Session III:
Hydrogen Resource Realities

Marianne Mintz

Participants

- Richard Doctor, Argonne National Laboratory
- Joan Ogden, University of California at Davis
- Gene Nemanich, Chevron-Texaco

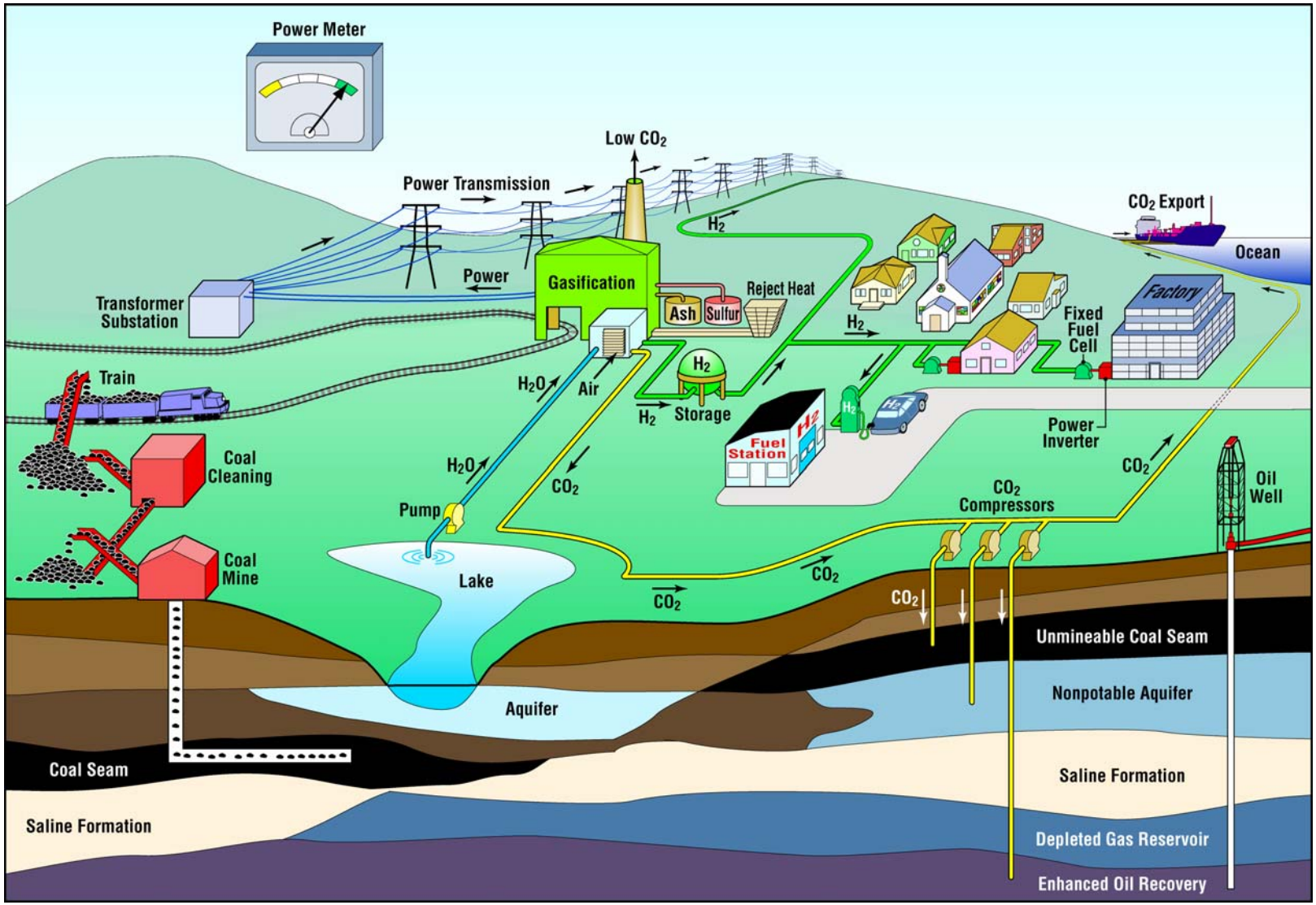
Hydrogen from Coal with CO_2 Capture and Sequestration – Richard Doctor

