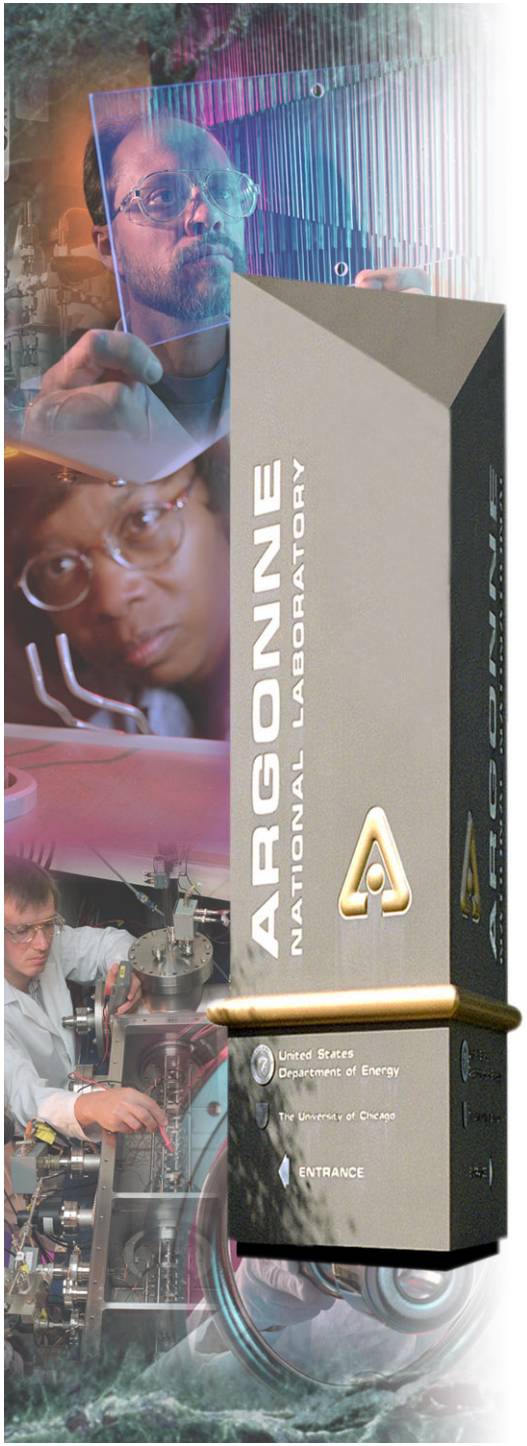

HDSAM: A Hydrogen Delivery Scenario Analysis Model to Analyze Hydrogen Distribution Options

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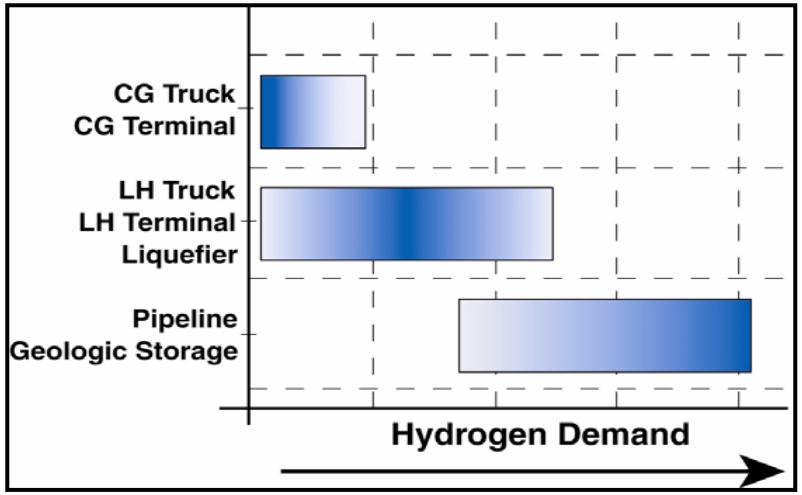
Delivery Scenarios Model Estimates Unit Cost of Bulk Transport, Local Distribution and Dispensing

Hydrogen can take many paths from “well-to-pump”. Since unit cost declines with increasing shipment size, bulk modes are more attractive at higher demand levels ---

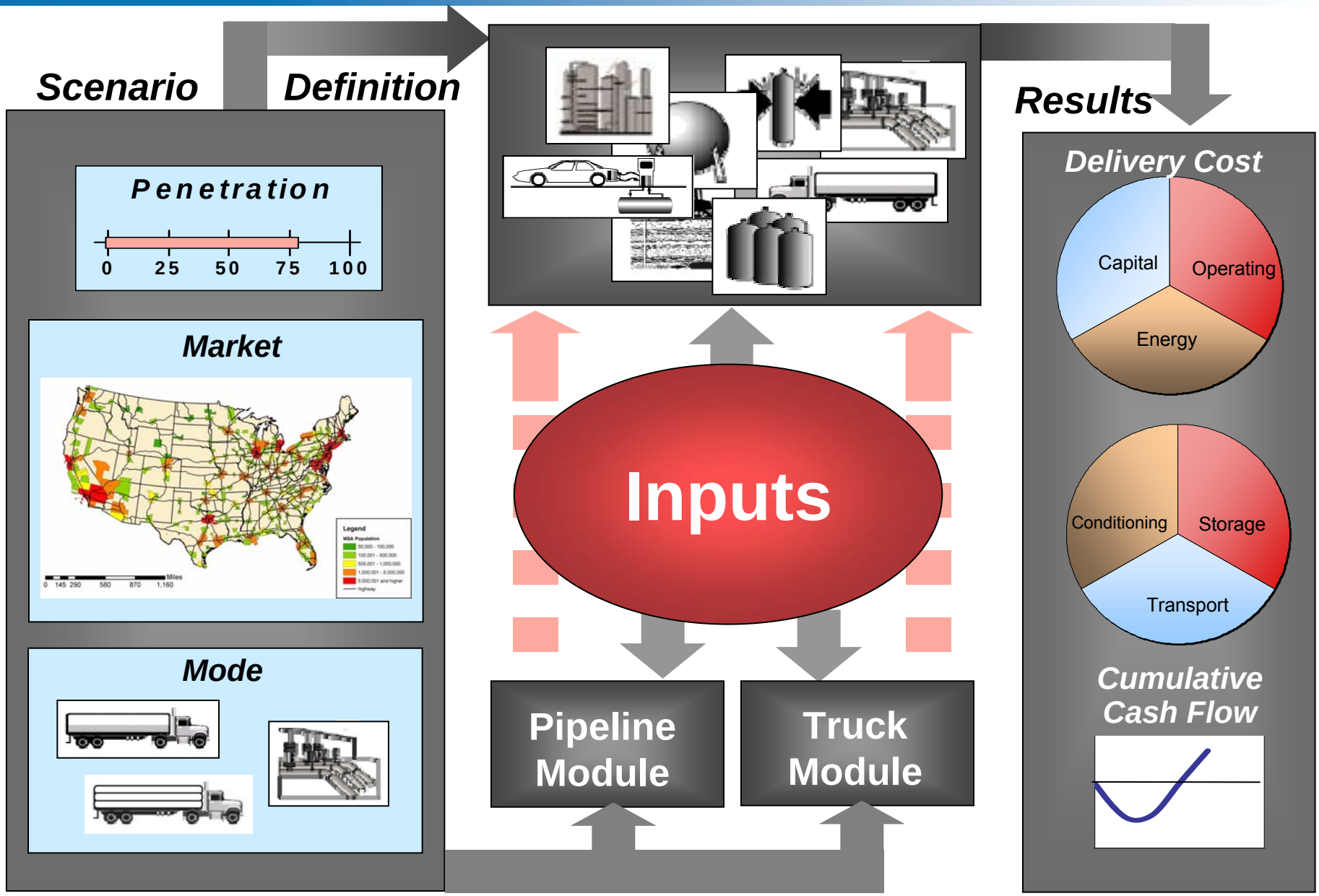
But where are the tipping points and how might delivered cost of H2 change with new technology?



