ARGONNE NATIONAL LABORATORY
TRANSPORTATION
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Hydrogen Distribution Infrastructure

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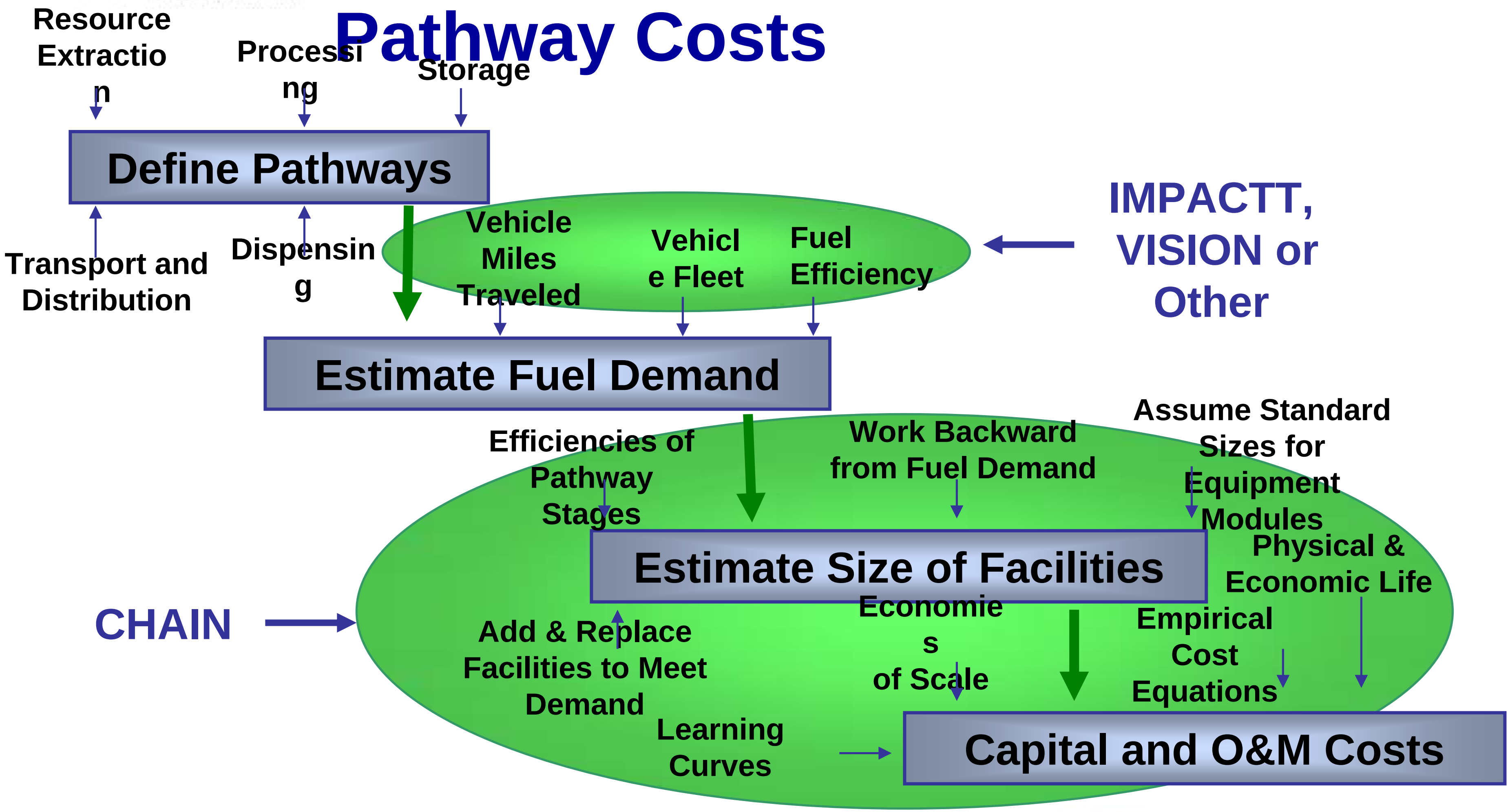
Topics

- Infrastructure components and “well-to-pump”modeling approach
- Assumptions and component cost analyses in CHAIN model
- “Well-to-pump” costs of hydrogen vs. gasoline by pathway and “build out”
- Conclusions

