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Hydrogen Delivery Analysis Models

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DOE H2A Delivery Models

- Spreadsheet model for delivery system component costs and performance: Components Model
- Delivery scenario model for Urban and Rural /Interstate markets and demand levels (Mkt. Penetration) Scenario Model
- Estimates the cost of H_2 ($/kg) (and V2: energy and GHG)
- Assumes 2005 delivery technologies
- We can insert our Research Targets to see the impact

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List of Delivery Components

- Compressed Hydrogen Gas Truck (Tube trailer)
- Compressed Hydrogen Gas Truck Terminal
- Liquid Hydrogen Truck
- Liquid Hydrogen Truck Terminal
- H2 Transmission Compressor
- H2 Forecourt Compressor
- Hydrogen pipelines
- H2 Liquefier
- LH2 Storage Tank
- Gaseous H2 Storage “Tank”
- Gaseous H2 Geologic Storage
- Dispenser
- Refueling Site: GH2
- Refueling Site: LH2

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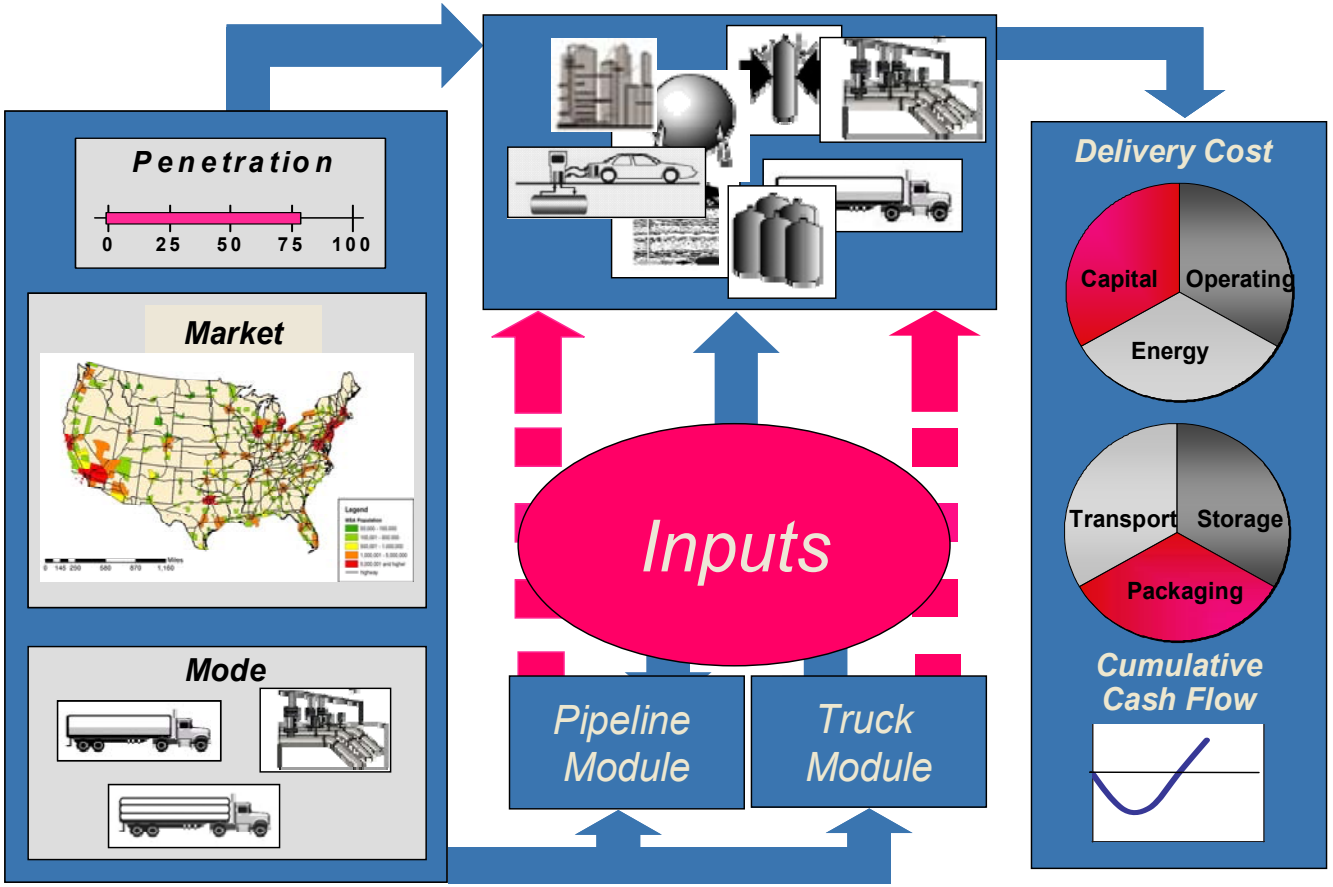
Overview of the H2A Delivery Scenario Model

Scenario Definition Components and Other Sub-Models Results



Delivery Modeling Accomplishments: FY07

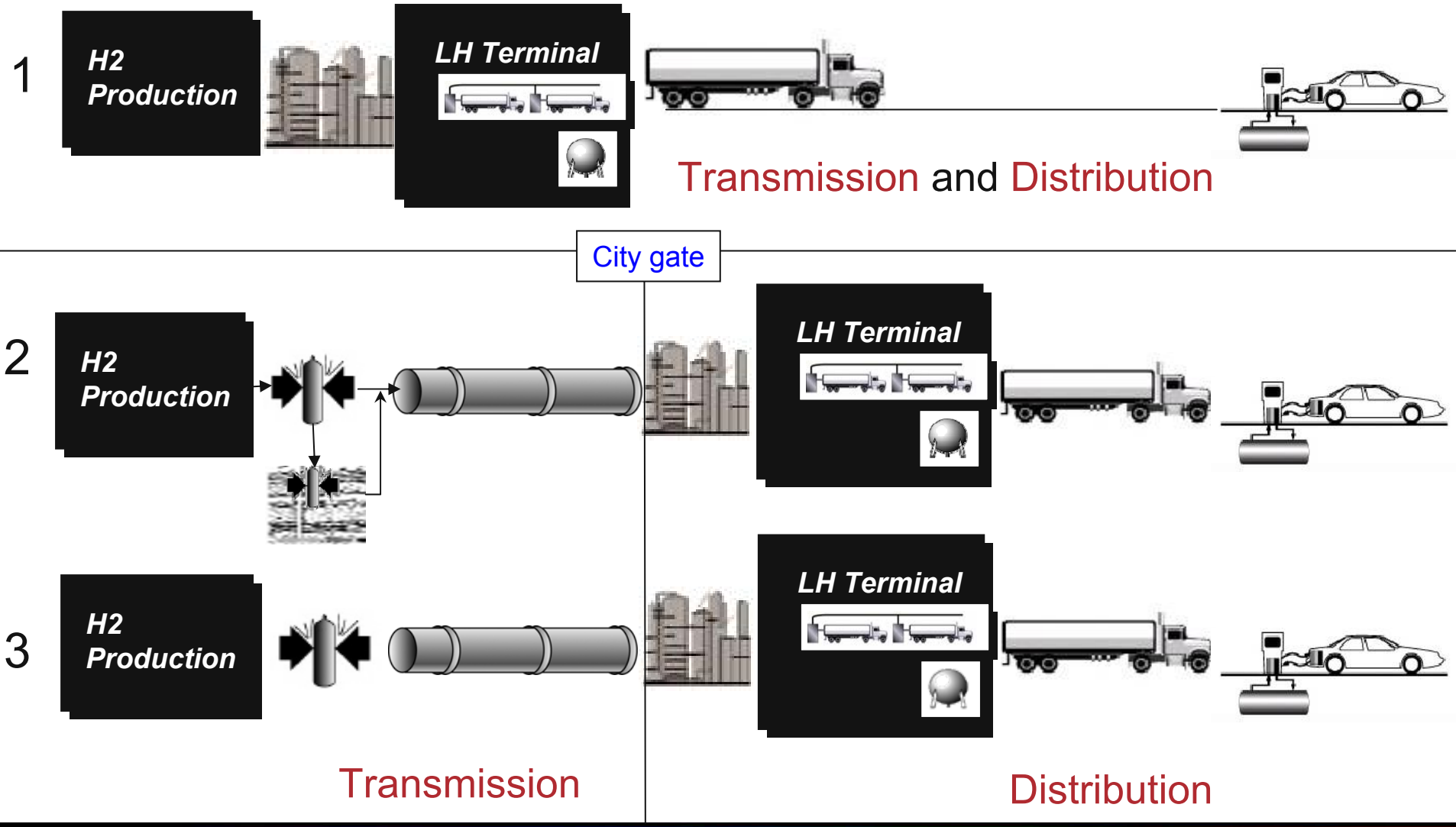
- ✓ Worked with Nexant team to review HDSAM 1.0 and develop improved inputs and approaches
  - Fuel demand profile
  - Forecourt design and optimization (TIAX)
  - Cost functions: (NEXANT)
    - Pipelines
    - Liquefier
    - Compressors
    - Storage vessels
  - Supply variations due to plant outages
- ✓ Components and HDSAM Model enhancements

Enhancements

- 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, combined markets, plant outage/summer peak handling)
- Cost and characteristics of all components reviewed and improved

HDSAM V2.0 Simulates Nine Urban Pathways

I. Liquid H2 Distribution:



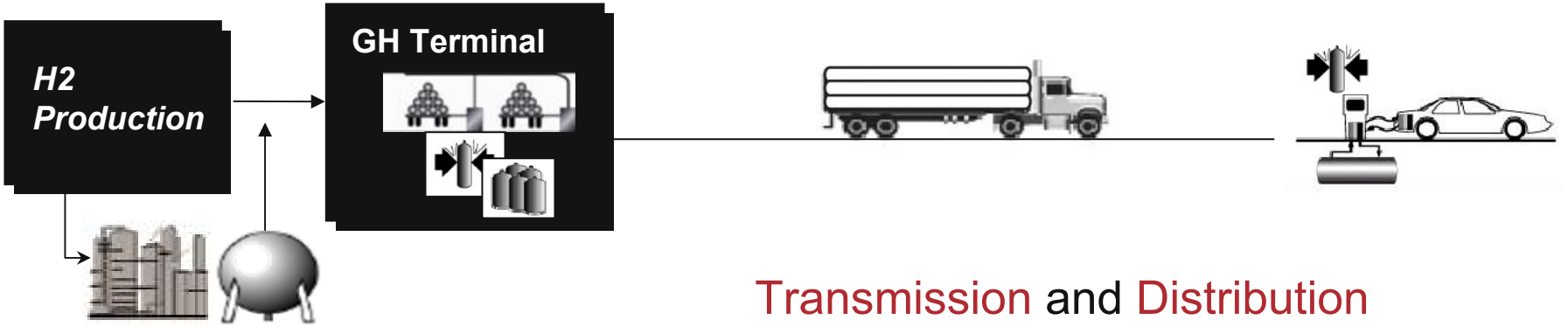
HDSAM V2.0 Simulates Nine Urban Pathways

