Hydrogen Supply: Pathways and Strategies

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Presented to

The Hydrogen and Fuel Cell Caucus

Washington, DC

January 11, 2005

H_2 is one of the only long-term fuels that allows radical reductions in greenhouse gases, air pollutants and oil use.

H_2 and fuel cells could enable innovative energy products and services.

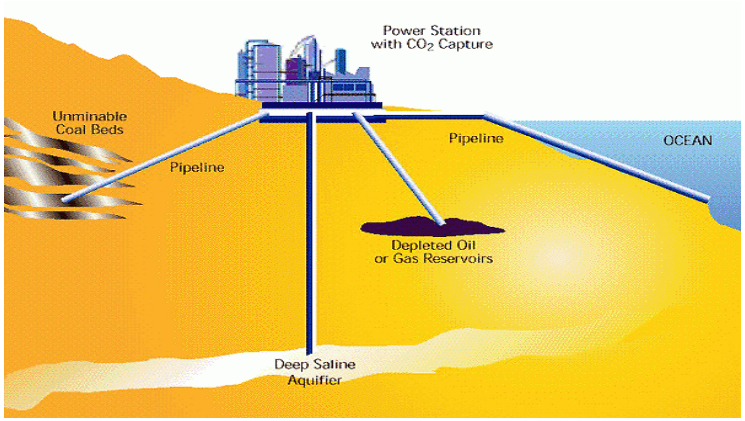
H_2 SUPPLY PATHWAYS

Like electricity, hydrogen is an **energy carrier** produced from **primary energy resources**