- Domestically secure coal supplies are abundant, low-cost & deliverable
- 1st-generation coal conversion to H_2 with CO_2 capture is not competitive against $2.85/MM Btu natural gas; but "FutureGen" should improve costs (coal currently produces 18% of the world's hydrogen)
- CO_2 transmission pipelines have been safely demonstrated since the 1970's – but pipelines have not traversed "population centers" (>1,000/sq. mile)
- Capacity estimates for CO_2 reservoirs in depleted gas and oil fields, brine formations and coal beds are highly variable – "GeoSeq" and other demonstration projects should resolve costs and capacities

Doctor -- Sequestration Issues (Cont'd)

- Sequestration in natural sinks is limited; with current anthropogenic emissions ~ 6 GT of carbon could be stored geologically in an estimated 300 – 3,200 GT of C of geological capacity
- Conversion of CO_2 to carbonates is proving too costly at present and may create a new set of disposal issues
- CO_2 export may need to be considered
- Ocean use for CO_2 sequestration is *highly controversial*

Illustration of "FutureGen" Coal to H_2



Where Will the Hydrogen Come From? System Considerations and Hydrogen Supply – Joan Ogden

- How is the evolution of a future hydrogen supply affected by the complex factors and sometimes conflicting goals that determine the best fuel production and distribution pathways for a given location and level of demand?
- Focus on relationships among various aspects of a hydrogen system—supply, demand, economics, externalities, technological progress—and what this implies about the lowest cost or lowest emission hydrogen supply over time, for a particular location.

Ogden -- Key System-Level Questions for Future Hydrogen Supply

- What does the goal of minimizing externalities (greenhouse gas emissions, air pollutant emissions, oil supply insecurity) imply about hydrogen supply during the early stages of a transition, when hydrogen demand is relatively small, and in the long term?
- What does the goal of keeping infrastructure costs low during transition, by matching supply and demand and utilizing existing infrastructure, imply about which primary resources are used for hydrogen production?

Ogden -- Key System-Level Questions for Future Hydrogen Supply (Cont'd)

- What do regional and geographic factors imply about hydrogen supply in developed and developing countries?
- How might interactions with the existing infrastructure and rest of the energy system impact the choice of hydrogen supply?

Session IV:
Rethinking Hydrogen Infrastructure

- Mark Paster, US Department of Energy
- Dave McCarthy, Air Products and Chemicals
- Chip Schroeder, Proton Energy
- Stefan Unnasch, TIAX

McCarthy

- Hydrogen is available now to get the transition started
- There will be many production/distribution options (pathways)
- Pathways will be flexible and renewable
- Both large-scale and distributed pathways will be needed
- The final solution is still being developed
- The final storage technology on-board the vehicle will play the biggest role in hydrogen infrastructure

Paster

- Energy security and climate change are the two principal drivers for the hydrogen economy
- Hydrogen will be produced from multiple paths, necessitating a range of R&D
- Production from fossil fuels requires carbon sequestration
- Renewables are the preferred solution and thus a principal focus of the DOE program
- In the initial stages of a hydrogen transition, onsite (distributed) production is likely
- Ultimately, a combination of on-site production and centralized production are likely