II. Compressed H2 Distribution:

4

Transmission and Distribution

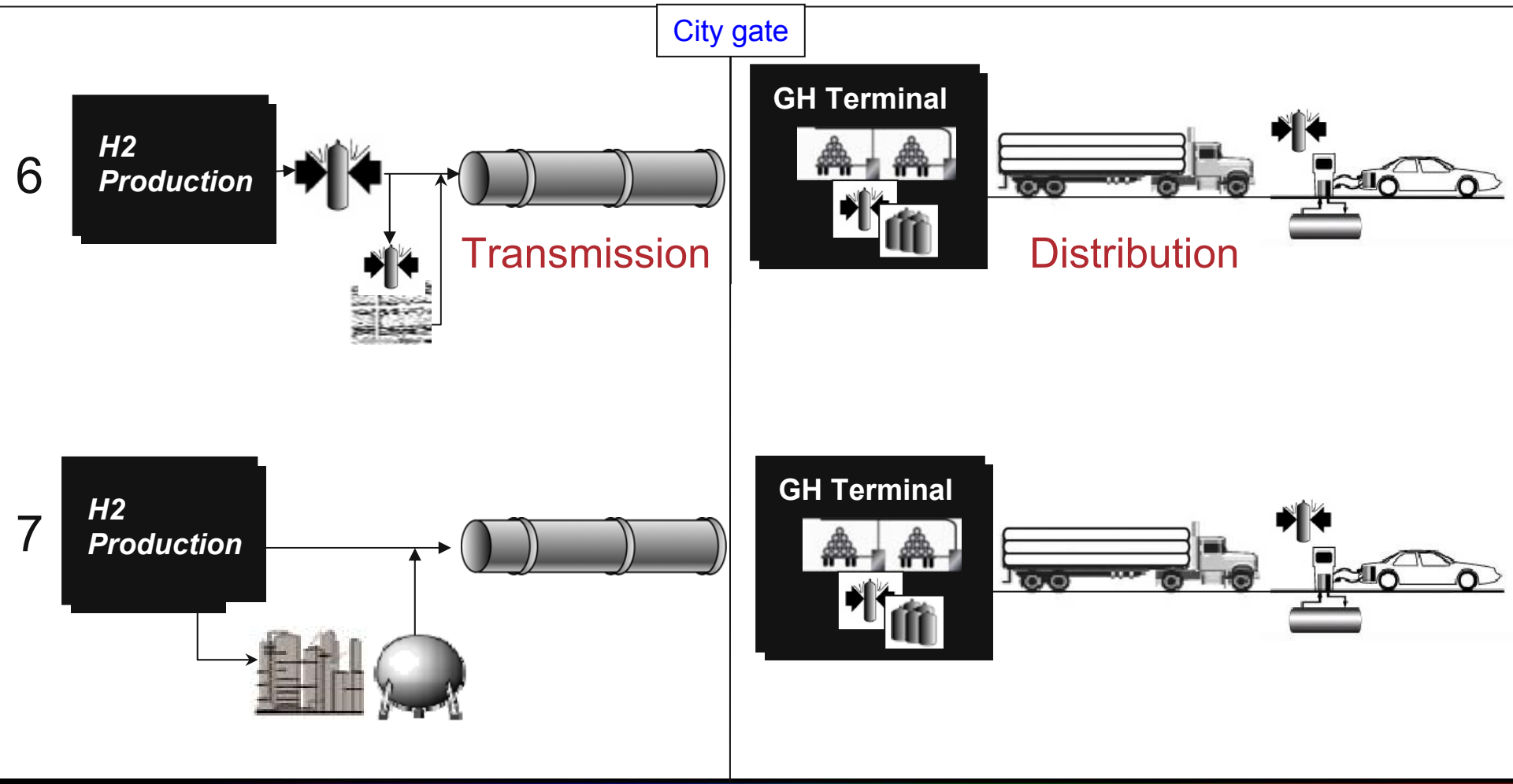
5



Transmission and Distribution

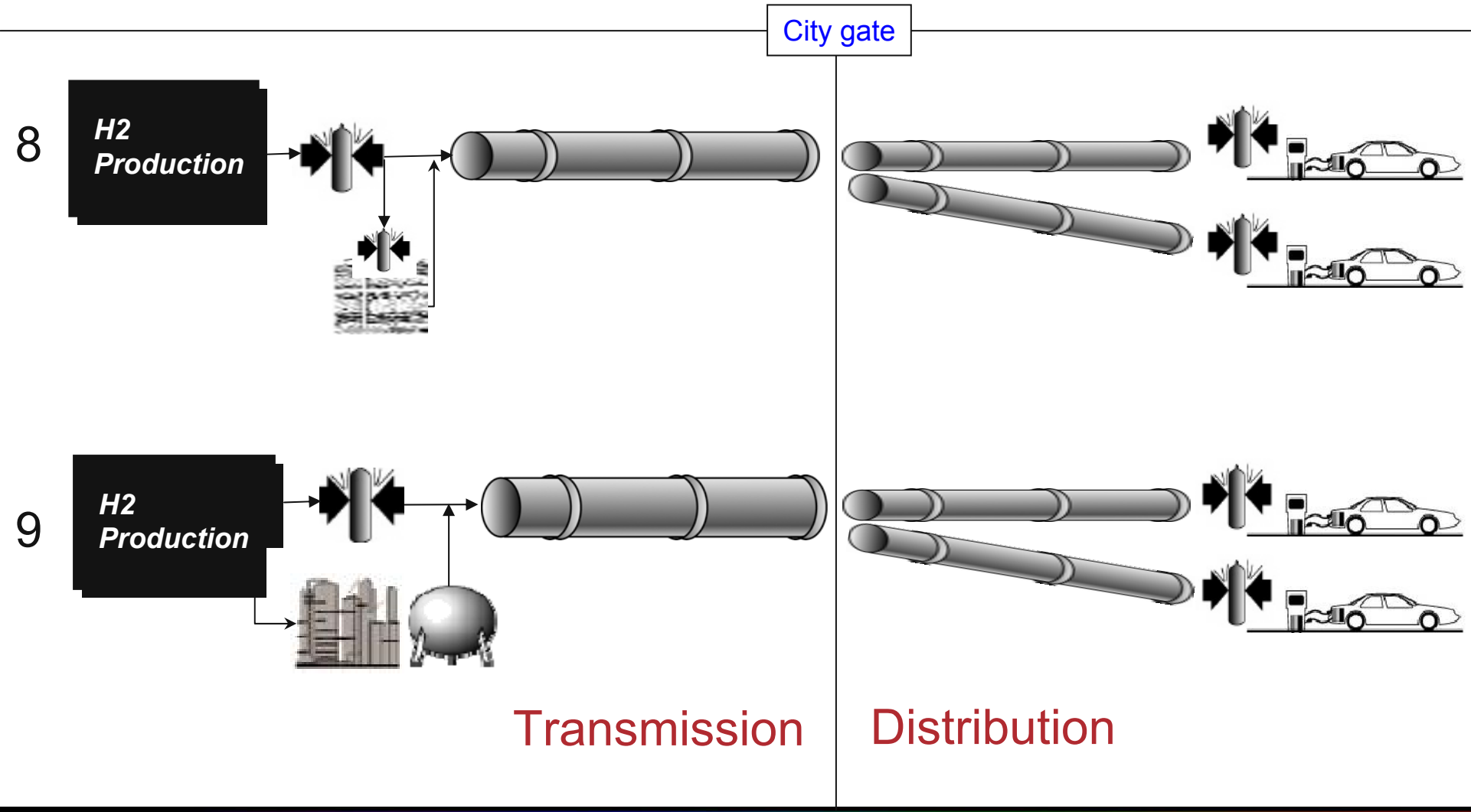
HDSAM V2.0 Simulates Nine Urban Pathways

II. Compressed H2 Distribution (cont'd):



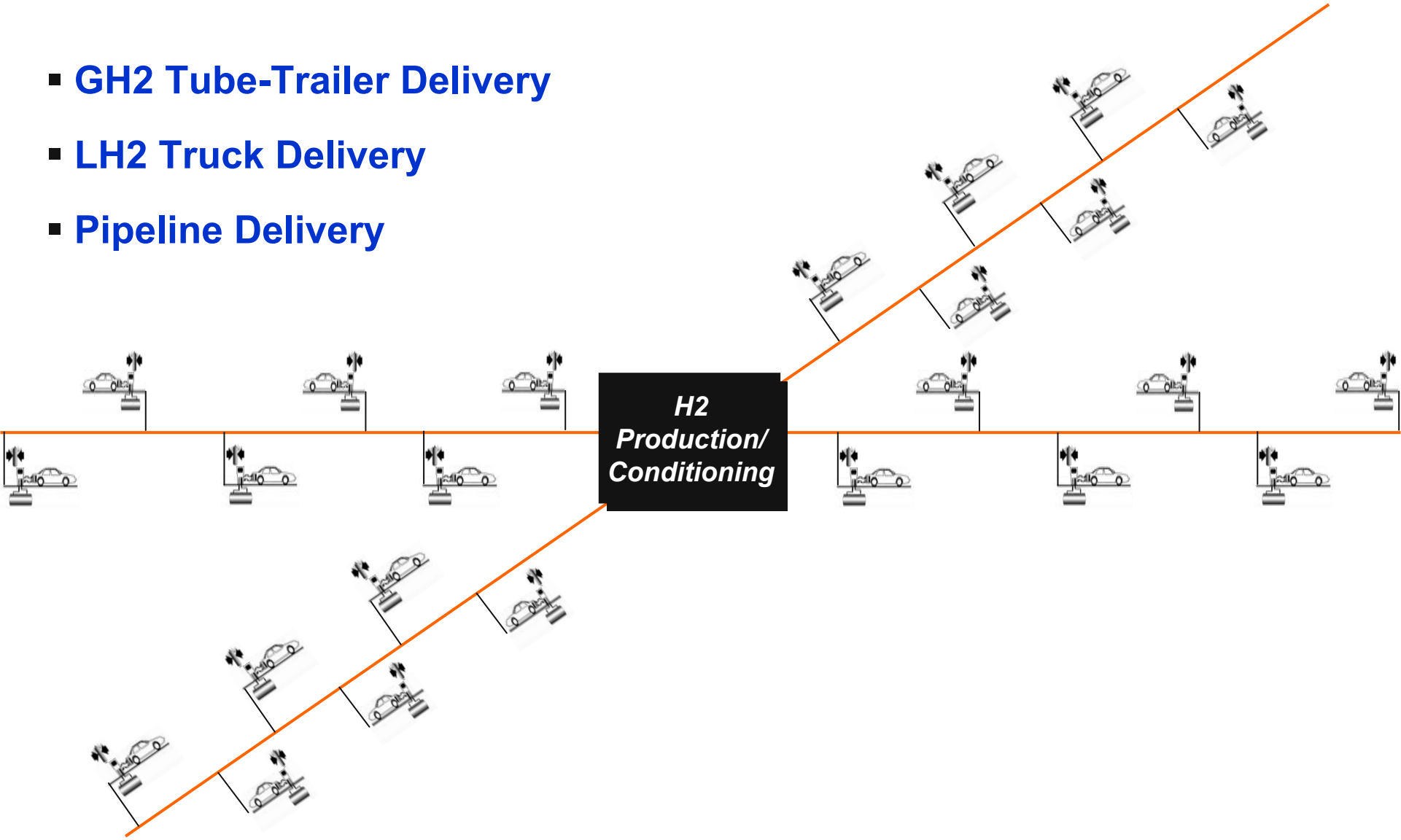
HDSAM V2.0 Simulates Nine Urban Pathways