Wind

Solar

Biomass



Coal w/CO2 Sequestration

Natural Gas

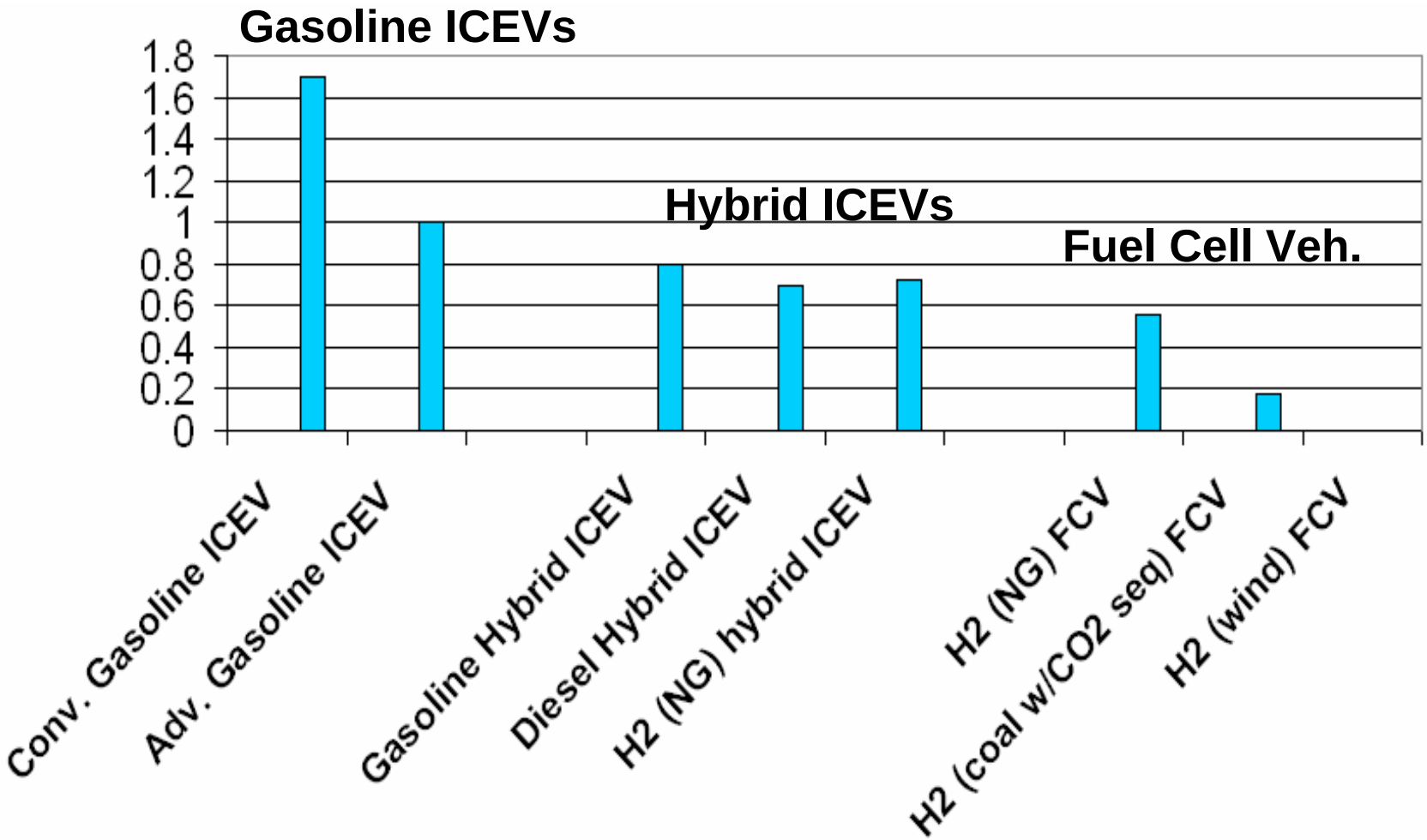
Nuclear

LONG-TERM VISIONS OF H_2 SUPPLY AND CHALLENGES

- **H_2 from renewables** (wind or solar electrolysis, biomass gasification), issue is cost rather than technical feasibility or resources.
- **Nuclear H_2** issues are cost (electrolytic H_2), technical feasibility (water splitting systems powered by nuclear heat). Same waste and proliferation issues as nuclear power.
- **Fossil H_2 with CO_2 capture and sequestration** near zero emissions, relatively low cost, assuming nearby CO_2 disposal sites, and large scale hydrogen production. Much unknown about potential environmental impacts and feasibility of CO_2 sequestration.

FULL FUEL CYCLE GREENHOUSE GAS EMISSIONS

(Normalized to Adv. Lightweight 46 mpg Gasoline ICEV)



Source: Ogden. Williams, Larson, Energy Policy, 2004.

DEBATE ABOUT H_2 SUPPLY: I (greenhouse gas emissions)

- Myth: Using natural gas to make hydrogen for vehicles would increase emissions of CO2 compared to gasoline vehicles.

Studies by ITS-Davis, Argonne and NAS show 10-40% well to wheels reduction of CO_2

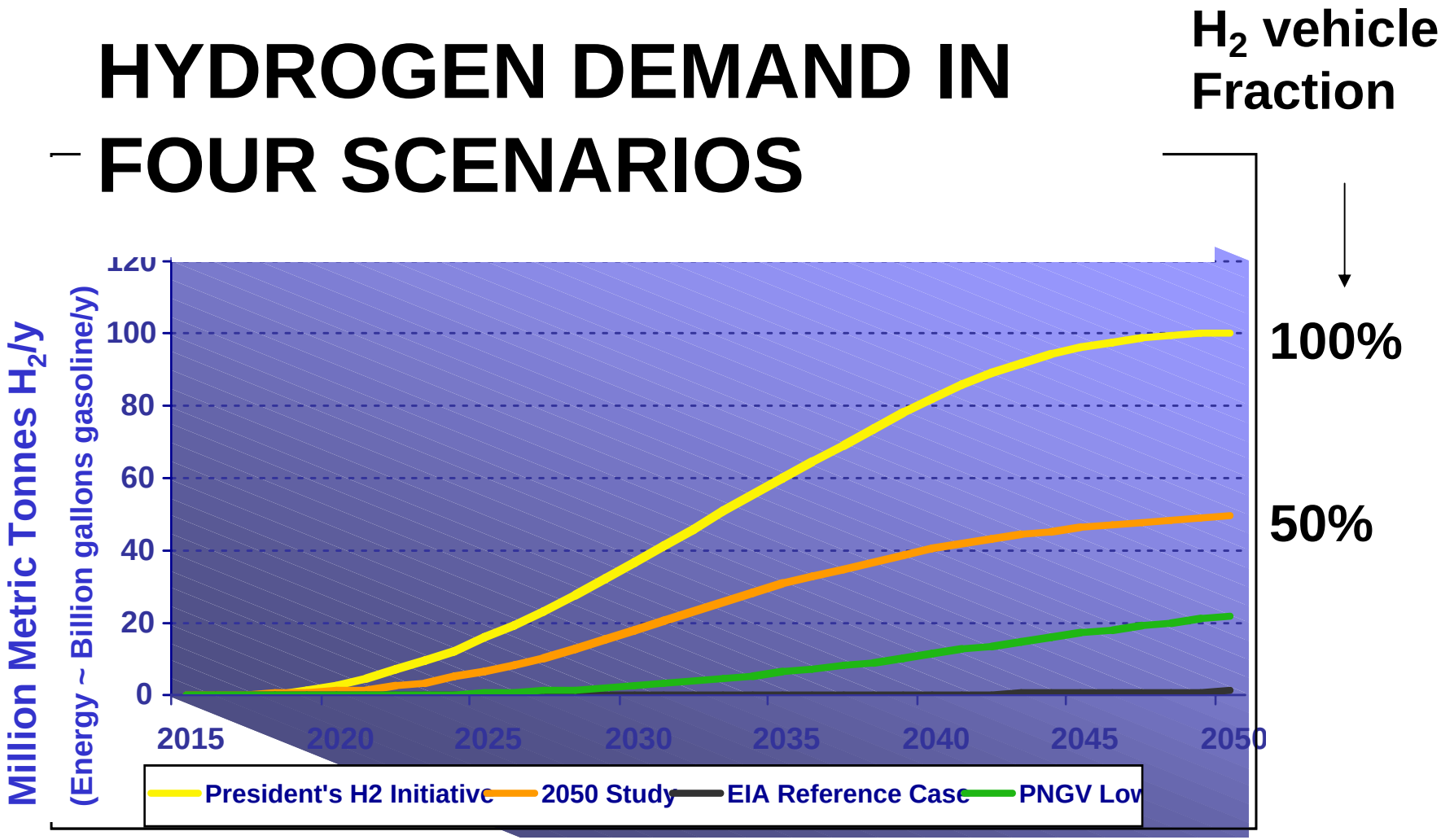
DEBATE ABOUT H_2 SUPPLY: II (carbon "efficiency")

