Scenarios for 2010 - 2025 & Beyond:
Analyzing the Impacts of Policies and Technological Change Using HyTrans

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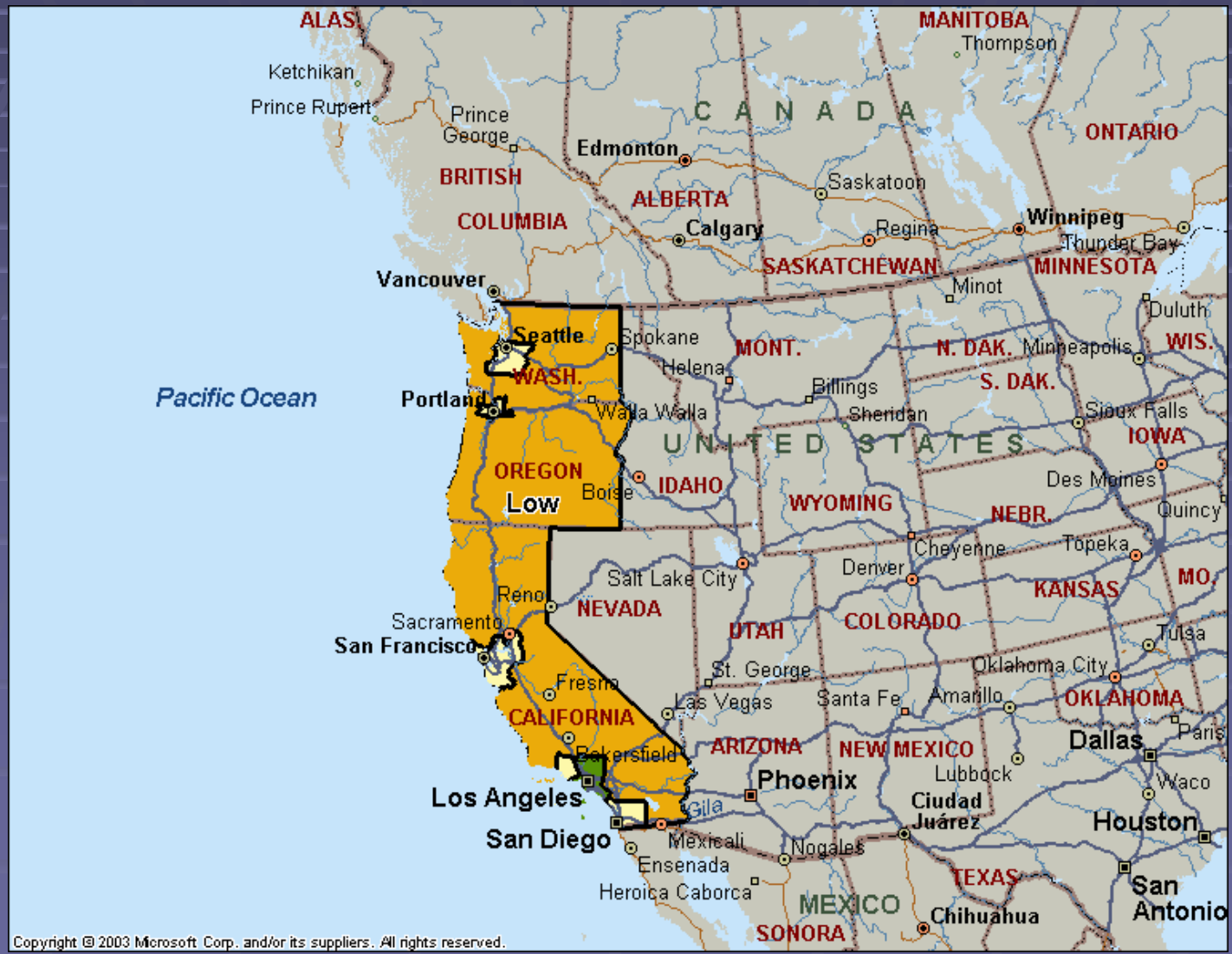
HyTrans merges the 2010-2025 scenarios with longer-term policies to simulate durable transitions.

- **Through 2025 the model is constrained to meet the scenario sales targets.**
  - Estimates costs of vehicles and hydrogen, infrastructure investments and implicit subsidies.
  - Estimates benefits of learning-by-doing, scale economies, fuel availability and market diversity.
  - 2010 DOE targets met, further progress beyond 2010.
- **In the later period (2025-2050) vehicle and fuel subsidies might be needed for a durable transition.**
  - Price of oil a key factor
  - Competition with other advanced technologies also important
  - How will societal benefits be taken into account?
    - Reduced oil dependence
    - Opportunity to reduce GHG emissions
    - Elimination of vehicle pollutant emissions

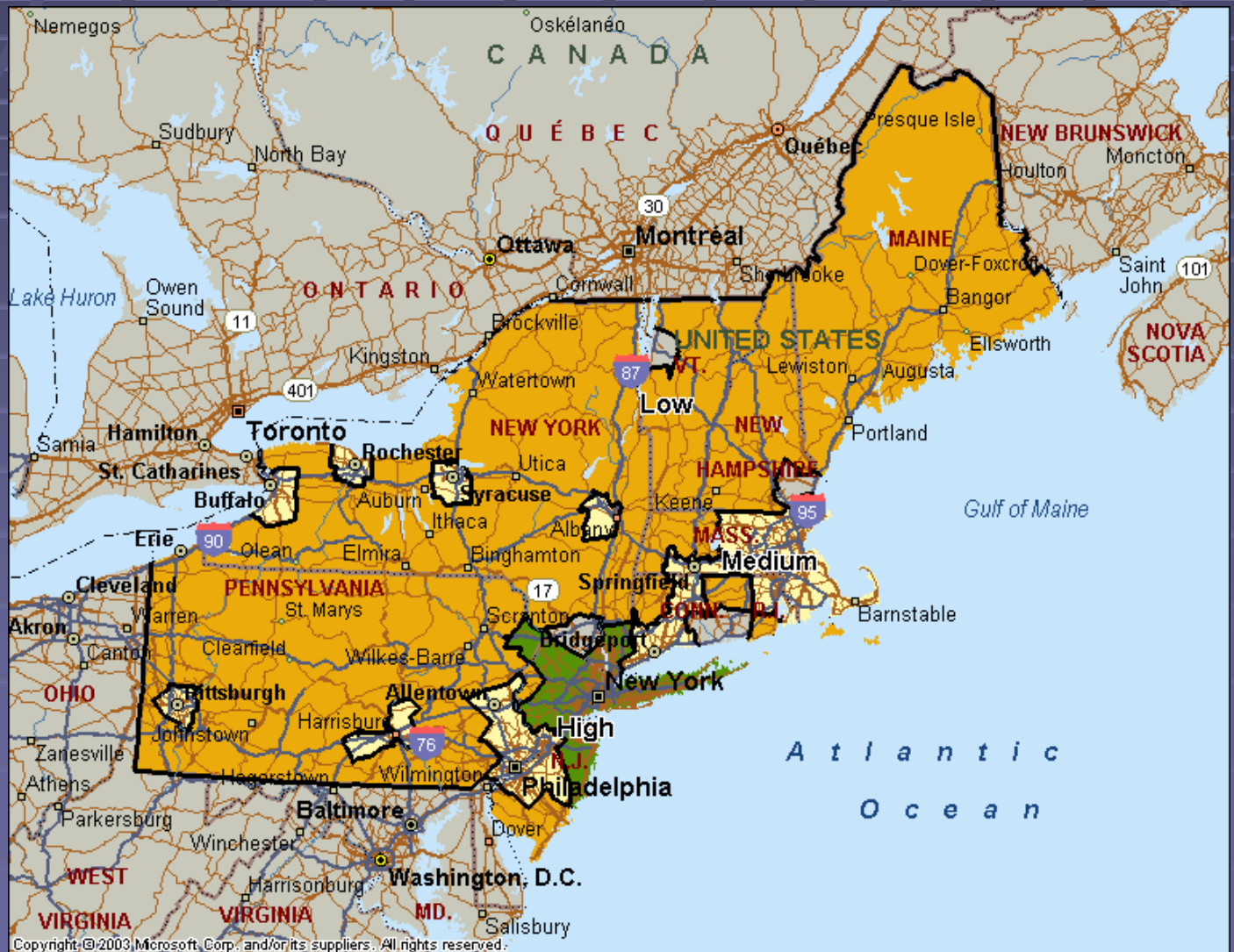
HyTrans integrates supply and demand in a dynamic market model to 2050.

- **H2A**
  - Hydrogen Production
  - Hydrogen Delivery
- **PSAT & ASCM**
  - Fuel economy
  - Cost
- **NMNL Vehicle Choice Model**
  - Fuel availability
  - Make & model diversity
  - Price, fuel economy, etc.
- **Vehicle Manufacturing**
  - Scale Economies
  - Learning-by-doing
- **GREET GHG emissions**
- Calibrated to **NEMS AEO 2006** through 2030

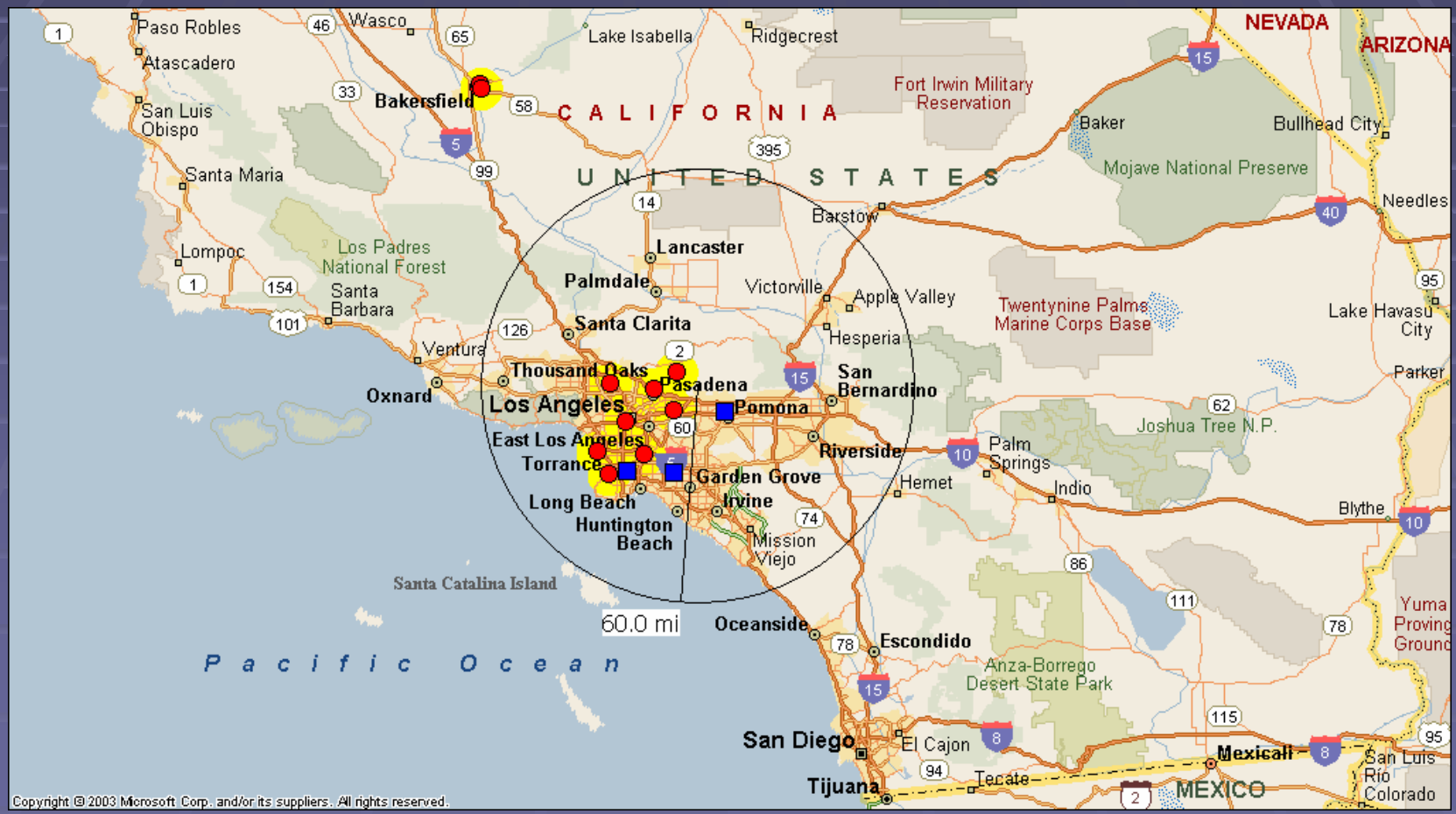
For the 2010-2025 analysis, two regions were added: Pacific & Northeast.



