Cost and Impacts of Policies

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2010-2025 Scenario Analysis for Hydrogen Fuel Cell Vehicles and Infrastructure

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Plan of presentation:

- Brief review of HyTrans
- Calibration of FCV learning, scale, technological change
- Scenarios and Policies
- RESULTS
  - 2010-2025 and long-run impacts
  - 2010-2025 Government/Industry Costs
  - Hydrogen production, infrastructure & cost

HyTrans merges the early transition scenarios with longer-term policies to simulate durable transitions.

- **In the early transition 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) HyTrans is run in unconstrained optimization mode.**
  - Additional policies may be needed depending on the scenario
    - Competition with other advanced technologies
    - Oil & energy prices
  - Benefits
    - reduced oil dependence
    - Near elimination of GHG emissions but only with strong GHG policies

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

- **H2A**
  - Hydrogen Production
  - Hydrogen Delivery
- **PSAT & ASCM**
  - Fuel economy
  - 2010 cost goals
- **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

A new vehicle cost model was calibrated with data provided by OEMs.

- Independent tech-progress, learning-by-doing and scale economies.
- Vehicle Price = Glider + Long-run Drivetrain Cost x Technology(time) x Learning-by-doing(stock) x Scale(volume)
- Technology calibrated to DOE goals
- Learning & Scale calibrated to average of manufacturers' cost estimates.

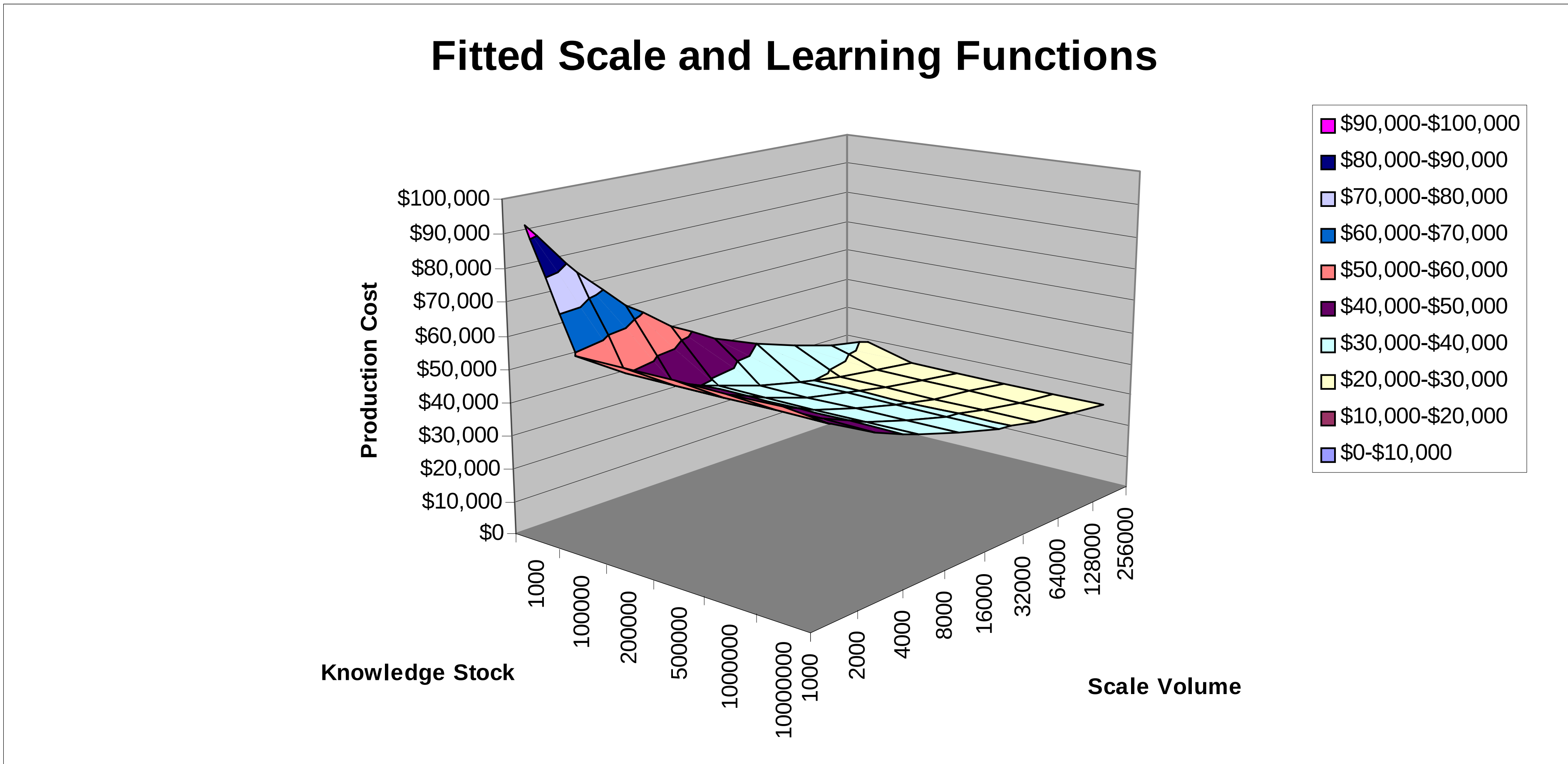
Technology cost and performance assumptions are based on the PSAT/ASCM analysis by Rousseau, Sharer, Pagerit & Das, 2005. In the “Rapid” case, DOE 2010 goals are met.

	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**

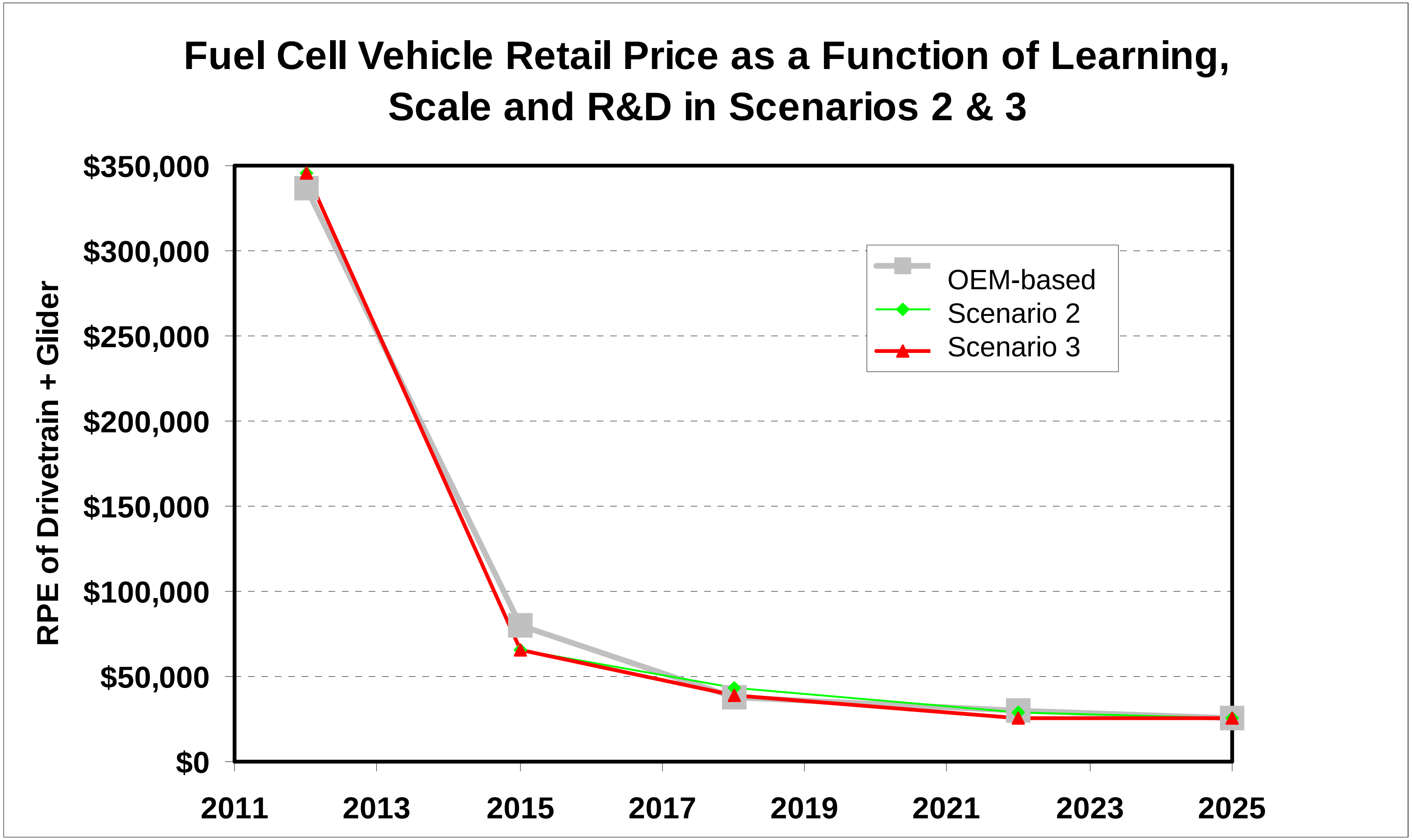
Component efficiency assumptions also reflect a combination of DOE 2010 program goals and judgment (Intermediate case).