- Myth: It is "carbon-inefficient" to use NG or renewables to make hydrogen for vehicles, when these resources could be used to displace coal fired electricity.

Only valid if resources strictly constrained (not true) AND if CO_2 reduction is the only goal (not true).

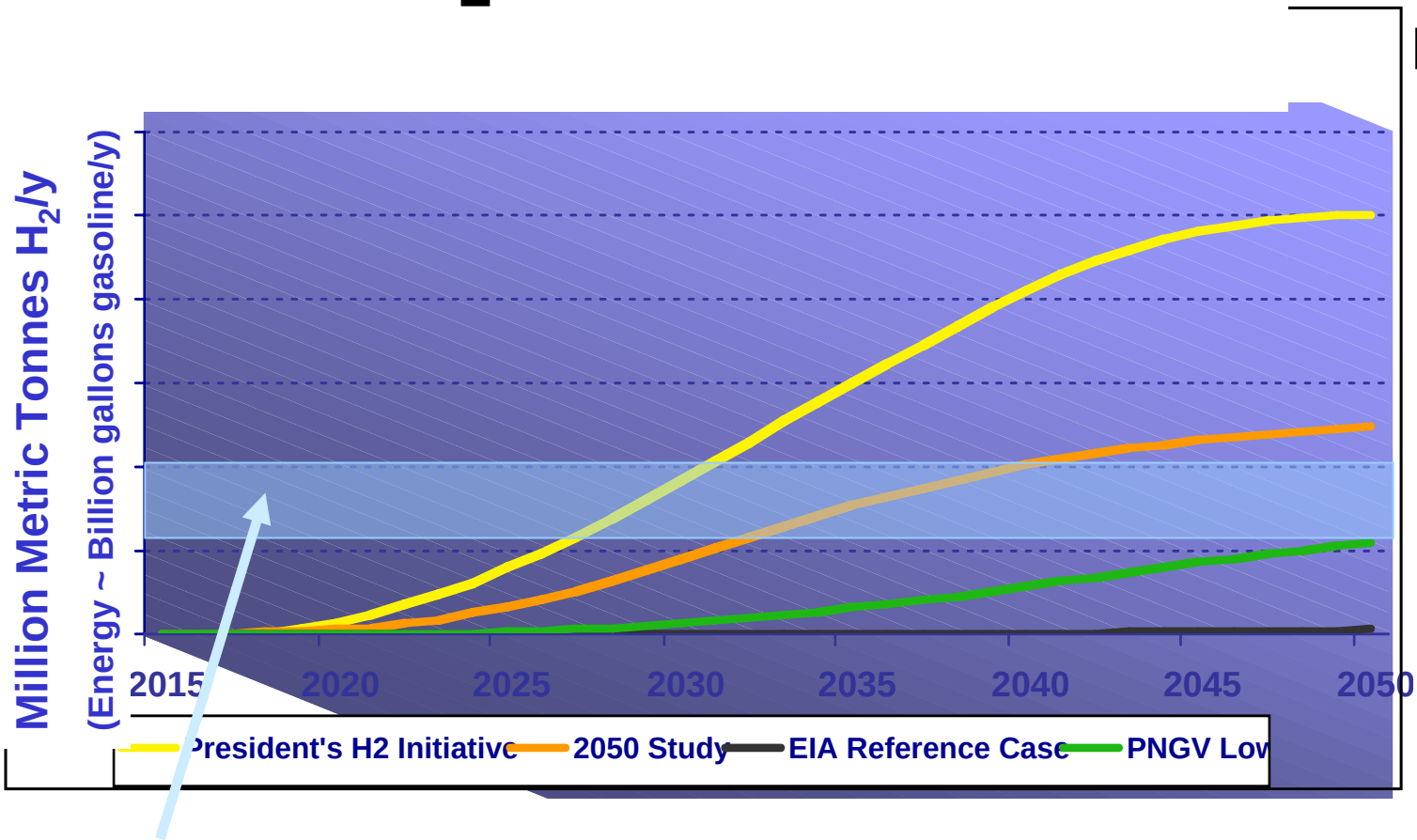
Use of primary resources for electricity and fuels will be determined by economics, end-use needs, resource availability, other factors