Objectives of Hydrogen Delivery Scenario Analysis Model (HDSAM):

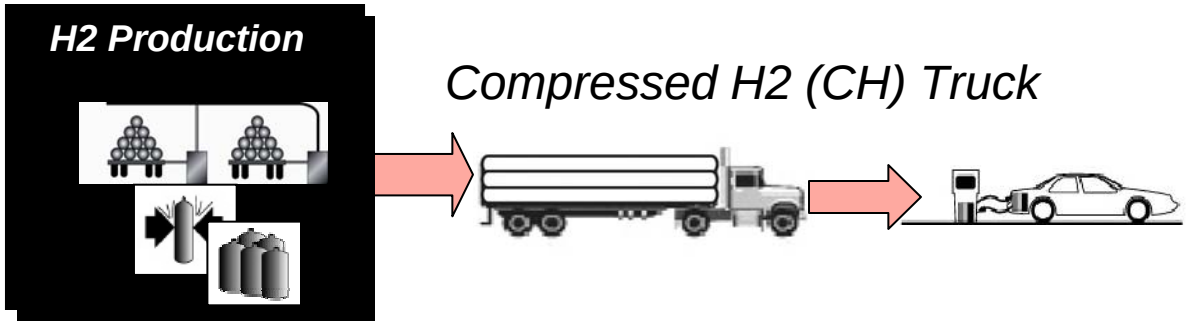
- Allow user to quickly and easily define scenarios of interest
- Display relevant input and output (H2A color coding)
- Incorporate "first principles" detail of Delivery Components Model (see www.hydrogen.energy.gov)
- Automatically link appropriate components into pathways
- Provide structure for efficiently examining
  - New technologies
  - Alternative delivery pathways and packaging options
  - Effect of demand density and scale

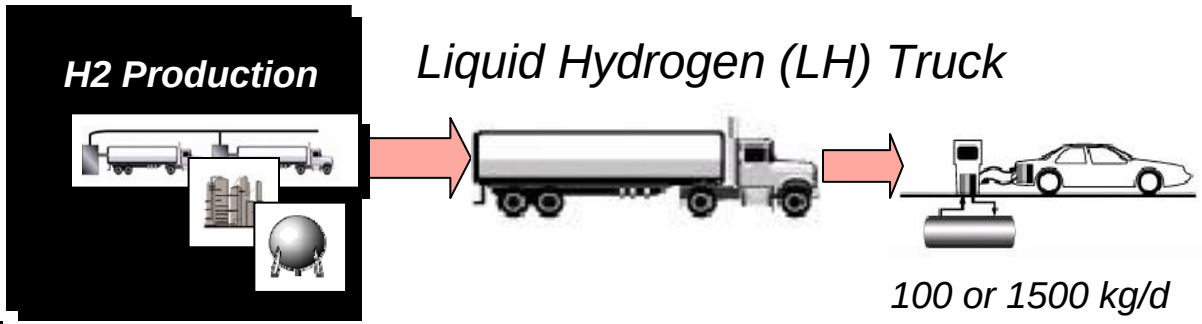
Provides "snap shot" of delivery cost resulting from input assumptions. Not a transition model.

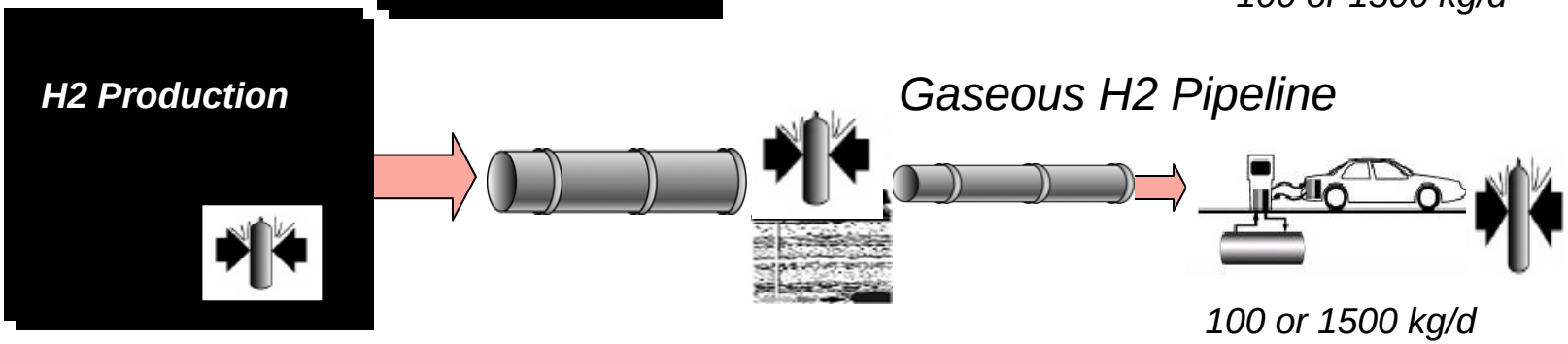

Scenario
Definition
Results
Penetration
0
25
50
75
100
Market
Mode
Inputs
Pipeline Module
Truck Module
Delivery Cost
Capital
Operating
Energy
Conditioning
Storage
Transport
Cumulative Cash Flow

HDSAM Estimates Delivery Cost by Pathway

Delivery is by a single mode in V1.0. Thus, loading, conditioning and storage are inside or adjacent to production. V2.0 will add 4 pathways (pipeline + liquid or gaseous truck, chemical carriers and distributed production).