	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%

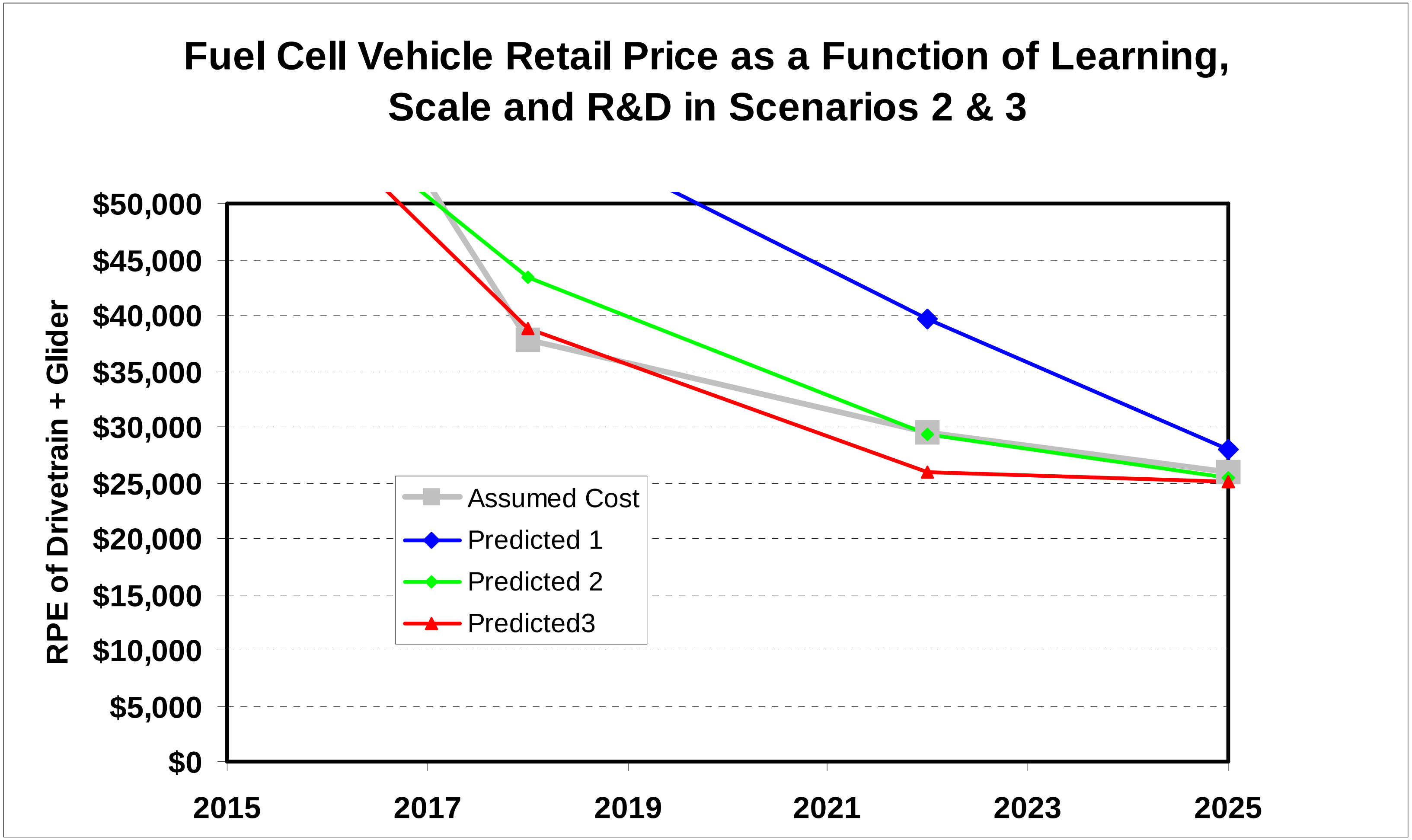
Learning is exponential and asymptotic to the program goals, scale has a constant elasticity of -0.38.



In all scenarios FCV costs decline dramatically with reasonable correspondence to the average of the manufacturers' estimates.