III. Pipeline Delivery:



HDSAM V1.0 & V2.0 Simulate Three Rural Scenarios

- GH2 Tube-Trailer Delivery
- LH2 Truck Delivery
- Pipeline Delivery



HDSAM V2.0 Delivery Pathways Expansion

H2 Market
- Urban
- Rural Interstate
- (•) Combined Urban/Rural

Market Penetration
H2 Vehicle Market: 20 %

Transmission Mode
- Compressed H2 Truck
- Liquid H2 Truck
- (•) Pipeline

Distribution Mode
- Compressed H2 Truck
- (•) Liquid H2 Truck
- Pipeline

Refueling Station Size
Desired Dispensing Rate [kg/day]: 850

City Selection
Los Angeles--Long Beach--Santa Ana, CA

Population: 11,789,487

Click Here To Calculate

Component for Plant Outage and Summer Peak
- Geologic Storage
- (•) Liquefier and Liquid Storage

Key Delivery Inputs and Assumptions

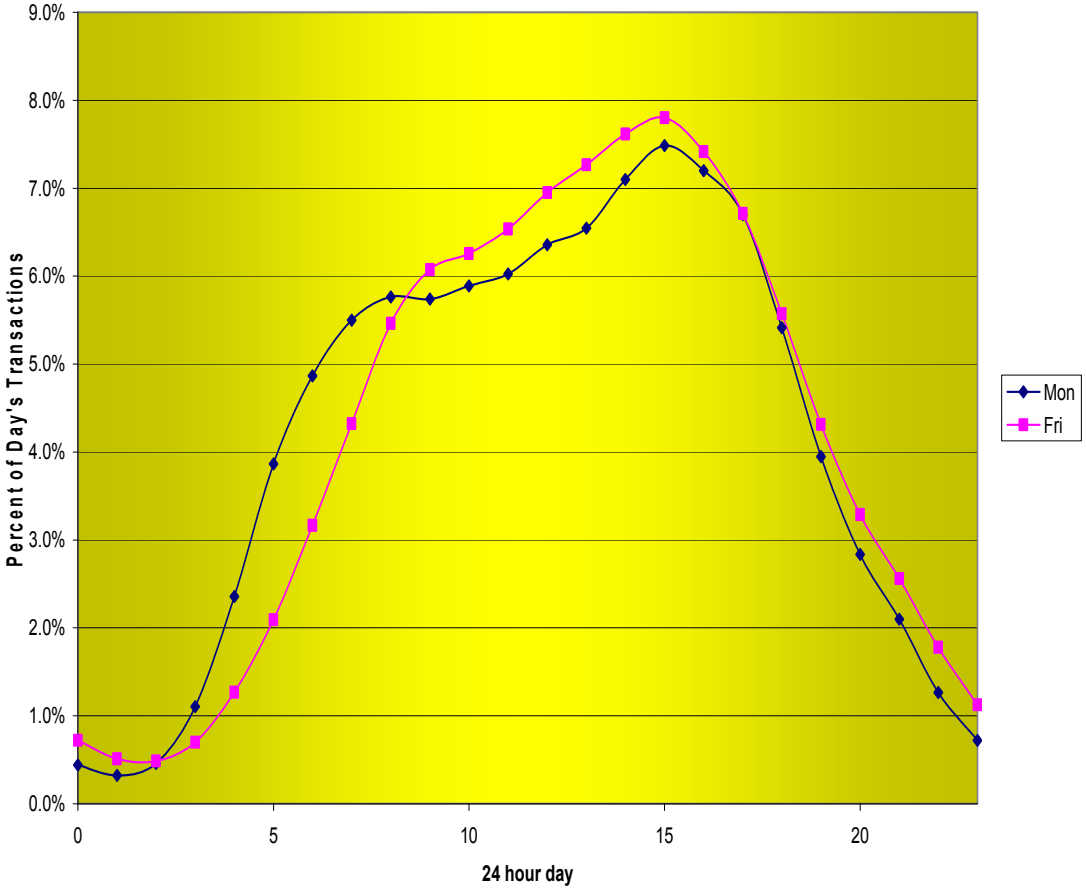
City population	11,789,487
City area (mi2)	1668
Population density (people/mi2)	7,068
Vehicles/person	0.65
Miles driven per year/ vehicle	12,823
Rural road segment Length (mi)	300
Ave. LDV Miles Travelled/Rural Interstate Hwy mile (mi/d)	17,000
Average station distance from interstate (mi)	0.5
Distance from production to city (mi)	62
Utilization of H2 stations full capacity (% of total number of H2 stations)	100%
Number of Days for Scheduled Production Plant Outage	10
Summer Surge: % above the System Average Daily Demand	10.0%
Number of Days for Surges (Above Average Demand)	120
Friday Peak: % above Daily Average Demand	8.0%
H2 Vehicles fuel economy equivalent (mi/gge)	67.30

Demand Calculations

Ave. H2 daily use (kg/d)	830151
Peak H2 daily use (kg/d)	913166
Number of H2 refueling stations	978
Number of H2 stations/Number of gasoline stations	25%

Analysis of Market Demand and Supply Variations

- Supply Side Variations: Central Production Plant Outages
  - Scheduled yearly maintenance: Typically 5 to 10 consecutive days each year
  - Unscheduled maintenance outages: Indeterminate time and length
  - Natural disasters: A few days?
- Demand side variations
  - Hourly at refueling sites
  - Day to day at refueling sites
    - *Friday is 8% higher than the average*
  - Winter/Summer demand variation
    - *Summer is 10% above average; winter is 10% below average*



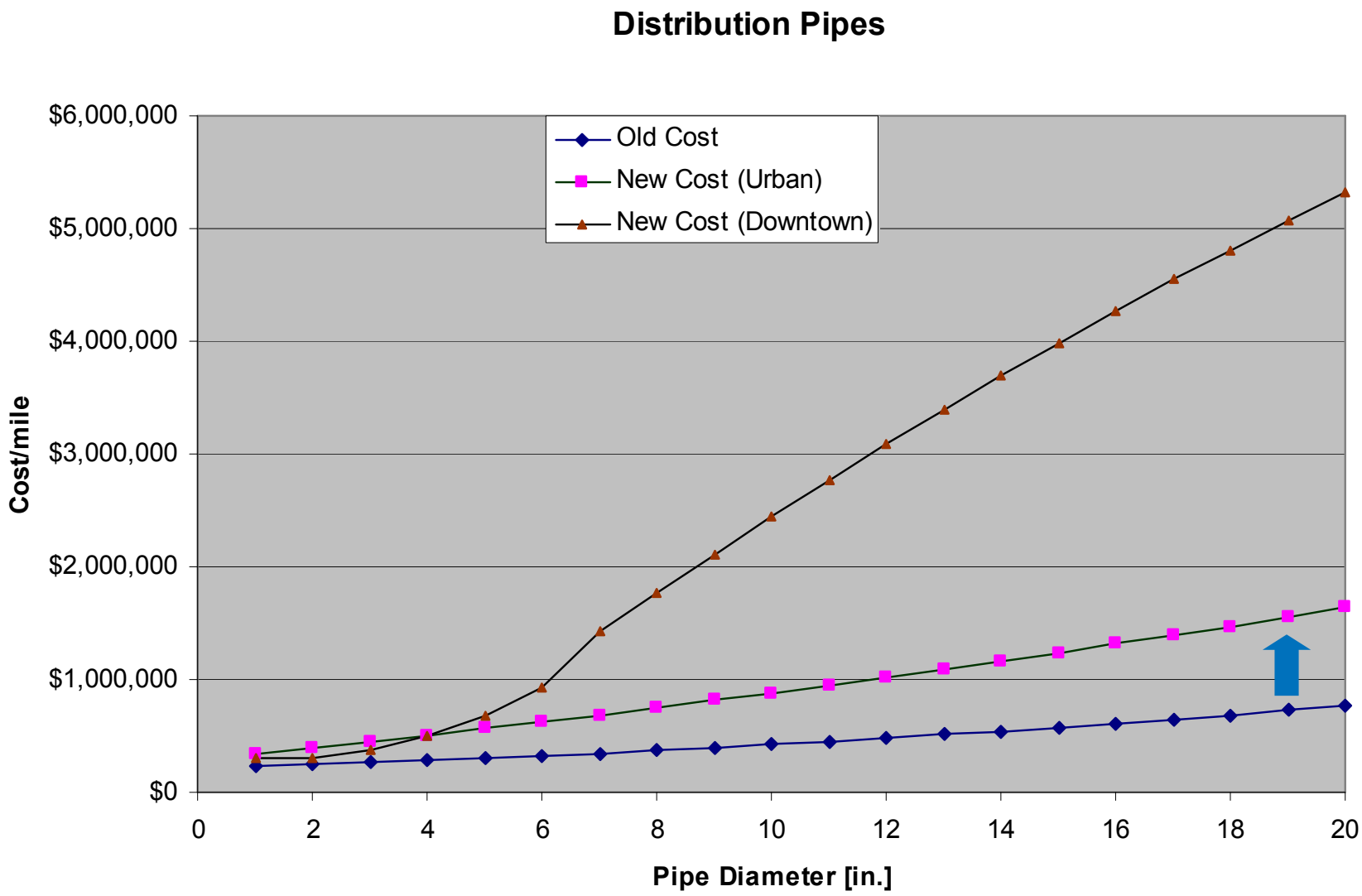
Analysis of Storage Options and Costs

- Storage Problem
  - *Production plants operate at constant rate, but demand varies*
- Storage Options
  - *Geologic gas storage*
    - Low cost for very large amounts of hydrogen
    - May not be conveniently located
  - *Liquefaction and liquid storage: Second best for large quantities*
  - *GH2 Tanks: Highest cost, but efficient for small volumes*

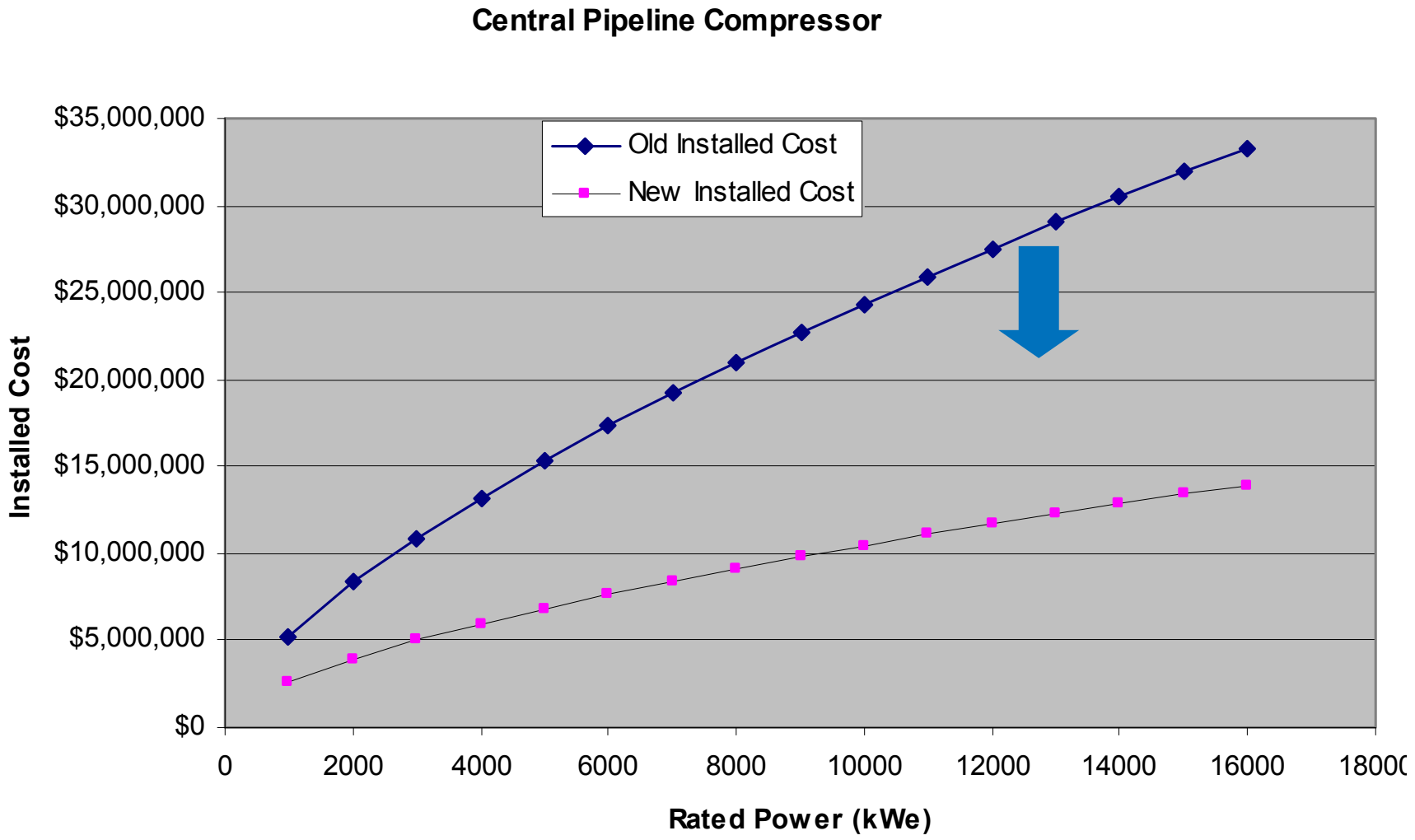
❖ ***Storage and compression can add significant cost to hydrogen delivery***