HDSAM Capabilities Have Grown Over Time

Pathways	Penetration	Markets
LH Truck	Fixed (1, 10, 30, 70%)	Generic large urban (1 M)
GH Truck		Generic small urban (100 K)
Pipeline		Short intercity segment (100 mi)
+ HPGH Truck (7000 psi)	Variable (1%-100%)	Long intercity segment (200 mi)
+ GH Forecourt (100, 1500 kg/d)		>450 individual urbanized areas
+ LH Forecourt (100, 1500 kg/d)		Variable population, generic urban area
+ Pipeline & GH Truck		Variable # and length intercity segments
+ Pipeline & LH Truck		
Variable Capacity Forecourt		
+ Distributed Production		Combined urban & intercity
+ Hydrogen Carriers		

Key Delivery Scenario Variables

Urban areas

- Population, land area, vehicle density
- Distance from central H2 production

Intercity/rural travel

- Highway miles
- Travel density, fuel demand

H2-fueled vehicles

- Number, fuel economy, utilization

H2 fuel stations (forecourts)

- Number, capacity, avg. kg dispensed
- Distance between stations
- Ratio to gasoline stations

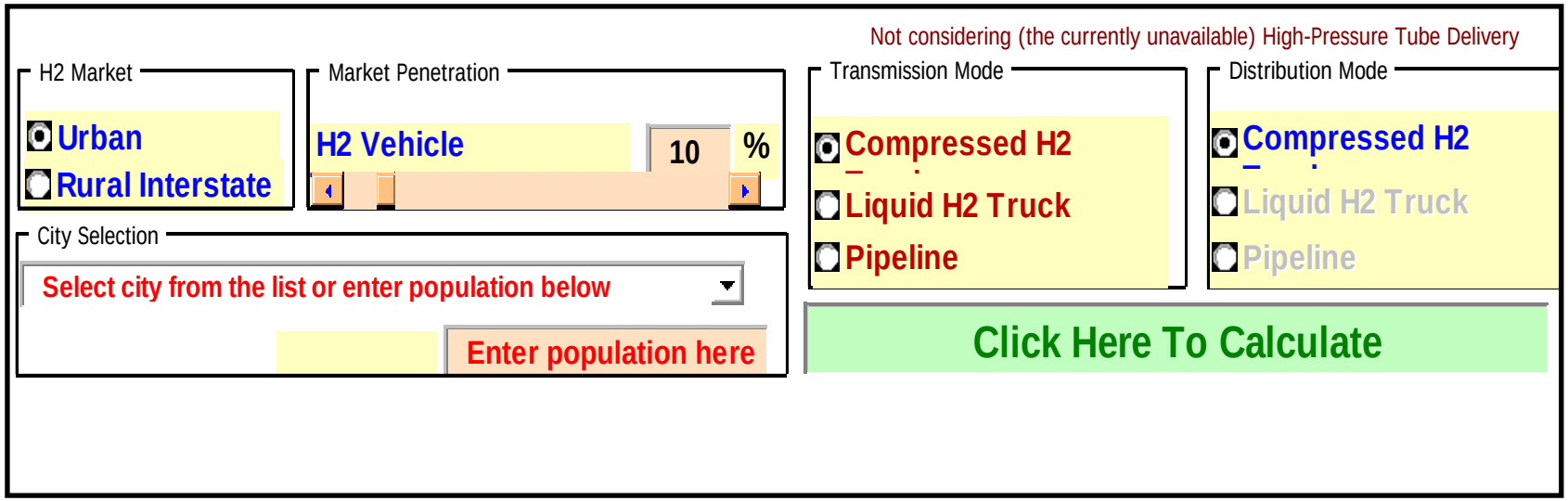
LH2 and CH2 trucks

- Fuel economy, losses (e.g., boiloff)
- Capacity, avg. delivery volume
- Speed, load/unload time, drops/trip
- Physical & economic life

Pipelines

- Inlet, city gate, forecourt pressure
- Transmission, distribution, service line lengths
- Circuity factors
- Physical & economic life
- Ratio to capital cost of natural gas pipelines

GUI Simplifies User-Selection of Market Type and Size, Penetration and Delivery Mode



Scenario Definition & Results Tabs (50% Urban Market Penetration, LH2 Truck, Indianapolis)

H2 Market
- Urban
- Rural Interstate

Market Penetration
H2 Vehicle 50 %

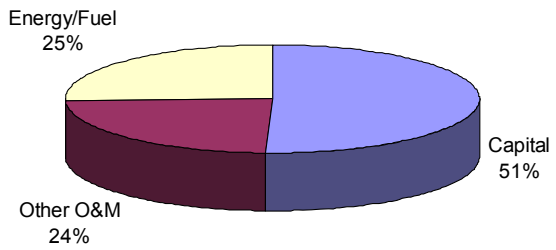
City Selection
Indianapolis, IN
1,218,919

Delivery Mode
- Compressed H2
- Liquid H2 Truck
- Pipeline

Calculate

Delivery Costs

Total Cost [$/kg]	2.49

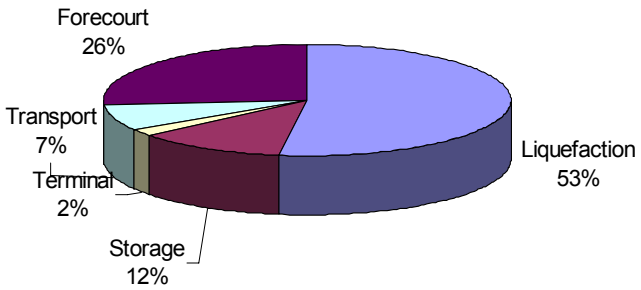


Key Delivery Inputs and Assumptions

City population	1,218,919
City area (mi2)	553
Population density (people/mi2)	2,205
Vehicles/person	0.85
Miles driven per year/ vehicle	13,748
Distance from production to city (km)	100
Actual refueling station capacity factor	0.7
H2 refueling station ave. H2 dispensed daily (kg/d)	1049
H2 Vehicles fuel economy equivalent (mi/gge)	57.50

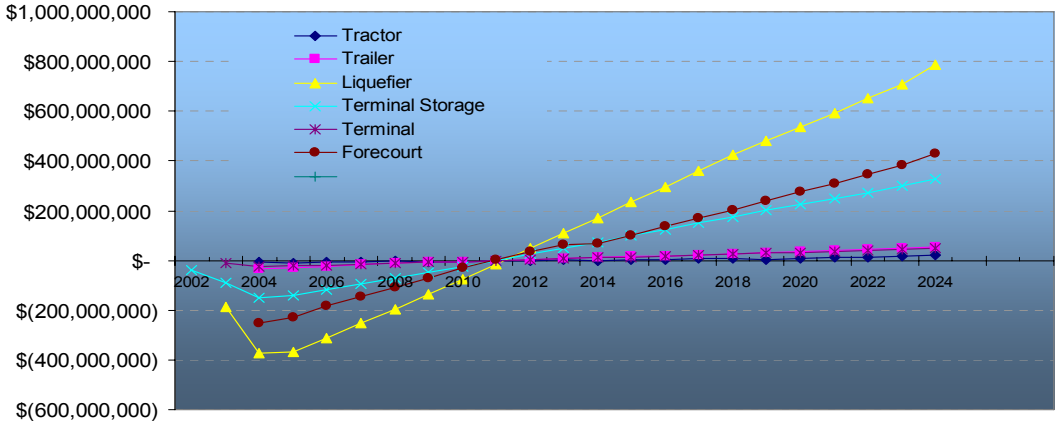
Demand Calculations

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	520,985
City H2 daily use (kg/d)	329,229
Number of H2 refueling stations in city	314
Number of H2 stations/Number of gasoline stations	60%
Average distance between stations (km)	2.14