The 2 regions were subdivided: LA/NYC, medium, and lower fuel use density.



Ten percent of merchant hydrogen production in the LA region was assumed to be available for vehicles at $1/kg, plant gate.

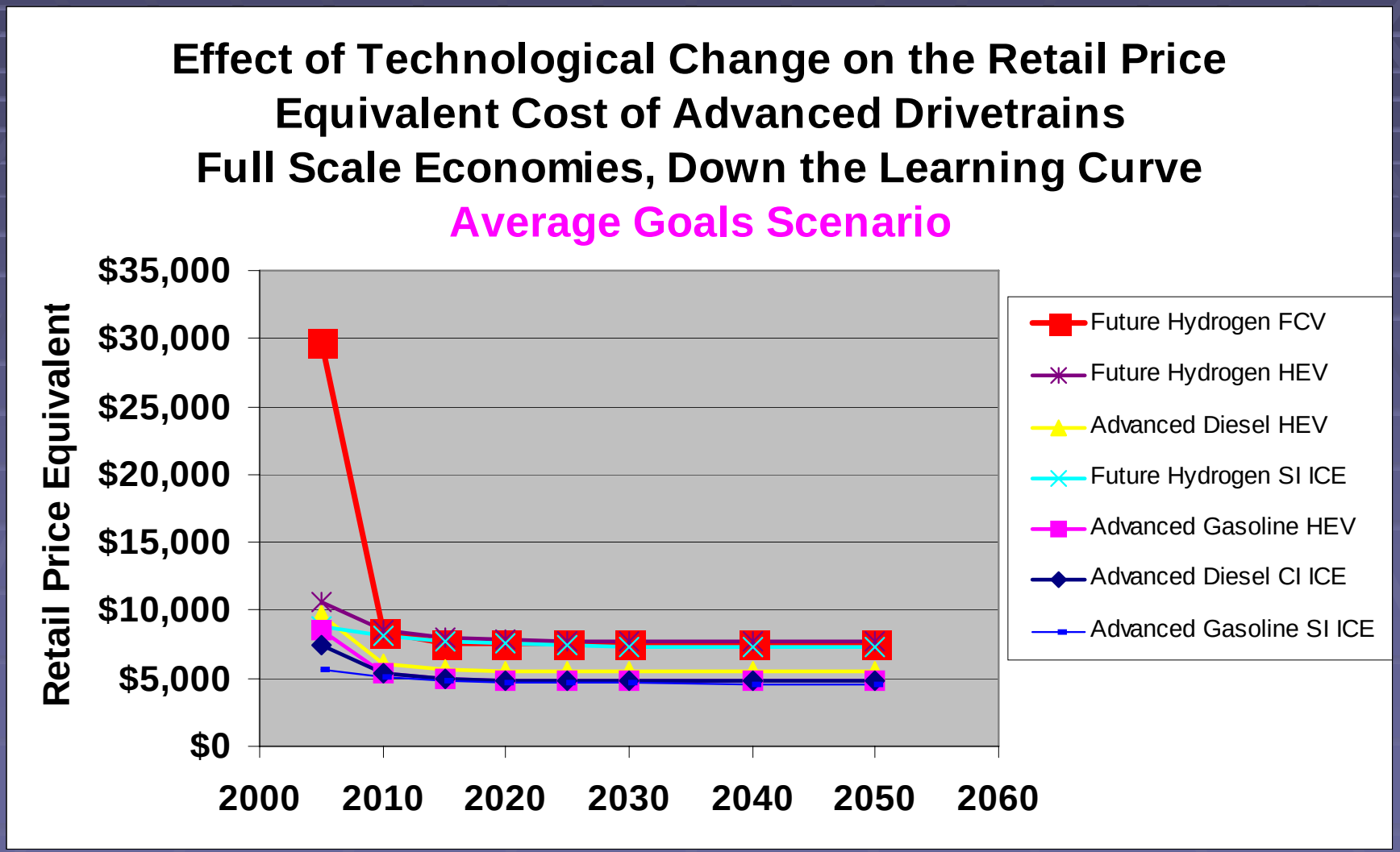


Technology cost and performance assumptions are based on the PSAT/ASCM analysis by Rousseau, Sharer, Pagerit & Das, 2005.

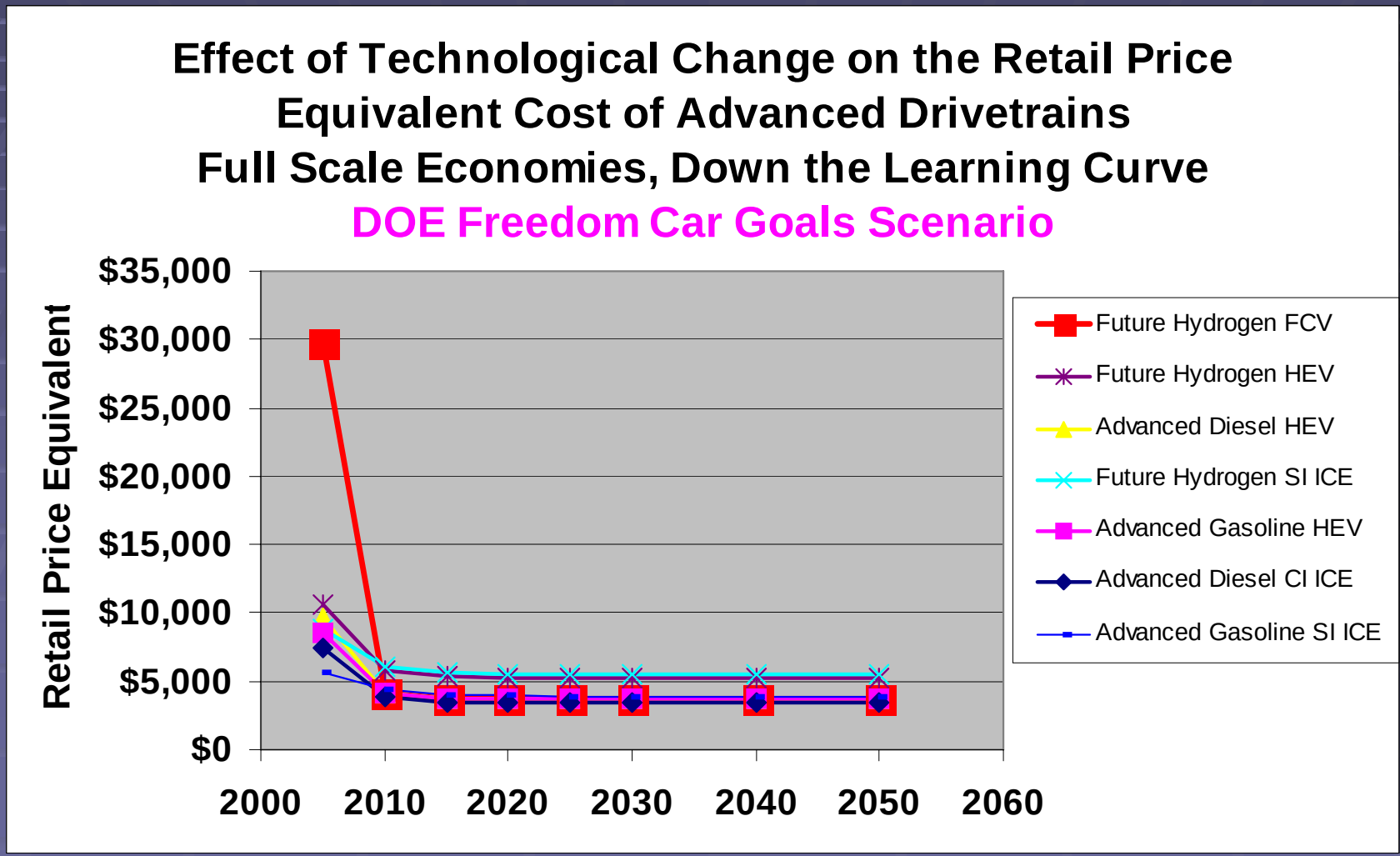
MORE PSAT SCENAIROS NEEDED.

	DOE 2010 Goals	Average	Intermediate Goals
Fuel Cell System $/KW	**$45**	**$60**	**$75**
Hydrogen Storage $/kWh	**$4/$10**	**-**	**-**
Motor $/kW	**$4**	**$4.50**	**$5**
Batteries $/kW	**$20**	**$25**	**$30**
Gasoline ICE $/kW	**$21**	**$22**	**$23**
Diesel ICE $/kW	**$21**	**$24**	**$27**

Two technology cost scenarios were taken from Rousseau et al.'s PSAT + ASCM simulations. The average case represents substantial technologic progress.