❖ ***Need to find the optimum storage solution***

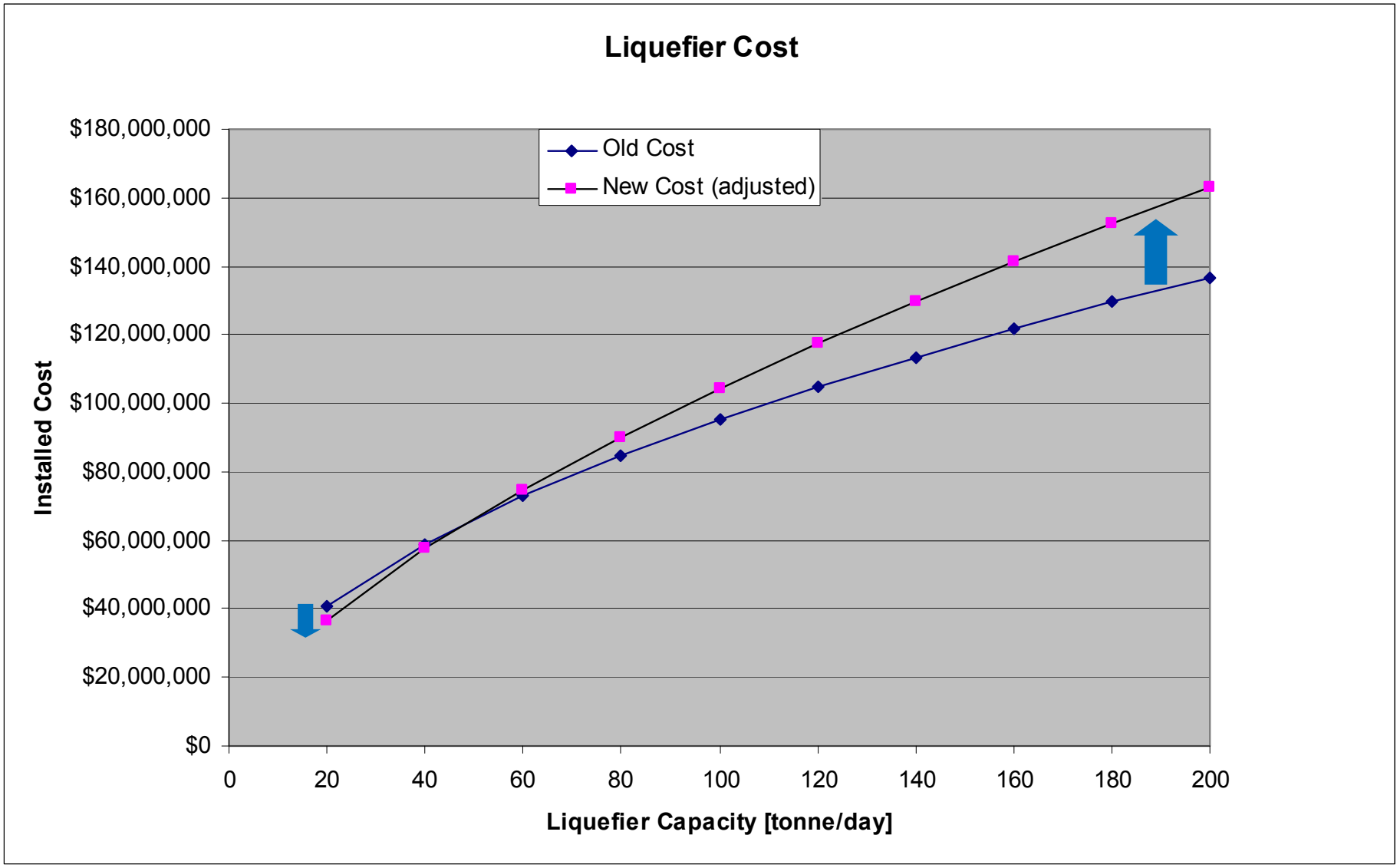
Distribution Pipeline Cost Functions



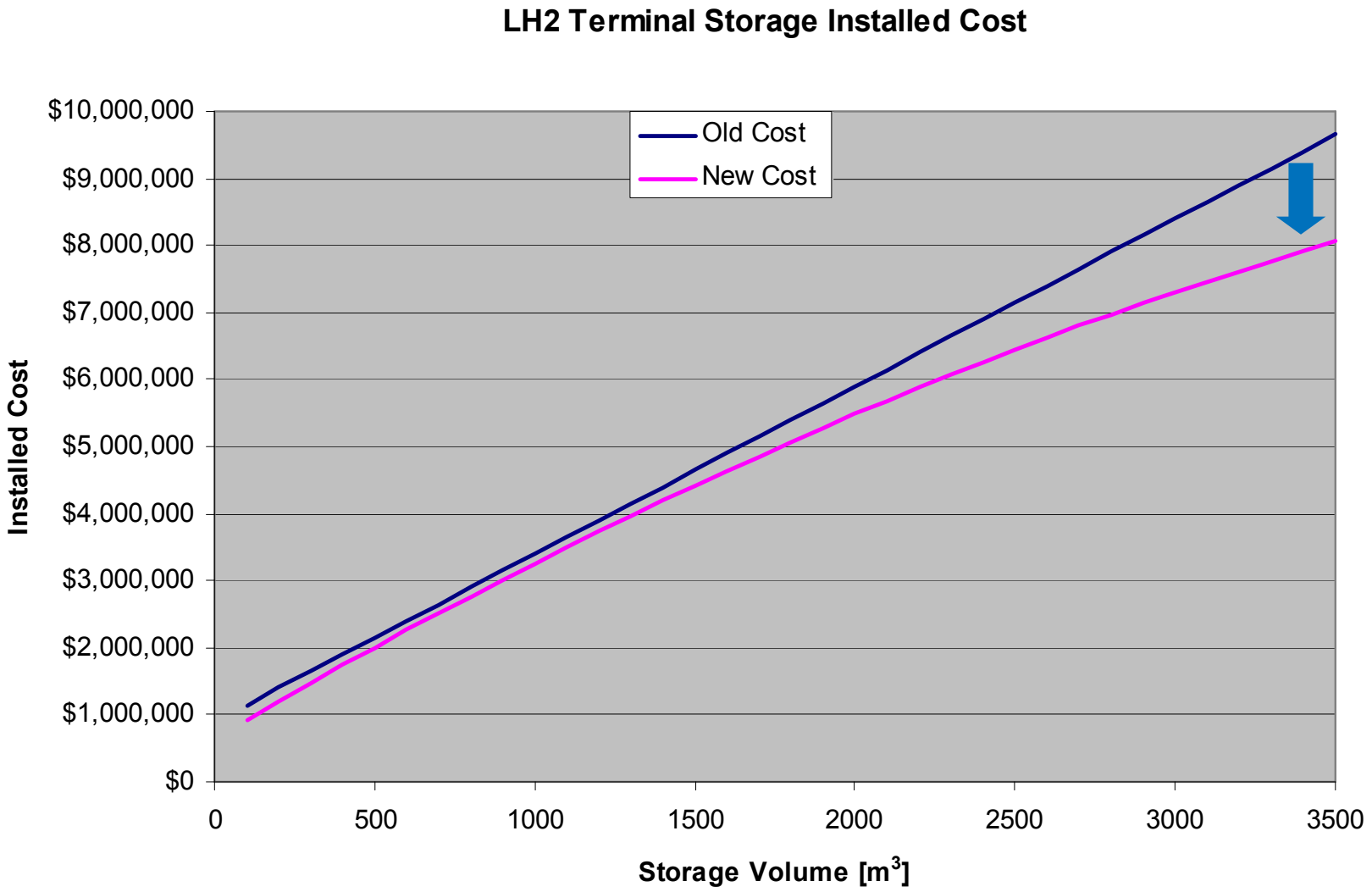
Large Compressor Cost Function: HDSAM V1.0 vs. V2.0



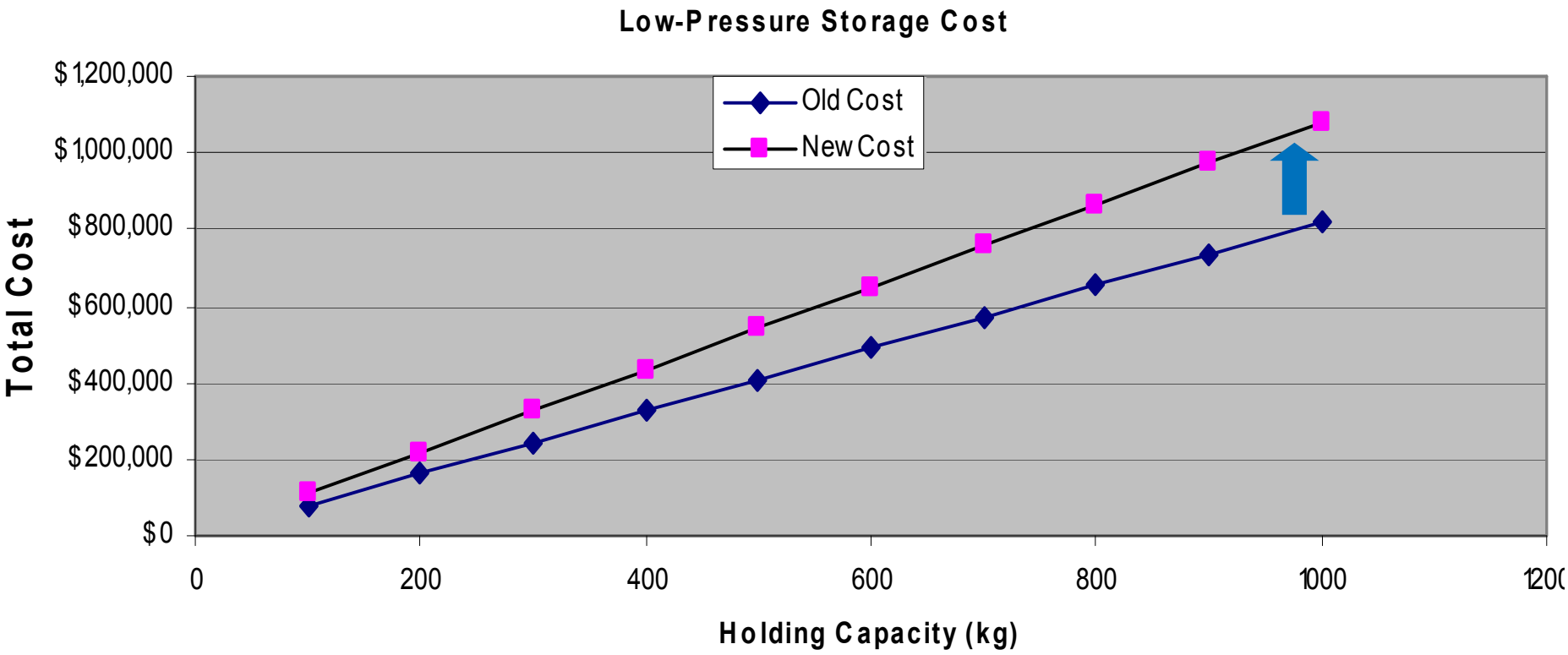
Liquefier Cost Function: HDSAM V1.0 vs. V2.0