HYDROGEN DEMAND IN FOUR SCENARIOS



Uncertainties (technology, policy, market pull) => difficult to project future H_2 demands

PRIMARY ENERGY TO MEET H_2 DEMAND



Percent of current US use to make H_2 for LDVs

NG	Coal	Wind*	Bio*
68	92	45	33
34	46	22	16
14	18	9	7

* > class 3 wind

** fraction of range + pastureland required for H2 via gasification

100 million H_2 vehicles w/ 2-3 X today's gasoline vehicle fuel economy

DEBATE ABOUT H_2 SUPPLY: III (Primary Supply)

- Myth: Making H2 for vehicles would vastly increase natural gas use.

During the transition period when NG would be used (next 20-30 years), H_2 use will be relatively small, so the increased NG demand to make H_2 would be <10%

WHERE WILL H_2 COME FROM?

- **Near term**: Natural gas "transitional" source for H_2 in US
  - 10-40% GHG emissions reduction v. Advanced gasoline vehicles
  - Small impact on natural gas use, at H_2 use <2025
- **Long term**: Ample resources for near-zero GHG emission H_2 production in US, globally
- **Many solutions for H_2 supply: depends on level of demand, resource availability, geography.**

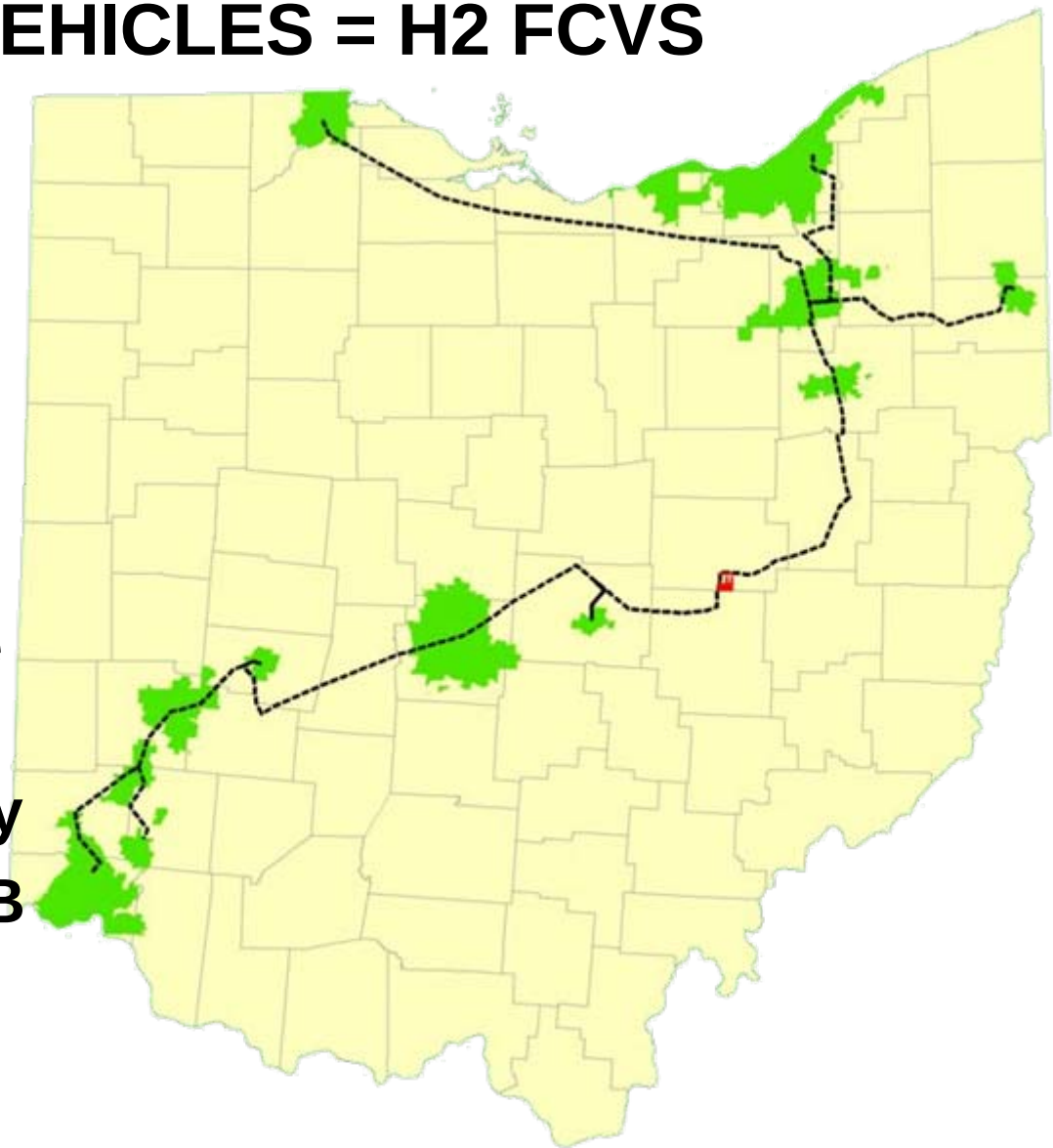
HOW MUCH WILL IT COST?

