forecourt cost)
- Pipeline geometry (4-ring capability, separate downtown calculations)
- Practical limitation on size of components (e.g., liquefier, compressors)
- Land area calculations (forecourt, terminals)
- Additional user options

Progress in HDSAM V2.0 (cont'd)

■ Better data

- Improved liquefier, pipeline, compressors, storage, labor, indirect capital, and O&M cost estimates
- Detailed Hourly, daily, seasonal fuel demand profiles

Progress in HDSAM V2.0 (cont'd)

H2 Market <input checked="" type="radio"/> Urban <input type="radio"/> Rural Interstate	Market Penetration H2 Vehicle Penetration 20 %	Transmission Mode <input checked="" type="radio"/> Compressed H2 Truck <input type="radio"/> Liquid H2 Truck <input type="radio"/> Pipeline	Distribution Mode <input checked="" type="radio"/> Compressed H2 Truck <input type="radio"/> Liquid H2 Truck <input type="radio"/> Pipeline	Refueling Station Size Desired Dispensing Rate (kg/day) 1000
City Selection Indianapolis, IN Population 1,218,919	Click Here To Calculate			Component for Plant Outage and Summer Peak <input checked="" type="radio"/> Geologic Storage <input type="radio"/> Liquefier and Liquid Storage

Key Delivery Inputs and Assumptions

City population	1,218,919
City area (mi ²)	553
Population density (people/mi ²)	2,205
Vehicles/person	0.85
Miles driven per year/vehicle	13,748
Distance from production to city (mi)	62
Number of Days for Scheduled Production Plant Outage	10
Summer Surge: % above the System Average Daily Demand	10.0%
Friday Peak: % above Daily Average Demand	8.0%
H2 Vehicles fuel economy equivalent (mi/gge)	57.50

Demand Calculations

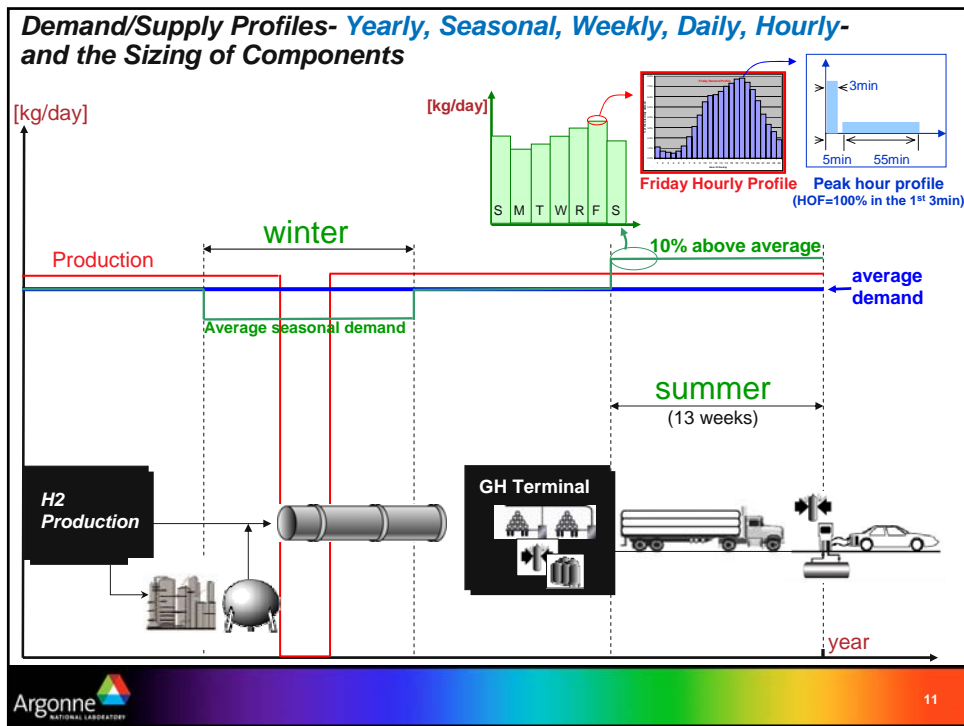
H2 use per LDV per year (kg/y)	231
H2 use per LDV kg H2/day (ave)	0.63
Number of H2 vehicles in city	208,394
City H2 daily use (kg/d)	131,692
Number of H2 refueling stations in city	132
Adjusted (actual) average H2 station daily dispensing rate (kg/day)	998
Number of H2 stations/Number of gasoline stations	25%
Average distance between stations (mi)	2.05

Delivery Mode Calculations

Average round trip time (h)	5.84
Total number of deliveries per day	262.0
Possible number of round-trips per truck /day	4.1
Maximum number of deliveries per day	309.7
Time between truck deliveries to a target station at peak demand (h)	10.2
Number of trucks required to provide H2 to city	77
Number of trailer (tube bundle)	165
Number of spare trailer (tube bundle)	14

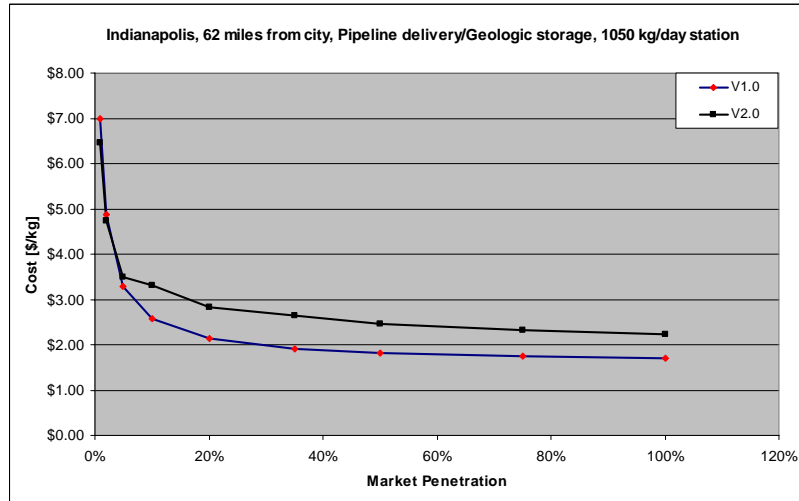
Transmission Mode Calculations

Pipeline transmission length (mi)	62
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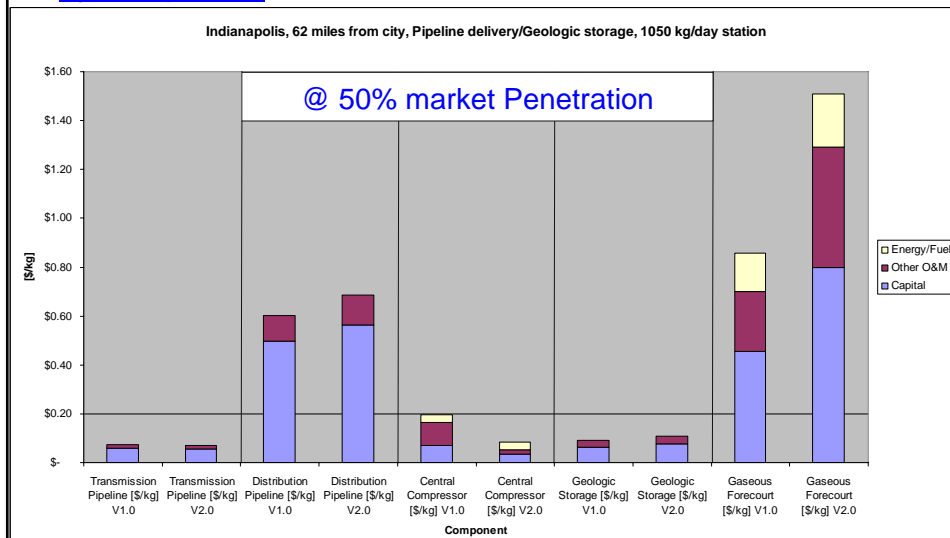
Comparison of Delivery Cost- V1.0 vs. V2.0