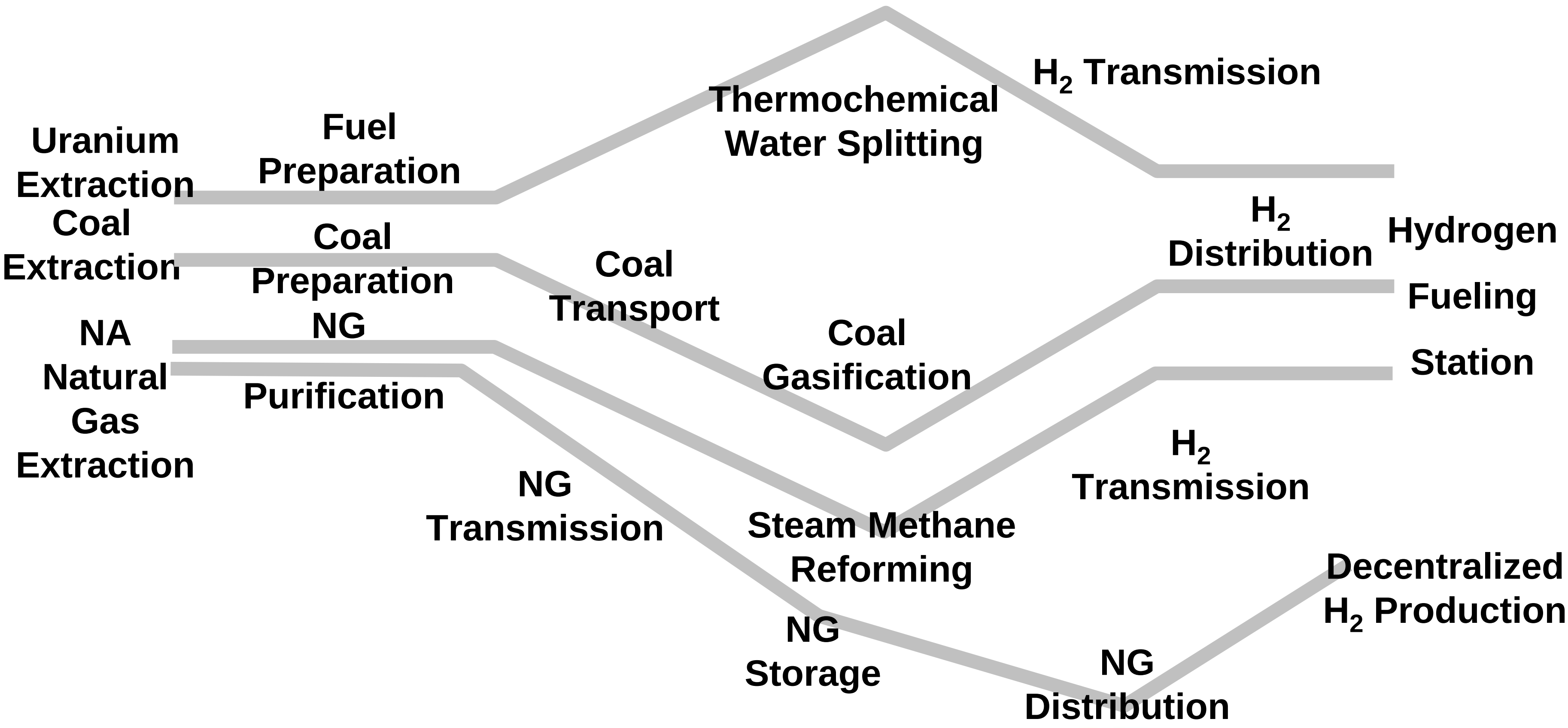
Components of "Well-to-Pump" Costs

- Feedstock acquisition
  - Crude oil
  - Natural gas
  - Uranium
  - Coal
- Feedstock transport and storage
- Processing
  - Petroleum refining
  - Hydrogen production
  - Coal, natural gas or uranium processing
- Product distribution and storage
  - Pipelines
  - Compressor stations
- Dispensing and retailing

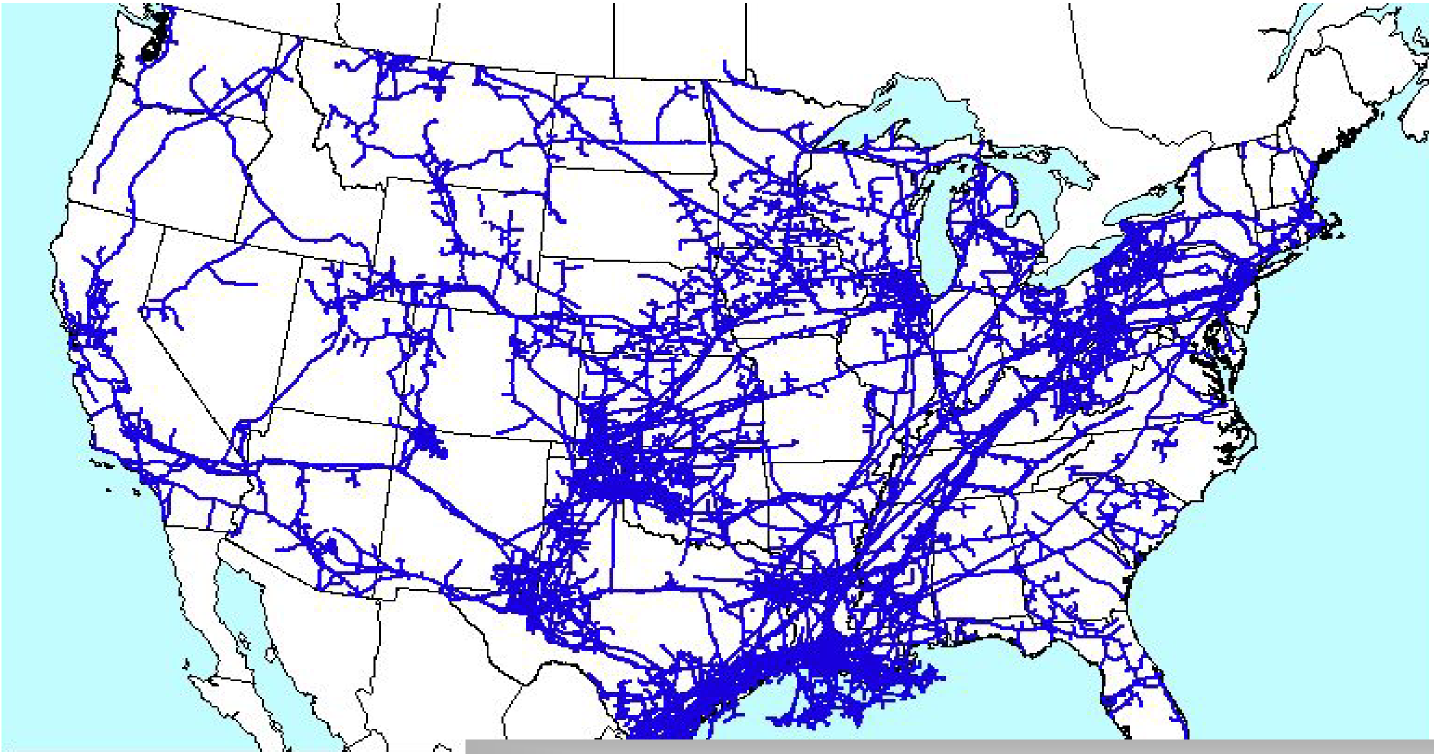
Stock Adjustment and Infrastructure Models Estimate Pathway Costs