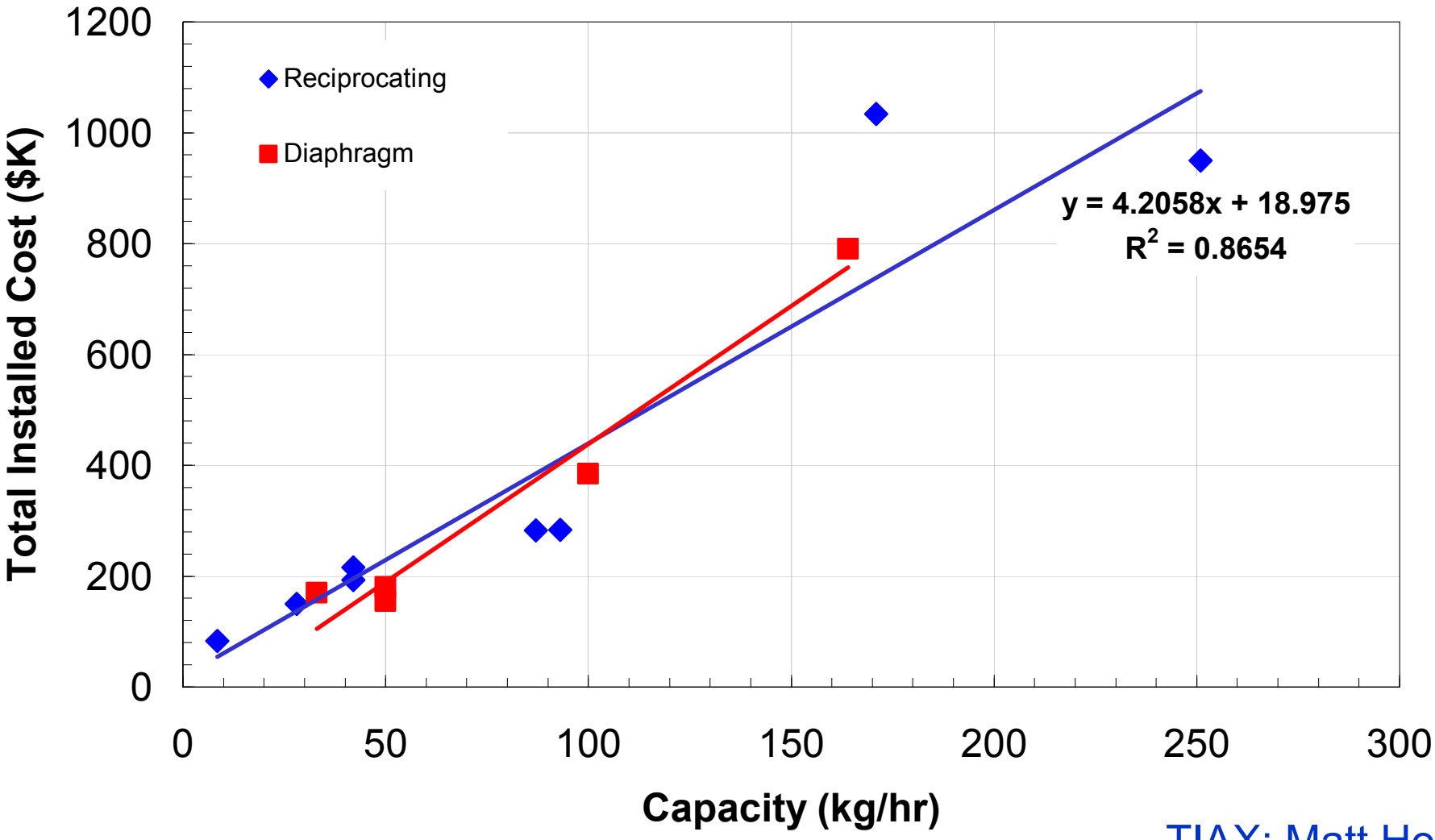
Liquid Storage Costs: HDSAM V1.0 vs.V2.0