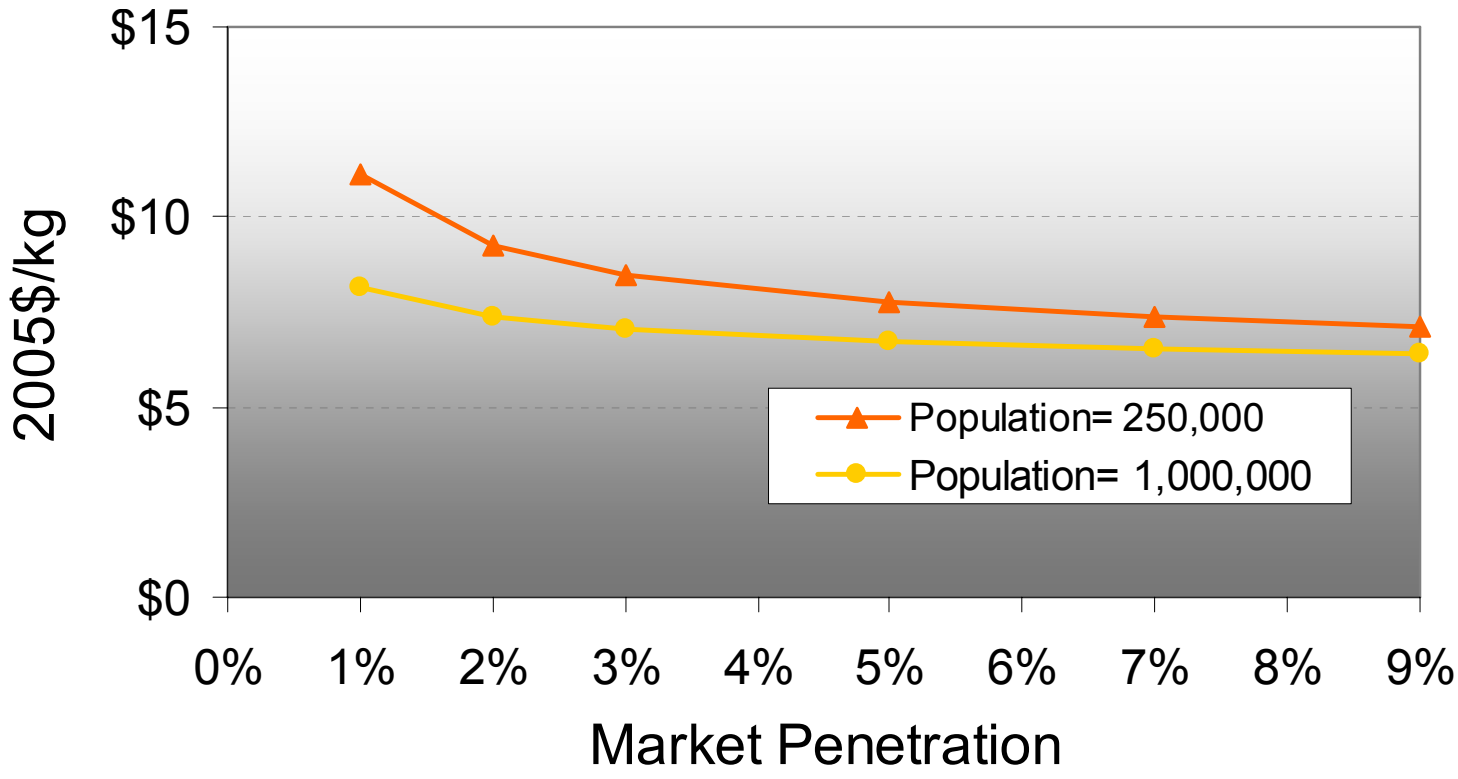


Delivery Mode Calculations

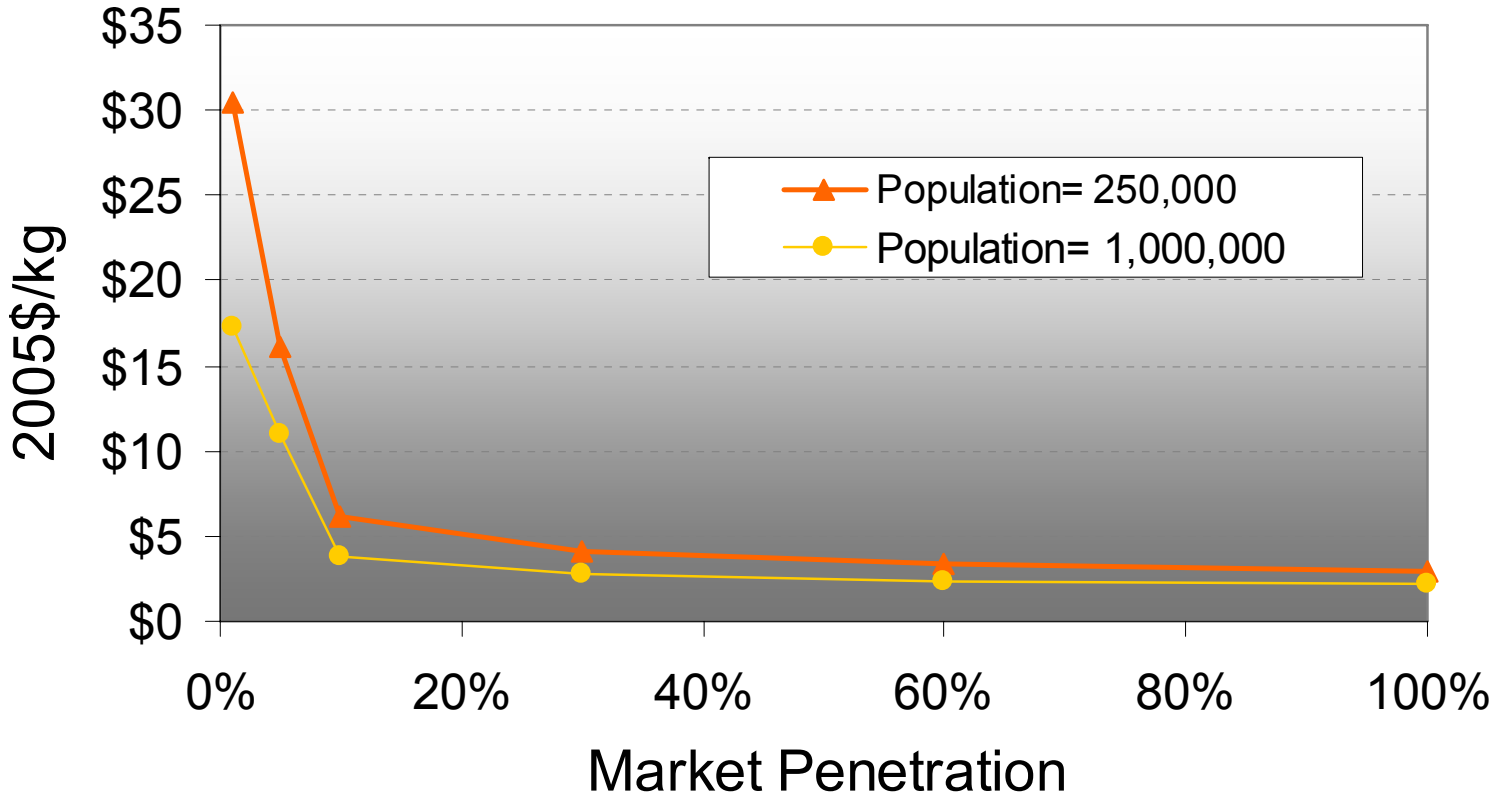
Average round-trip time (h)	12.20
Total number of deliveries per day	84.7
Possible number of round-trips per truck /day	2.0
Maximum number of deliveries per day	120.9
Number of trucks required to provide H2 to city	62