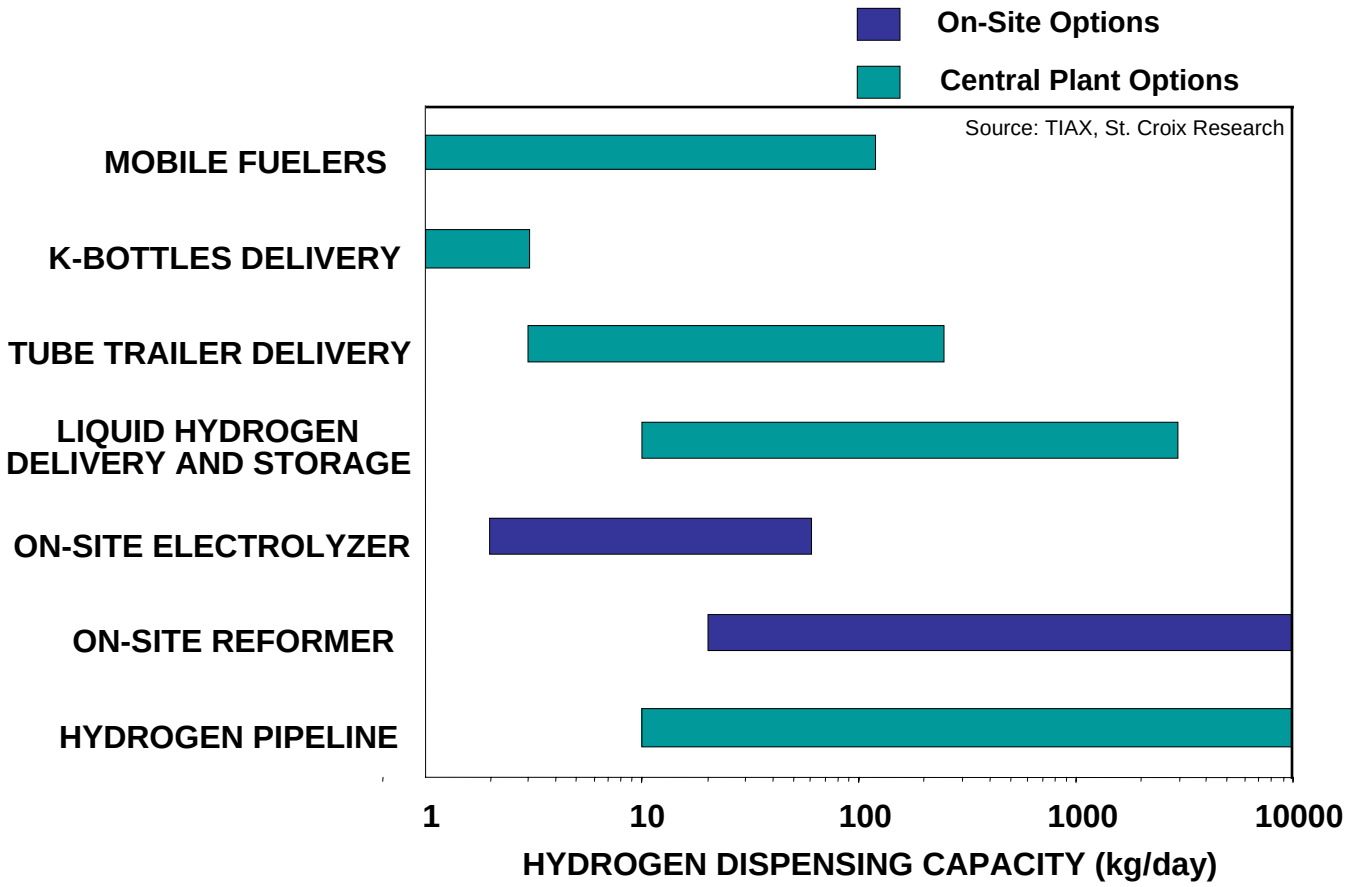
Schroeder

- Electrolysis is a currently available, commercial technology
- There are niche markets today where hydrogen can be profitably produced via electrolysis