- Several hundred to several thousand $ per vehicle for **mature** H_2 refueling infrastructure. (Near term costs higher. Costs decrease w/learning, scale)
- Shell estimates 11,000 H_2 stations needed nationwide for “coverage”, initial cost $12 B
- Full implementation of H_2 infrastructure $100sB
- But costs to maintain, expand conventional transport fuels infrastructure also large.
- Delivered H_2 cost range ~$2.5-4/kg for mature H_2 economy. With efficient (2-3 X) H2 FCV, fuel cost per mile < current cost for gasoline cars. (near term H_2 costs higher)
- (energy in 1 gallon gasoline ~ energy in 1 kg H2)

OPTIMIZED PIPELINE NETWORK

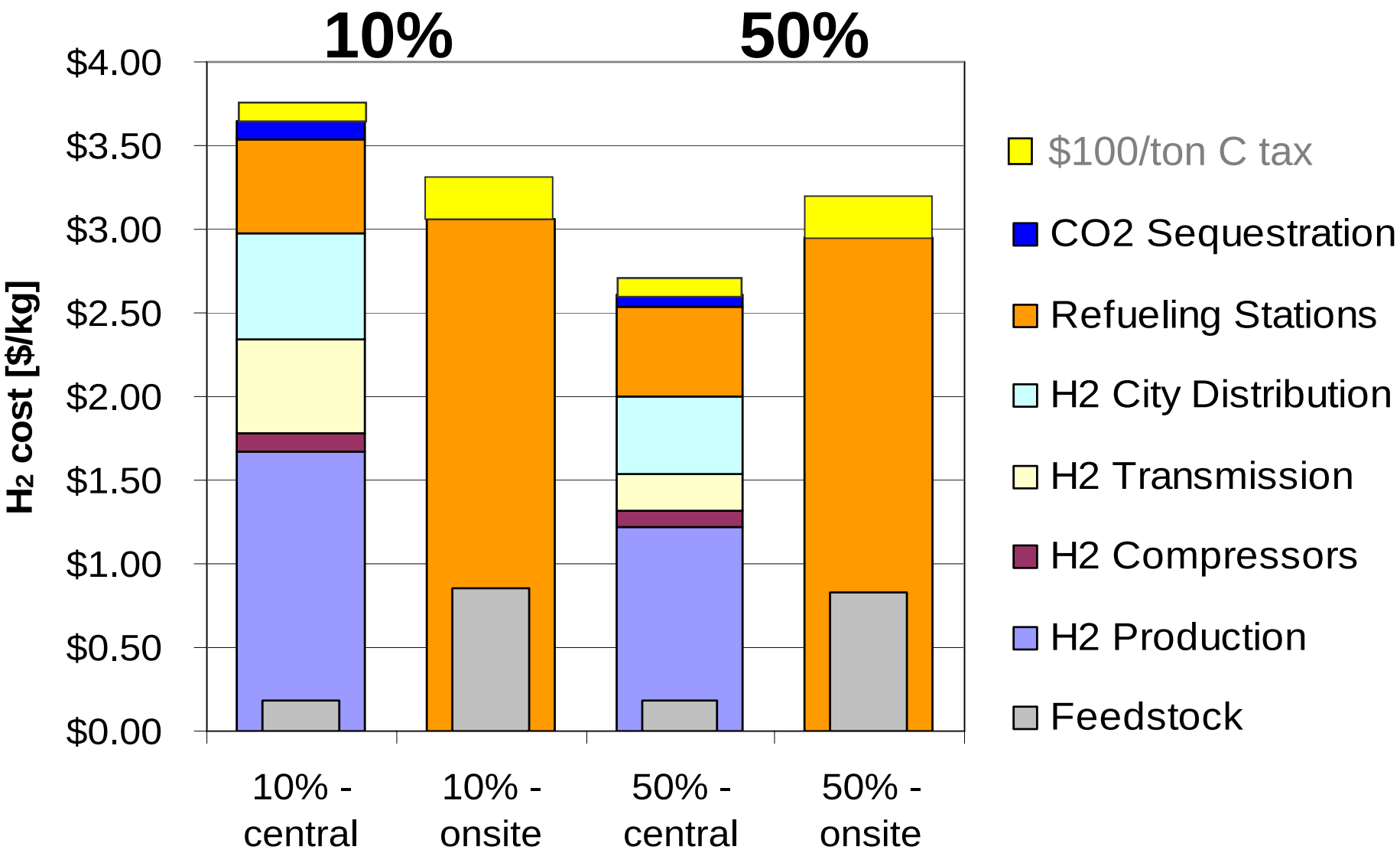
IF 10% OF VEHICLES = H2 FCVS