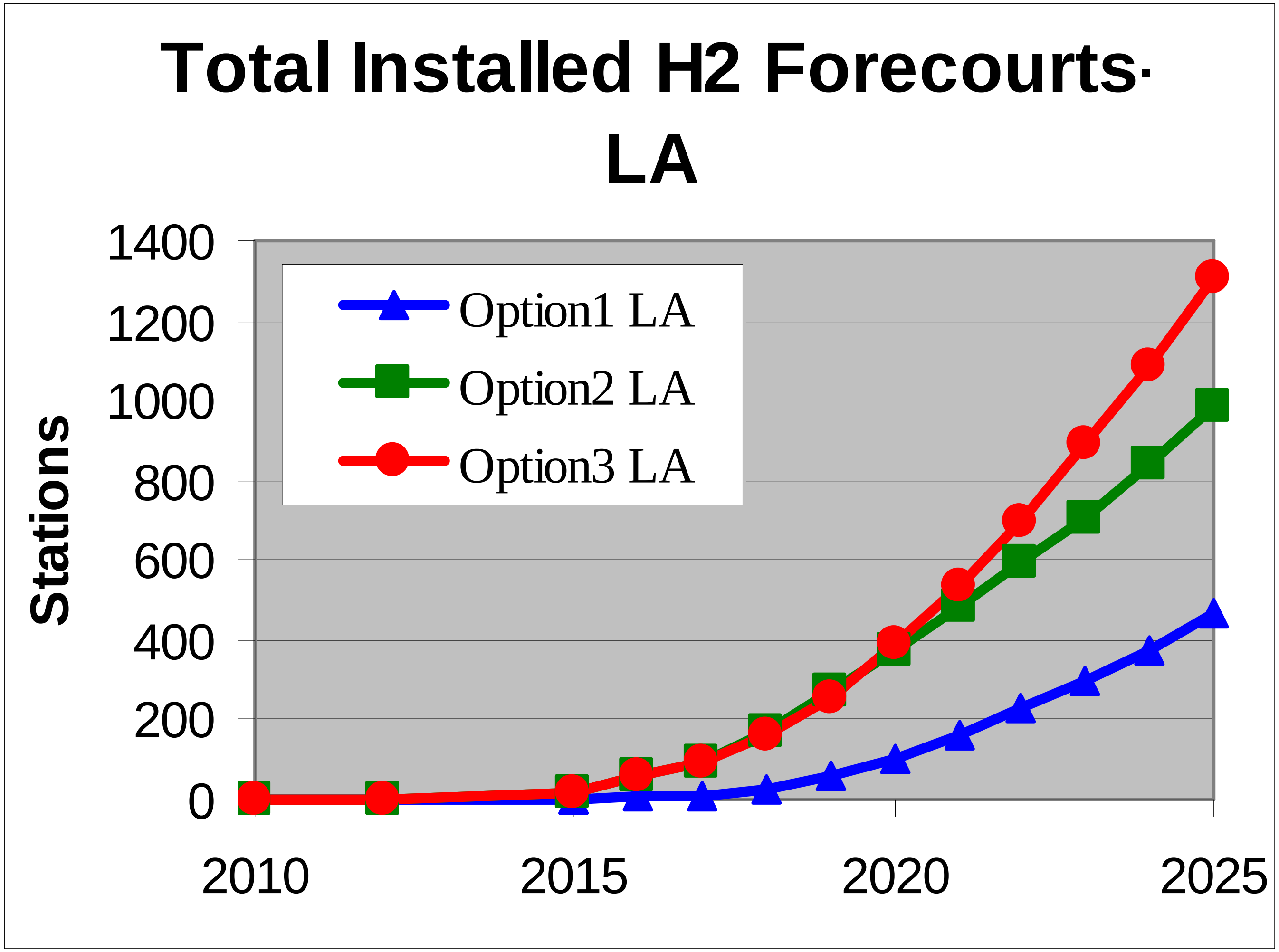
A closer look shows that only scenario 3 meets the long-term price target by 2025.



Twelve 2010-2025 cases reflect different policy scenarios, energy prices and degrees of technological success.

POLICIES / FUTURES	0	1	2	3
Fuel Cell Success + High Oil Price	X	X	X	X
Fuel Cell Success + Reference Oil Price	X	X	X	X
All Technologies Success + High Oil Price	X	X	X	X
Cases run with and without C policy.				

Time Path of Infrastructure Development (Cumulative Number of Forecourts, LA)



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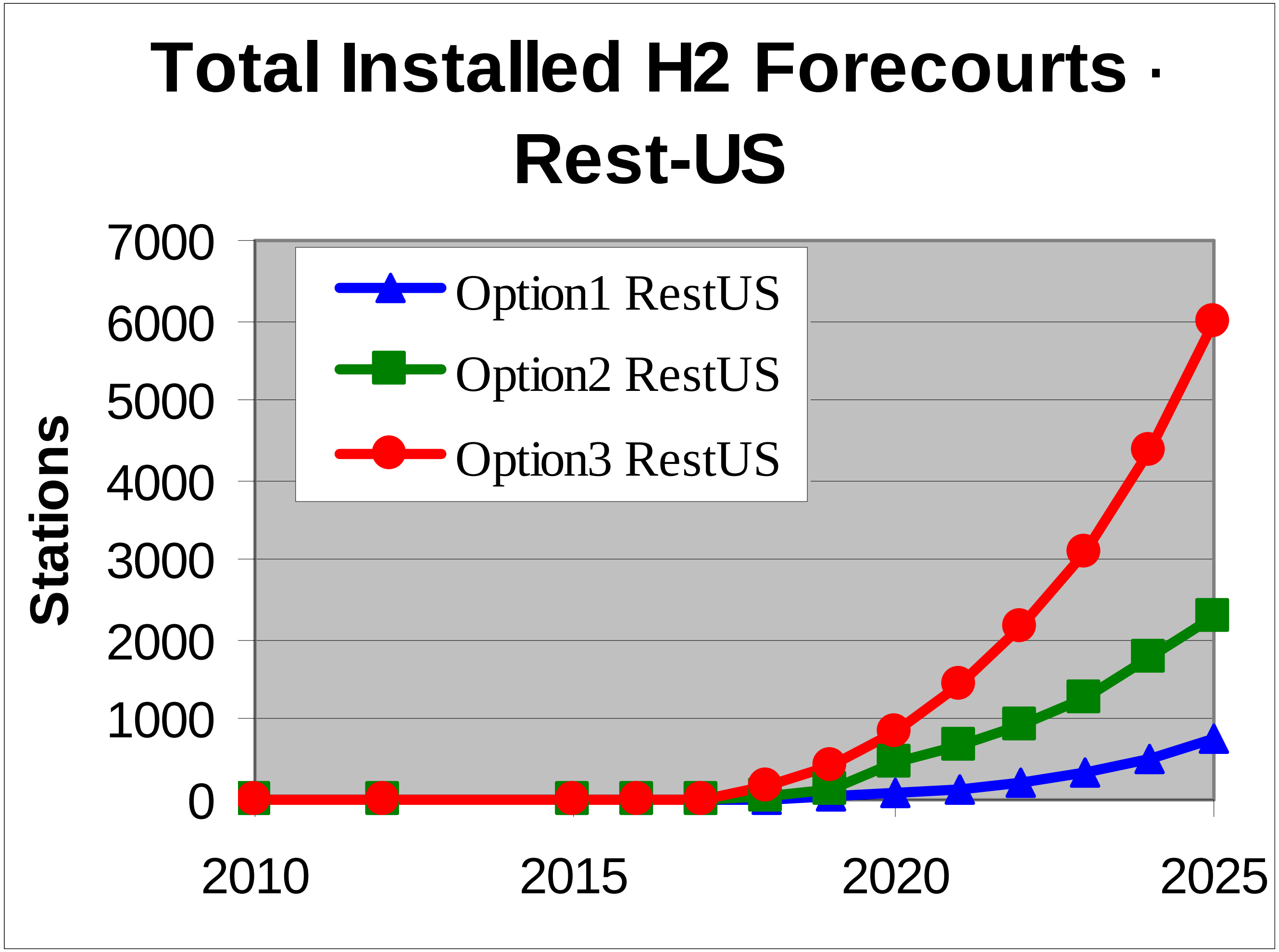
Time Path of Infrastructure Development (Cumulative No. Forecourts, Rest of US)