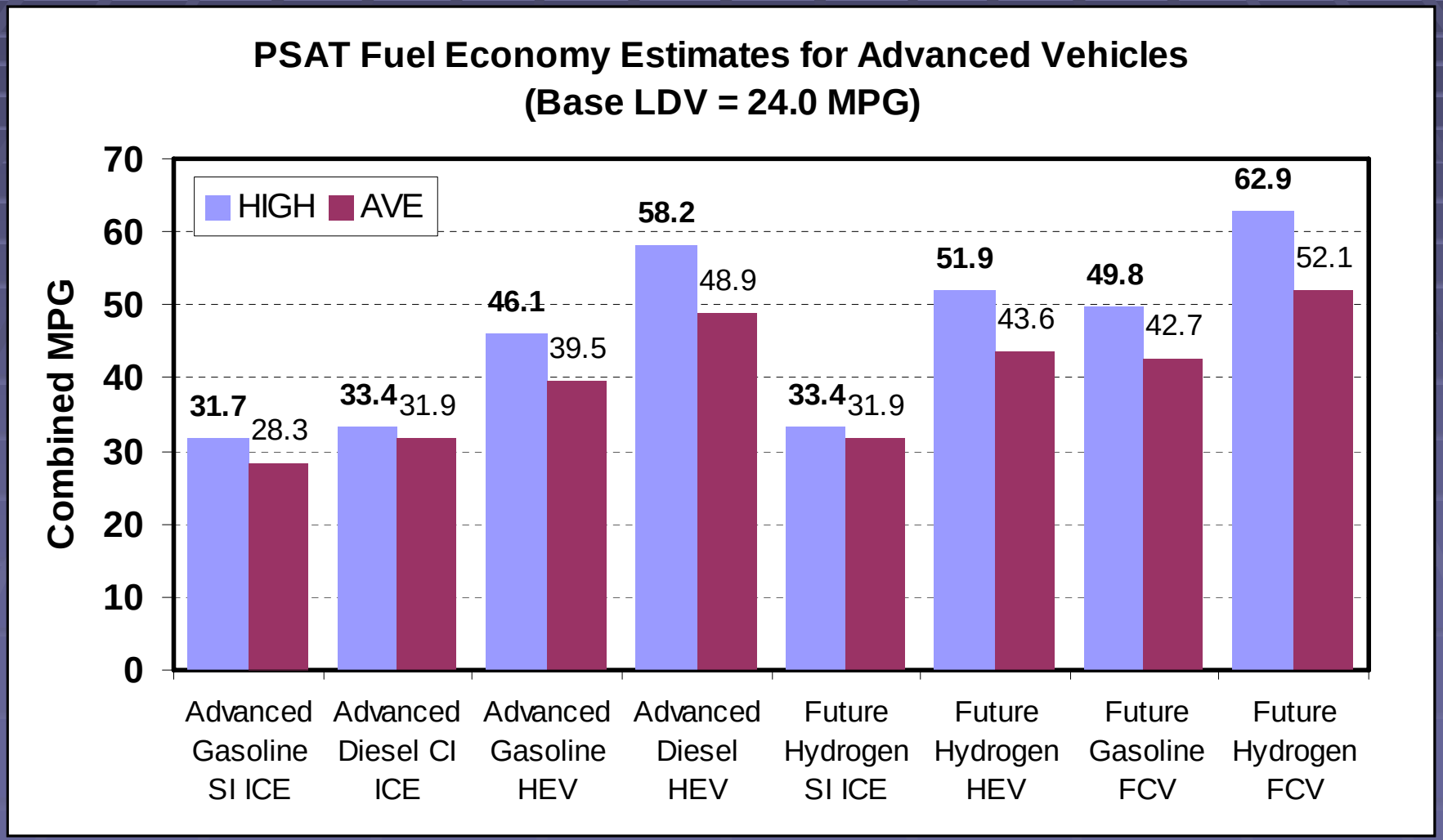
In the DOE 2010 Goals scenario, all technologies meet FreedomCar **2010** goals.



Component efficiency assumptions also reflect a combination of DOE 2010 program goals and judgment (Intermediate case).

	DOE 2010 Goals	Average	Intermediate Goals
Fuel Cell	60%	57.5%	55%
Gasoline ICE	38%	36.5%	35%
Diesel ICE	45%	42.5%	40.5%
Hydrogen ICE	42%	40%	38%

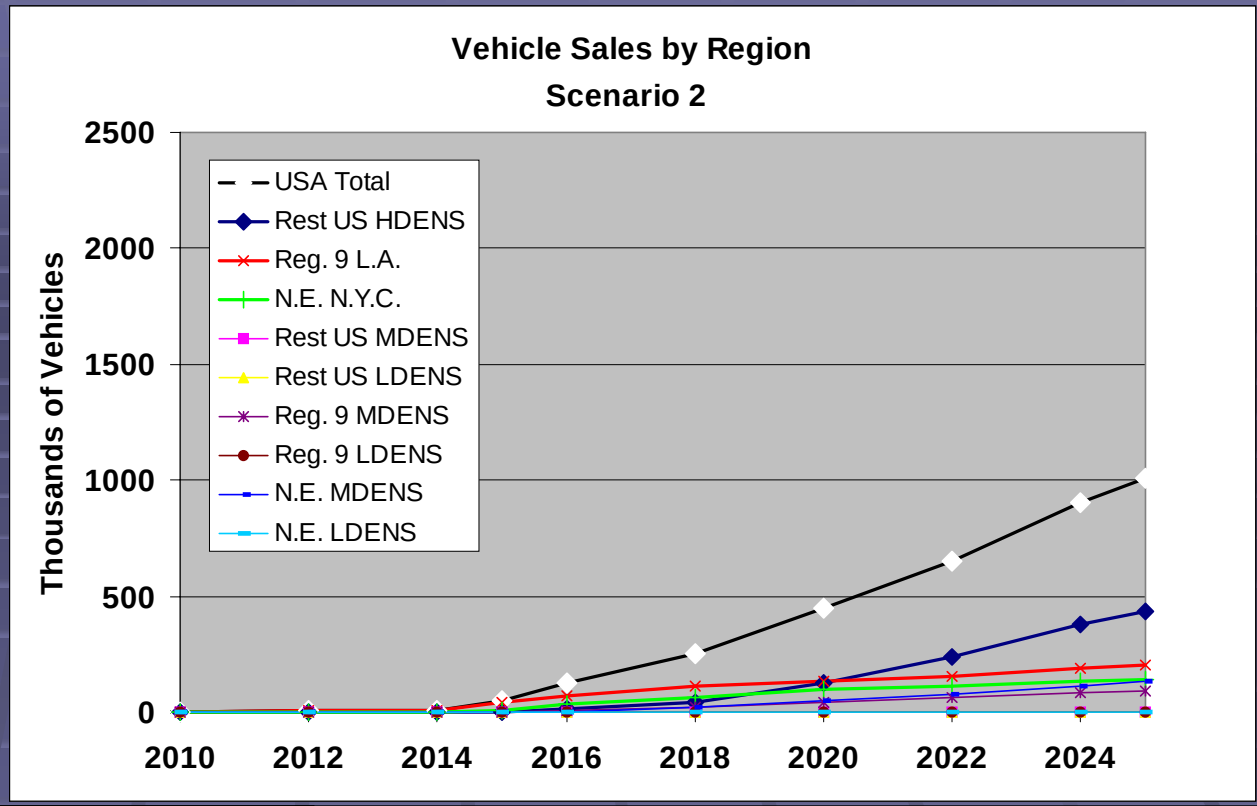
The DOE 2010 Goals scenario estimates higher MPG, especially for electronic drive systems.

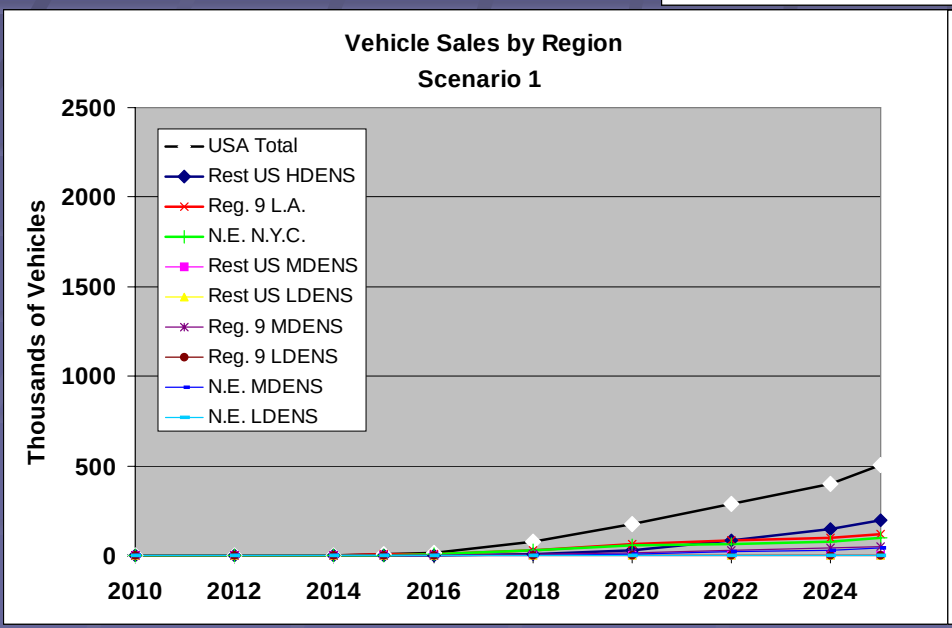


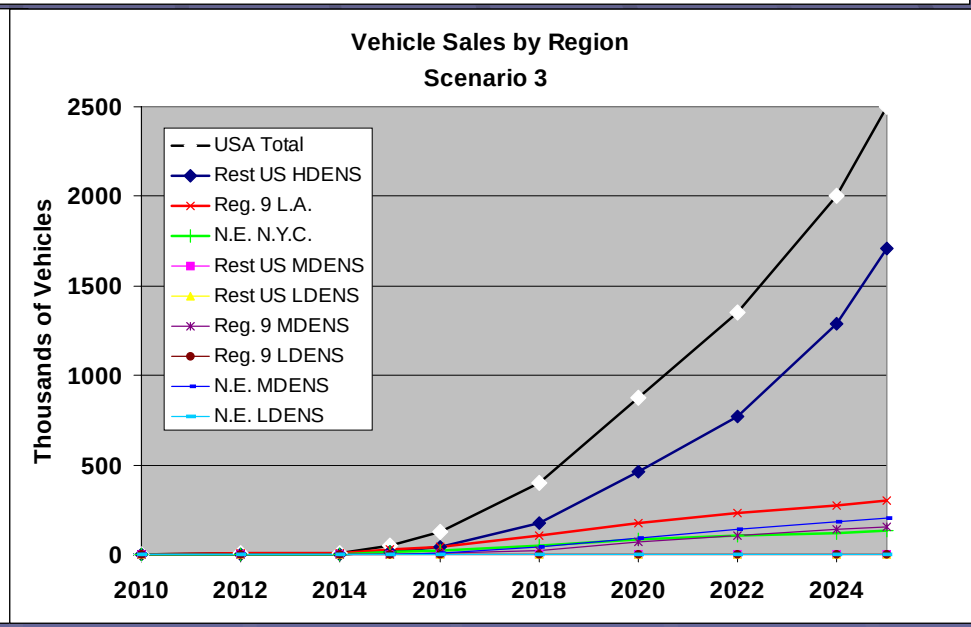
Our hydrogen "fuel cell success" scenario combines DOE 2010 goals for FCVs with "average" progress for other technologies.

- AEO 2006 High World Oil Price Case: $90/bbl by 2030
- May not need post-2025 policies equivalent to:
  - $1,000/vehicle for 10 years
  - Exemption from motor fuel excise tax for H2
- Greenhouse gas restrictions equivalent to:
  - $50/ton CO_2 from 2015-2030
  - $100/ton CO_2 from 2030 on

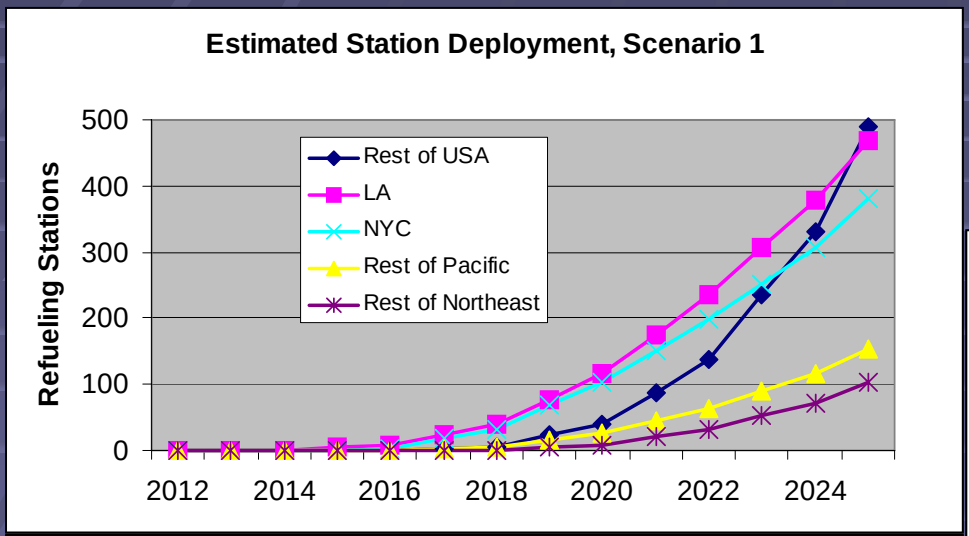
In scenarios 1 and 2 L.A. and N.Y.C. get most of the early FCVs. In scenario 3 FCVs are distributed to cities across the U.S.