Gaseous Storage Cost Function: HDSAM V1.0 vs. V2.0

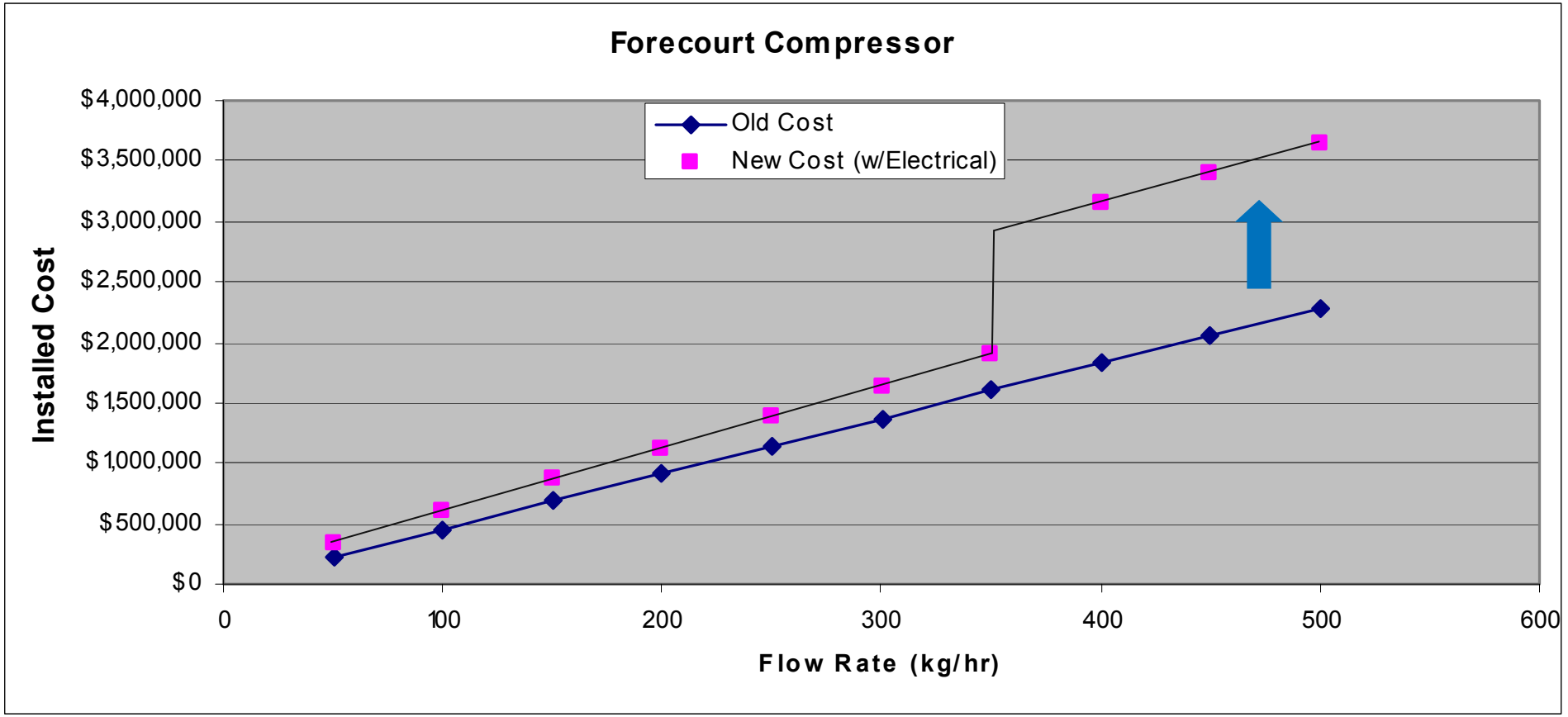


Small Forecourt Compressor



TIAX: Matt Hooks

Small Compressor Cost Function: HDSAM V1.0 vs. V2.0



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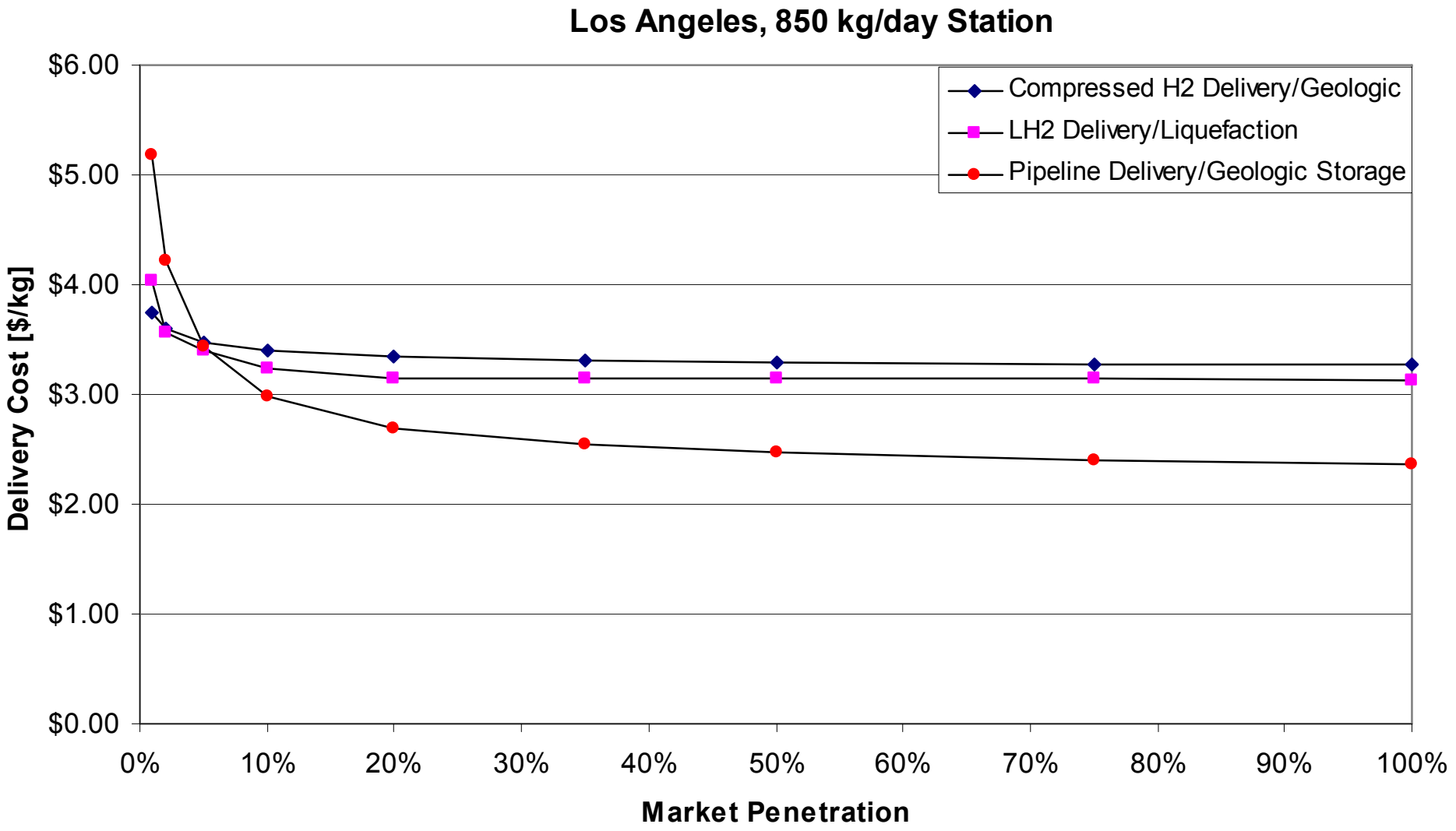
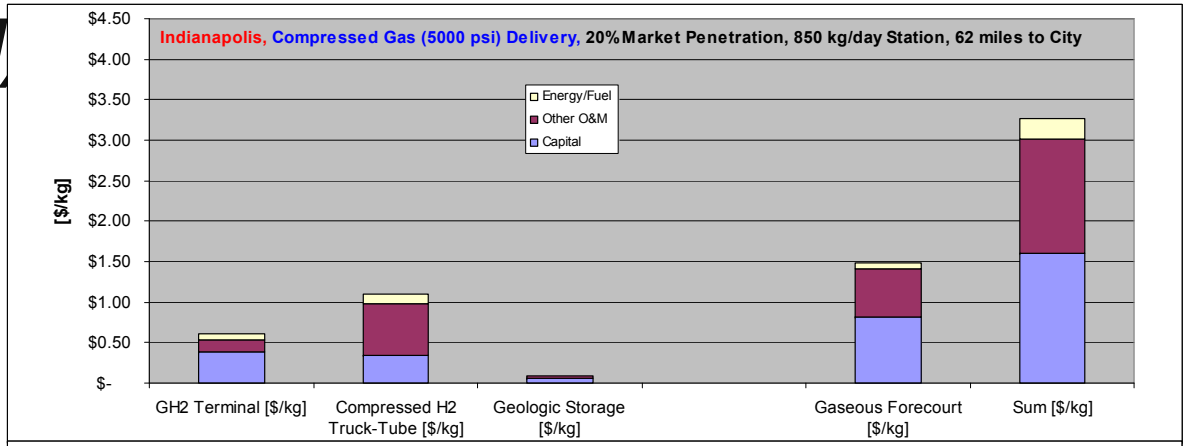
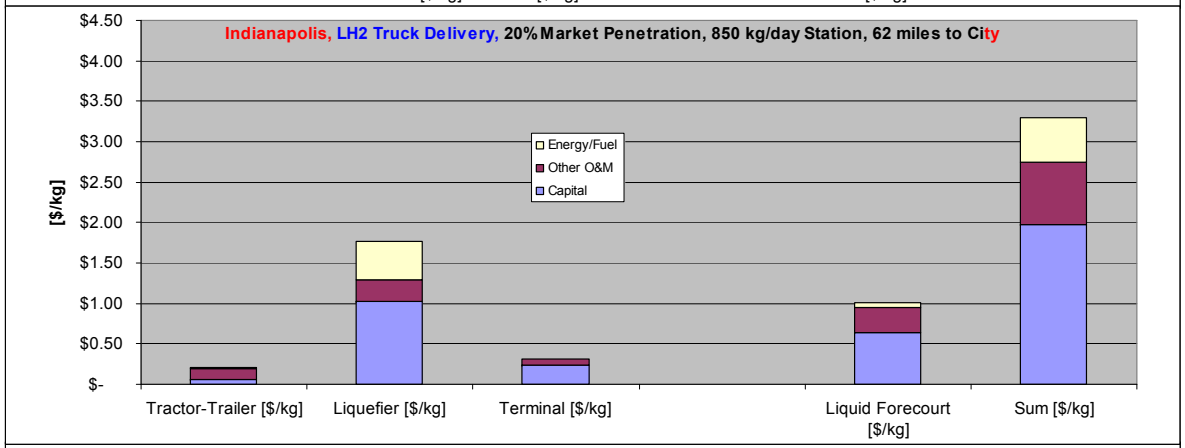
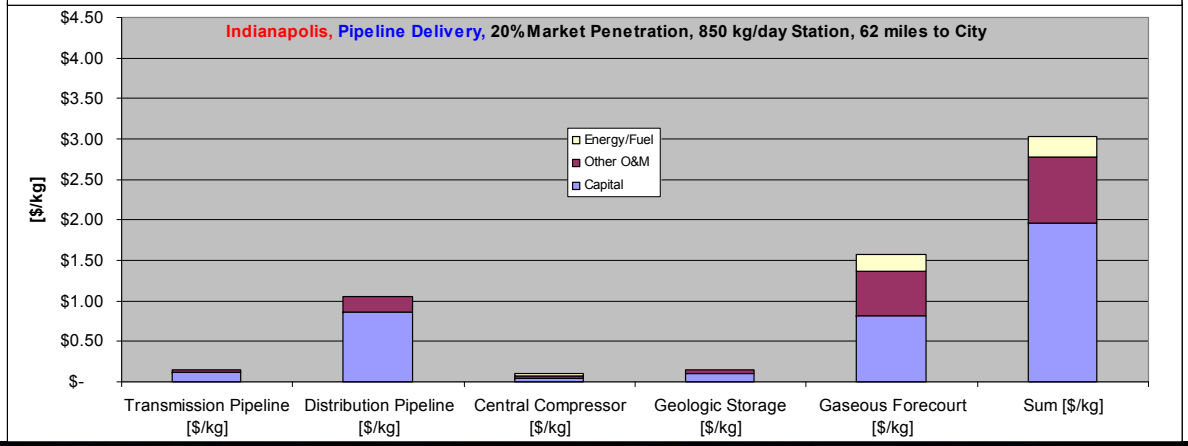
Comparison of Delivery Modes: Los Angeles



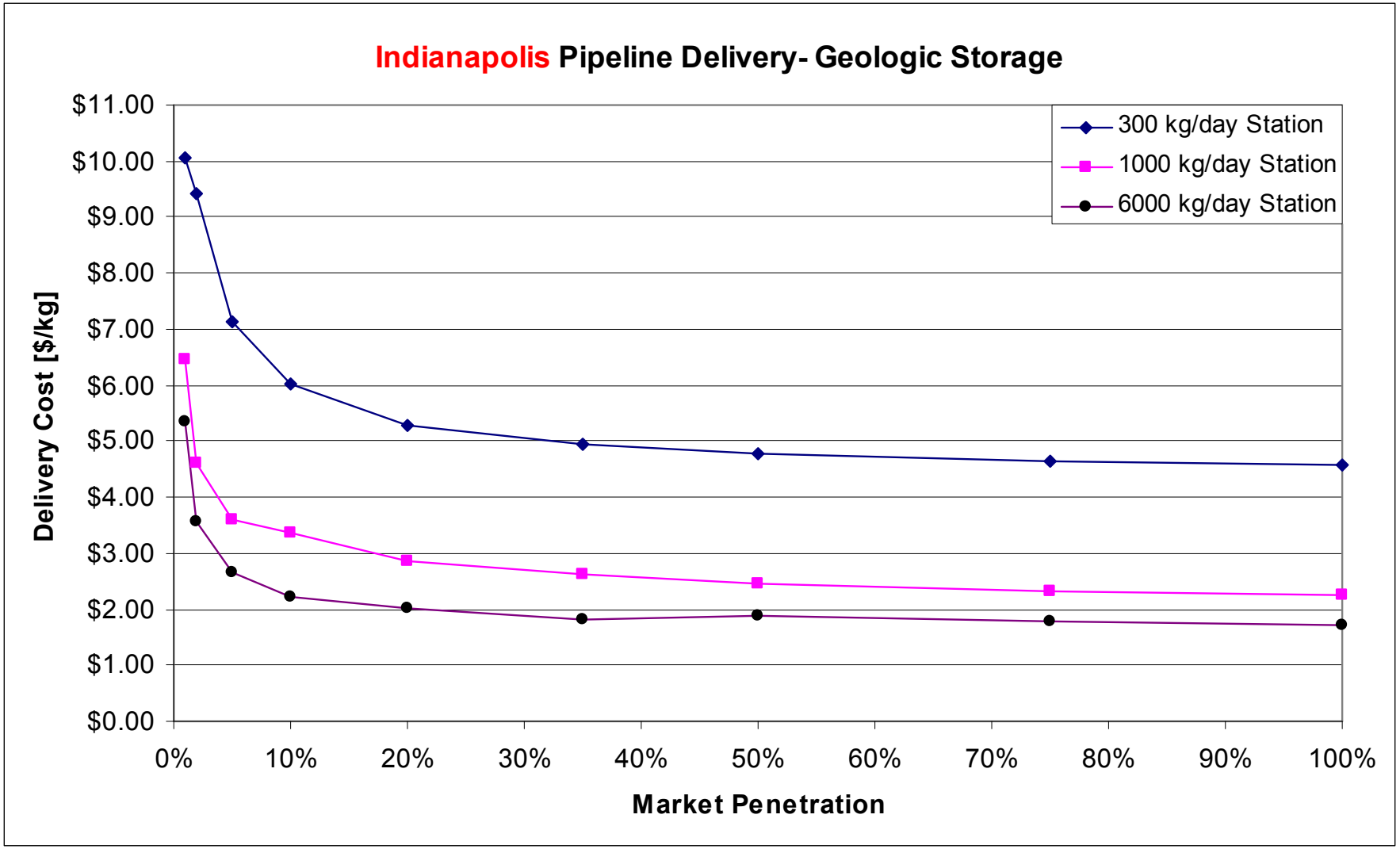
Los Angeles (cont'd)