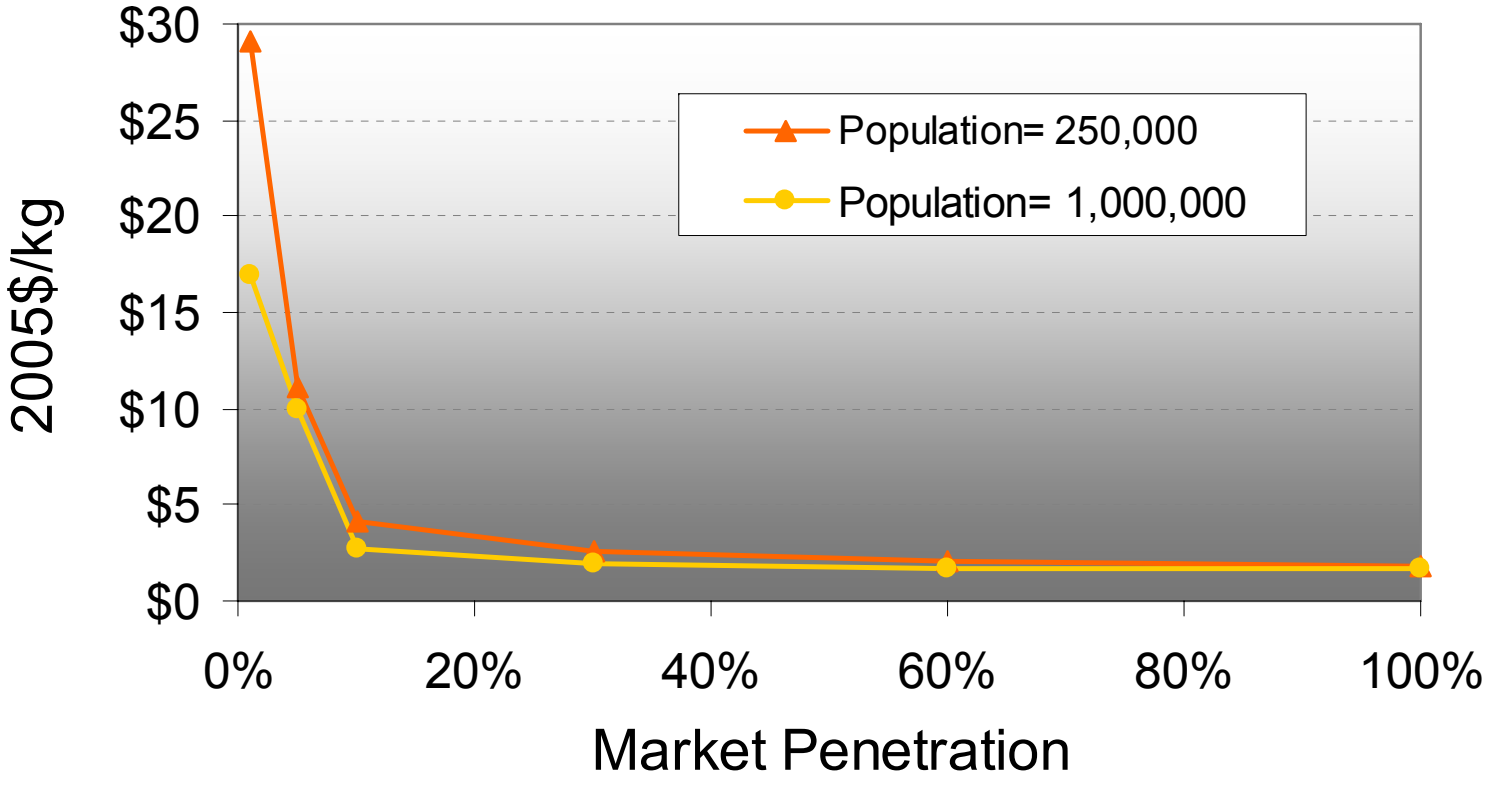
Conventional Tube Trailers Are Limited to Scenarios with Relatively Low H2 Demand