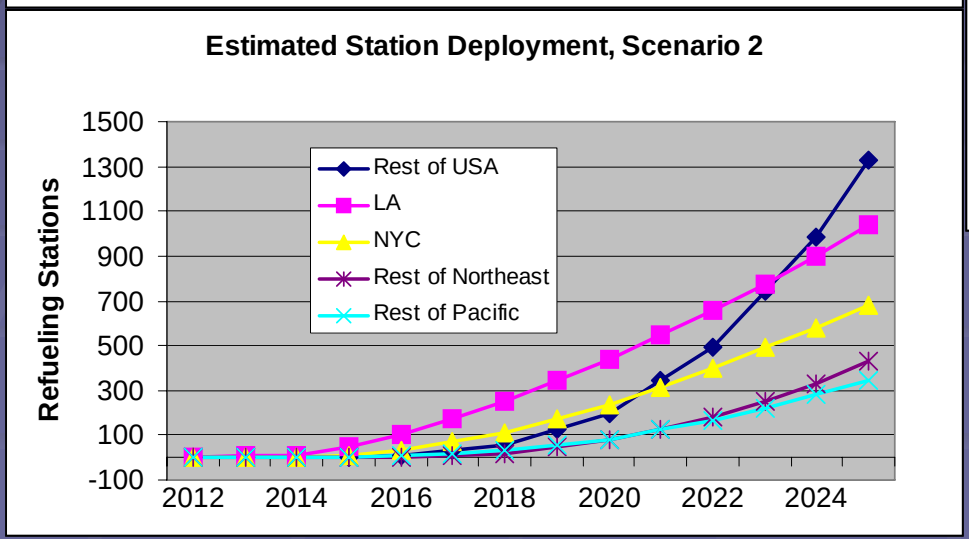


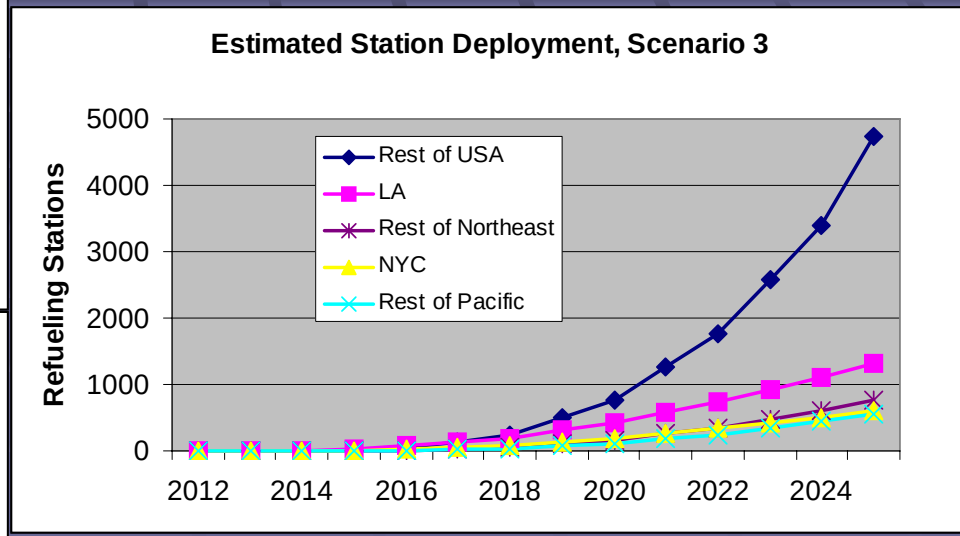




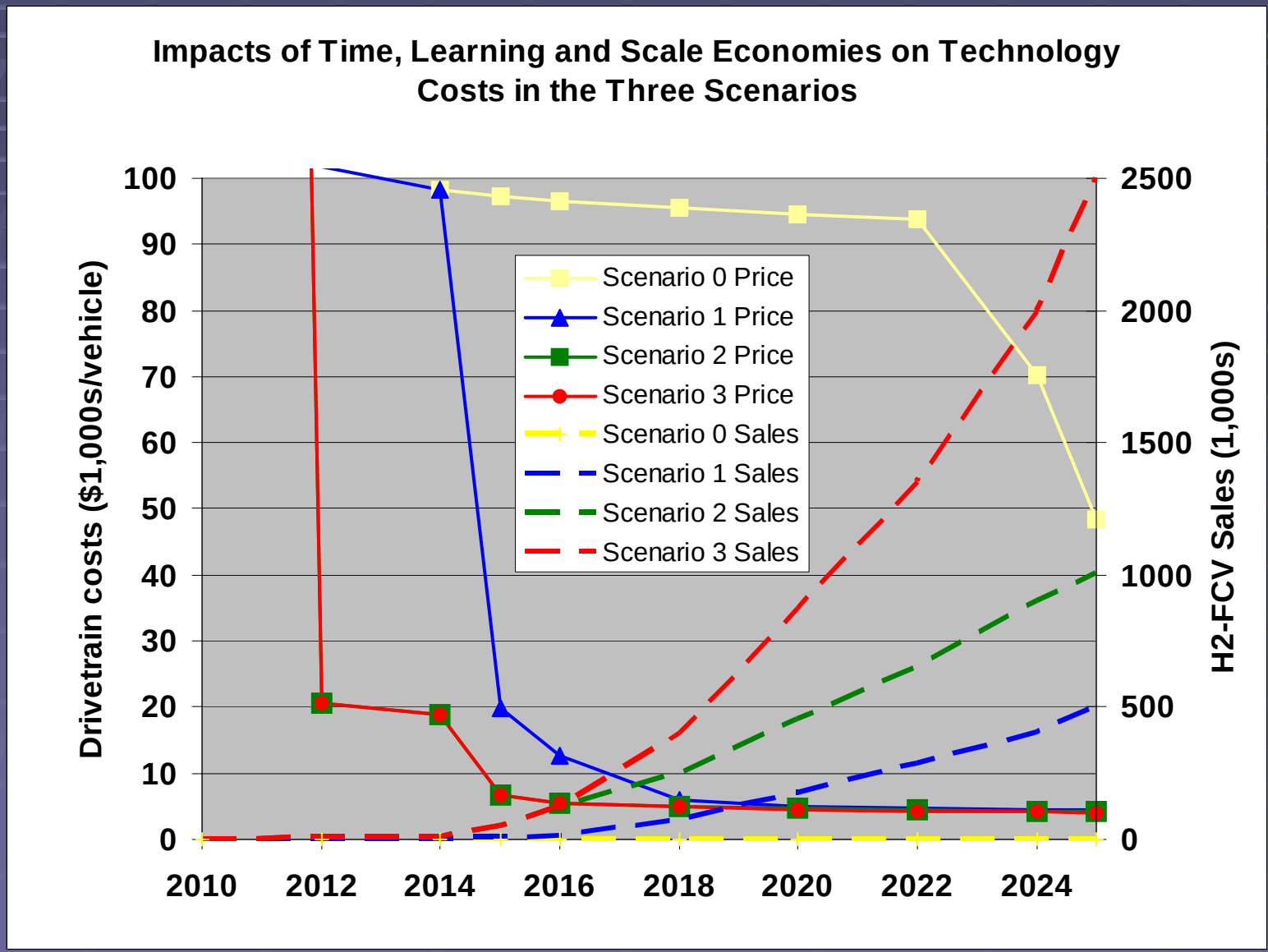
In addition to more stations overall, Scenario 3 gives a greater role to cities other than NY and LA.