Infrastructure Costs Are Estimated for Four H2 “Well-To-Pump” Pathways



NG-Based Pathways Require Additional Natural Gas Transmission Lines

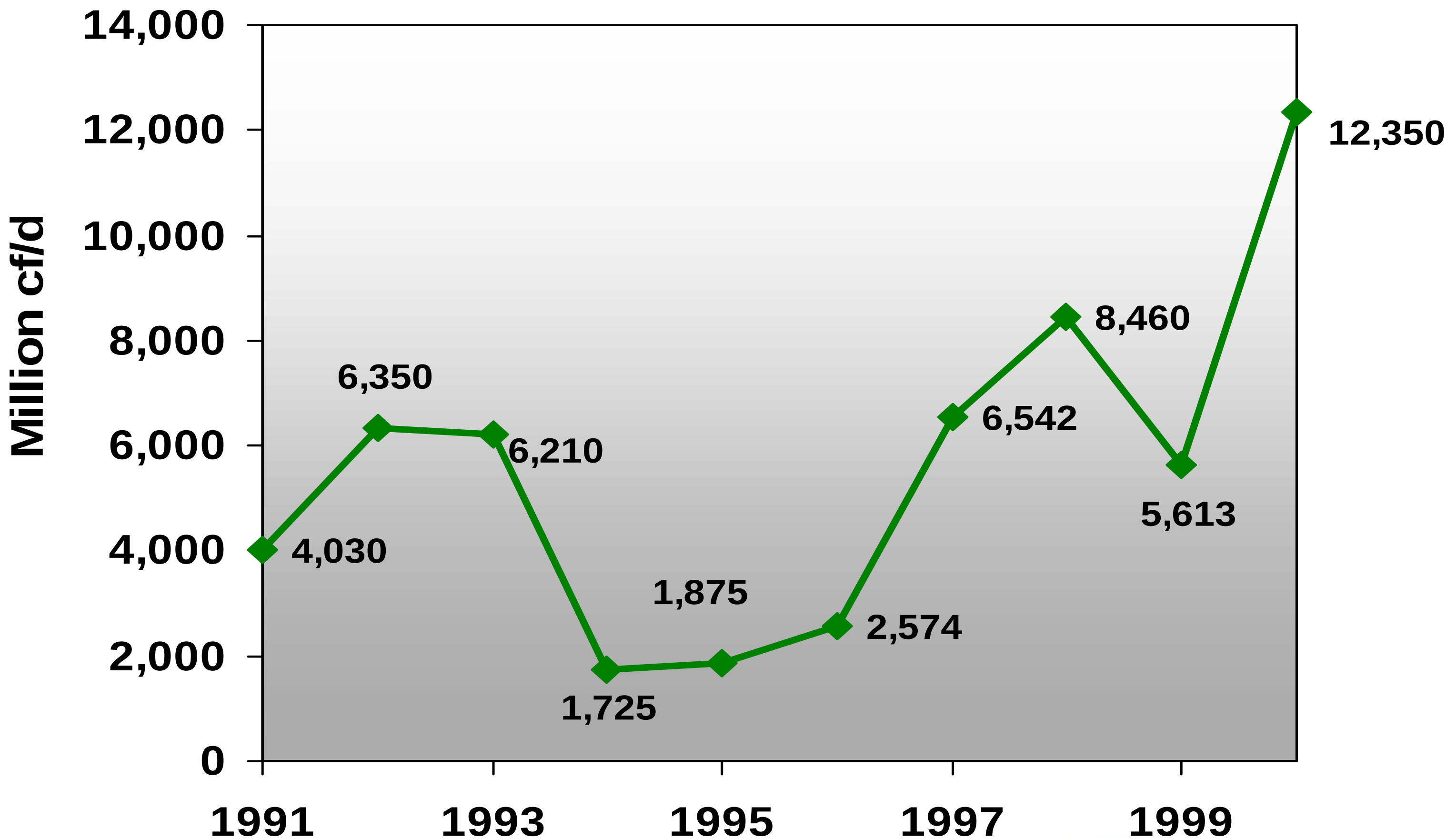


The US has an extensive in-place NG transmission infrastructure …..