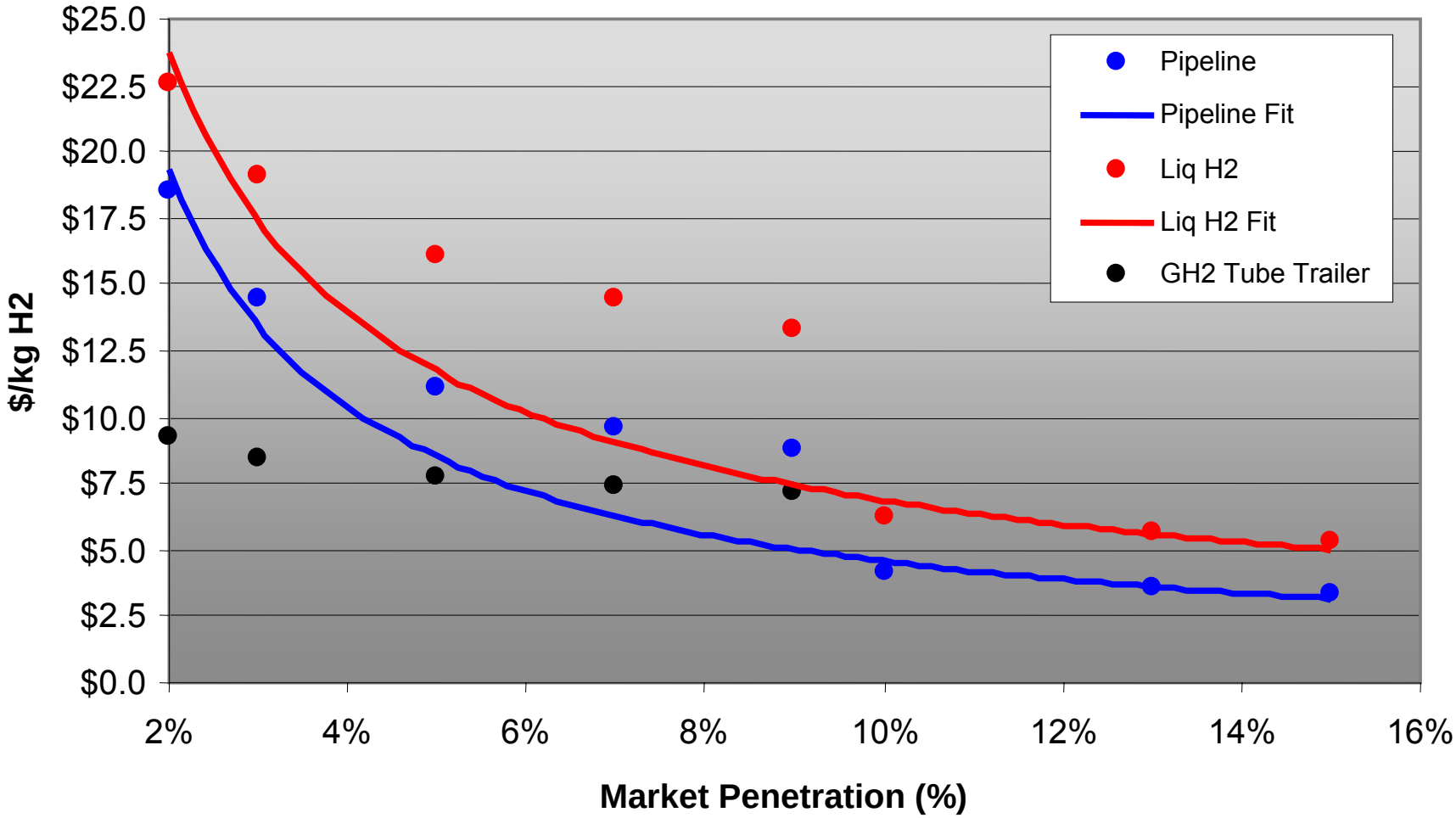
Liquid Delivery Cost Also Depends on Demand (Market Size & Penetration)



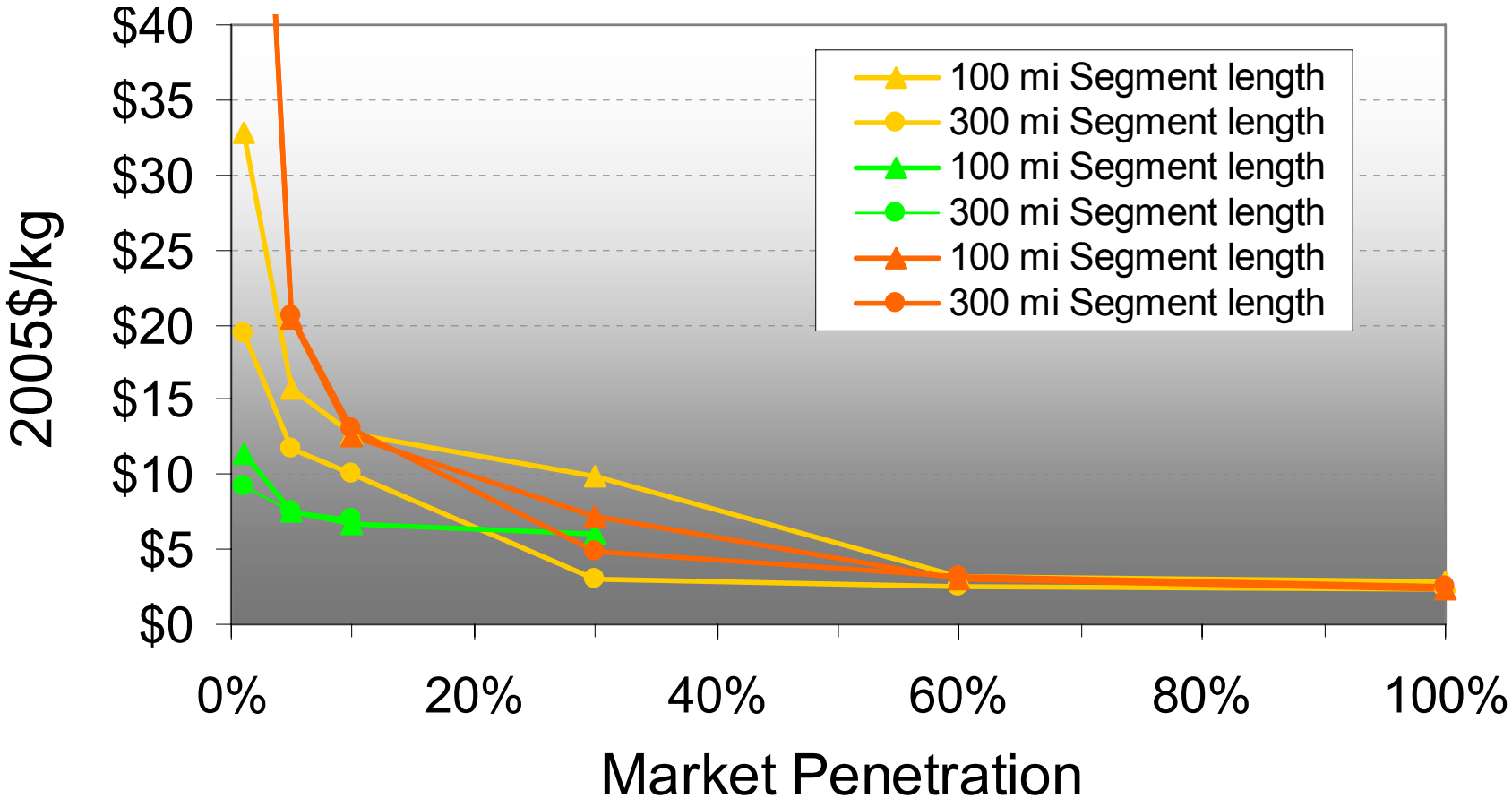
Pipeline Delivery Is Attractive above 10% Penetration in Urban Markets