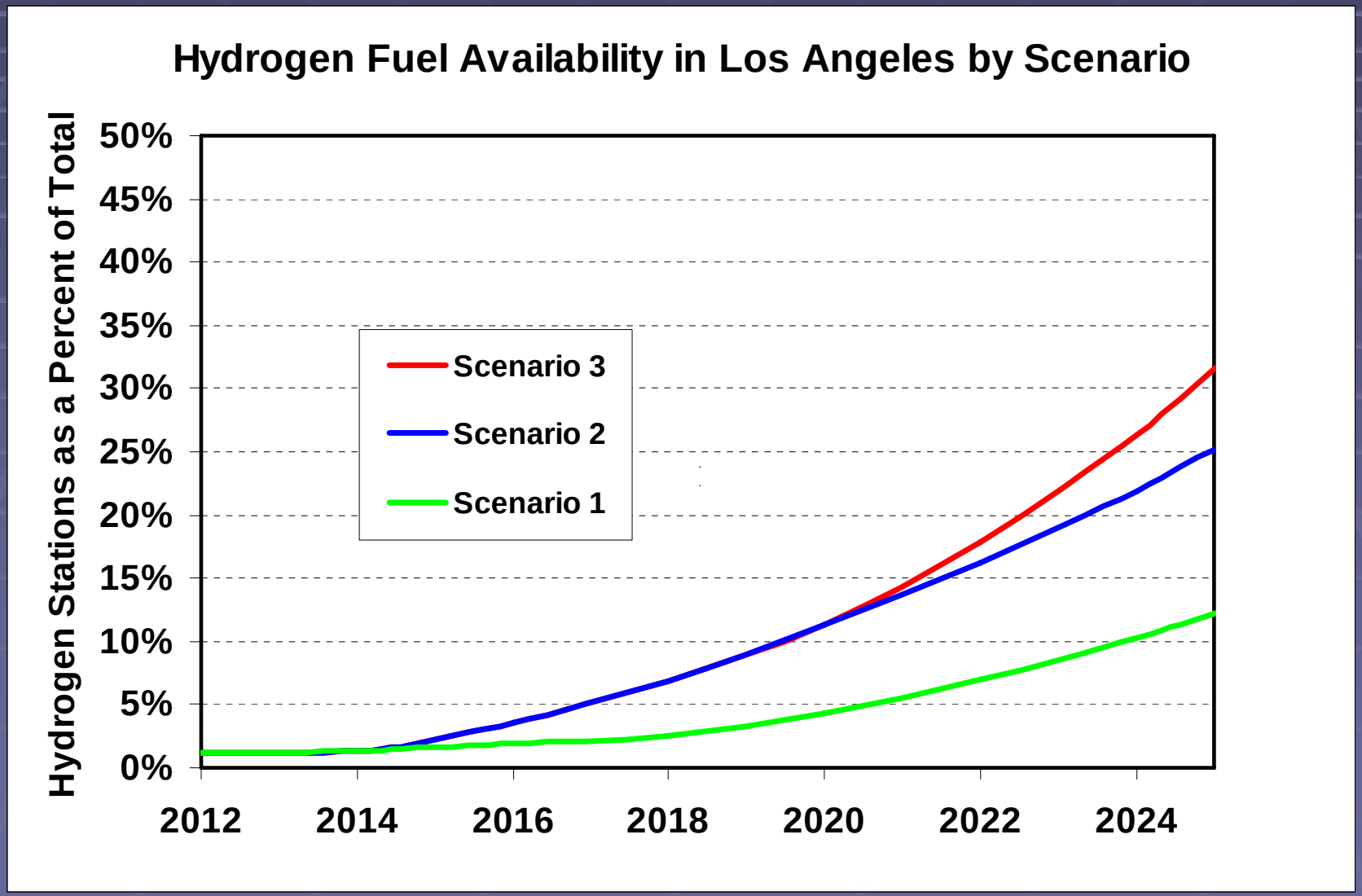




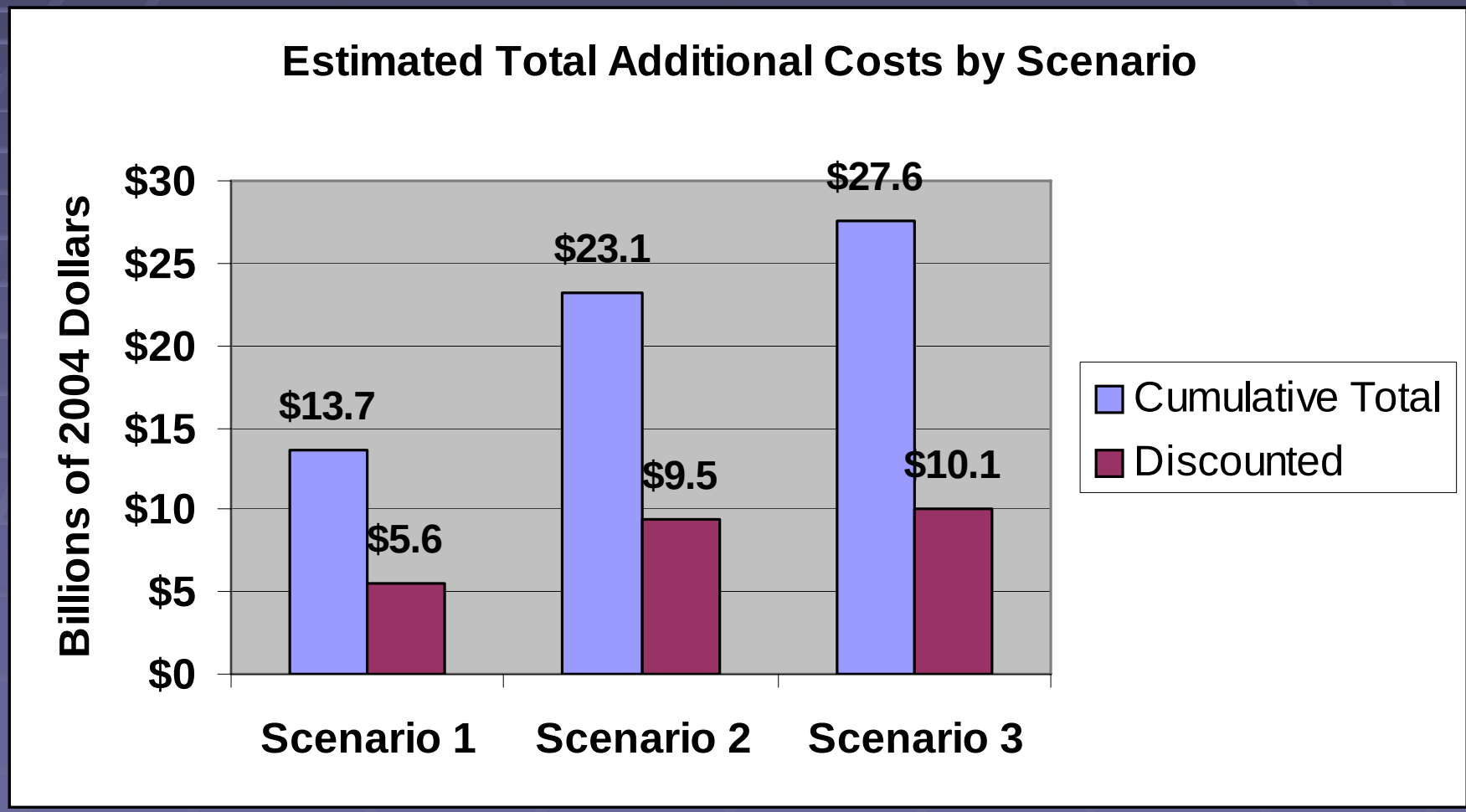
The 2010-2025 scenarios reduce the costs of hydrogen vehicles via learning-by-doing & scale economies. (Progress ratio = 0.95)



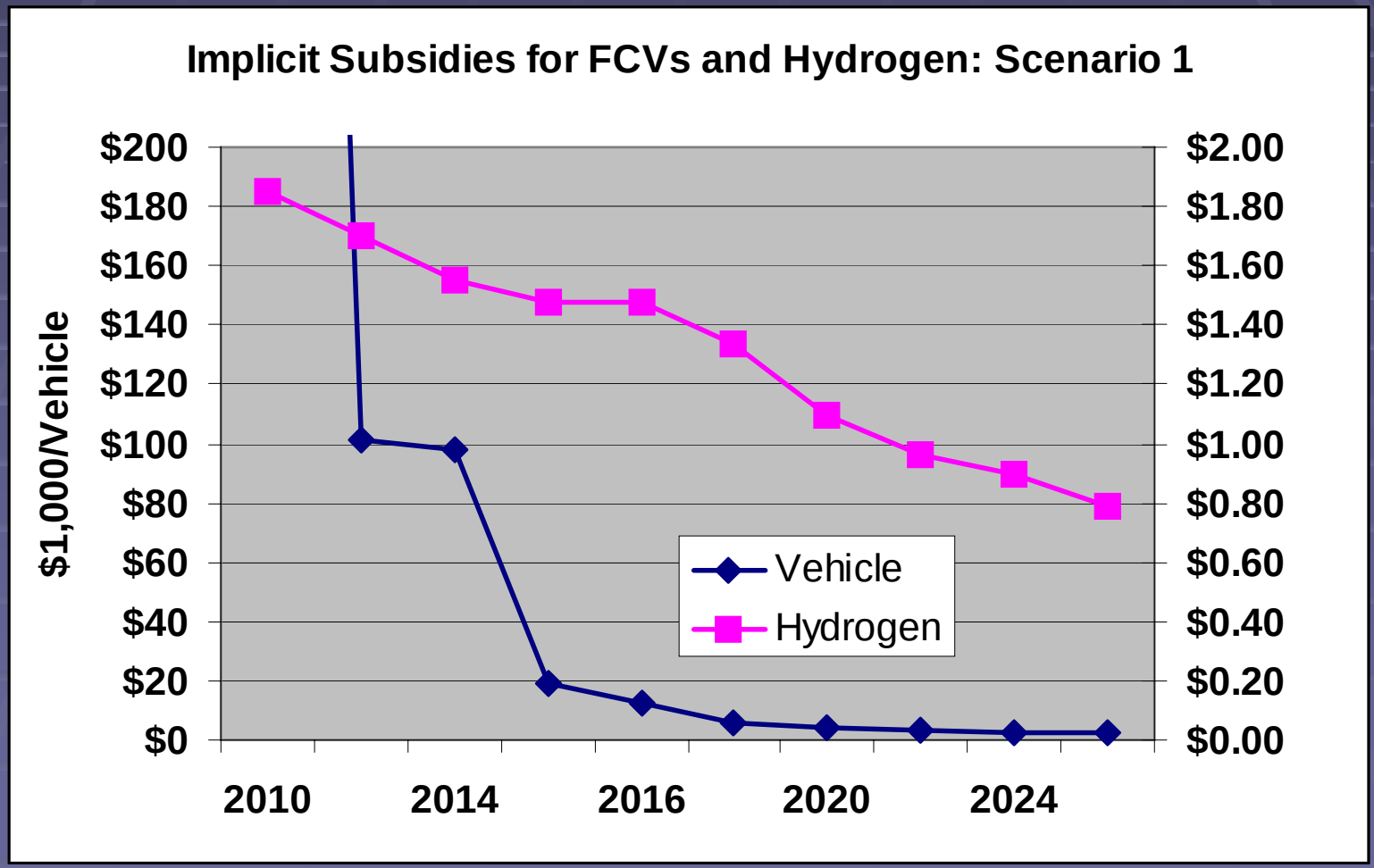
They increase hydrogen availability within the lighthouse regions to 10%-15% by 2020 in scenarios 1 & 2 and by 2025 in scenario 3. Levels somewhere between 10% and 30% are considered acceptable to most consumers.



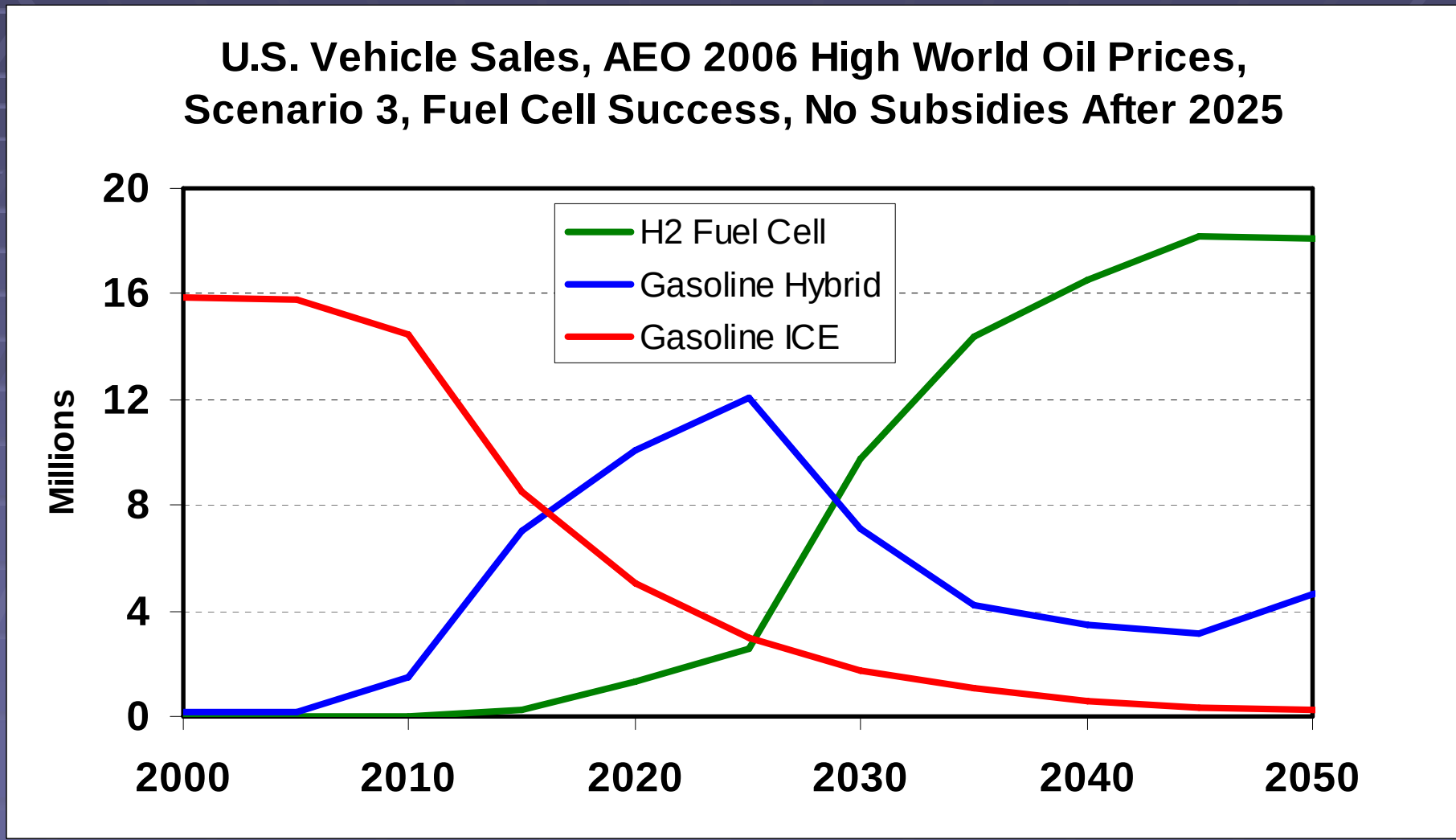
Estimated program costs begin at about $250-$500 million per year in 2012 and increase to $2-$4B per year in 2025.