Unnasch

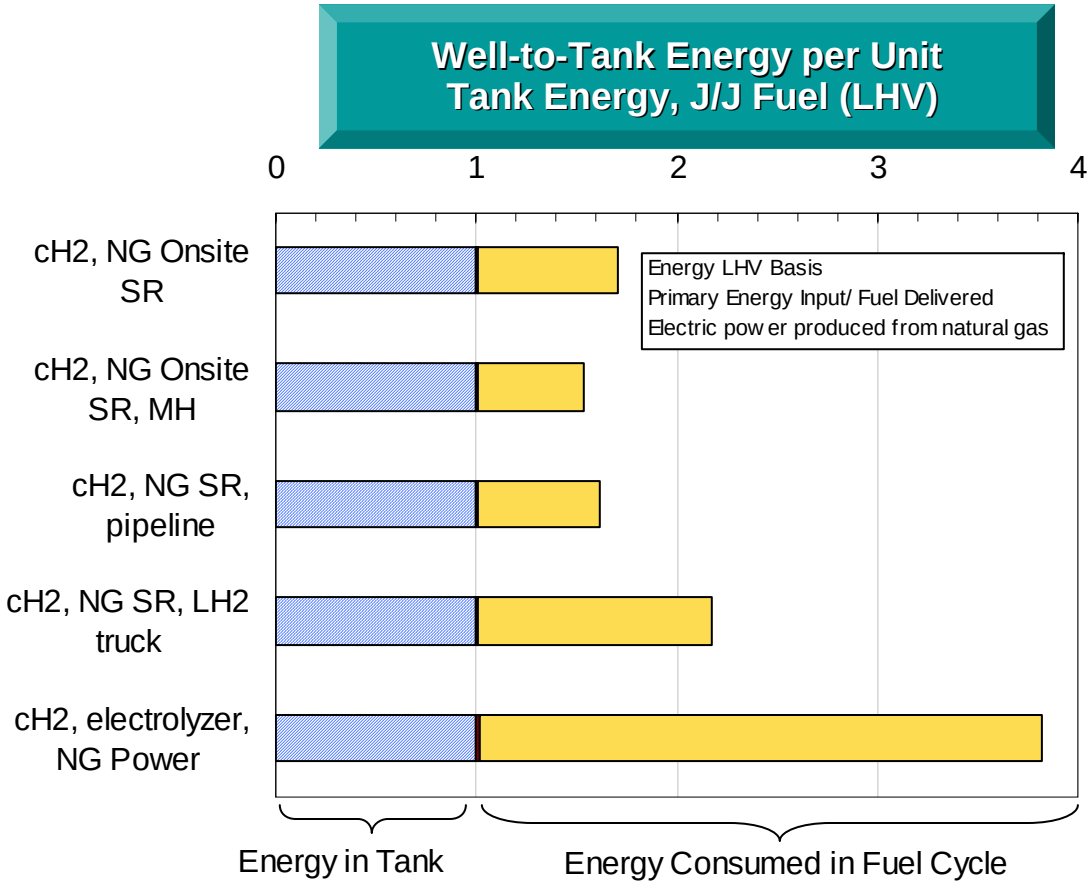
- Criteria pollutant and potential for greenhouse gas reductions provide motivation for hydrogen ICE and fuel cell vehicles
- Hydrogen vehicles and fuel will not compete on cost with gasoline and diesel fueled ICEs for a very long time -- unless vehicles are designed and marketed differently, and fuel distribution systems are restructured
- Both vehicle and infrastructure cost reductions are needed before vehicles can achieve commercial success (>10,000 vehicles/yr)
- Hydrogen supply options and vehicle introduction pathways affect all aspects of vehicle operation