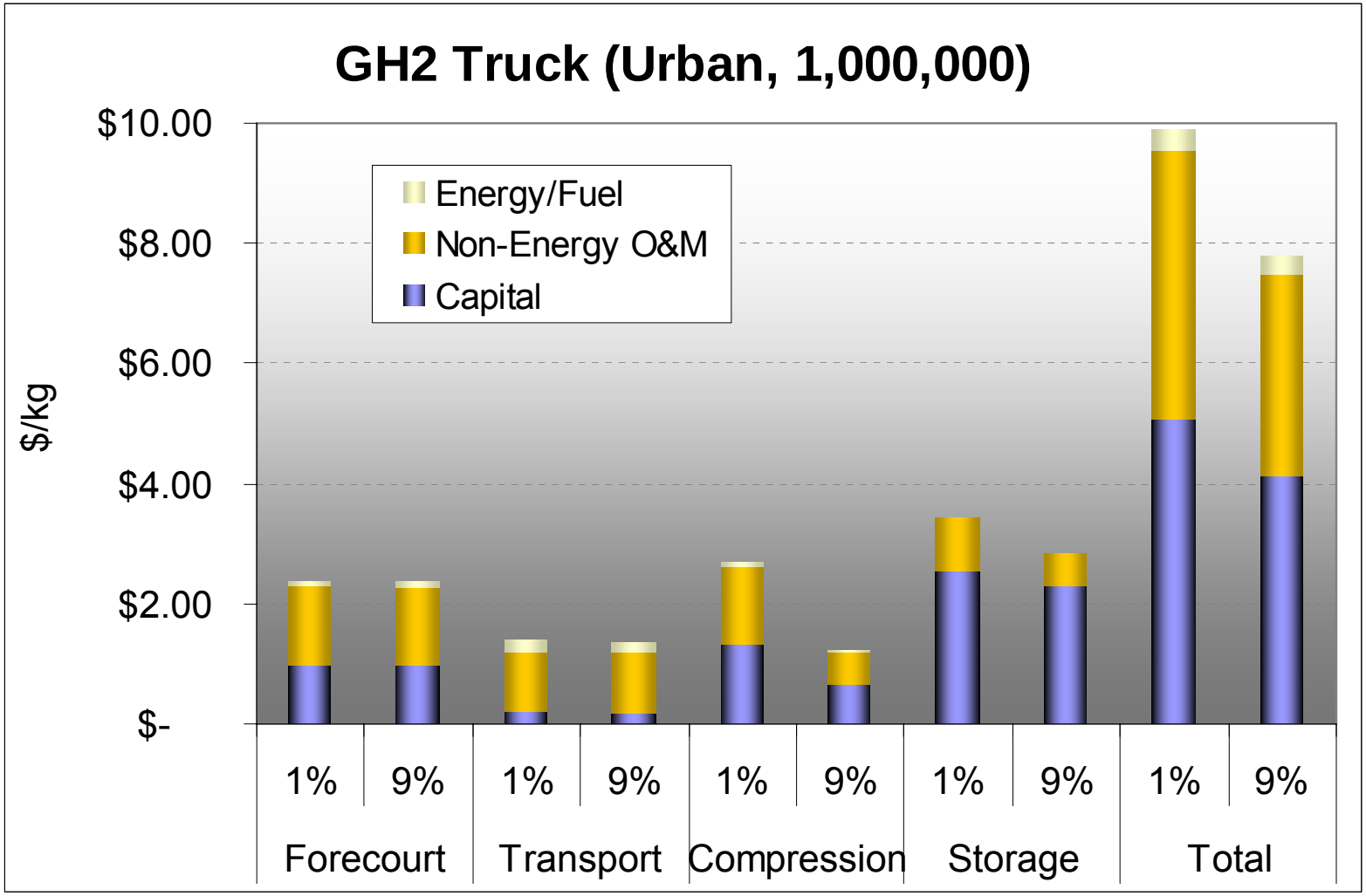
Urban Delivery Cost Declines with Increased Market Penetration and Forecourt Size (250,000 case)



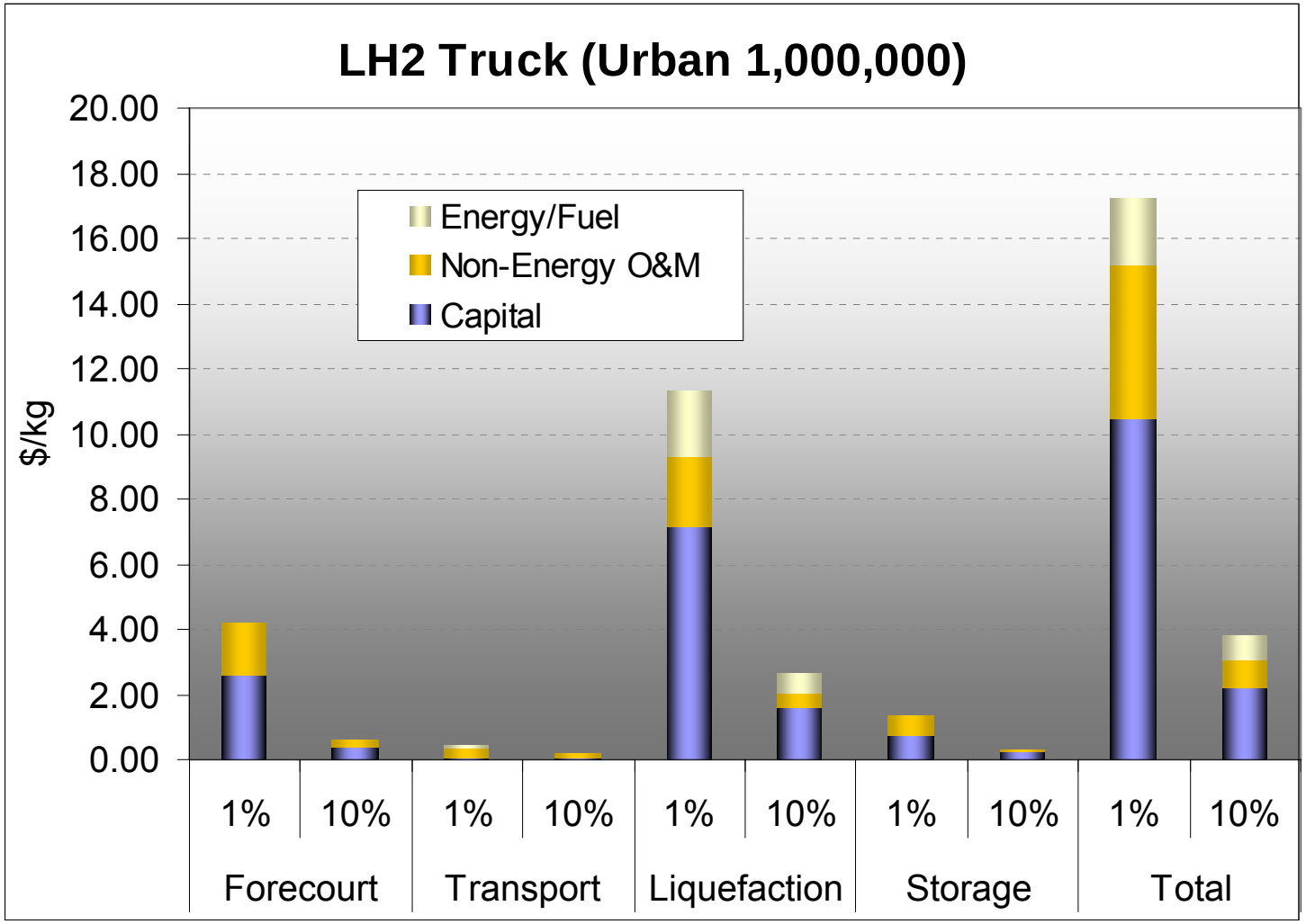
Interstate Delivery Cost Exceeds Urban; Pipeline More Costly Below 60% Penetration