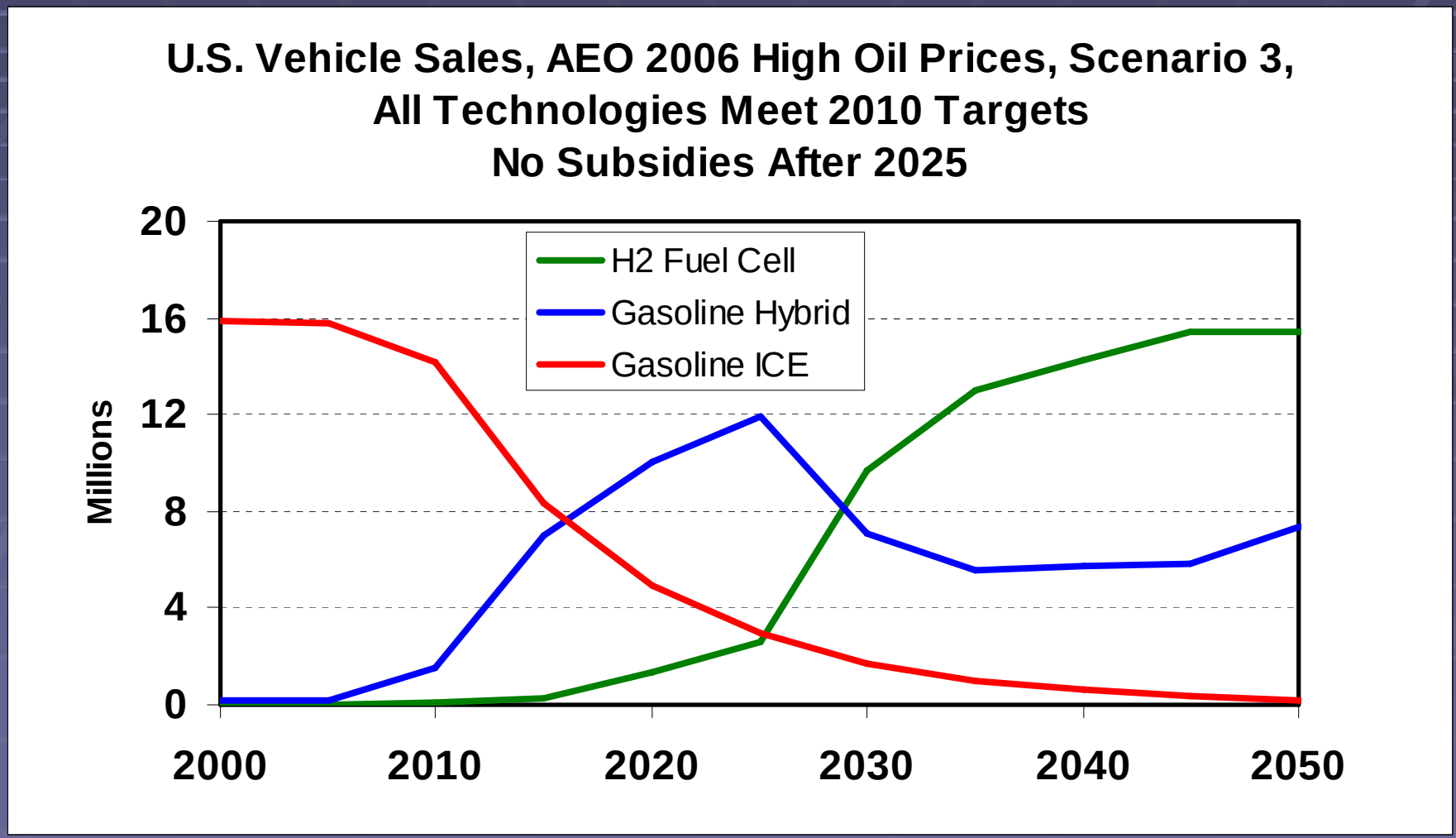
Implicit vehicles subsidies reflect far more learning-by-doing and scale economies.



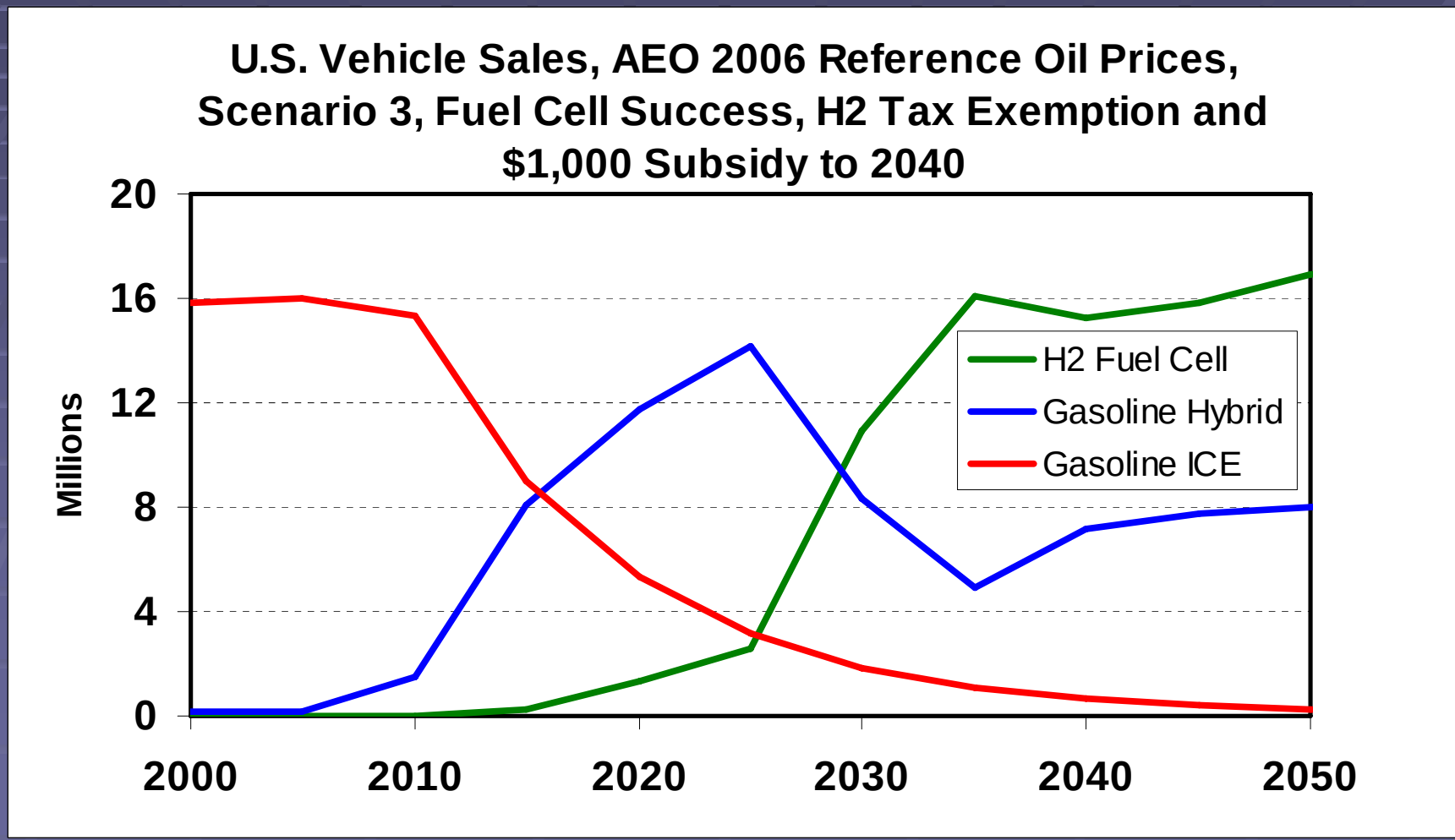
If world oil prices go to $90/bbl and FCVs are superior, Scenario 3 alone may be enough.



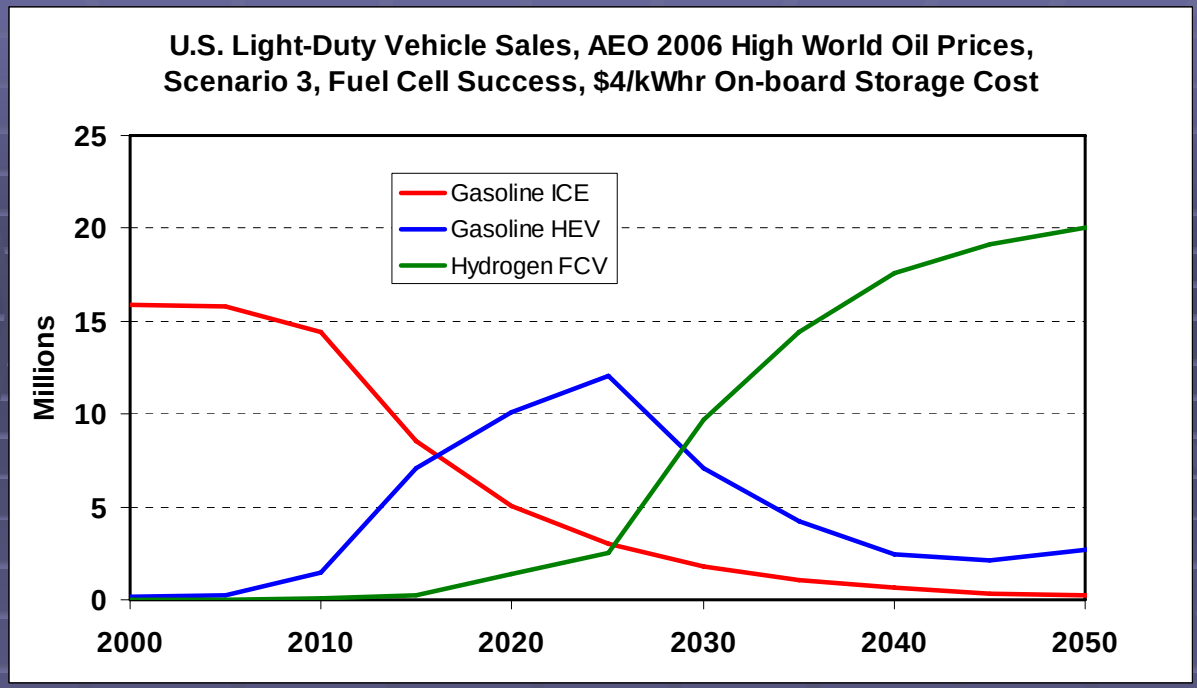
If oil prices remain high and all technologies meet their 2010 targets, FCVs may share the market.