- **1 coal plant - 253 tons H_2/day**
- **12 cities**
  - 1345 km of local distribution pipelines
  - 187 refueling stations,
- **936 km intercity pipeline**
- **CO_2 sequestration system 4500 ton CO_2/day**
- **Total capital cost = $1.3B or $3400/vehicle**



Source: Ogden, Yang, Johnson, Ni, Johnson, Lin, Report to NETL, 2004.

DELIVERED H_2 COST
v. H2 VEHICLE FRACTION



DEBATE ABOUT H_2 SUPPLY: IV (Cost)

- Myth: Hydrogen infrastructure will be extraordinarily expensive.

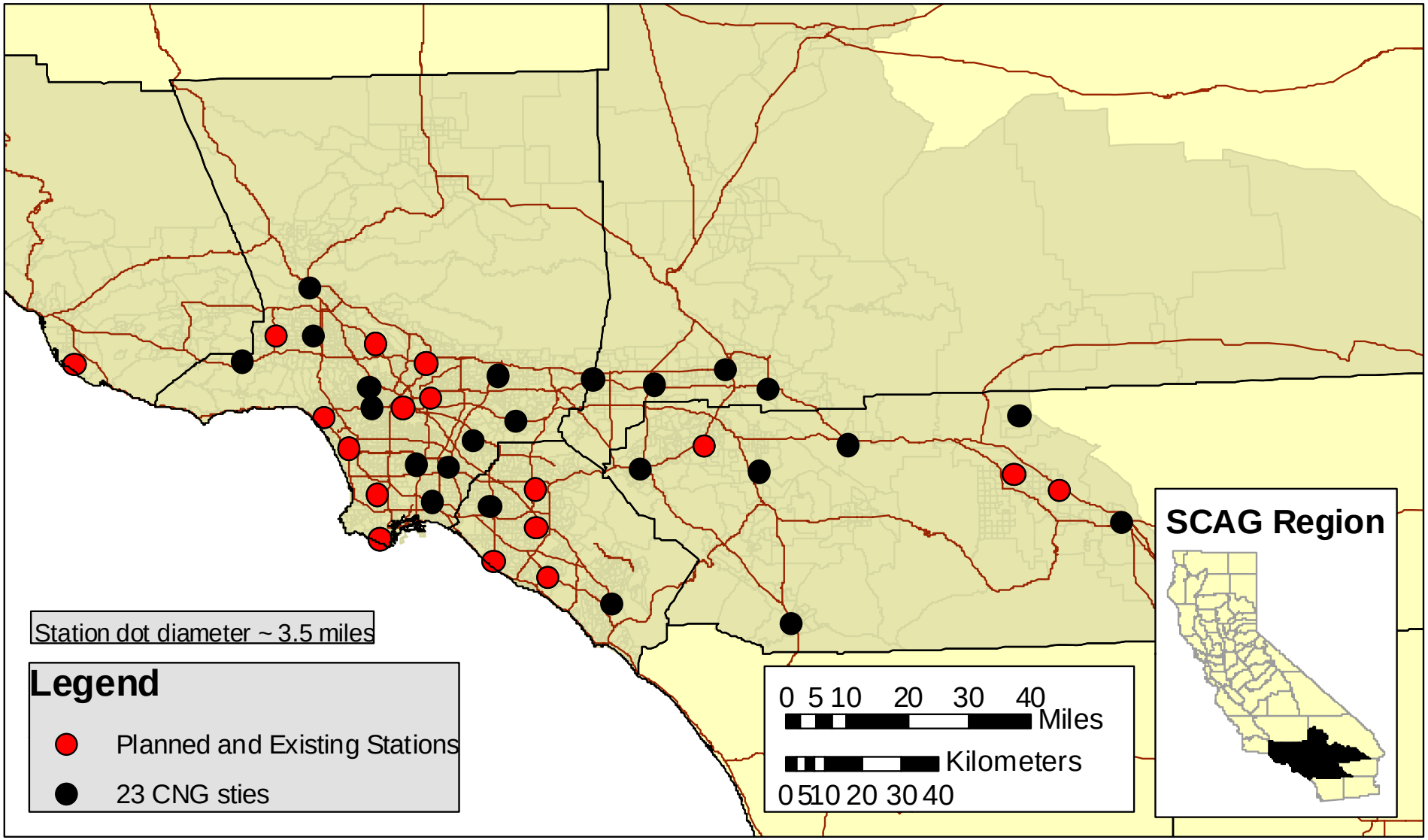
Initial cost barrier. Mature costs may be comparable to maintaining and expanding conventional fuel infrastructure

- Myth: Hydrogen fuel will be extraordinarily expensive at the pump.