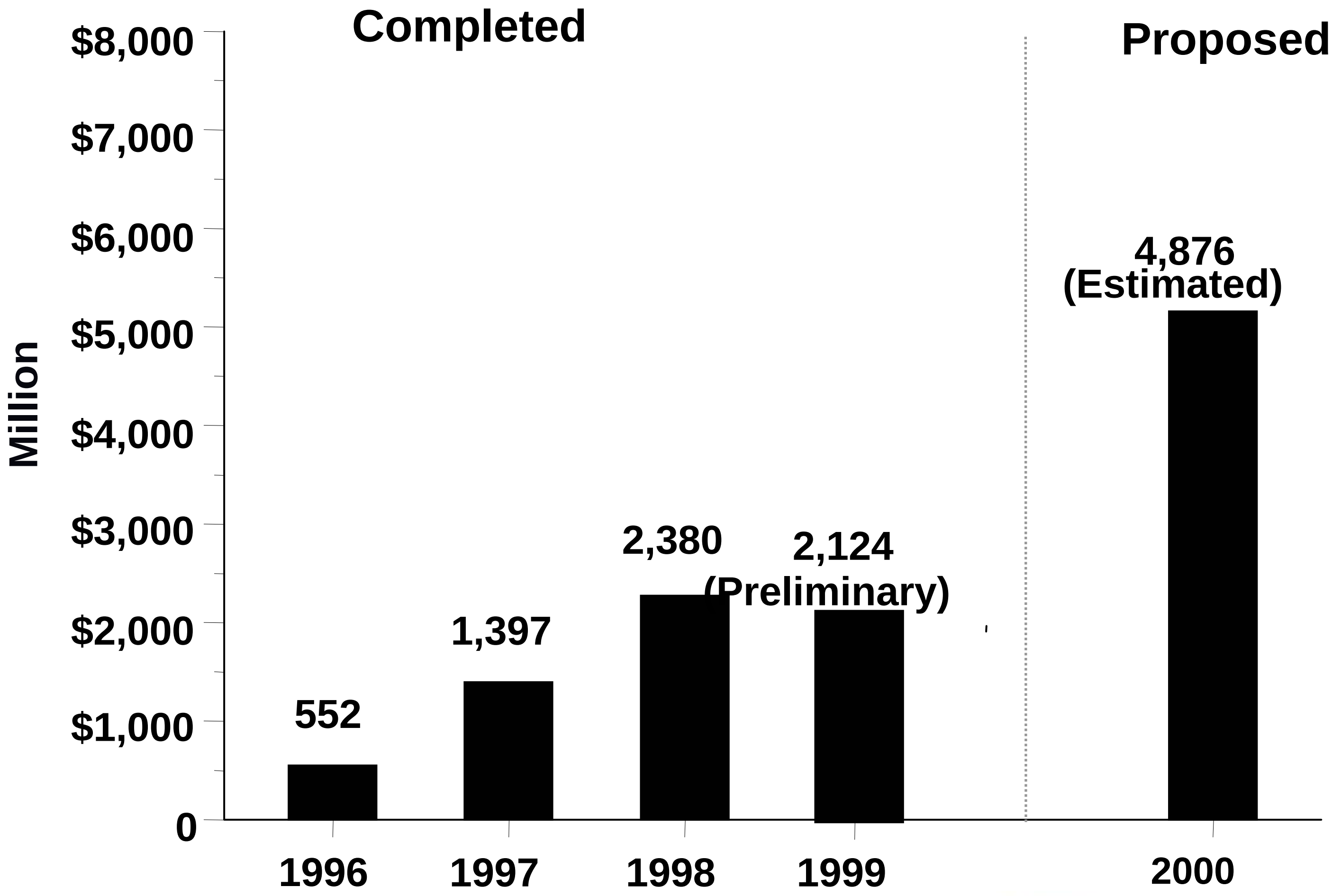
And a Track Record of Continually Expanding Transmission Capacity

- New pipelines
- Additional compression
- Looping
- All of the above

Since the Mid-1990's Transmission Capacity Has Grown > 4 Bcf/d Each Yr



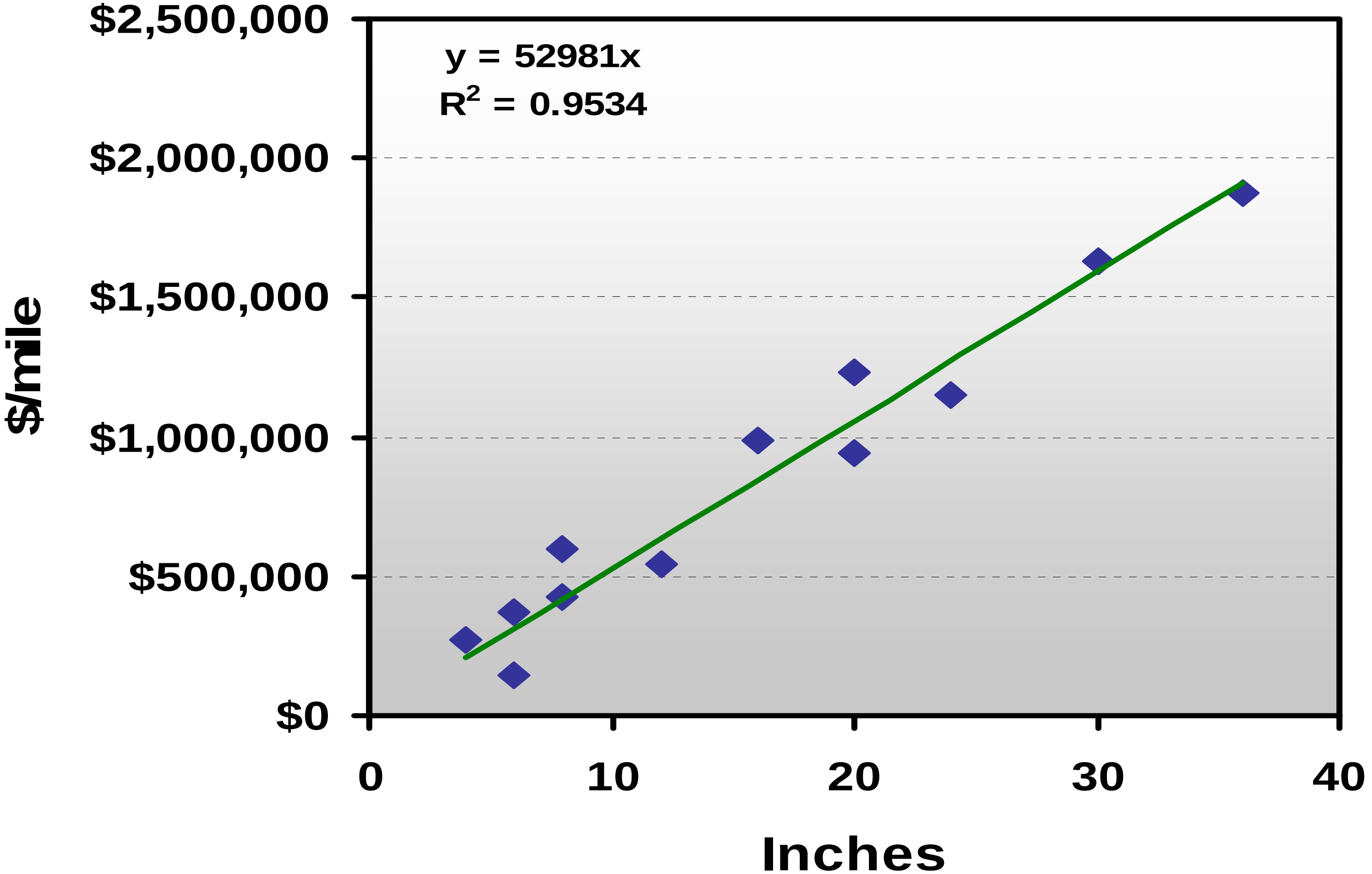
According to EIA, Nearly $5 bln Was Spent on Pipeline Expansion in 2000