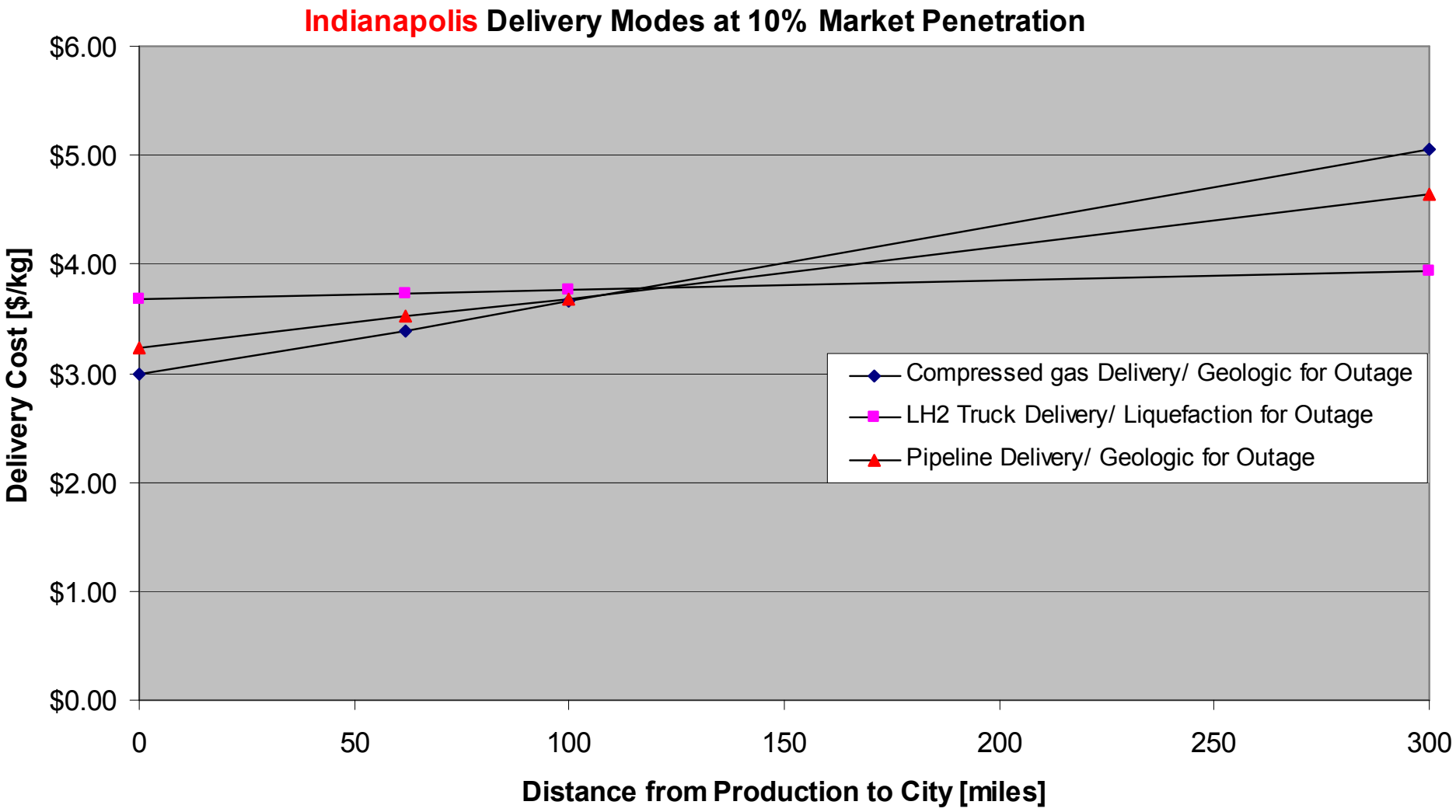




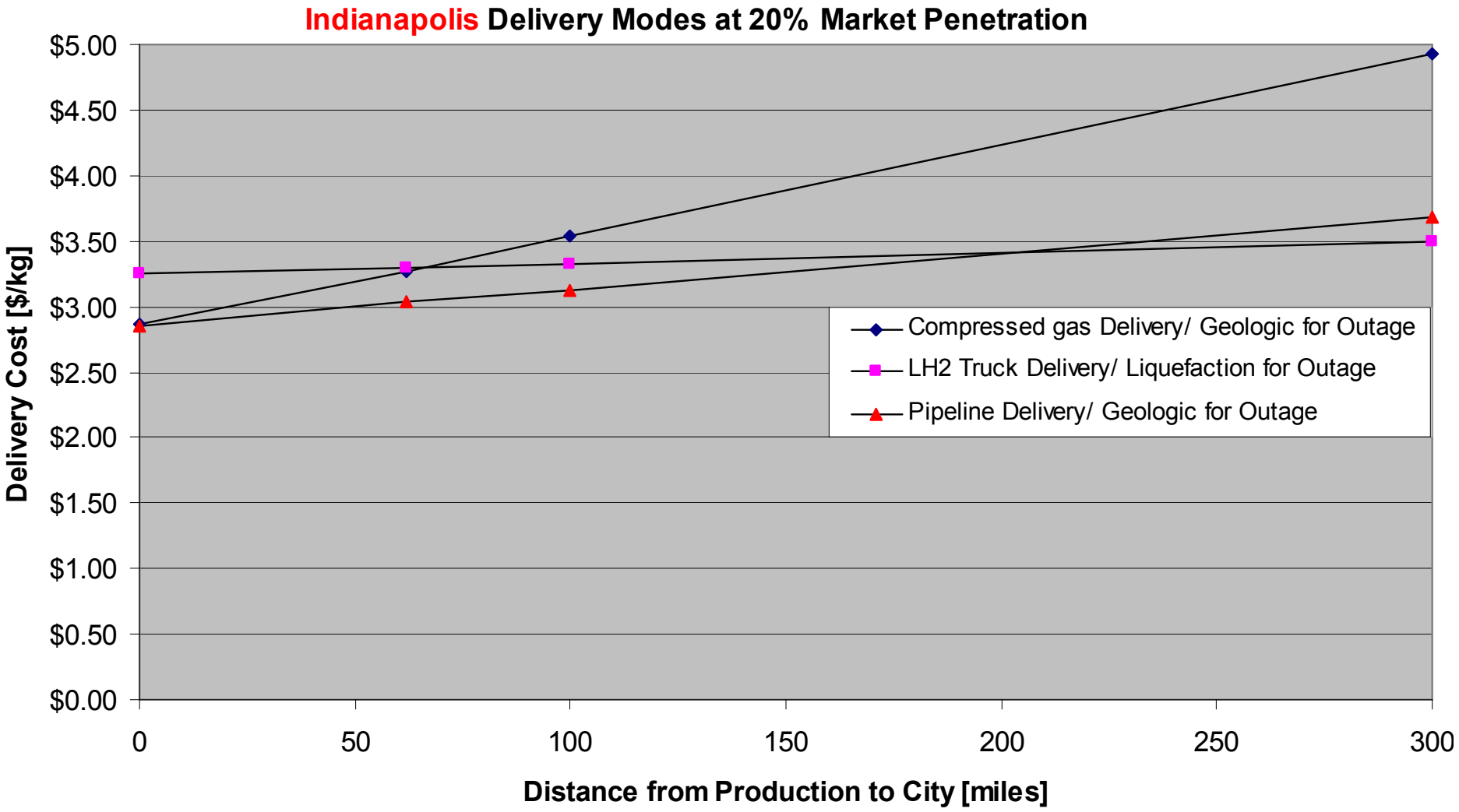
Comparison of Different Station Sizes



Indianapolis at 10% Market Penetration

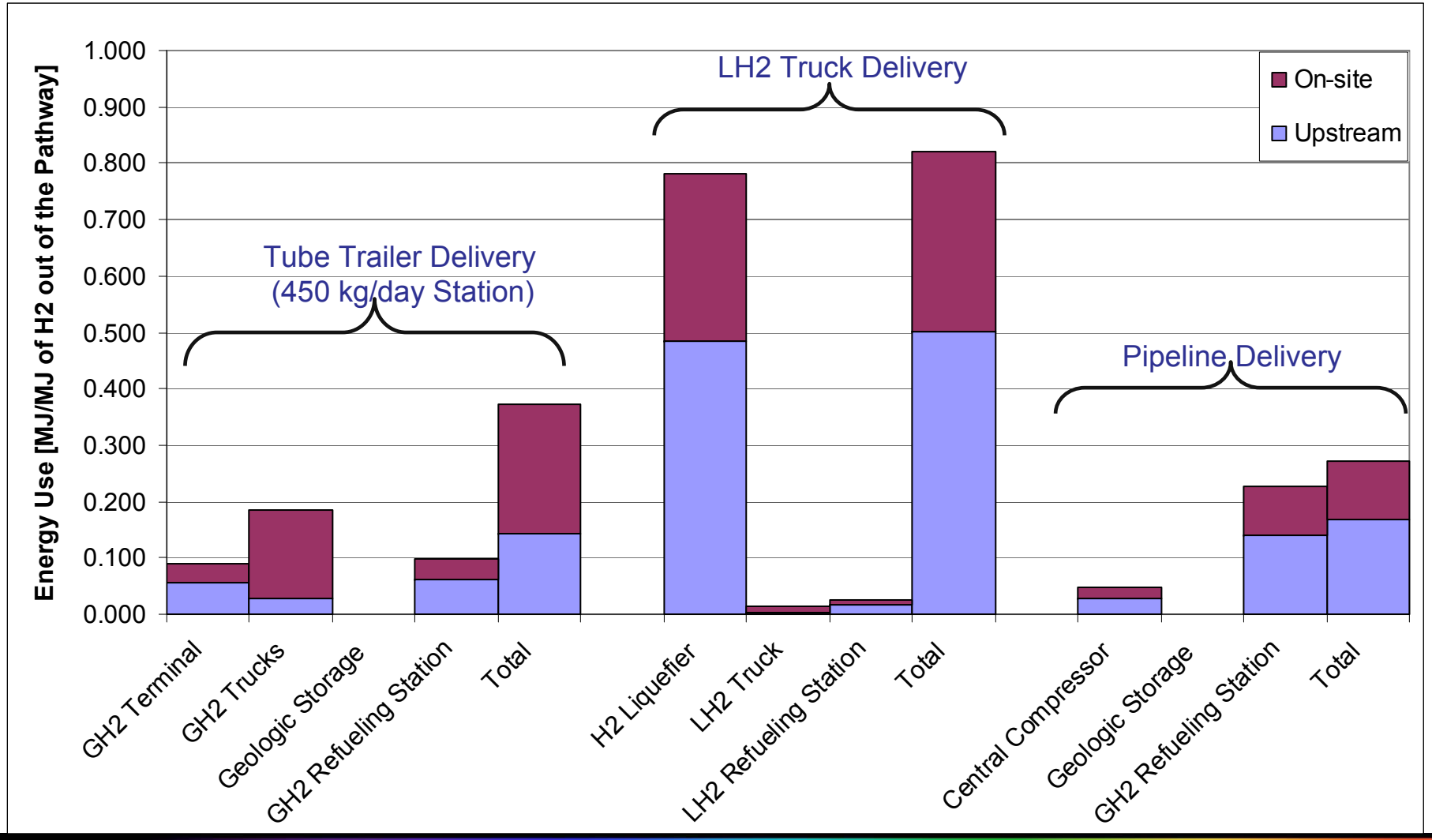


Indianapolis at 20% Market Penetration



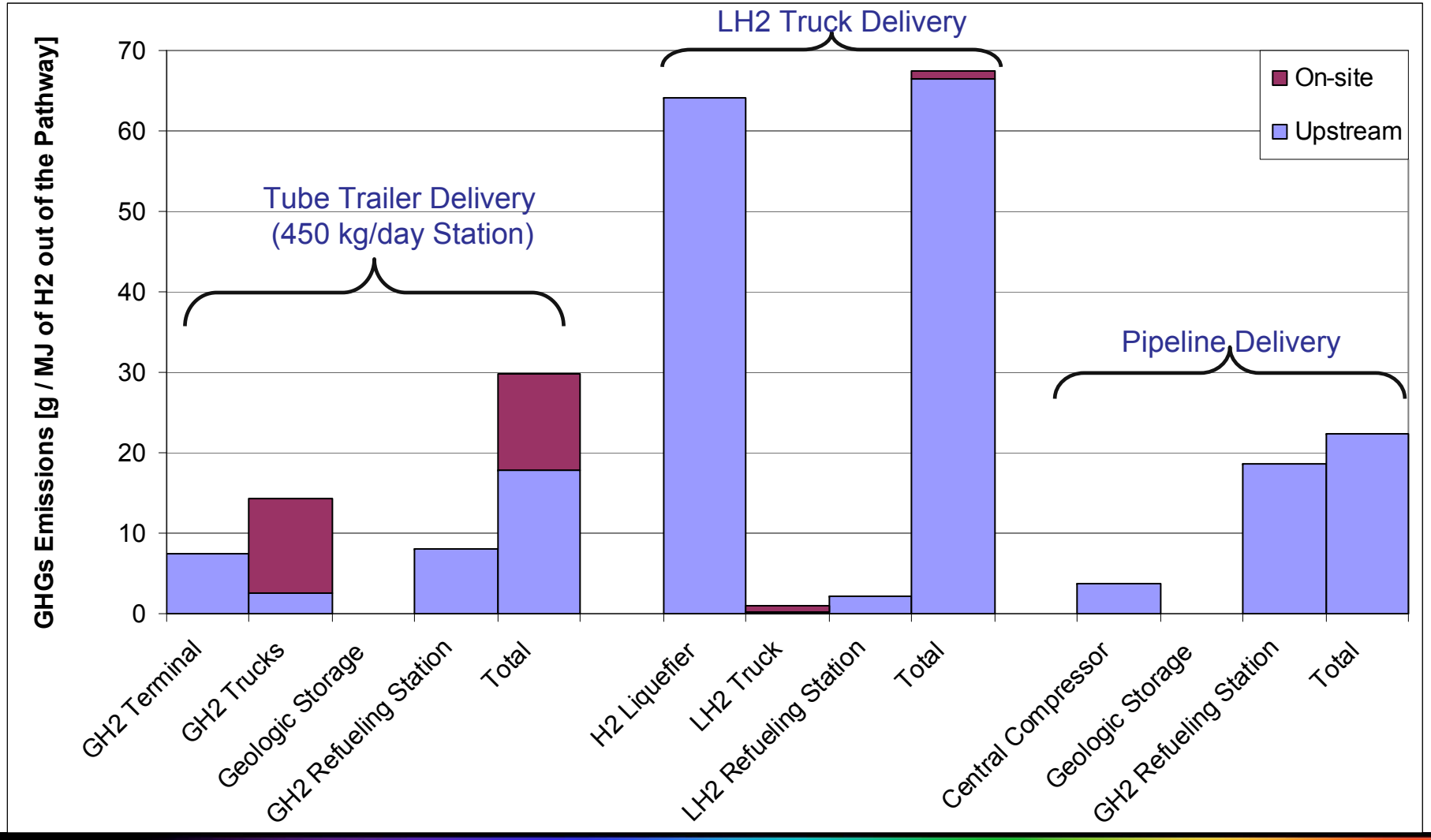
Energy Use by Delivery Mode- Indianapolis

20% Market Penetration, 1000 kg/day Station, 62 miles to City



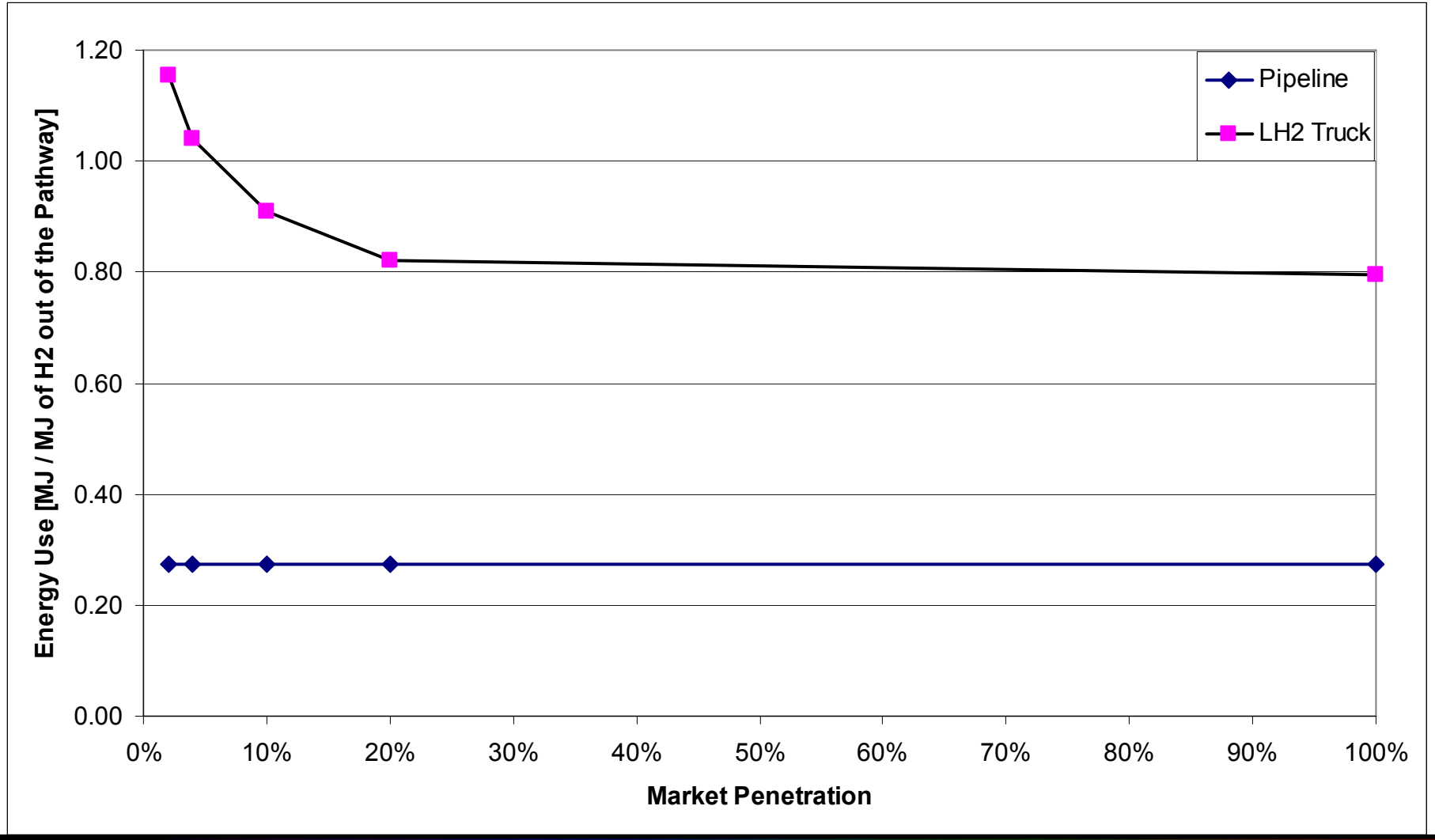
GHGs Emissions by Delivery Mode- Indianapolis

20% Market Penetration, 1000 kg/day Station, 62 miles to City