Distribution System Capacity Affects the Economics of Hydrogen Supply Systems

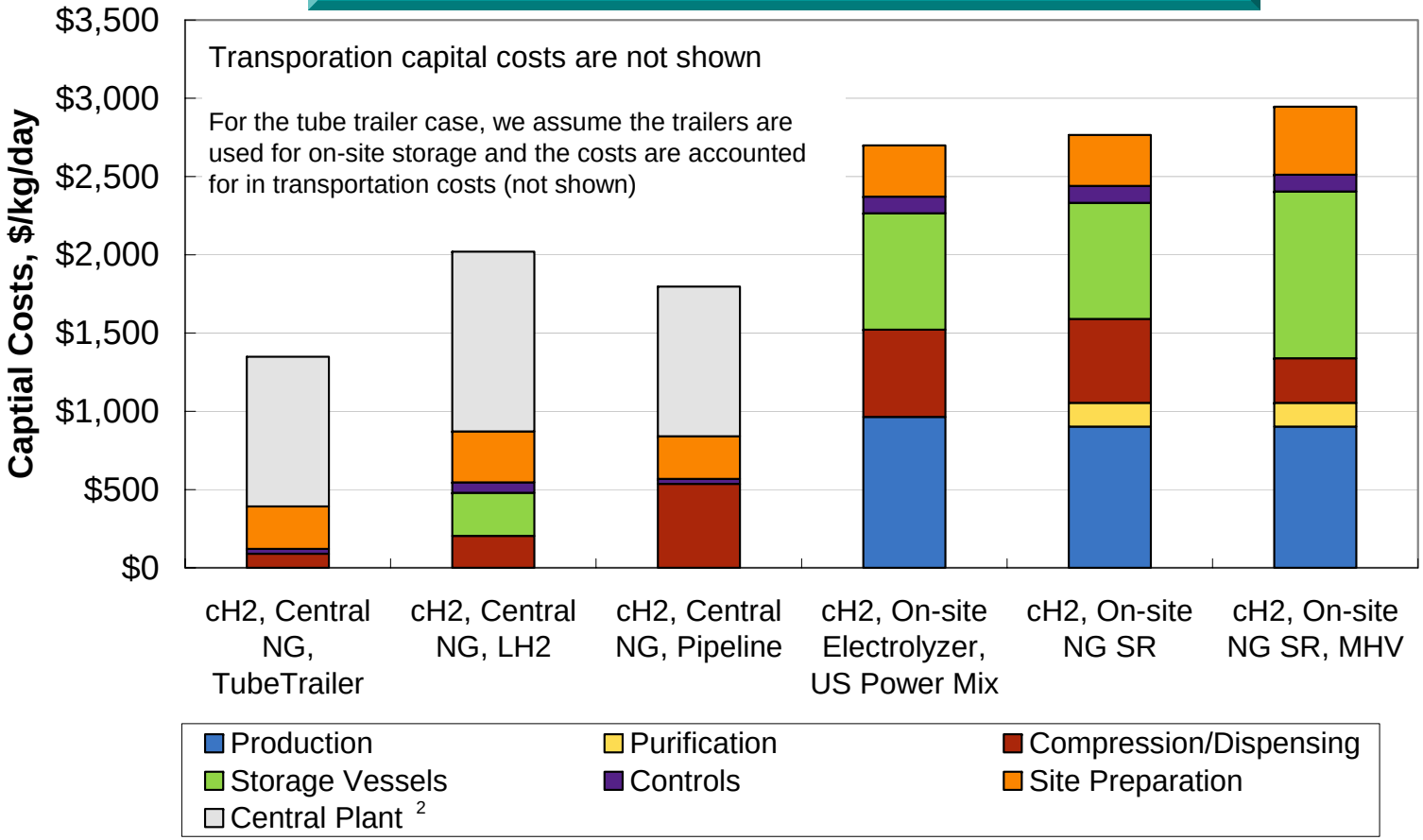


Options Also Differ in Their Energy Intensity and Greenhouse Gas Emissions

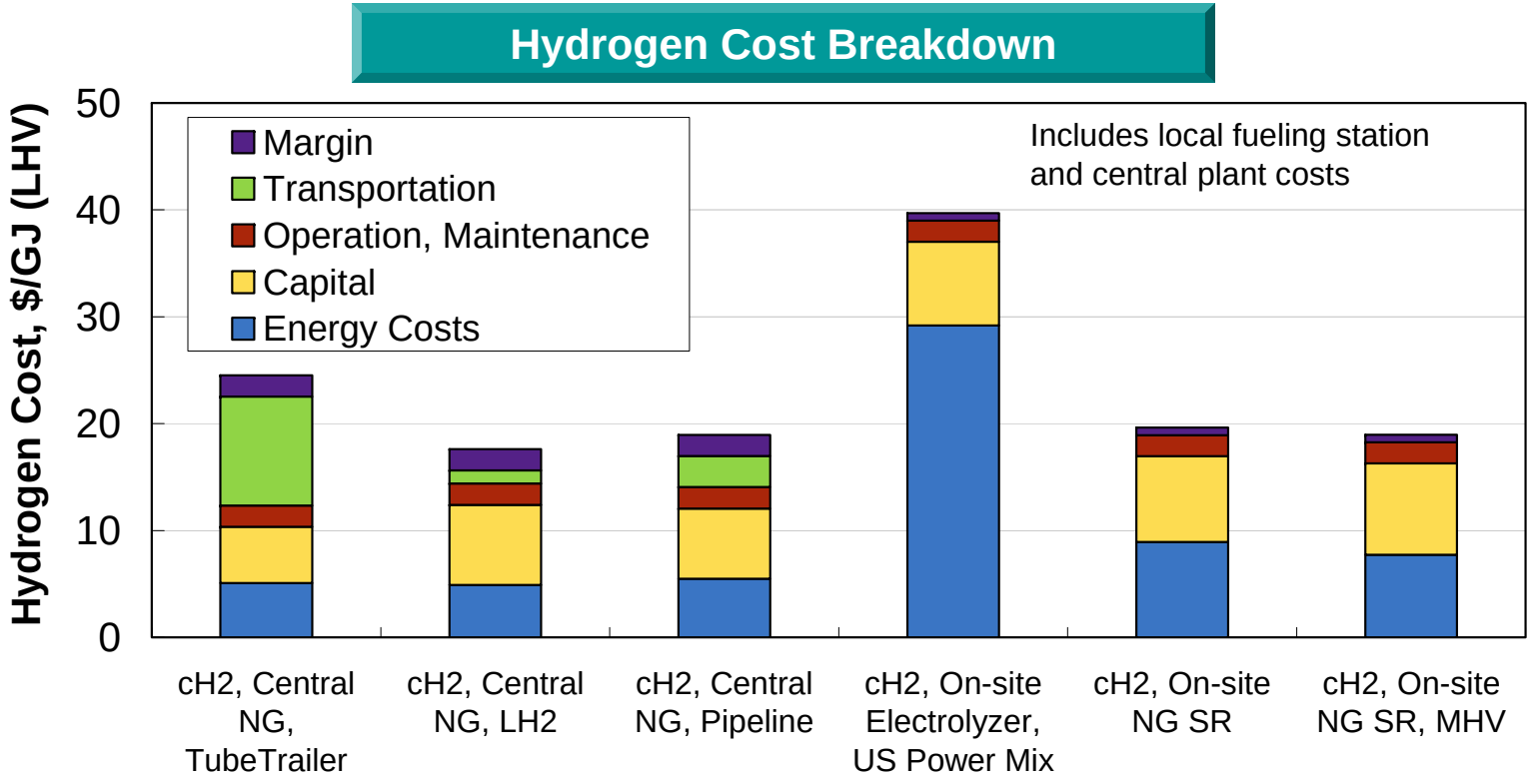
- WTT natural gas energy input for on-site SR is 1.7 J/J (59% η)
- Less energy use with central plant and MH vehicle fueling
- More energy use with LH2
- Over two times energy use from electrolysis
- Most near term production pathways involve natural gas