Expansion Reflects Shifts in the Structure of the Industry and Its Resource Base

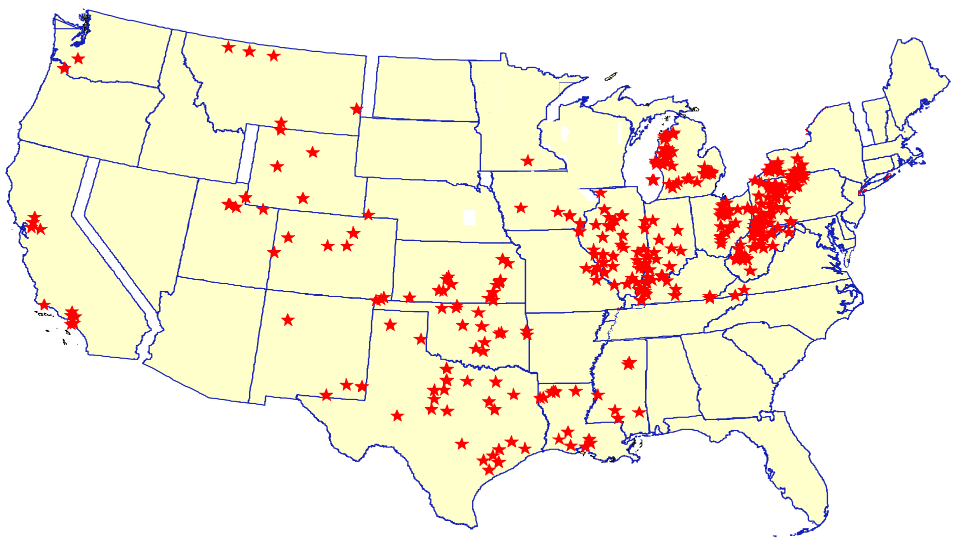
- Increased production in deep-water Gulf of Mexico and in western and offshore eastern Canada
- Reduced production in mature provinces
- Shippers seeking greater access to alternate sources of supply
- Producers seeking greater access to non-traditional markets (market integration)
- Increased use for power generation with resulting shifts in seasonal demand patterns

Unit Cost of Natural Gas Transmission Pipelines Is a Function of Diameter



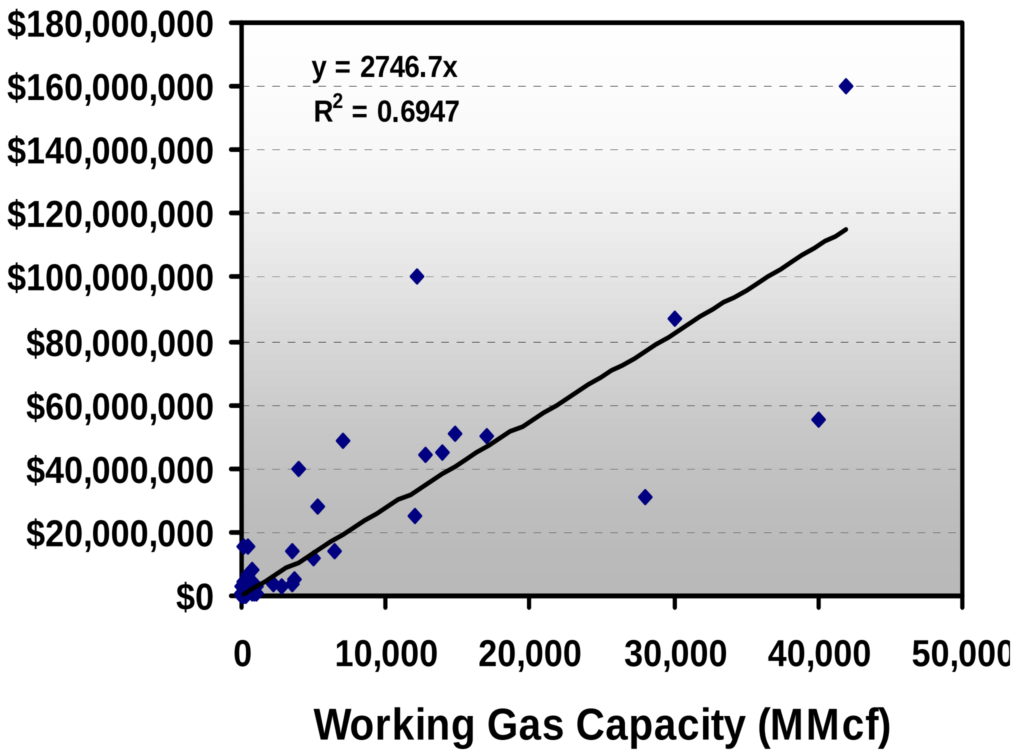
NG-Based Pathways Require Underground Storage

At the end of 1998 there were 410 underground natural gas storage sites in the U.S.