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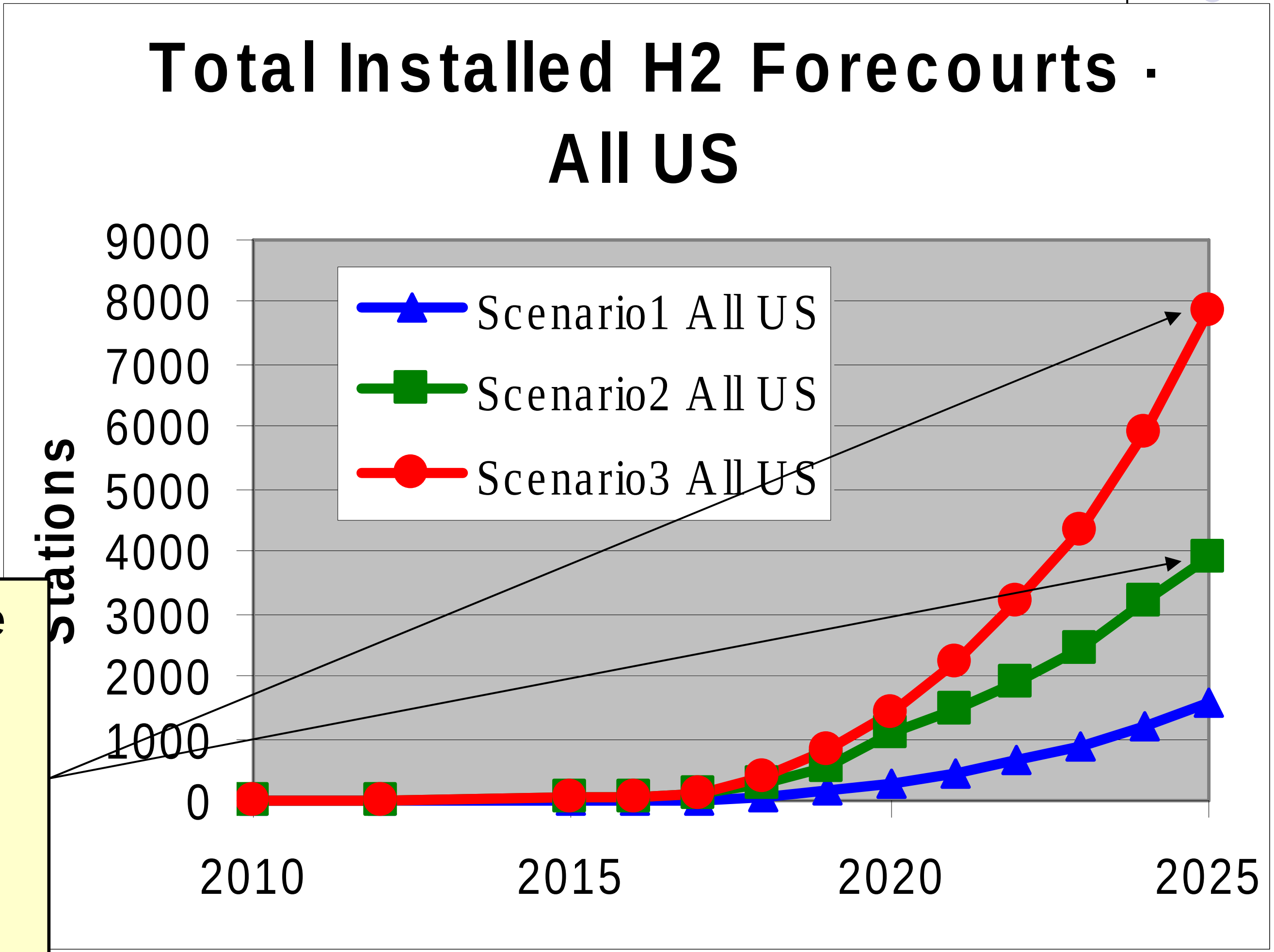
Time Path of Infrastructure Development (Cumulative No. Forecourts, ALL US)



Note that by 2030, the 8,000 stations in scenario 3 gets down the distributed SMR learning curve to \$2.85/kg, while the 4,000 stations in scenario 2 get only to \$3.30.

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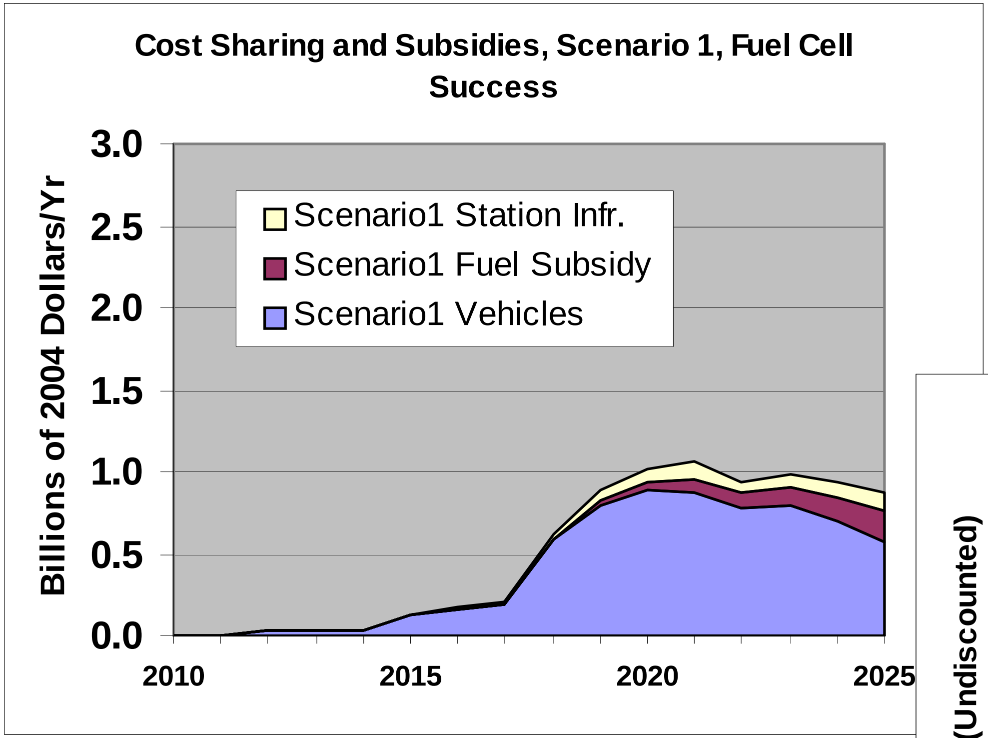
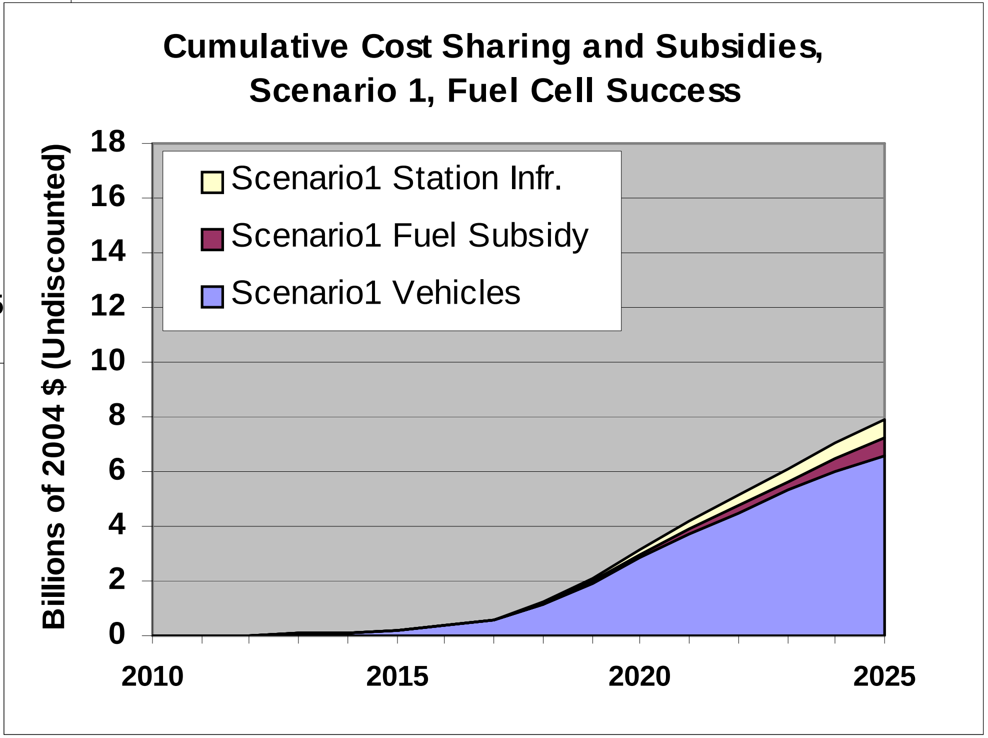
Policy Case 1 Incremental cost share of vehicle (50/50)