Energy Use by Market Demand- Indianapolis

1000 kg/day Station, 62 miles to City



GHGs Emissions by Market Demand- Indianapolis

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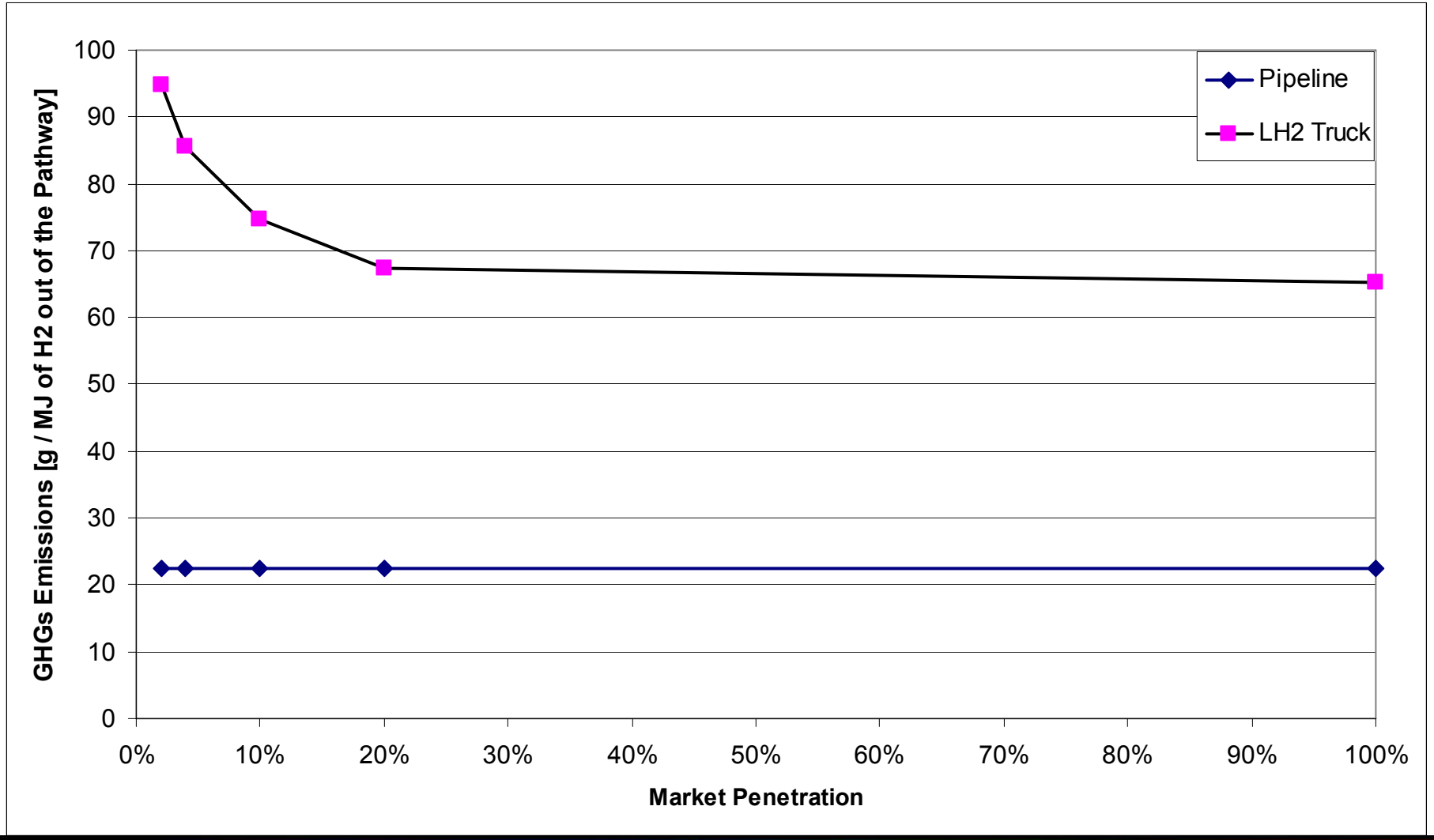

Acknowledgements

Other members of H2A Delivery team:

- Mark Paster, *DOE*
- Jerry Gillette, *ANL*
- Matt Ringer, *NREL*
- Daryl Brown, *PNNL*
- Bruce Kelly and TP Chen, *Nexant*
- Matt Hooks, *TIAX*

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- GTI
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