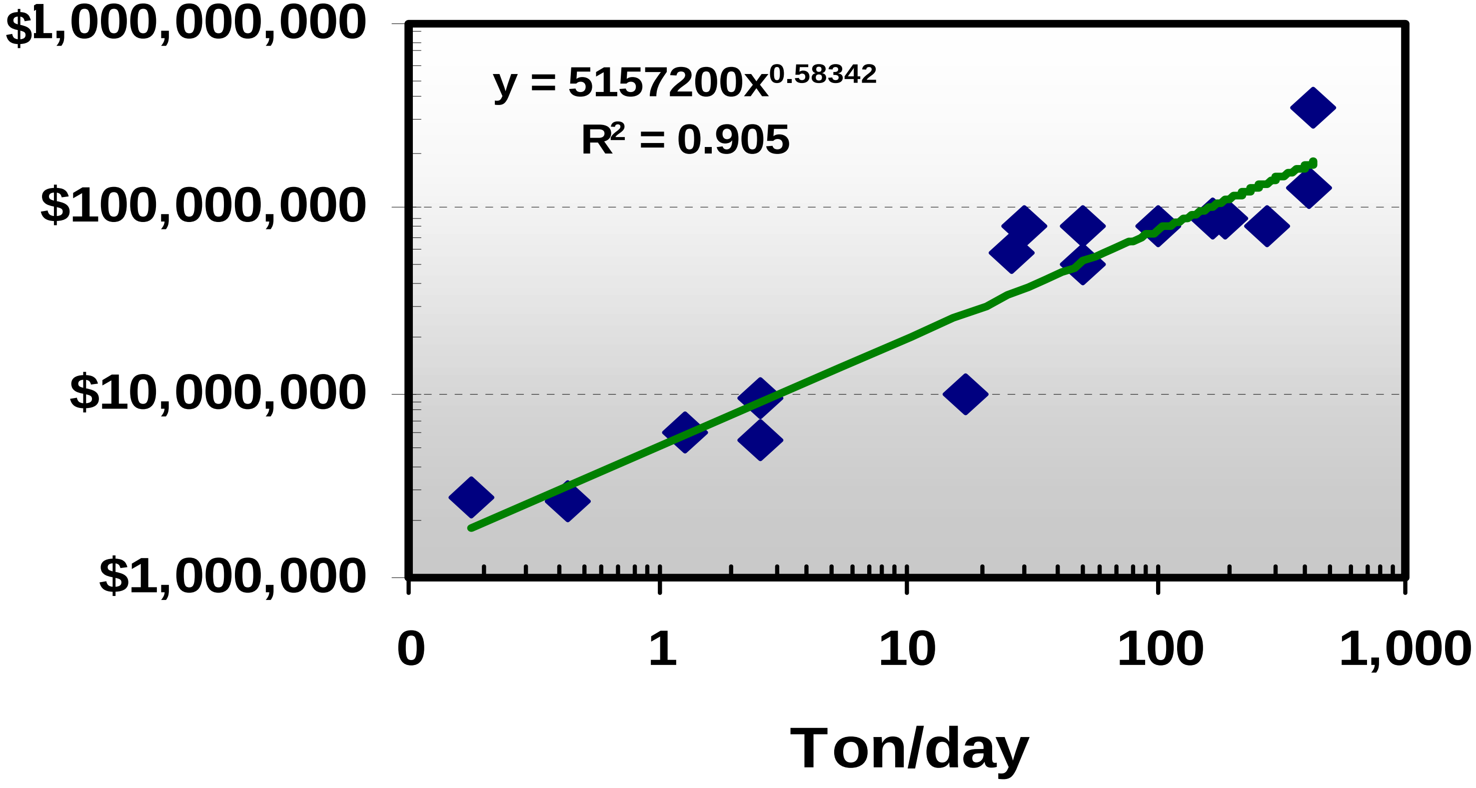
With 76 Bcf per day of Withdrawal Capability and 3,933 Bcf of Working Gas Capacity

The Cost of Underground Storage Varies by Type and Capacity



- Capital cost of underground storage is a function of working gas capacity (projects with 2001-04 completion, 1999$)
- Working gas capacity per field: 5×10^9 scf
- Unit O&M cost: \$0.224 per 10^3 scf delivered (Young Storage Field, CO)