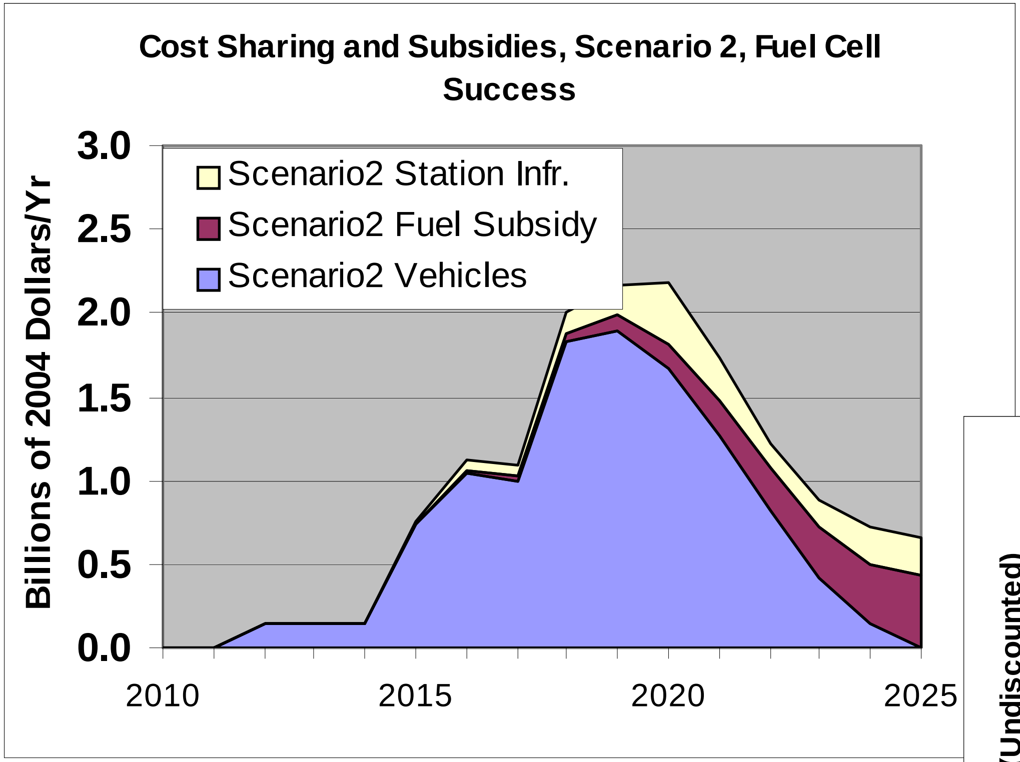
- “Fuel Cell Success” technology assumptions
- FCV incremental vehicle production costs (RPE vs HEV) shared 50% through 2025
- Distributed SMR station capital cost starts at $3.3 million, declining to $2.0 million
  - Cost share $1.3 million/station, 2012-2017
  - Cost share $0.7 million/station, 2018-2021
  - Cost share $0.3 million/station, 2022-2025
- H2 fuel Subsidy
  - $0.50/kg through 2018
  - Declines to $0.30/kg by 2025

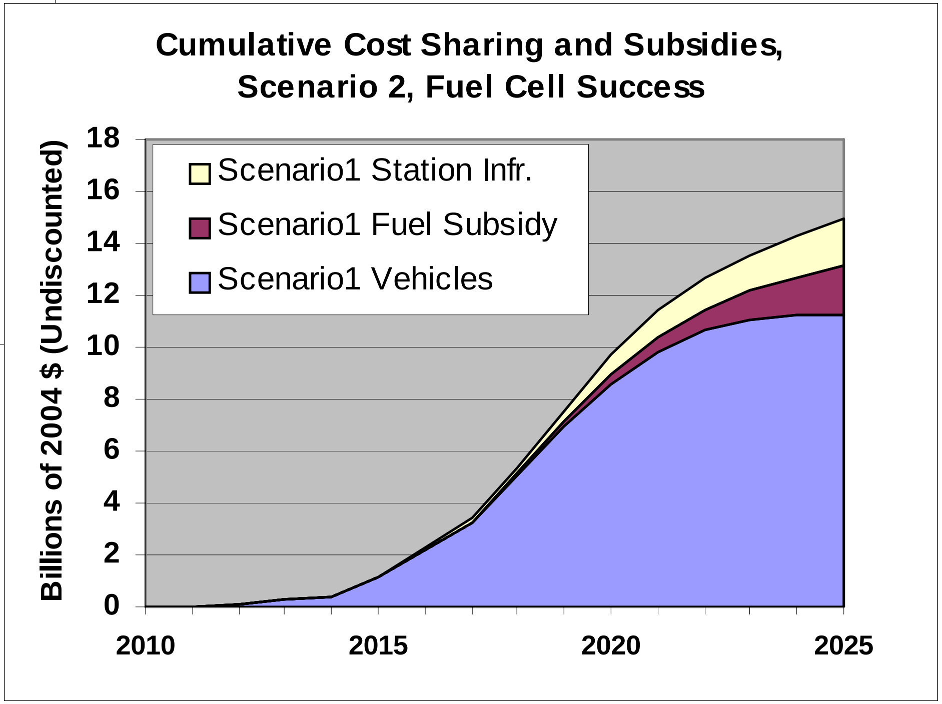
In general, vehicle subsidies far outweigh station and fuel subsidies through 2025. In scenario 1, annual costs peak at $1B, cumulative costs reach $8B.