Comparison of Delivery Cost- V1.0 vs. V2.0



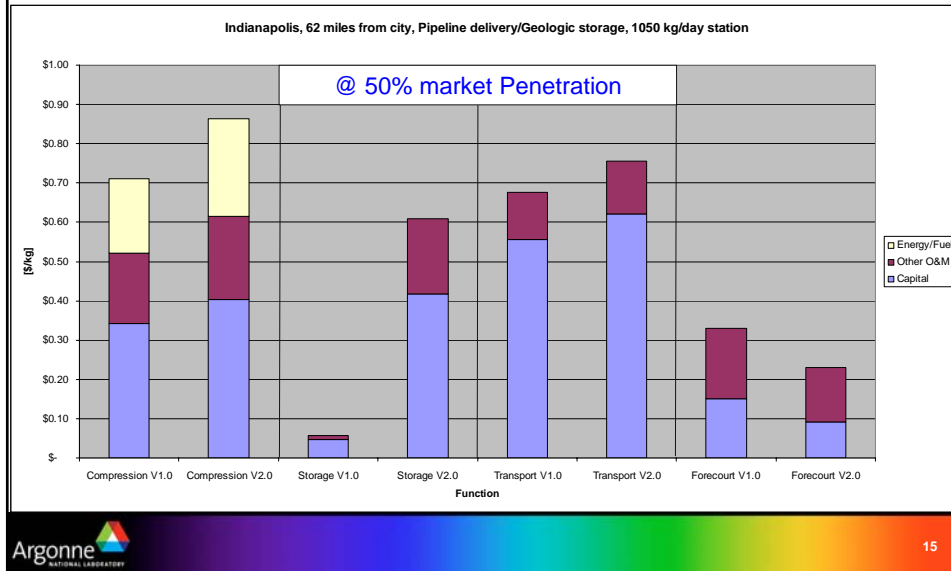
Comparison of Delivery Cost -V1.0 vs. V2.0 (cont'd)

by Component



Comparison of Delivery Cost -V1.0 vs. V2.0 (cont'd)