For H2 FCV, fuel cost per mile < today's gasoline vehicles

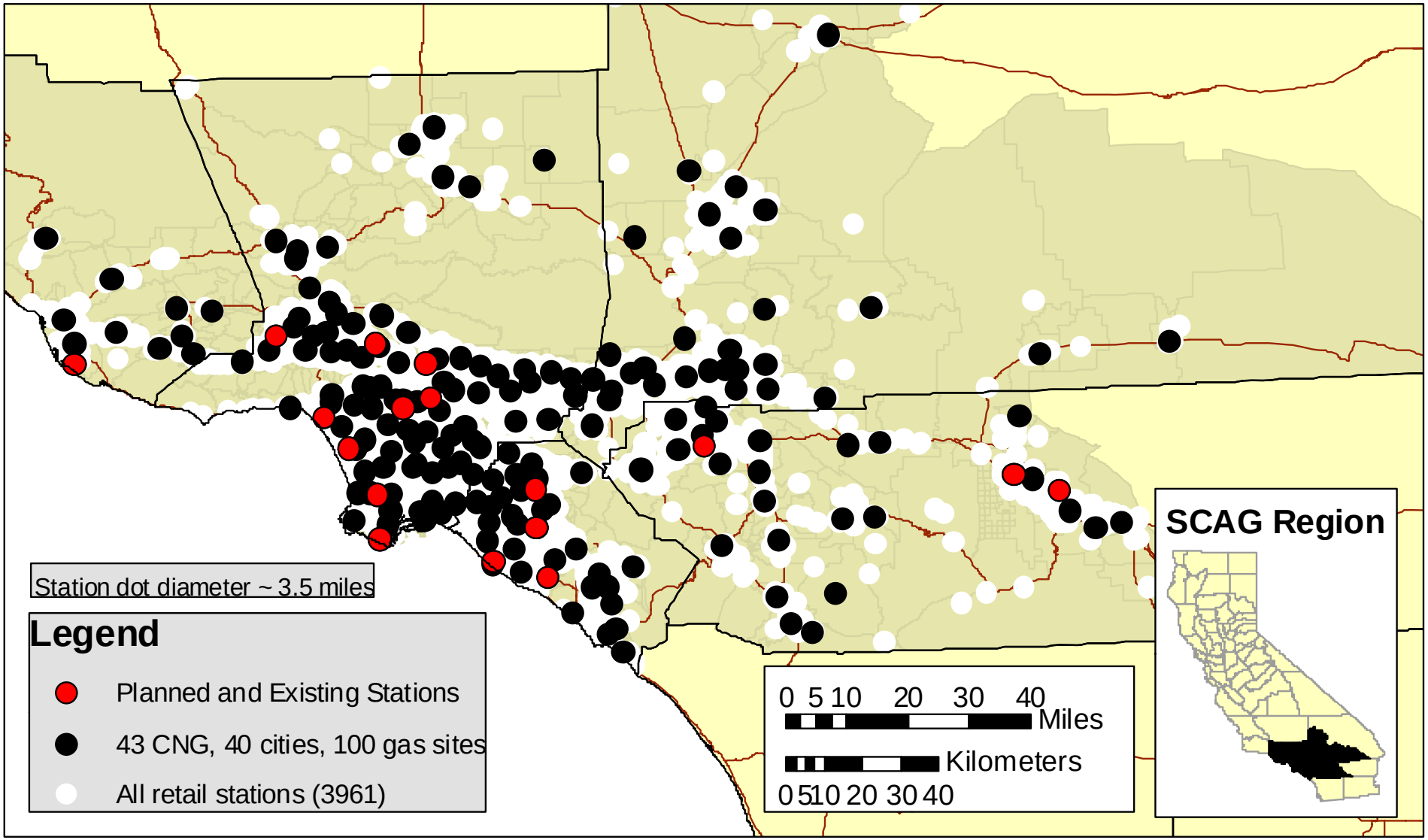
Case study for CA H2 Highway Network:

17 planned H2 stations + 23 fleet sites



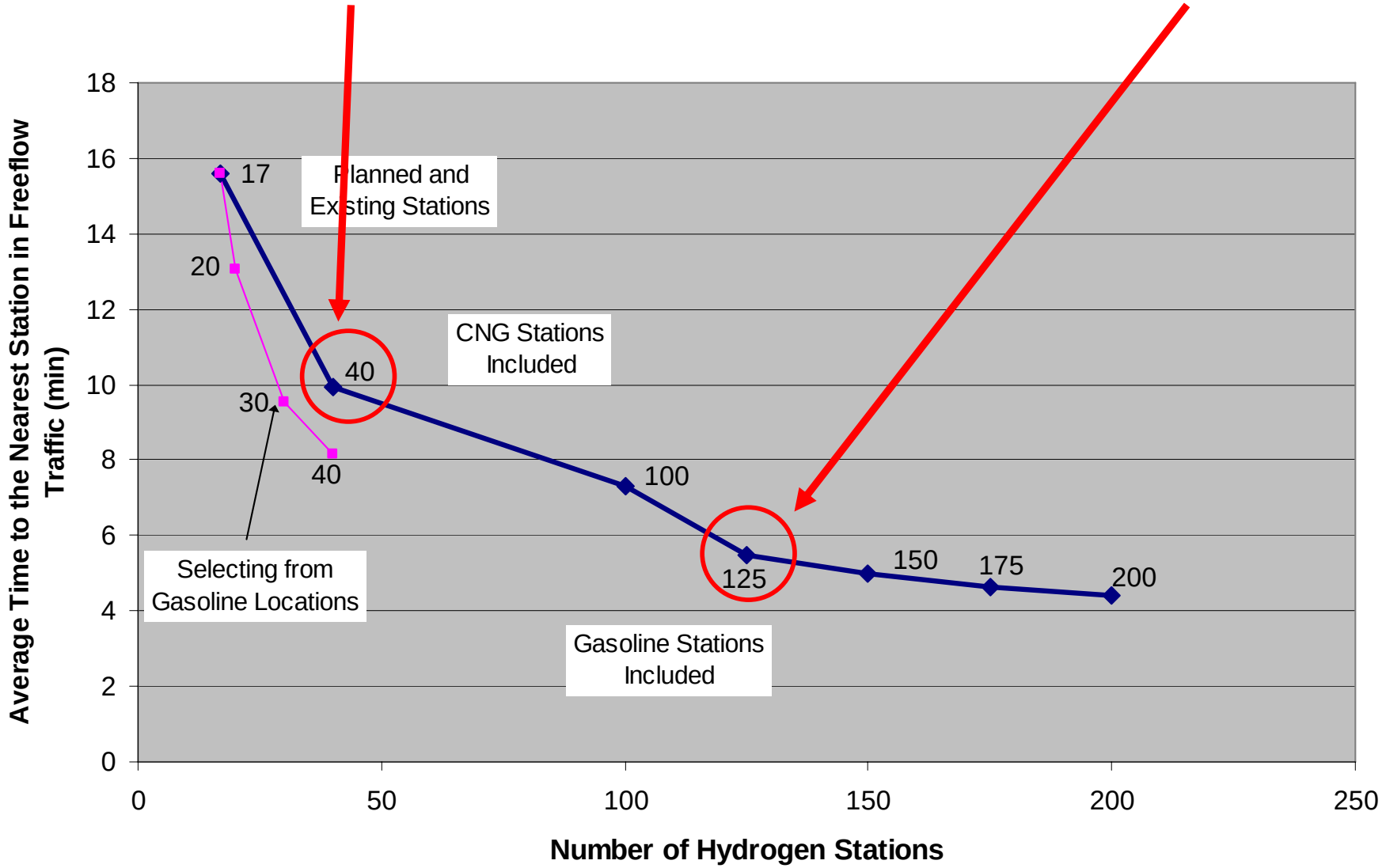
Source: M. Nicholas, ITS-Davis, for CA H2 Highway Blueprint Plan 2004.

17 planned H2 stations + 43 fleet sites + 40 largest cities +100 gasoline locations



Ave. Travel Time to Nearest Station

H2 at 1% of gasoline sta. => 10 minutes; 3% => 5 minutes



HOW SOON COULD H_2 MAKE A MAJOR DIFFERENCE?

- Time to change energy system ~ decades.
- H_2 end-use technologies need more development before entering mass markets, and time to penetrate markets.
- It will be several decades before hydrogen could reduce emissions and oil use on a global scale. (local impacts sooner)
- Beyond 2025, potential for large impact of H_2 technologies on reducing emissions.
- Potential to transform energy production and use

ACTIONS TO ENABLE A H_2 ECONOMY

- **RD&D** :
  - Fuel cells
  - H_2 storage for vehicles
  - Small scale H_2 production systems
  - Advanced vehicle systems (ICEs, hybrids. FCVs)
  - Low-cost “zero-C” energy supply (elec, H_2, fuels)
- **Demonstrate/enable H_2 infrastructure**
  - Demonstrate technology
  - Codes and standards
  - Infrastructure transition cost barrier
  - Strategies for H2 infrastructure
- **Policies reflecting external costs of energy (near term->long term)**