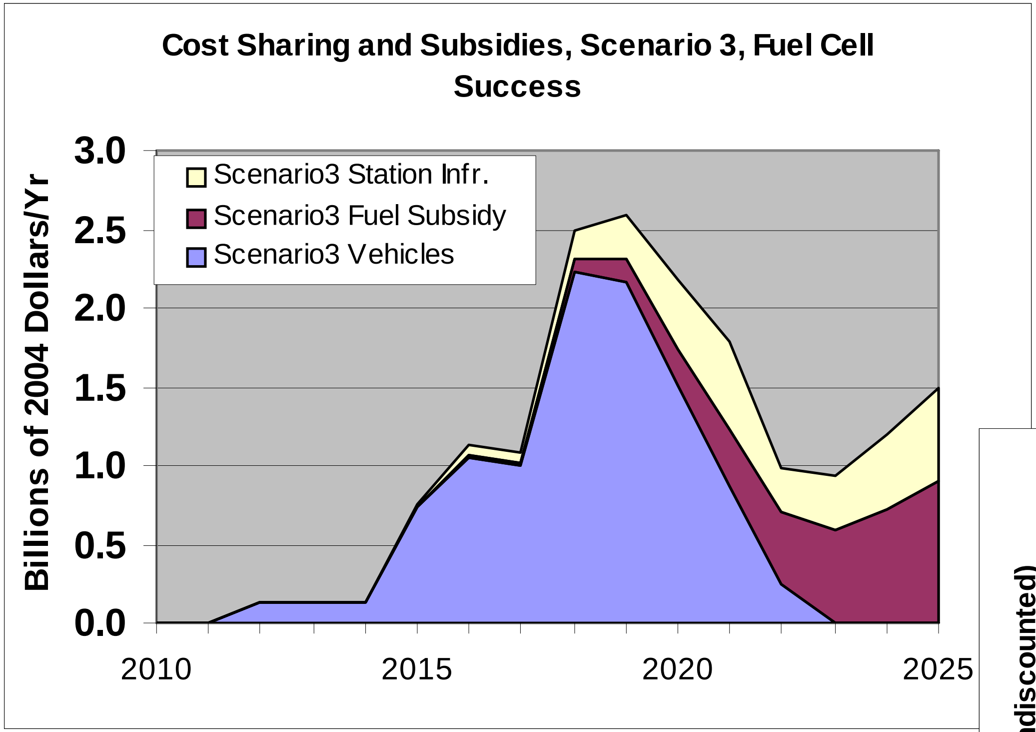


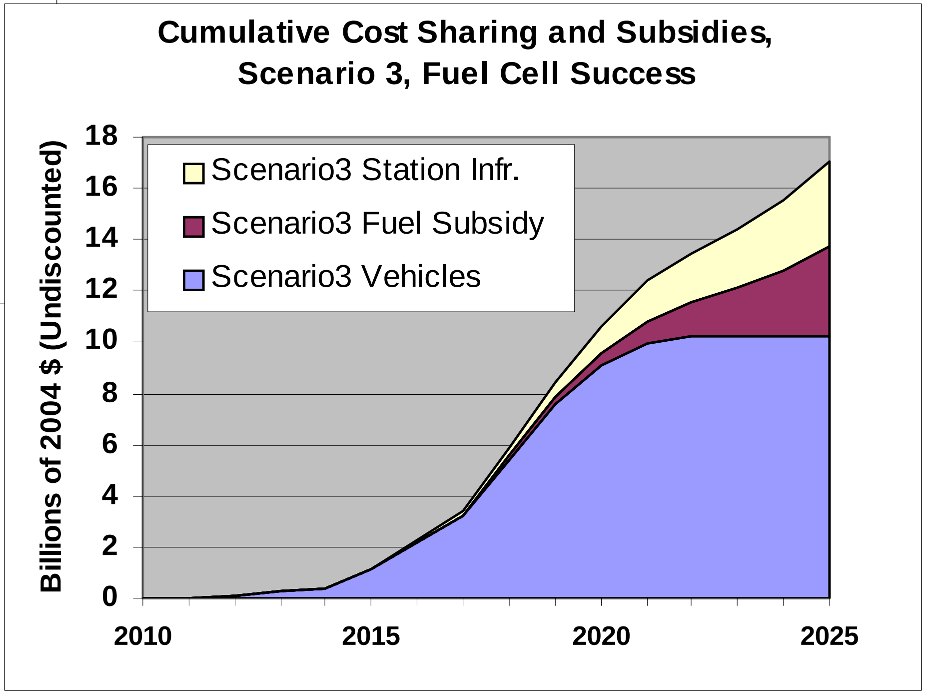
In scenario 2, vehicle subsidies decline to almost $0 by 2025 as long-run cost targets are met.





In scenario 3 vehicle subsidies decline to $0 in 2023 but fuel and station subsidies rise.

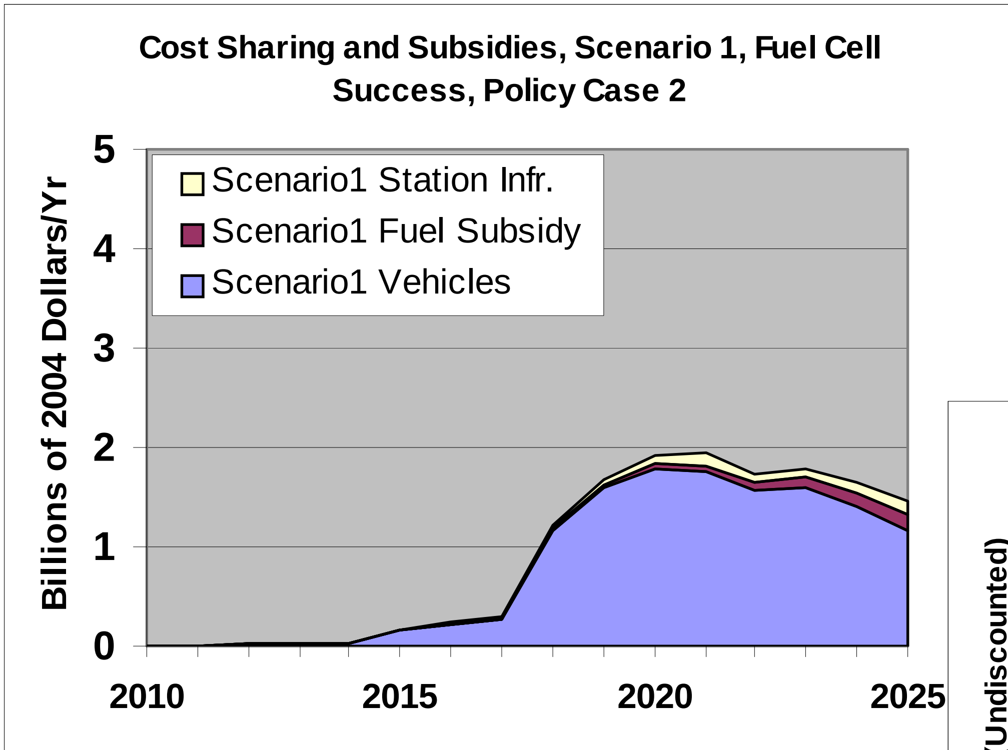


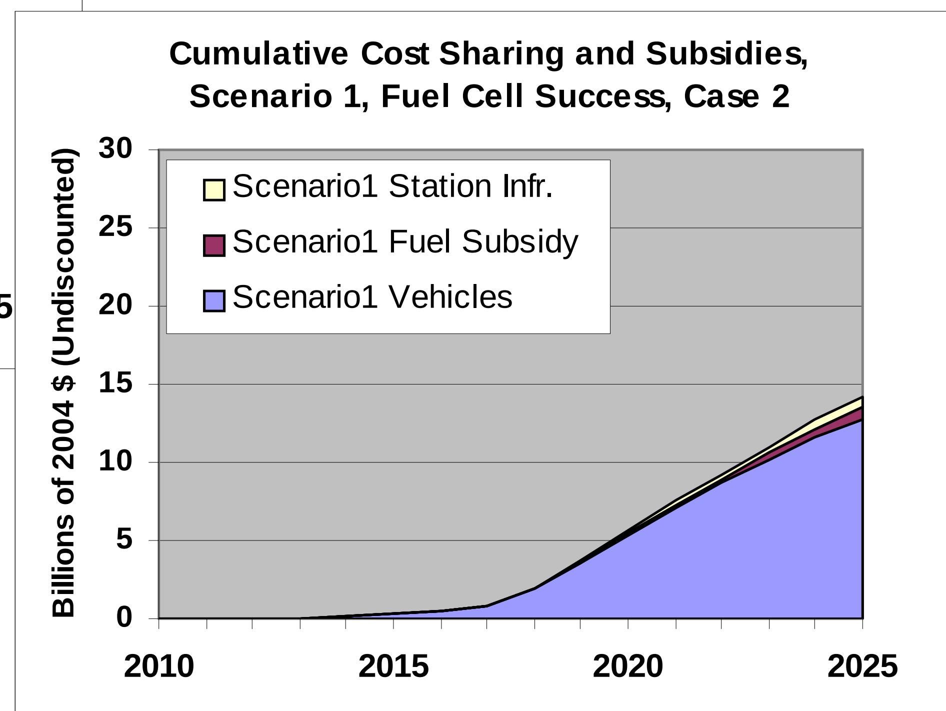


Policy Case 2 – Government cost shares vehicle costs 50/50 to 2017 and provides tax credits after 2018