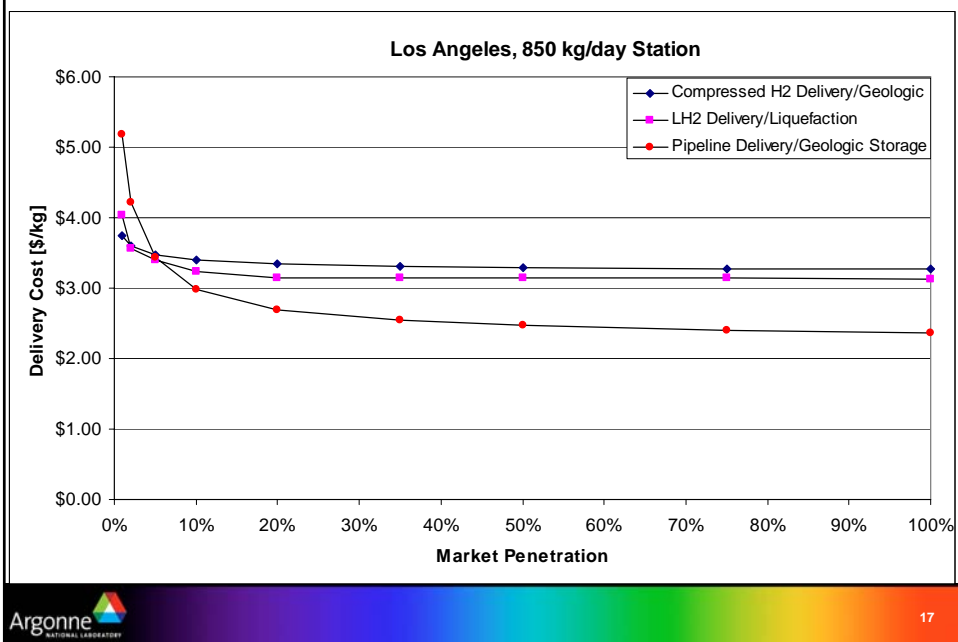
by Function



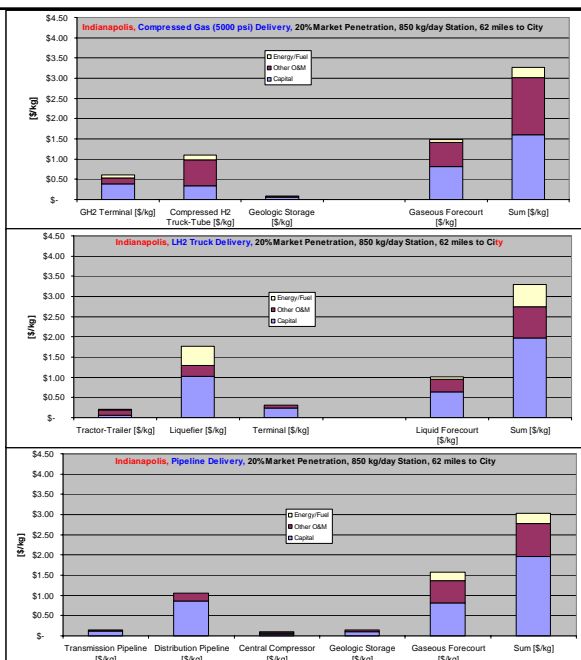
Results of V2.0 of The Scenario Model

Comparison of Delivery Modes at Different Market Penetrations

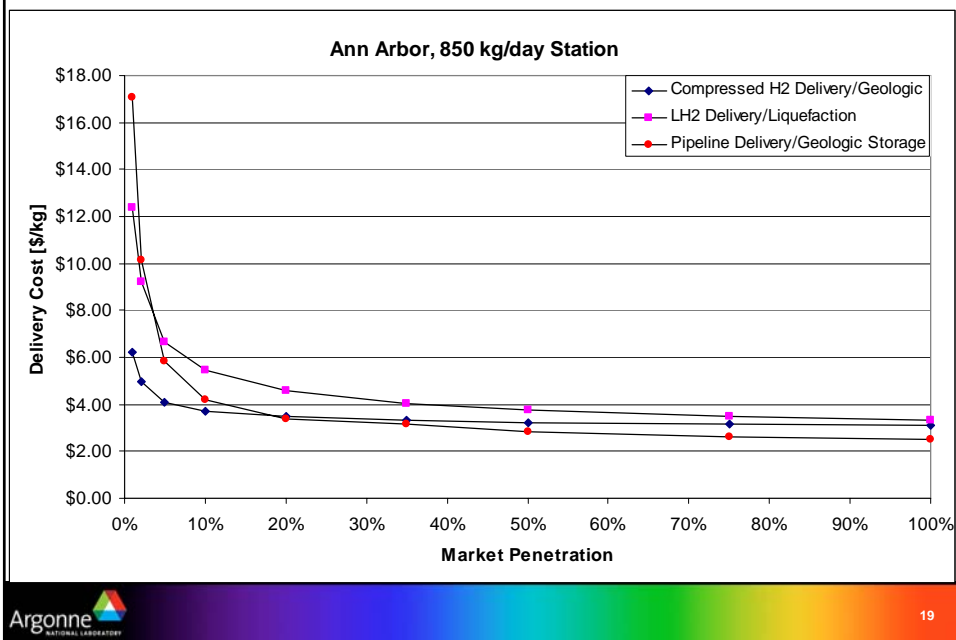
Comparison of Delivery Modes- Los Angeles:



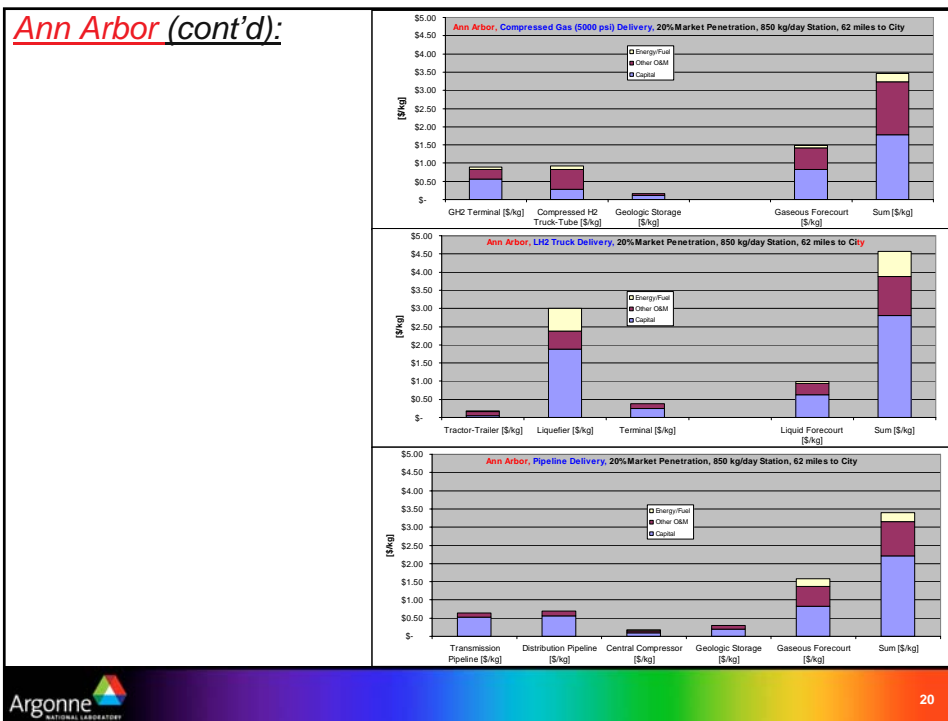
Los Angeles (cont'd):



Comparison of Delivery Modes- Ann Arbor:



Ann Arbor (cont'd):

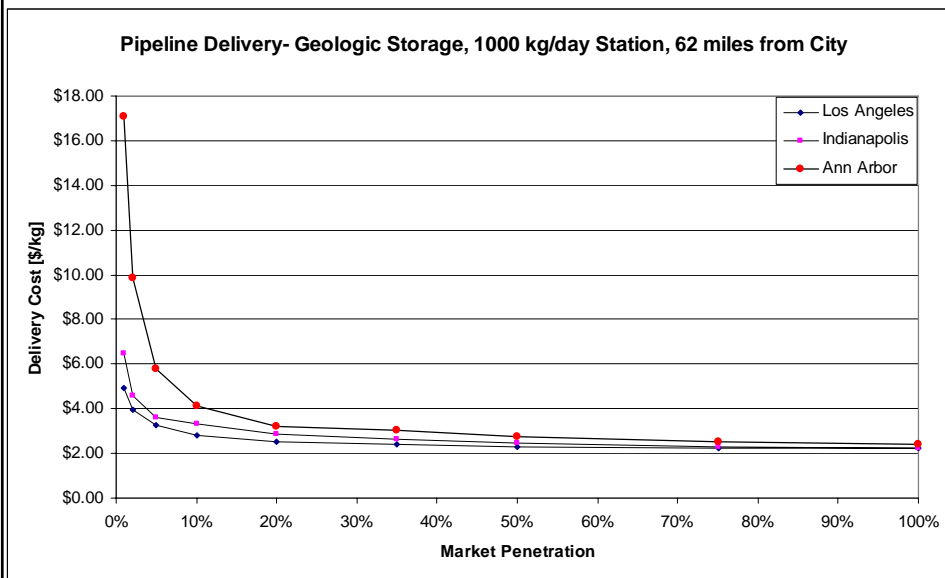


Results of V2.0 of The Scenario Model

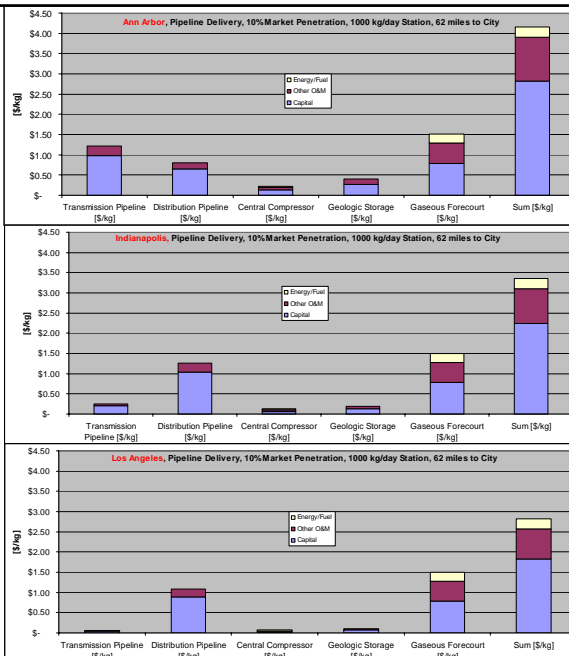
I. Pipeline Deliveries:

- Market Size
- Forecourt Station Size
- Distance from Production to City

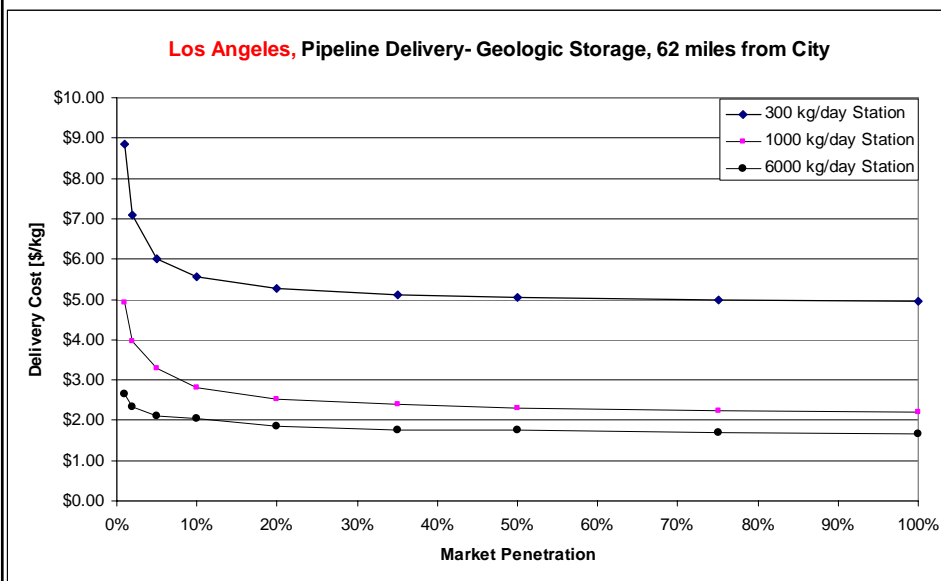
Market Size



Market Size (cont'd)

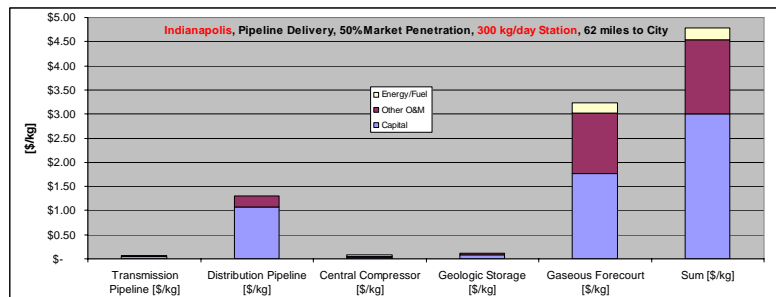


Station Size

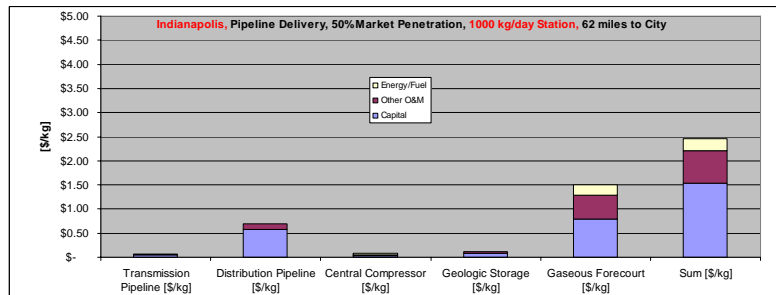


Station Size (cont'd)

4 Rings

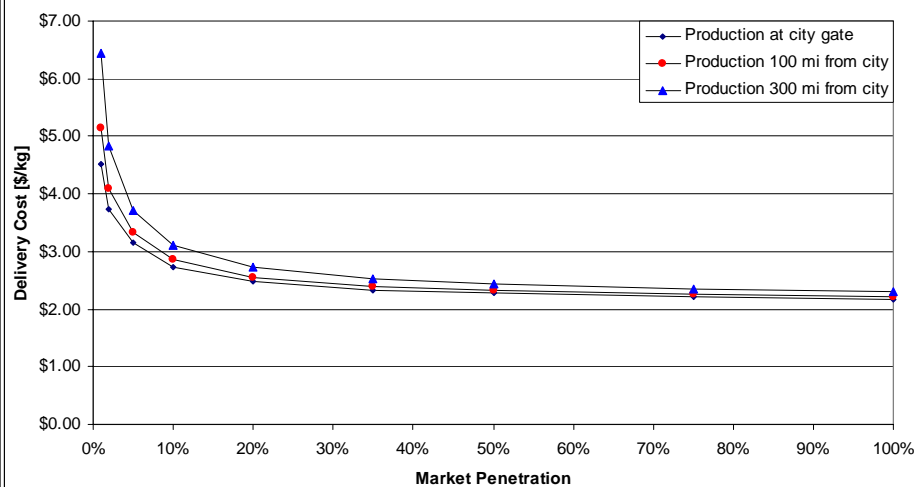


2 Rings



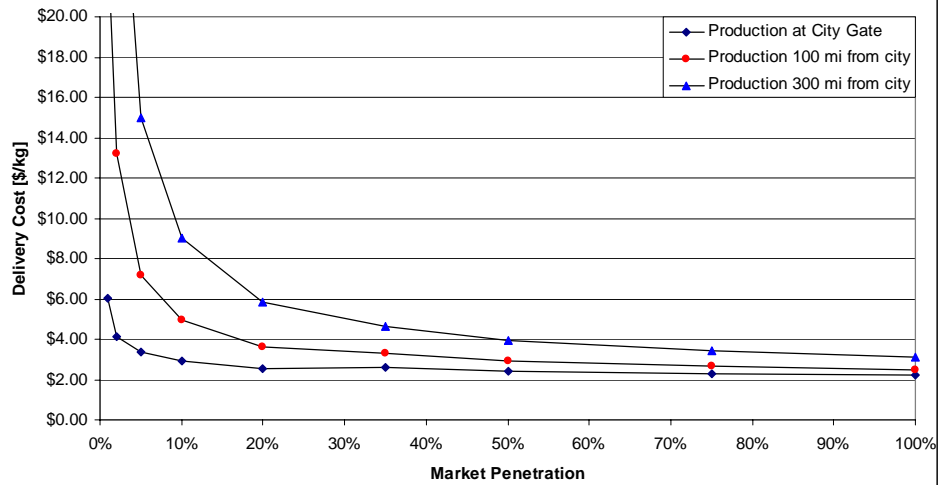
Distance from Production to City- Los Angeles