Hydrogen Fueling Station Capital Costs[1]

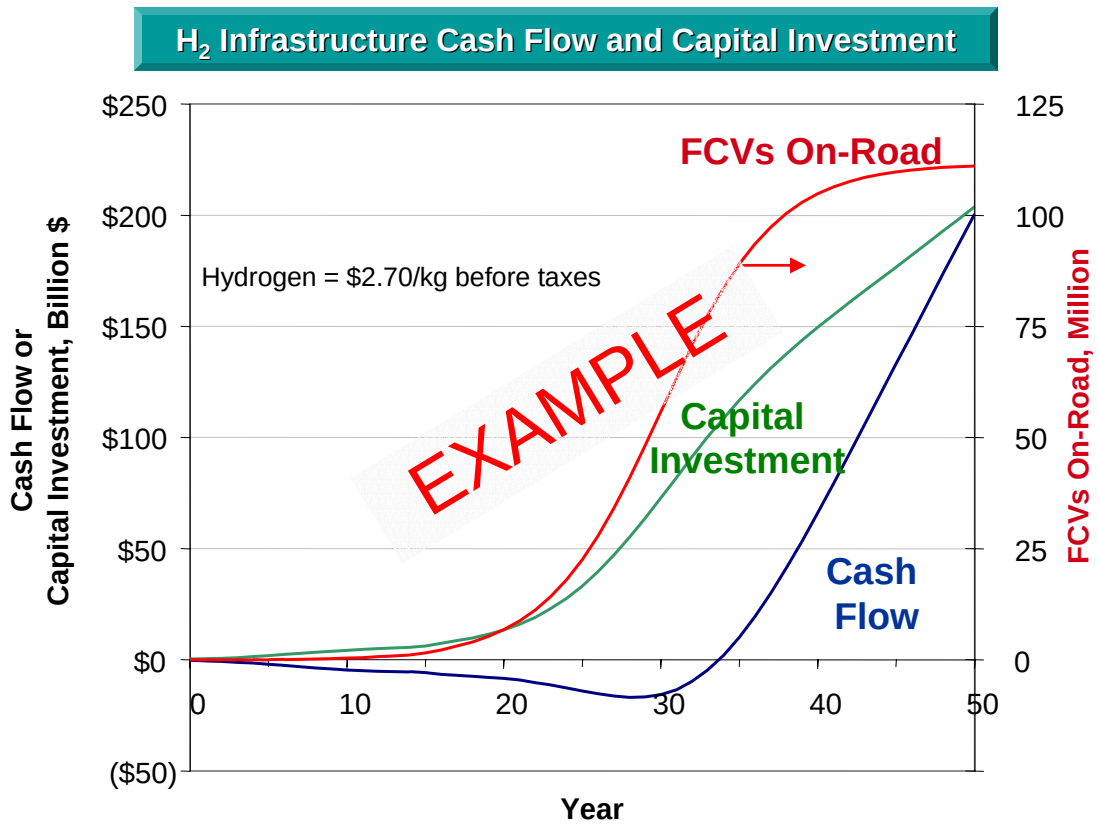


Most hydrogen production options range from about $1.80 to $3.00/kg (before taxes)



Local fueling station capital costs are significant, ranging from $300,000 to $2 million per station, far outstripping franchise owners' resources.