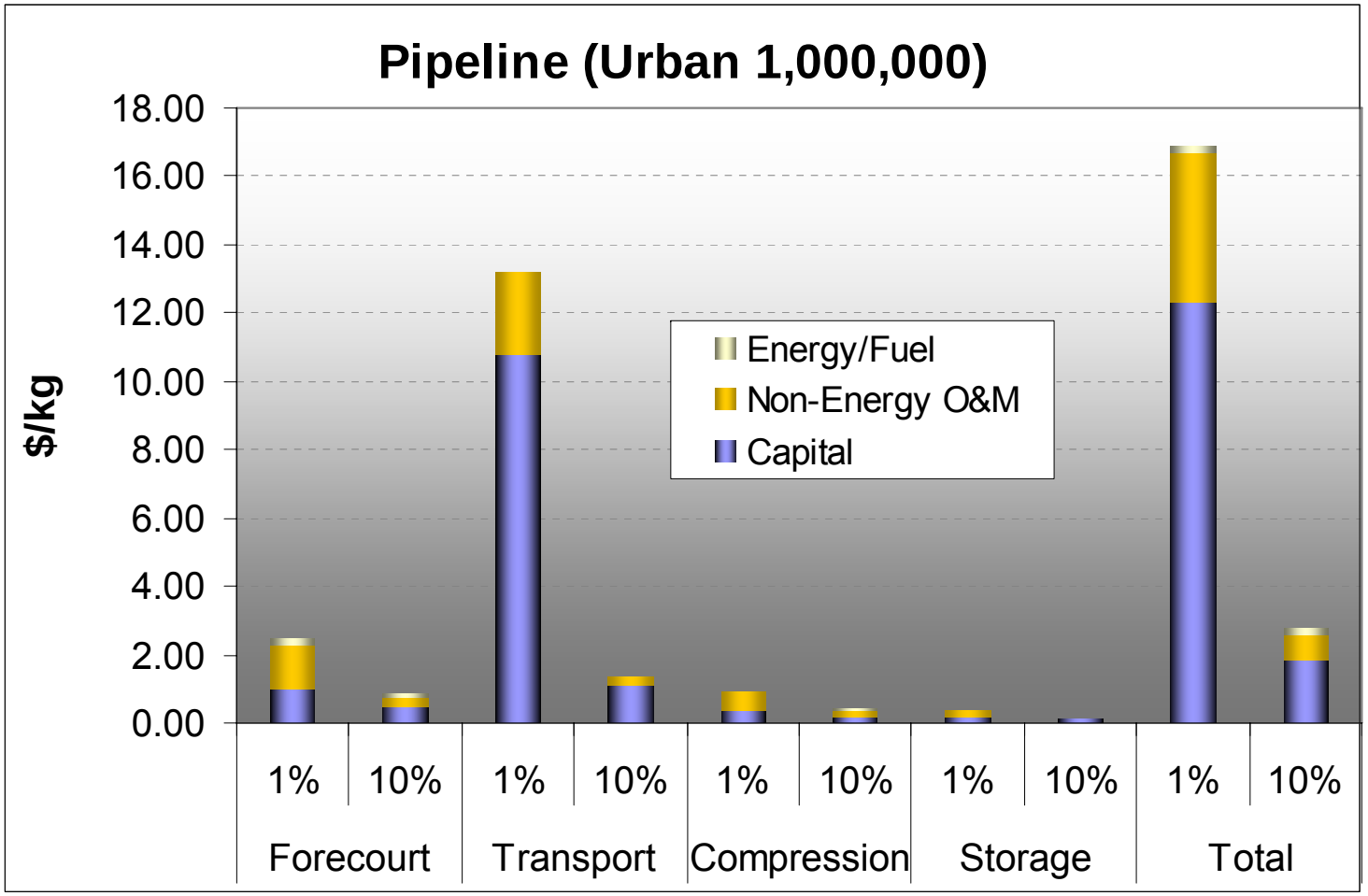
Conventional GH2 Truck Delivery Is Capital and Labor Intensive with Little Scale Economy (100 kg/d forecourts)



LH2 Truck Delivery Requires More Energy, Especially for Liquefaction; Significant Forecourt & Liquefier Scale Economies



Pipeline Delivery Is Capital Intensive and Has Significant Scale Economies



Enhancements Underway for HDSAM V2.0

- Additional mixed delivery pathways (e.g., pipeline to liquefier)
- Mixed demands/markets (e.g., combining urban demand with interstate demand)
- Variable forecourt size
- Hydrogen carrier characterizations and pathways
- Energy efficiencies and CO_2 emissions
- Initial overbuilding of delivery infrastructure
- Sensitivity analyses (service ratio, service lines, storage/compression tradeoffs, etc.)

Plan to complete Version 2 by end of FY06

This work has benefited from the effort of many individuals, especially:

Daryl Brown, PNNL
John Molburg, ANL
Joan Ogden, UC Davis
Mark Paster, DOE
Matt Ringer, NREL

Thank You All!

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Delivery Scenarios Approach Builds on Past Efforts and Common Analytical Tools

- To allow maximum flexibility, the Delivery Scenarios Model:
  - Programmed as series of Microsoft EXCEL spreadsheets (“Delivery Components”)
  - Designed to “synchronize” with improvements to Delivery Components Model
  - User friendly interface (GUI)
  - Will be posted on EERE Website
- Common building blocks include:
  - Delivery Components Model
  - Forecourt model
  - Discounted cash flow analysis
  - Financial assumptions
  - Fuel properties