Los Angeles Pipeline Delivery- Geologic Storage



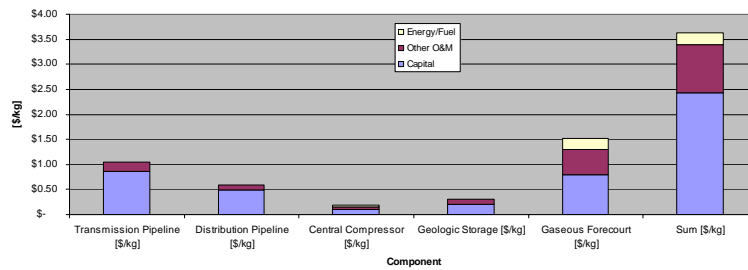
Distance from Production to City- Ann Arbor

Ann Arbor Pipeline Delivery- Geologic Storage

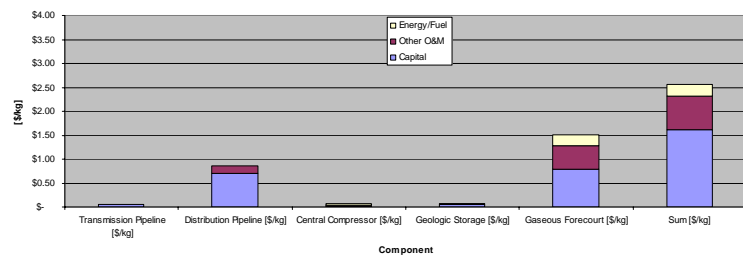


Distance from Production to City- Ann Arbor vs. Los Angeles

Ann Arbor, Pipeline Delivery, 20% Market Penetration, 1000 kg/day Station, 100 miles to City



Los Angeles, Pipeline Delivery, 20% Market Penetration, 1000 kg/day Station, 100 miles to City

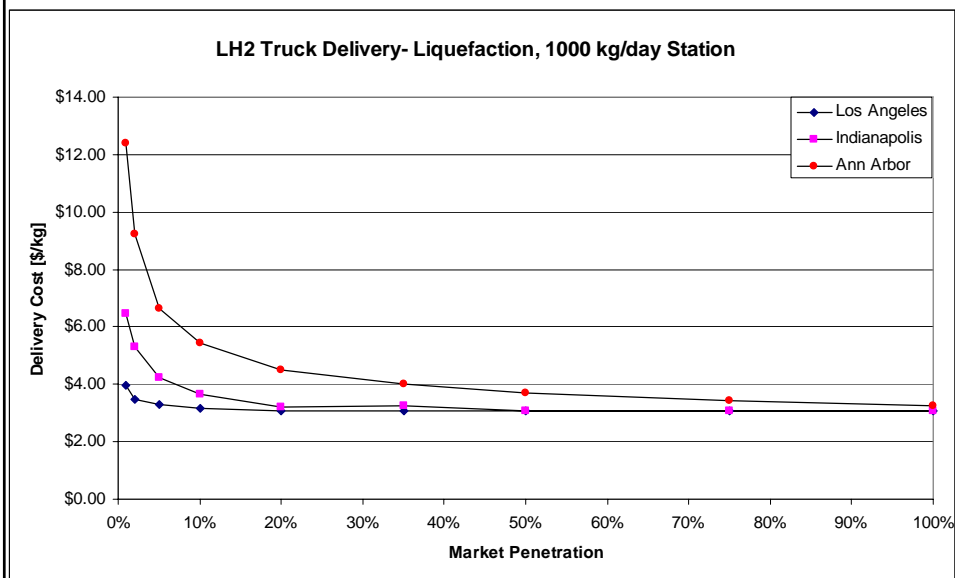


Results of V2.0 of The Scenario Model

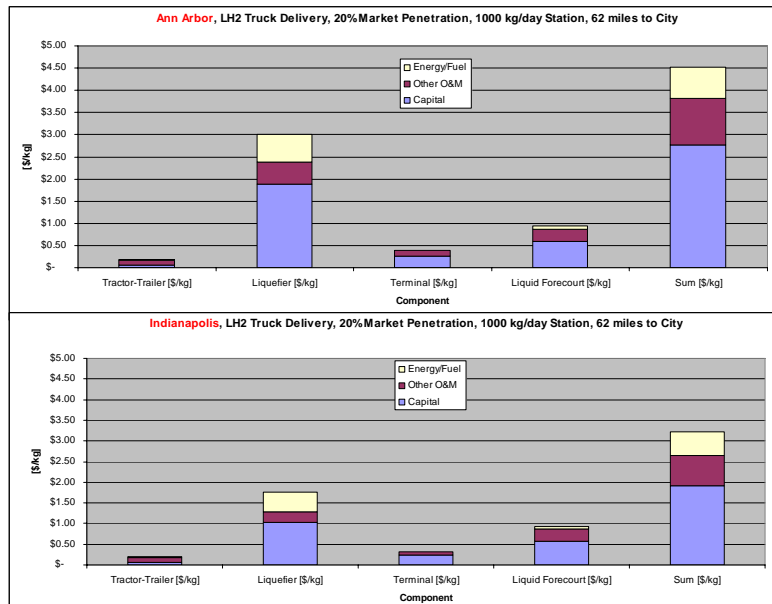
II. LH2 Truck Deliveries:

- Market Size
- Forecourt Station Size
- Distance from Production to City gate

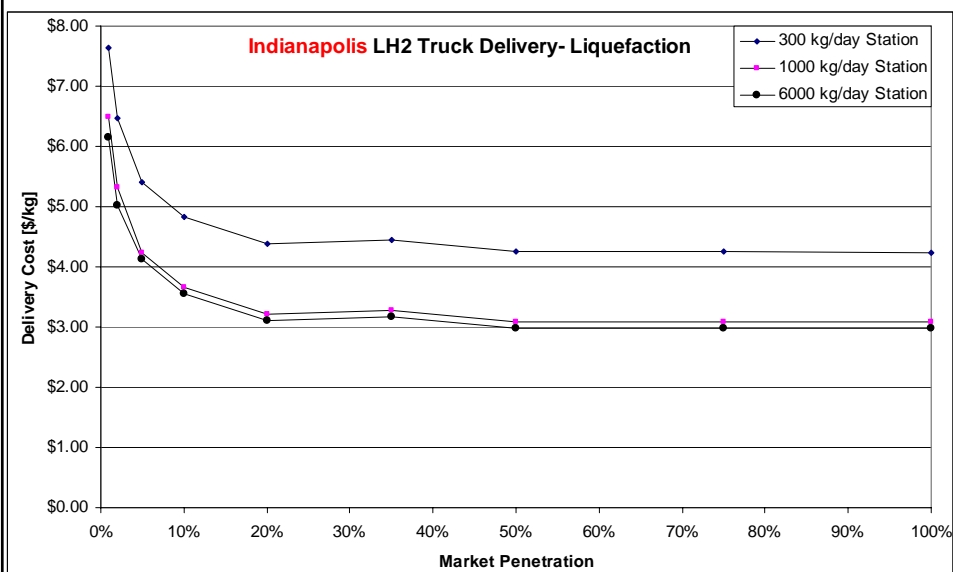
Market Size



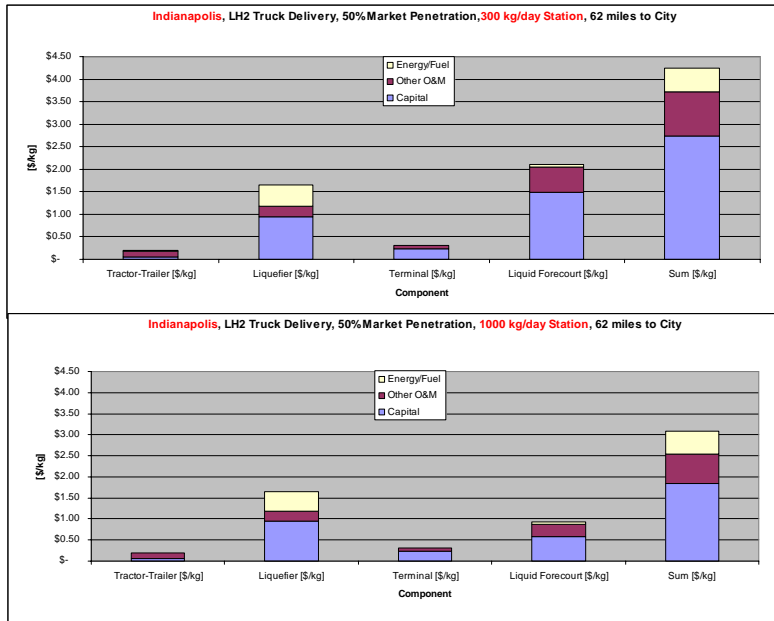
Market Size (cont'd)



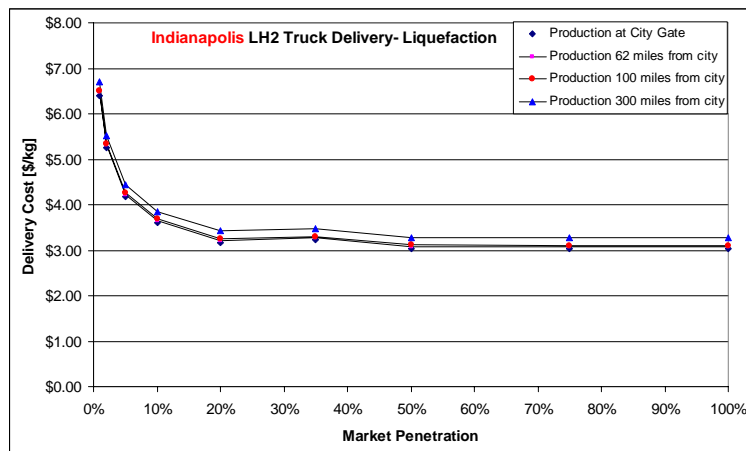
Station Size



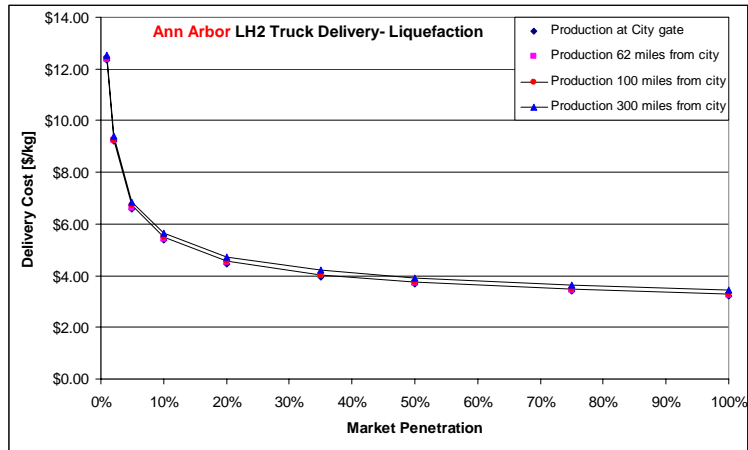
Station Size (cont'd)



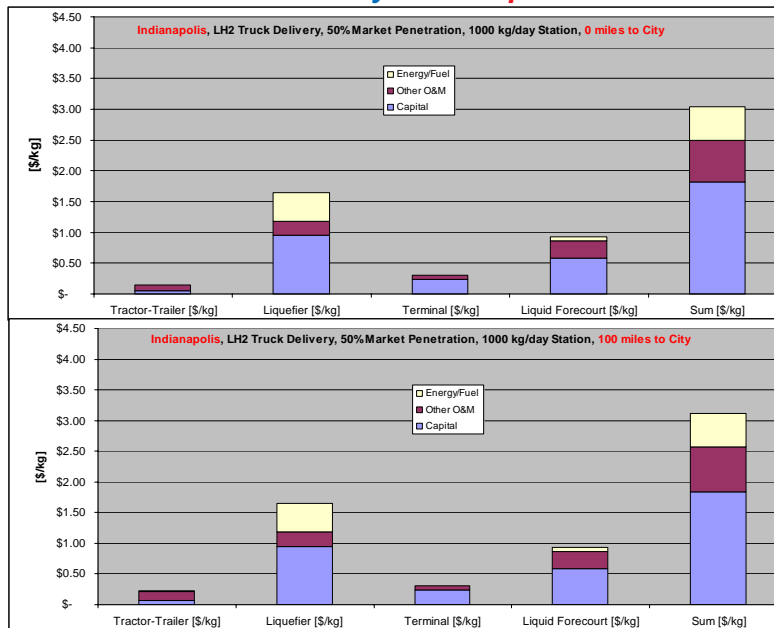
Distance from Production to City- Indianapolis