Using preliminary assumptions, if H_2 were priced to provide cost-parity with conventional vehicles, break-even would occur in about 30 years...



In the long-run, stakeholders can turn a profit if hydrogen is sold for $2.50-$3.00/kg

- Acceptable to FCV owners if fuel economy is 2-3 times better?
- Near-term pathways are needed to improve CF and reduce capital cost

…if an initial premium of 50-100% (1.5-2x gasoline ICEV cost/mi) is accepted, break-even may occur in about 20 years.

For an aggressive FCV program, H_2 production costs would ultimately reach $2/kg, but initial costs are high

- Initial capital cost and utilization (capacity factors) must be improved
- Innovative introduction could help bring the initial costs down:

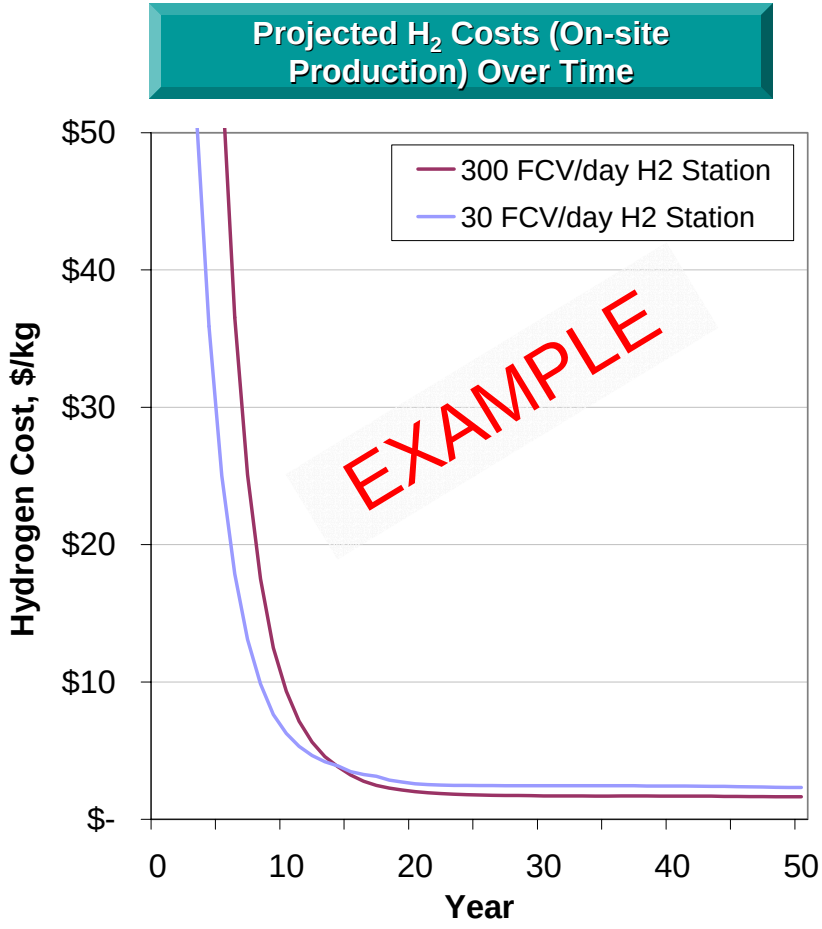
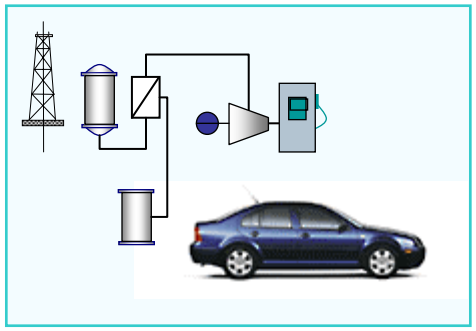
Utilize existing excess H_2 capacity (e.g. methanol and fertilizer plants)

FCV demonstrations and fleets (buses, government vehicles, etc)

Hydrogen ICEVs

Energy station (e.g. hydrogen for fueling and stationary power)

Alternative FCV and H_2 infrastructure introduction scenarios



50 buses would consume 10 percent of California merchant hydrogen capacity.