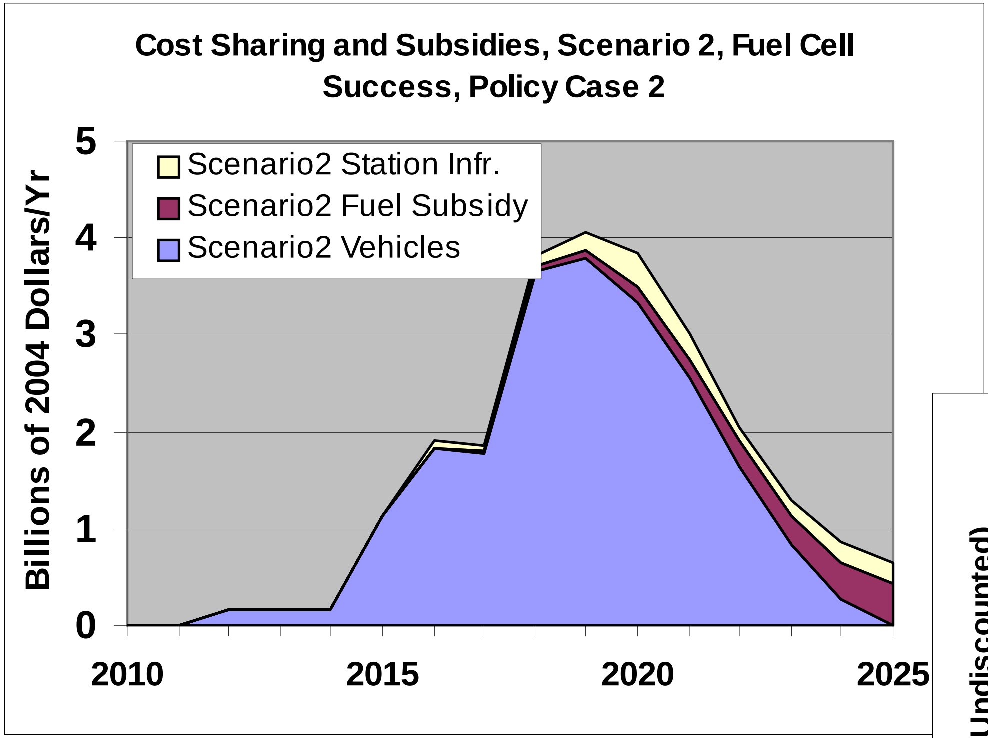
- "Fuel Cell Success"
- FCV vehicle production costs (RPE vs HEV) shared
  - 50% **total** vehicle cost through and including 2017
  - Tax credit covers **100% of incremental** cost 2018 to 2025
- Station capital cost starts at $3.3 million, declining to $2.0 million
  - Cost share $1.3 million/station, 2012-2017
  - Cost share $0.7 million/station, 2018-2021
  - Cost share $0.3 or 0.2 million/station, 2022-2025
- H2 fuel Subsidy
  - $0.50/kg through 2018
  - Declines to $0.30/kg by 2025

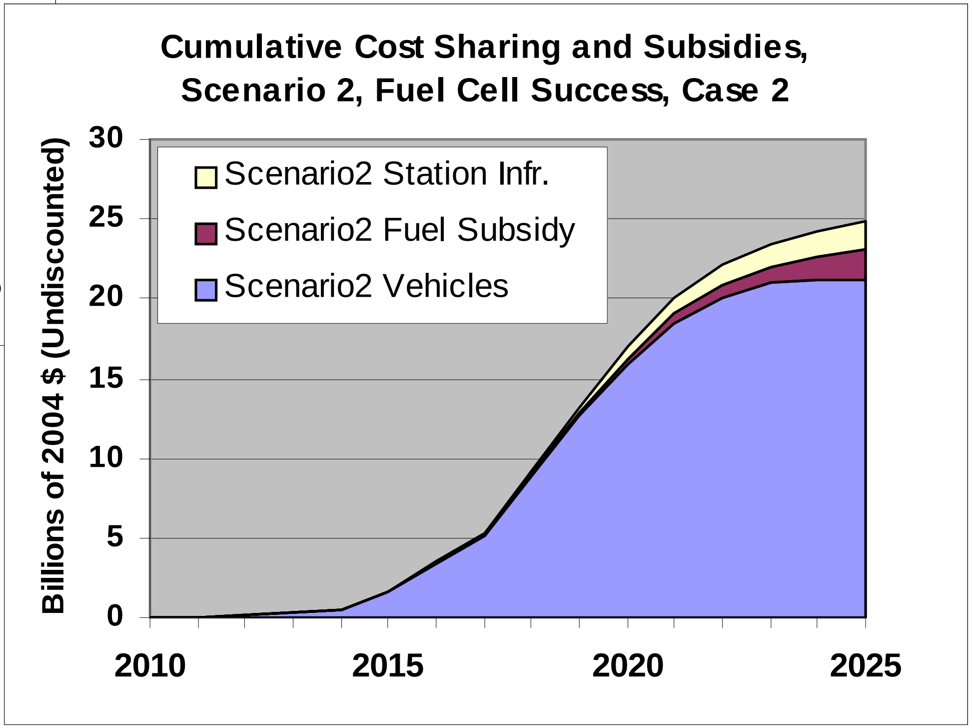
Tax credits covering the incremental costs of FCVs raise the max annual cost in Case 1 to $2B.