Distance from Production to City- Ann Arbor



Distance from Production to City- Indianapolis

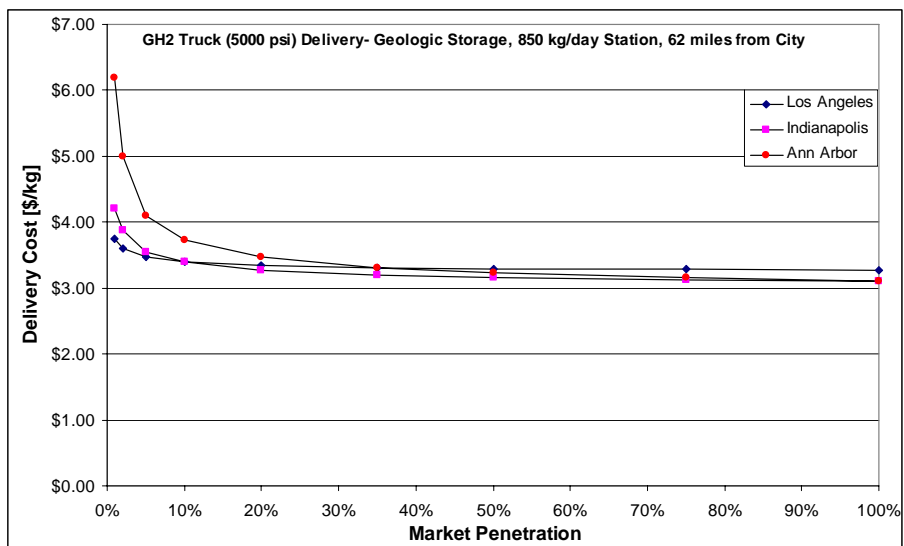


Results of V2.0 of The Scenario Model

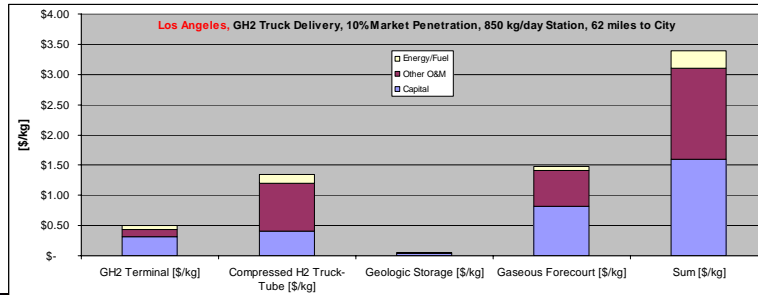
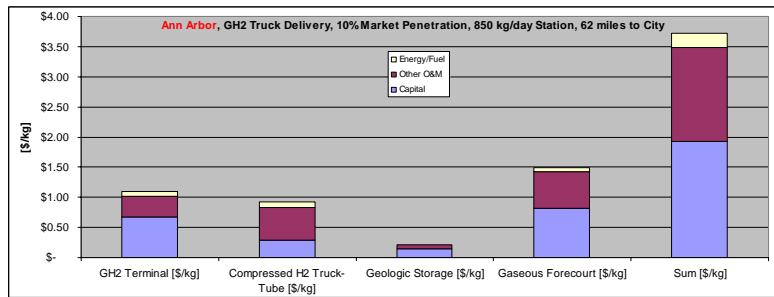
III. Compressed H2 Truck Deliveries:

- Market Size
- Forecourt Station Size
- Distance from Production to City gate

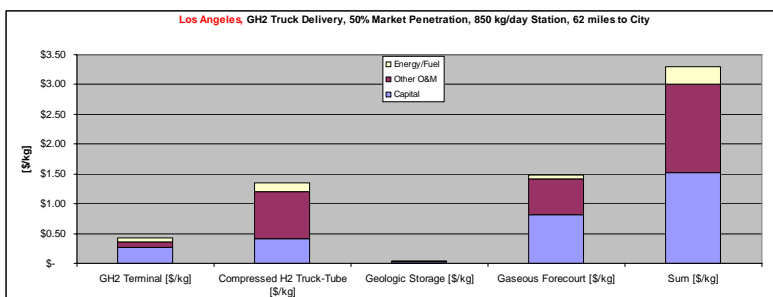
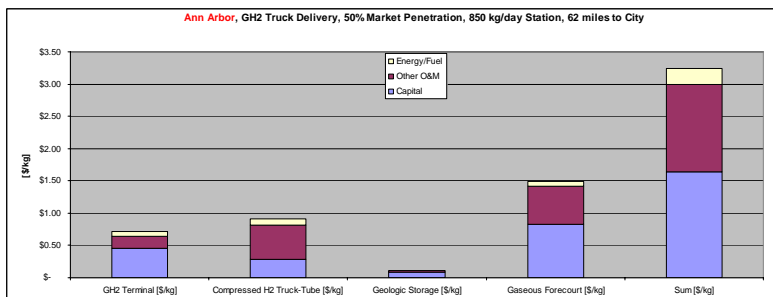
Market Size



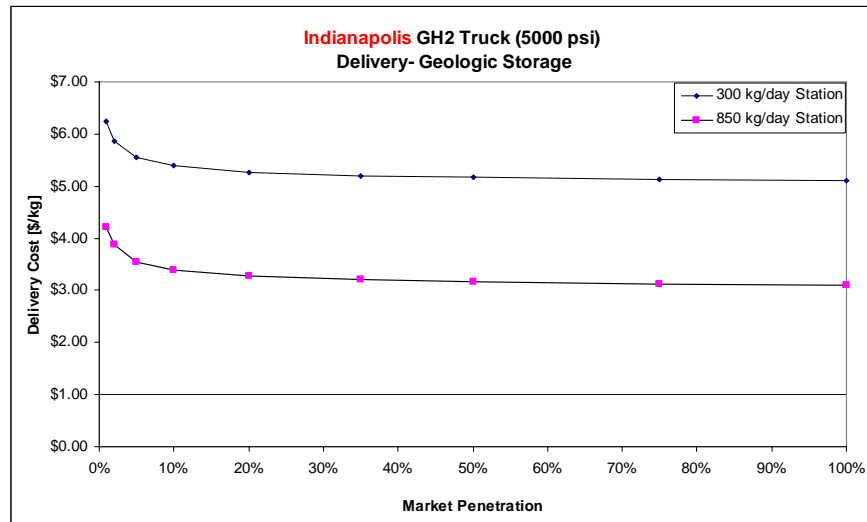
Market Size (cont'd)



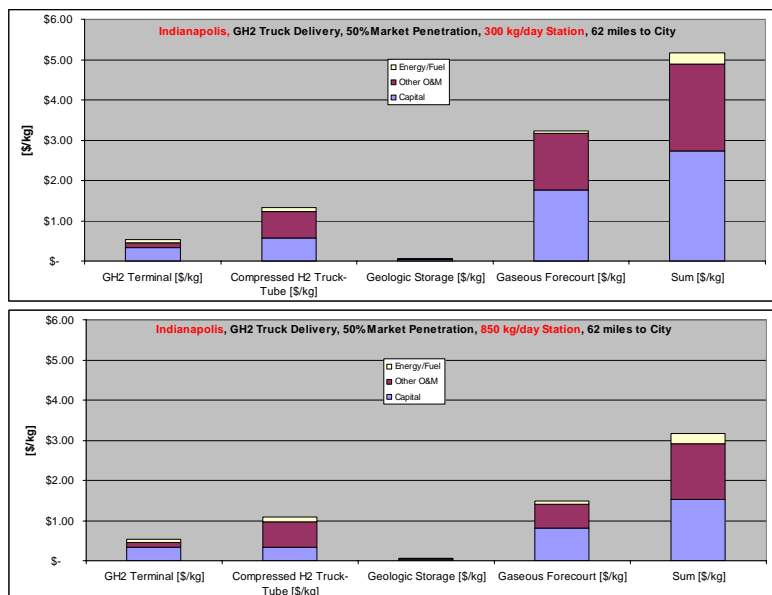
Market Size (cont'd)