Steam Methane Reforming Has Large Economies of Scale



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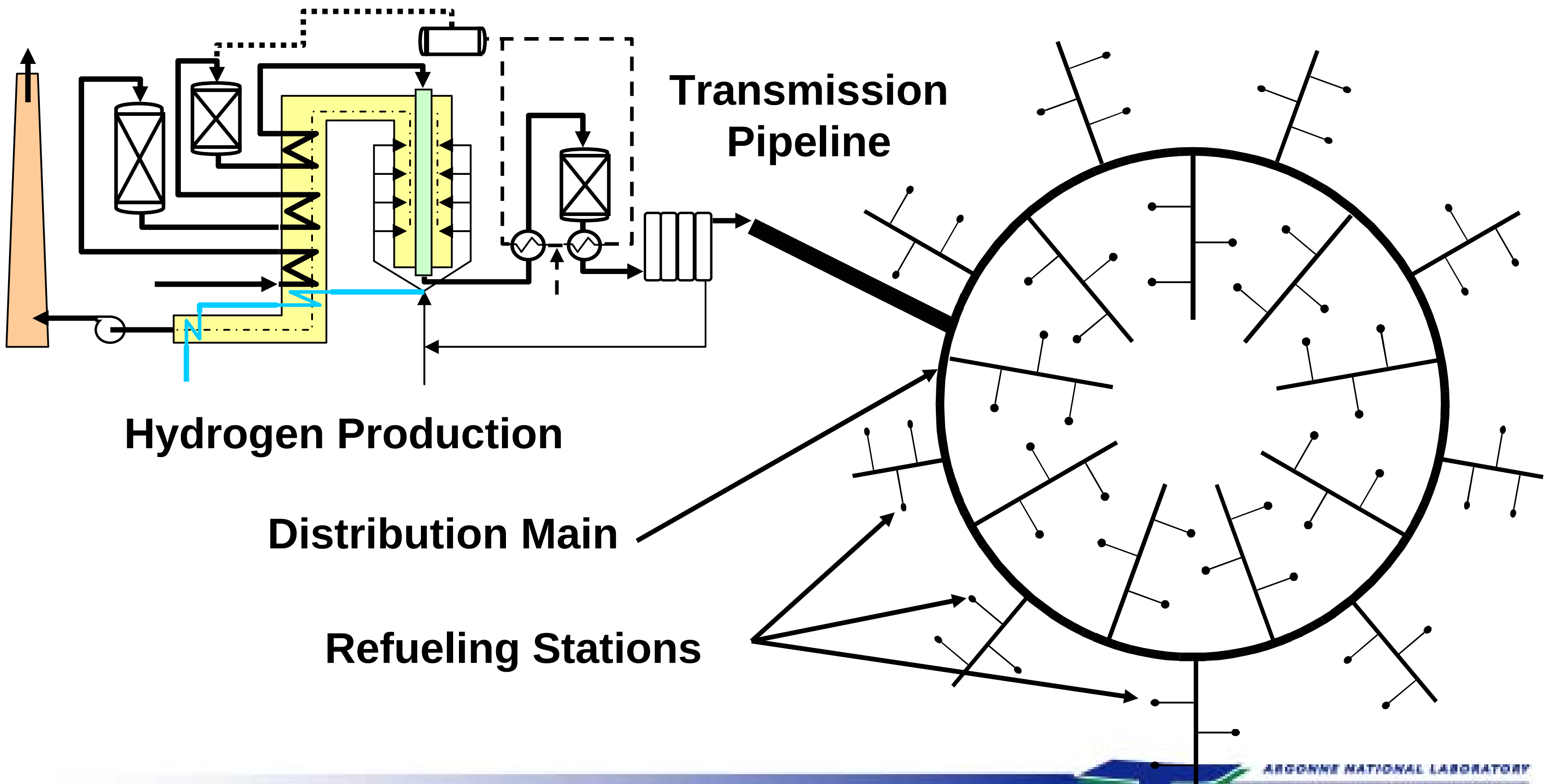
Conceptual Illustration of Pipeline Loop Supporting Local Hydrogen Delivery