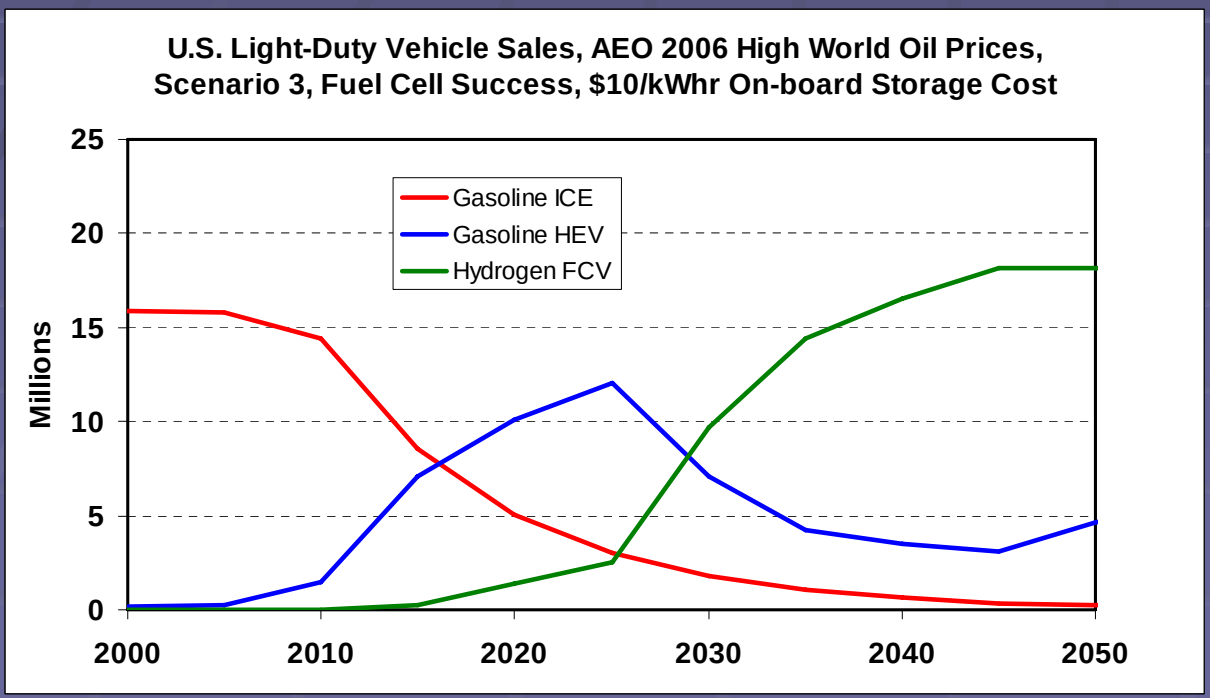


If oil is $50/bbl in 2030, subsidies may be required to achieve a durable transition to hydrogen.

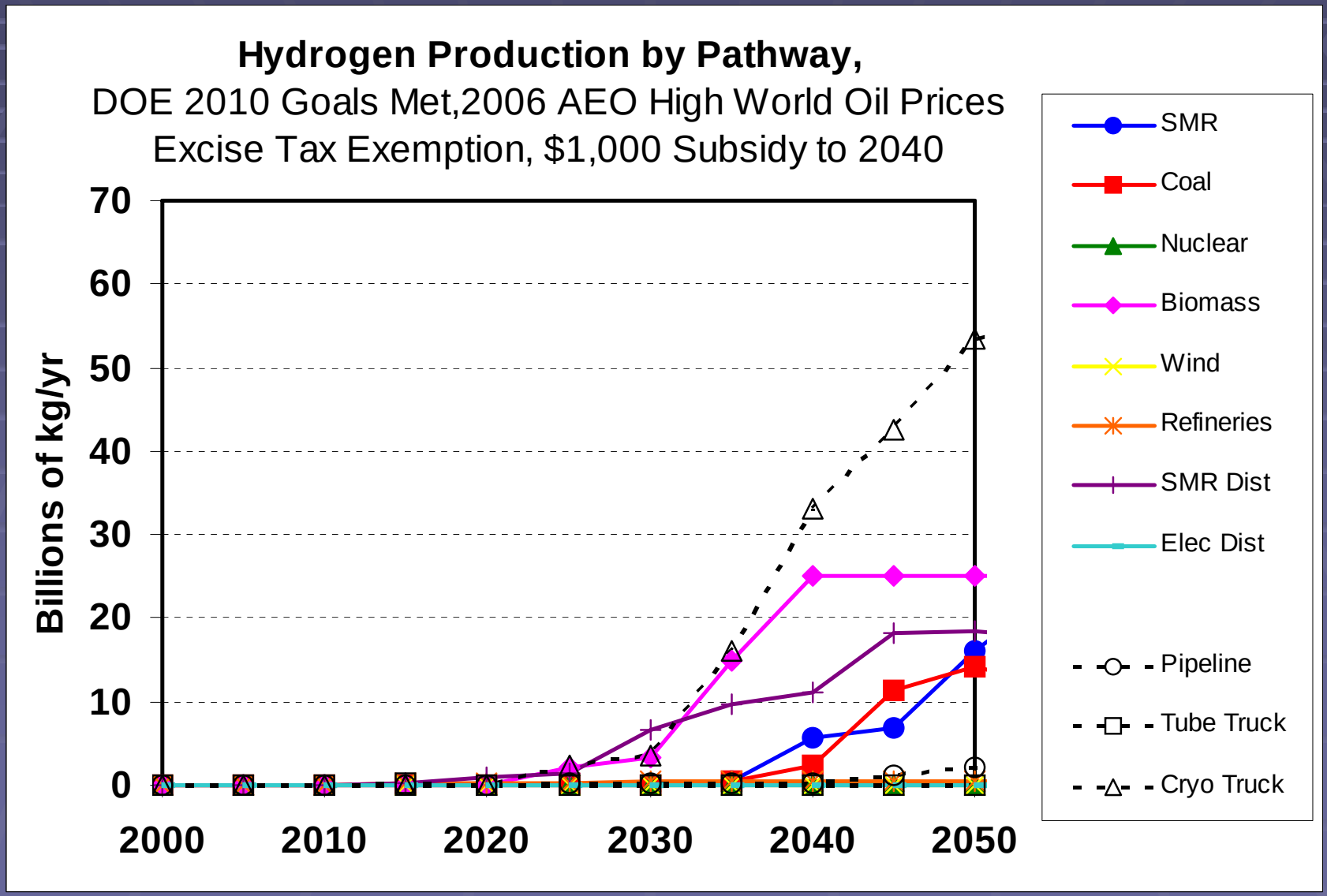


Higher on-board storage costs affect the competition with hybrids.