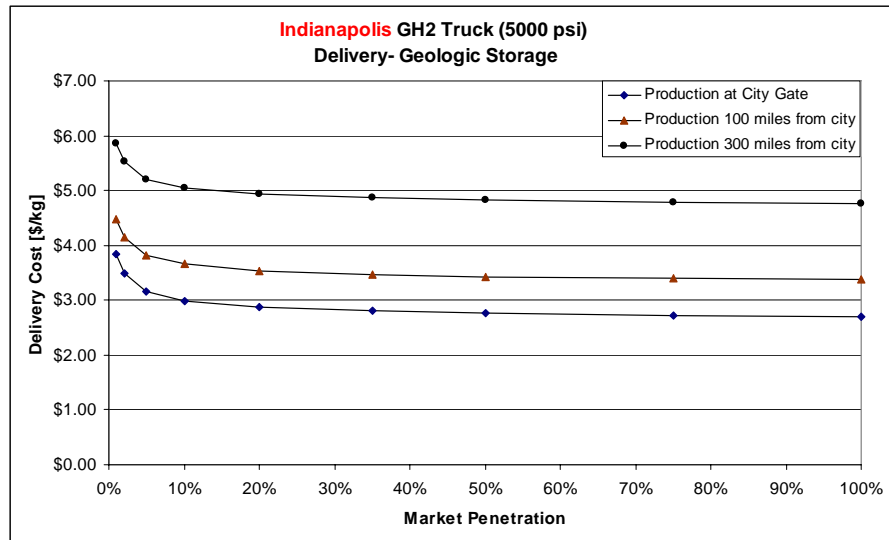
Station Size



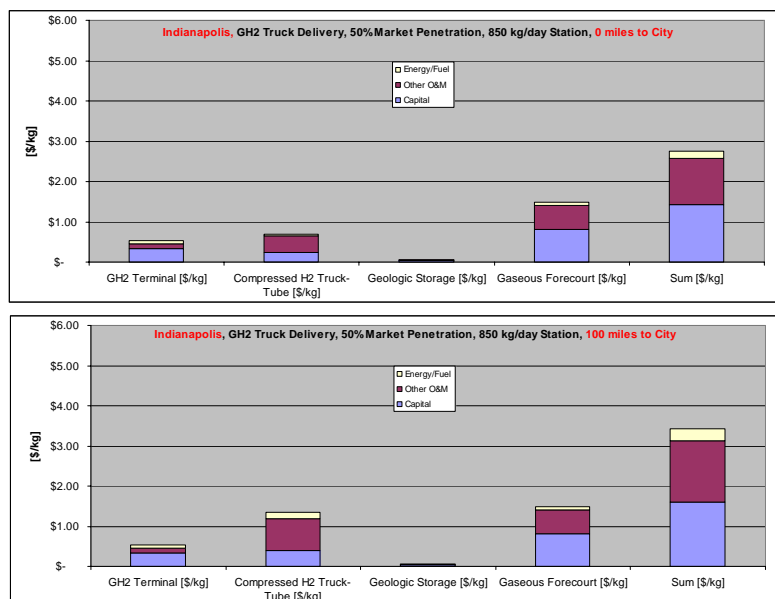
Station Size (cont'd)



Distance from Production to City



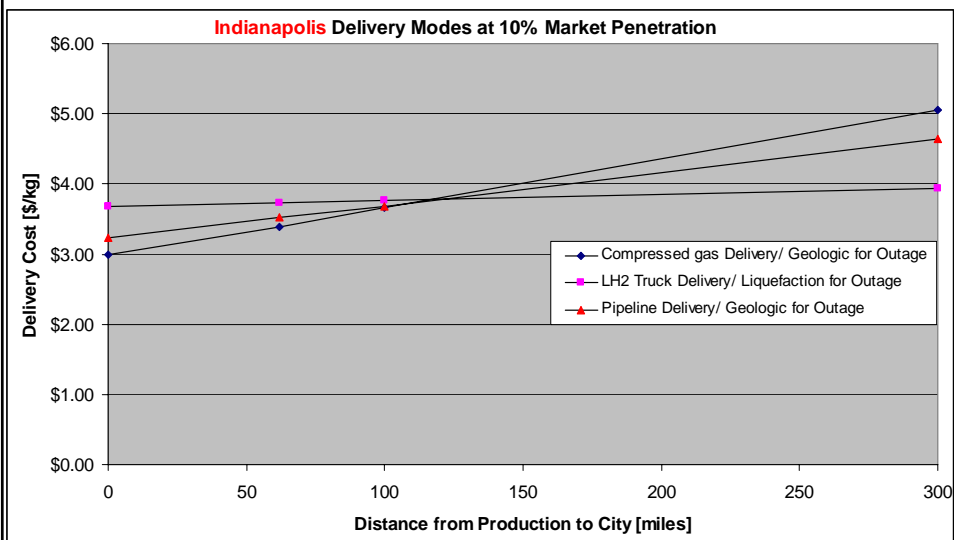
Distance from Production to City (cont'd)



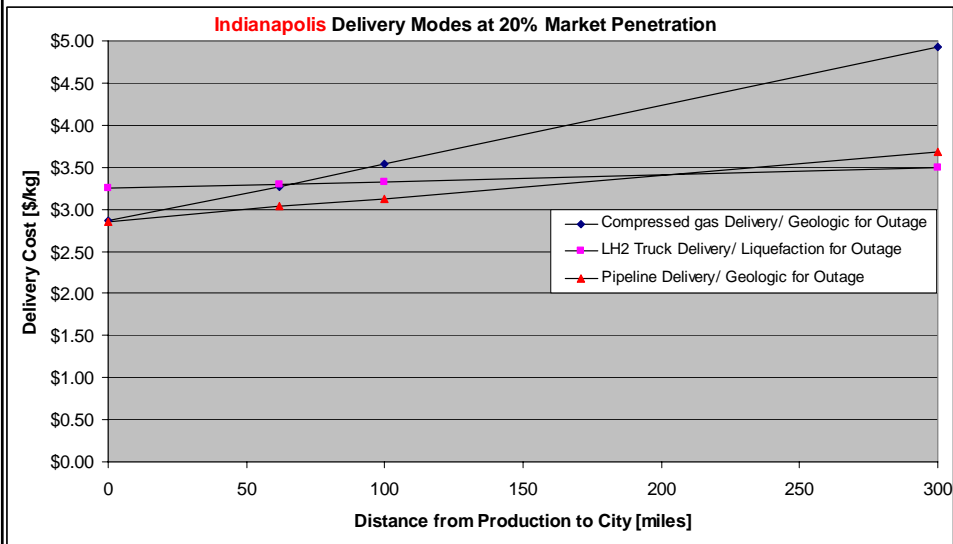
Results of V2.0 of The Scenario Model

Comparison of Delivery Modes at Different Distances from City

Indianapolis at 10% Market Penetration



Indianapolis at 20% Market Penetration



Acknowledgements

Other members of the team:

- Mark Paster, [DOE](#)
- Marianne Mintz and Jerry Gillette, [ANL](#)
- Matt Ringer, [NREL](#)
- Daryl Brown, [PNL](#)
- Bruce Kelly, [Nexant](#)
- Matt Hooks, [TIAX](#)