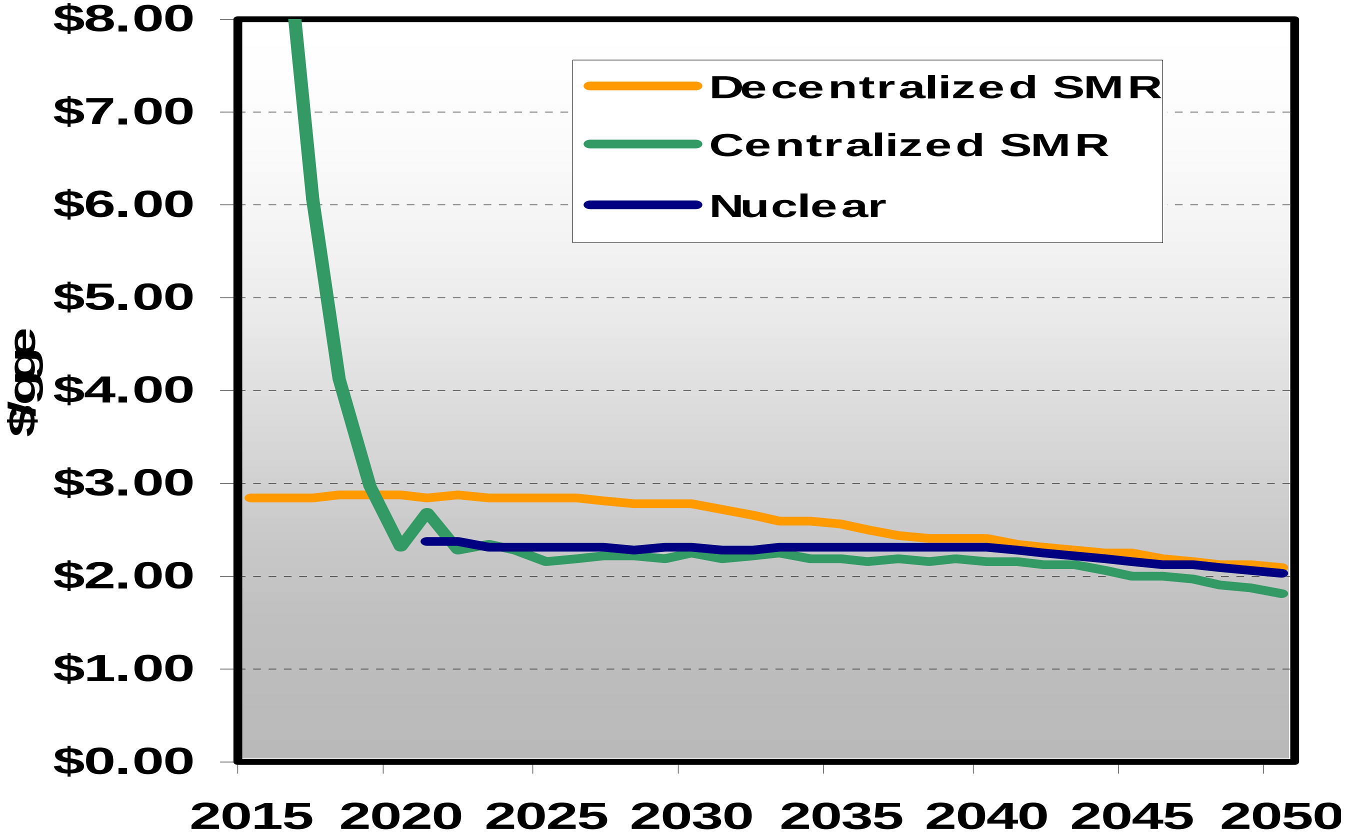


Hydrogen Distribution Assumptions for Centralized H2 Production

Component	Unit Cost ($/mi)	Diameter (in)	Length (mi)
H_2 Transmission Pipeline Connecting Pipeline Ring with H_2 Production Plant	$1,000,000	12	100
H_2 Distribution Pipeline Ring	$1,000,000	12	157
H_2 Service Pipeline Connecting H_2 Refueling Stations with Pipeline Ring	$400,000	3	900 [a]

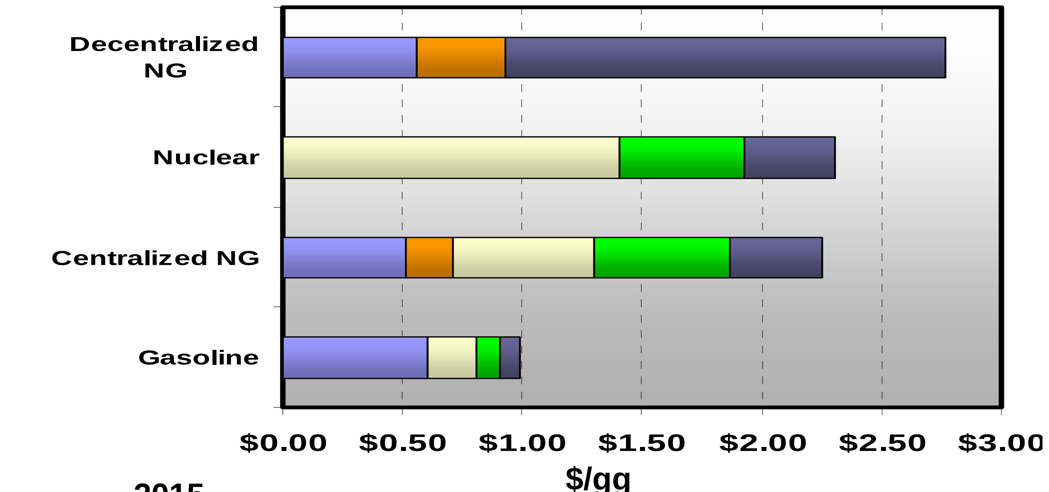
[a] Assumes 180 refueling stations, a service pipeline unit length of 15 miles, and 3 stations per service pipeline.

Annualized H_2 Cost Declines with Scale and Investment Amortization



More Costly Production and Distribution Increase H_2 “Well-To-Pump” Cost Relative to Gasoline

2030



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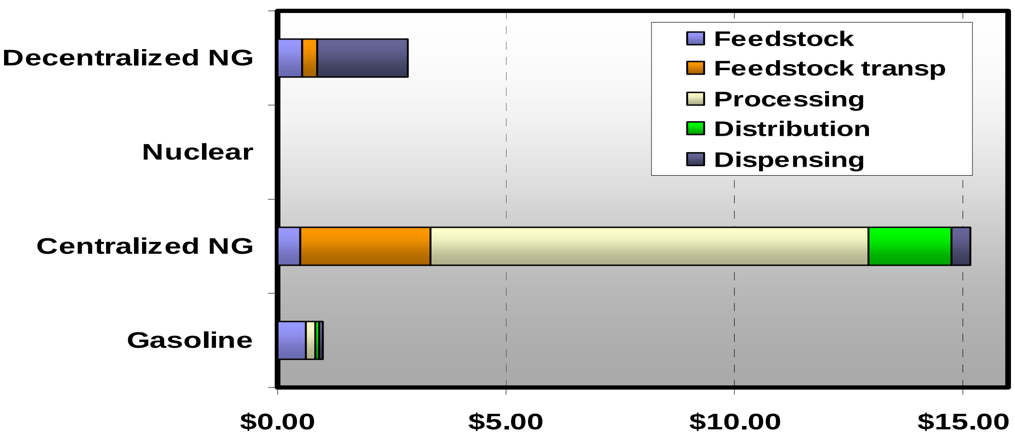

- Crude oil represents 61%, distribution 10%, and refining 21% of gasoline cost (for $28/bbl crude)
- H_2 production accounts for >60% of cost in nuclear path; ~25% in centralized NG path
- Distribution accounts for ~25% of H_2 cost in nuclear and centralized NG paths
- Costs decline over time as infrastructure is “built out” and amortized

Some Conclusions

- With current technologies, on a well-to-pump basis, unit cost of hydrogen is likely to be 2-3 times gasoline.
- To offset this, mpge of H2-fueled LDVs must be at least an equal factor better than comparable vehicles.
- H2 transport and production are the largest components of all paths examined, hence appropriate focus for cost reduction.
- “Bi-” fuels, engines and distribution networks offer potential cost reductions, especially in the transition.