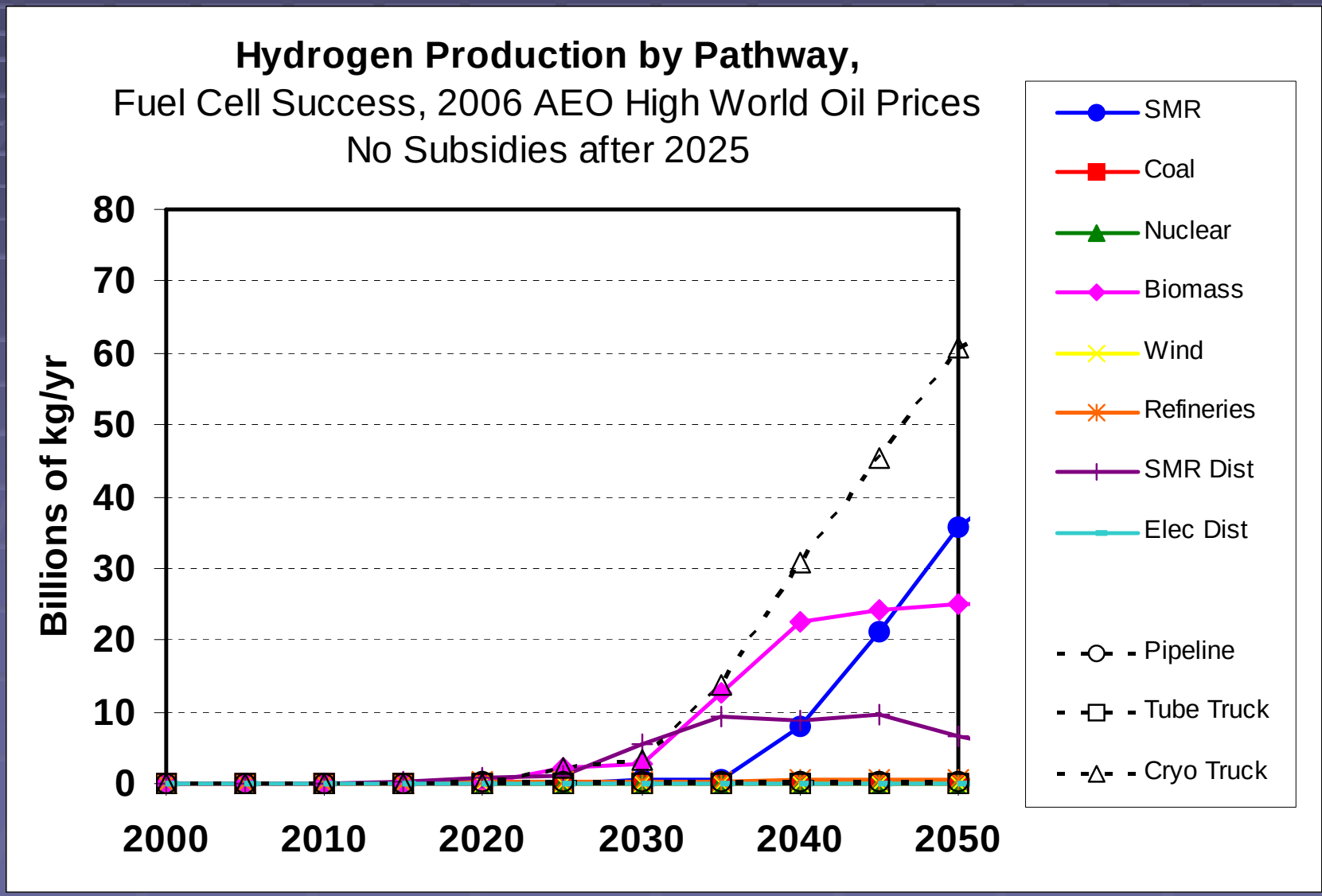




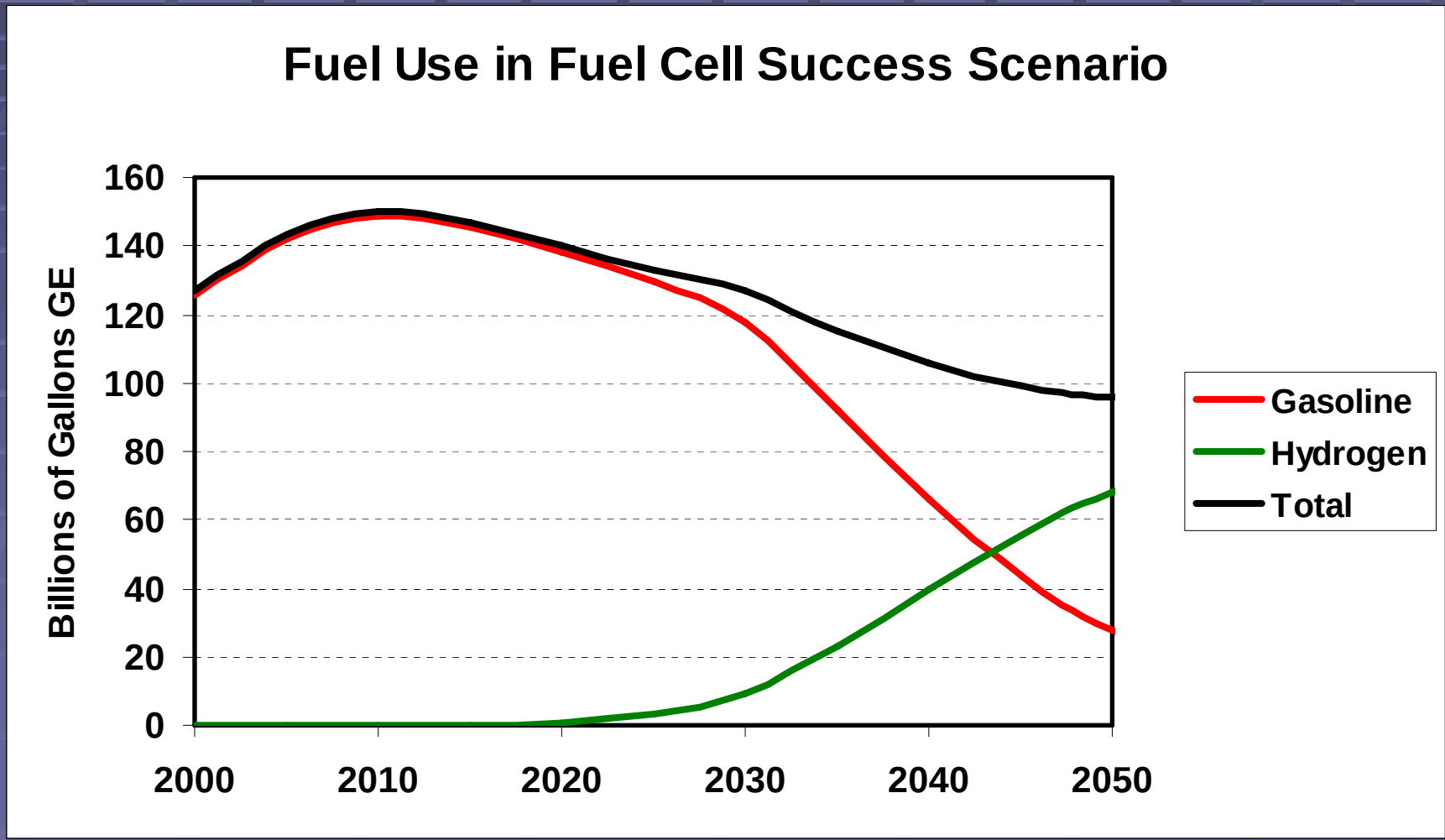
Several pathways are able to deliver hydrogen at nearly equal costs. This scenario shares production among four.



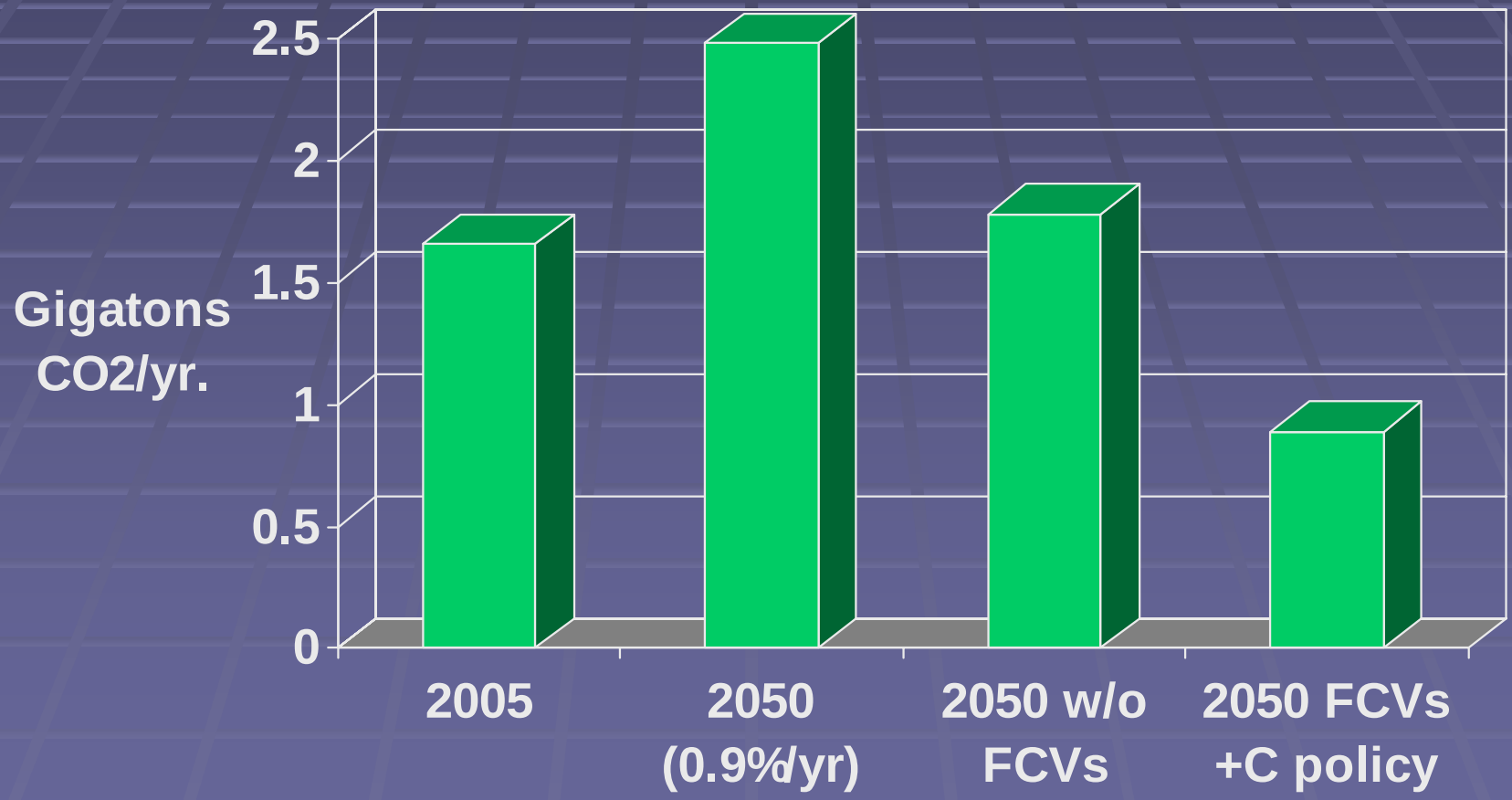
In this scenario, for example coal does not appear but there is no impact on the cost of hydrogen.



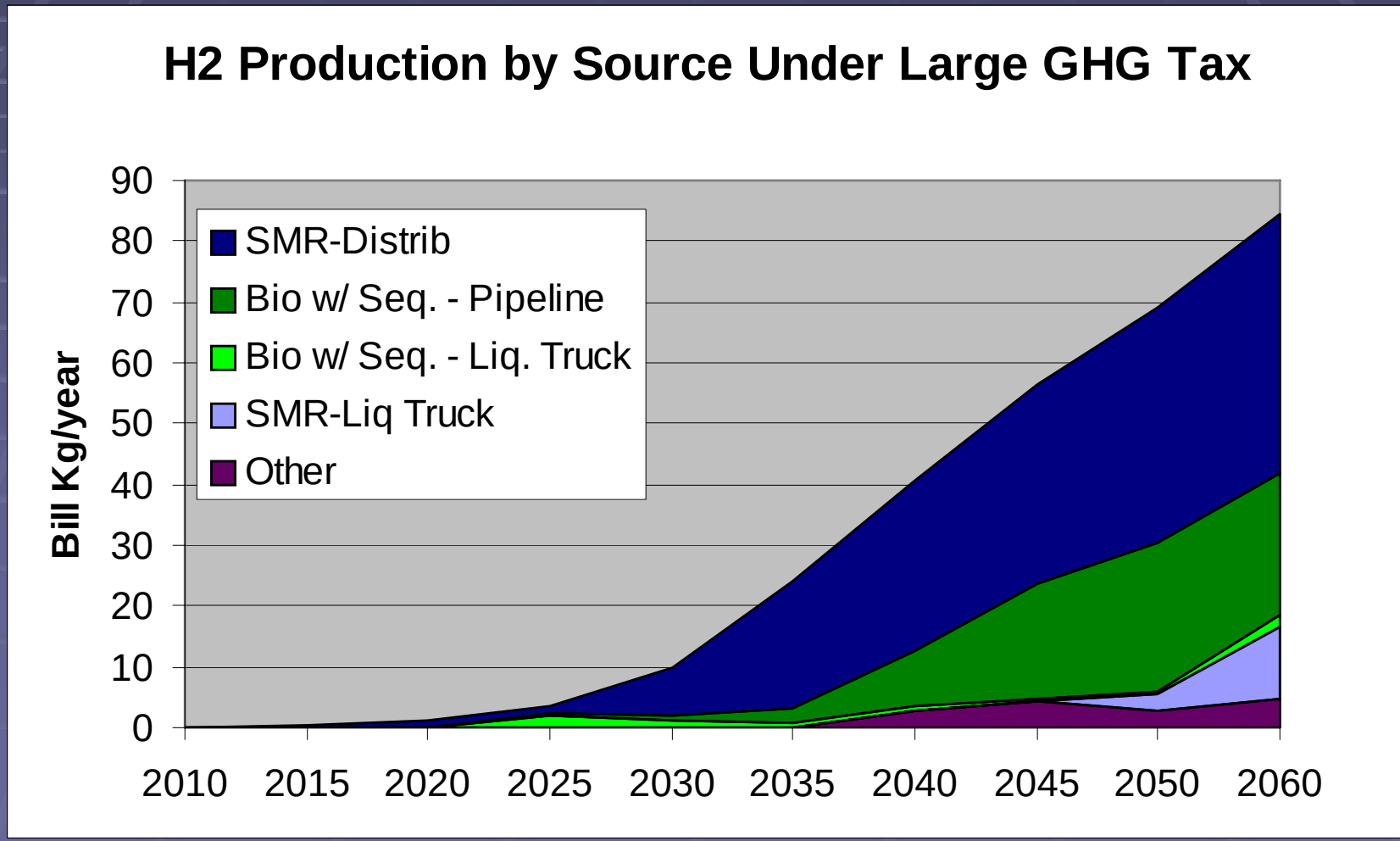
By 2050, advanced HEVs and H2FCVs cut car and light truck petroleum use to less than ¼ the current level.



With strong GHG policies, carbon dioxide emissions reductions of 1.6 Gt CO_2 versus extrapolated 2050 LDV emissions are achievable.



Strong constraints ($50-$90/tCO_2) on GHG emissions shift hydrogen production to low or negative net emissions processes, surprisingly to distributed SMR.



Given that the FreedomCar goals are met in 2010, a durable transition to hydrogen fuel cell vehicles can be achieved by 2050.

- The 2010-2025 scenarios,
  - drive costs down the learning curve and establish scale economies
  - induce fuel availability of 10% to 30% in “lighthouse” regions
- Depending on technical success, policies equivalent to subsidies of $1-$2,000/vehicle over a decade combined with a motor fuel excise tax exemption for hydrogen should induce a complete or nearly complete transition.
- Several hydrogen pathways can supply hydrogen at a competitive price (<$3/kg).
- Oil use by light-duty vehicles would be cut by 75% by 2050.
- With strong GHG policies, energy efficiency and hydrogen from renewable resources or fossil fuels with sequestration, could reduce light-duty vehicle C emissions by 65% by 2050.

Key factors contributing to a successful transition include:

- **Meeting the FreedomCar technology goals for FCVs (Rousseau et al., 2005).**
- Incentives comparable to those extended to hybrid vehicles (~$1-2,000/vehicle) but at a much larger scale (all new LDVs for 10 years) or equivalent regulations.
- Recognition of the lower societal costs of hydrogen equivalent to a motor fuel excise tax exemption (or continued high world oil prices).
- Strong policies to constrain C emissions (equivalent to $50-$100/tC) to shift the mix of hydrogen production to sustainable fuel cycles.

THANK YOU.