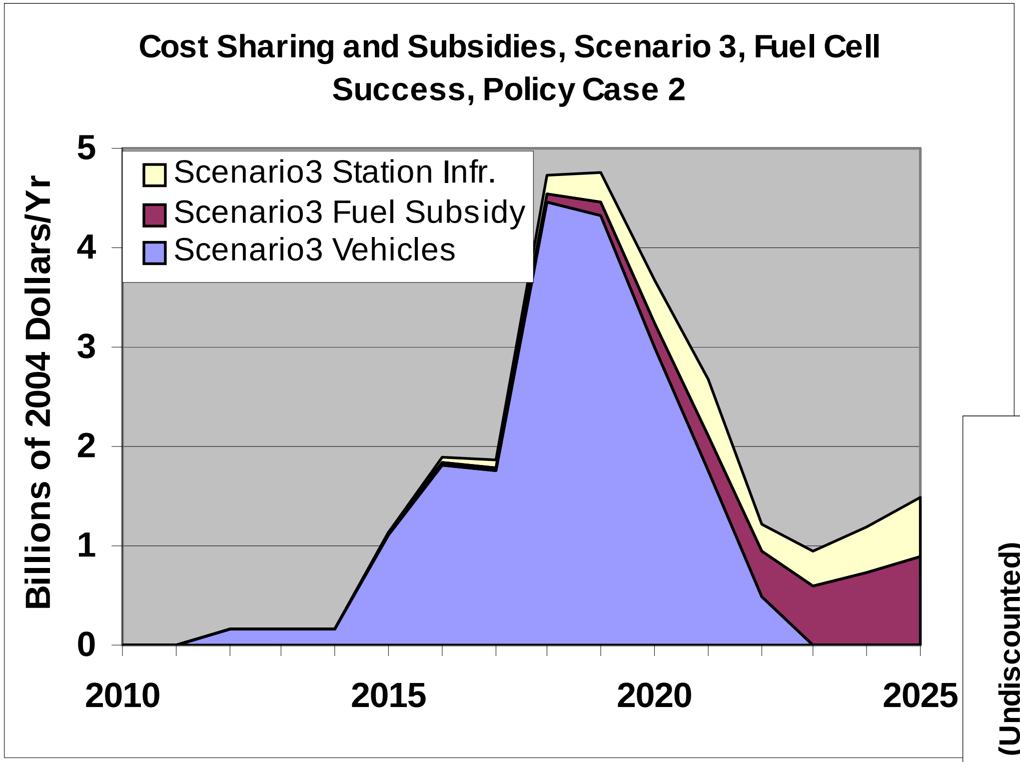


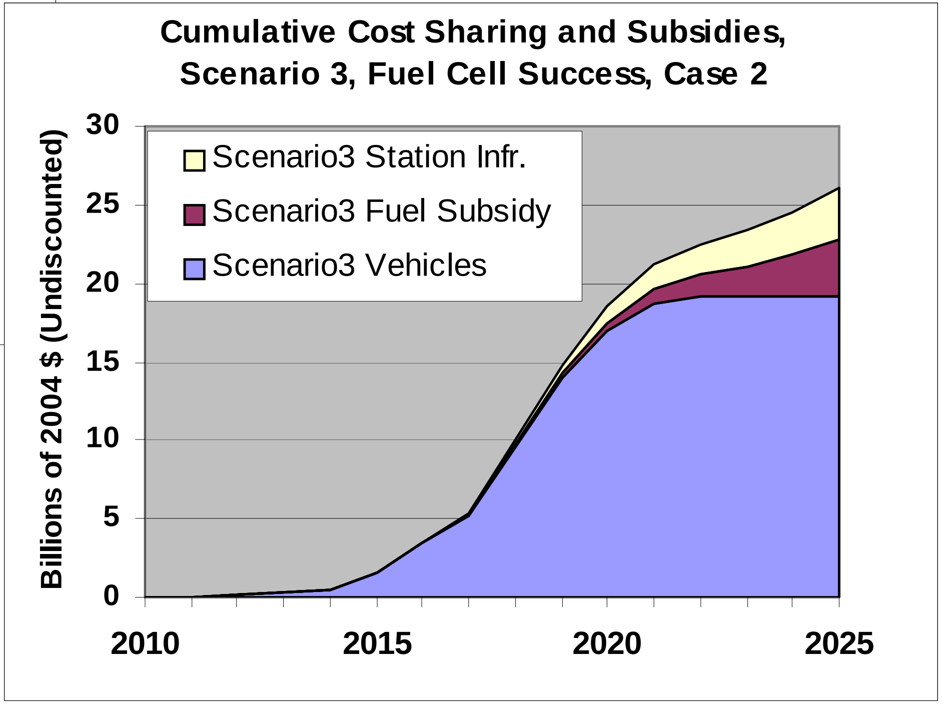
In scenario 2, annual costs peak at $4B, cumulative costs reach $25B.





In scenario 3, annual costs reach almost $5B and cumulative costs exceed $25B.

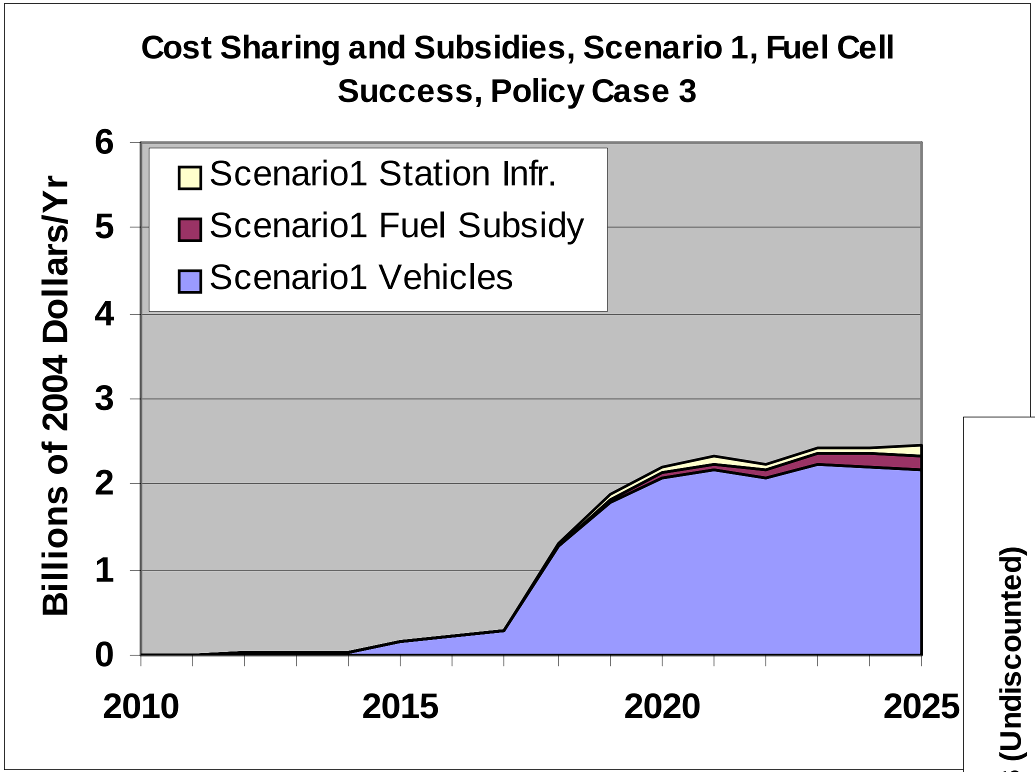


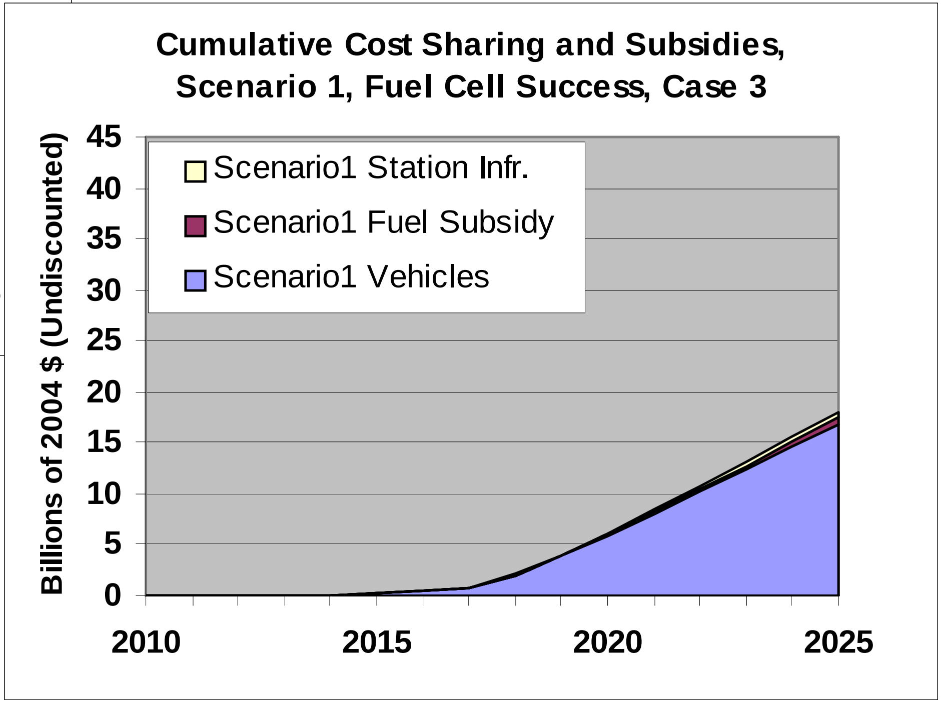


Policy Case 3 – Additional tax credits are applied as market introduction incentive.

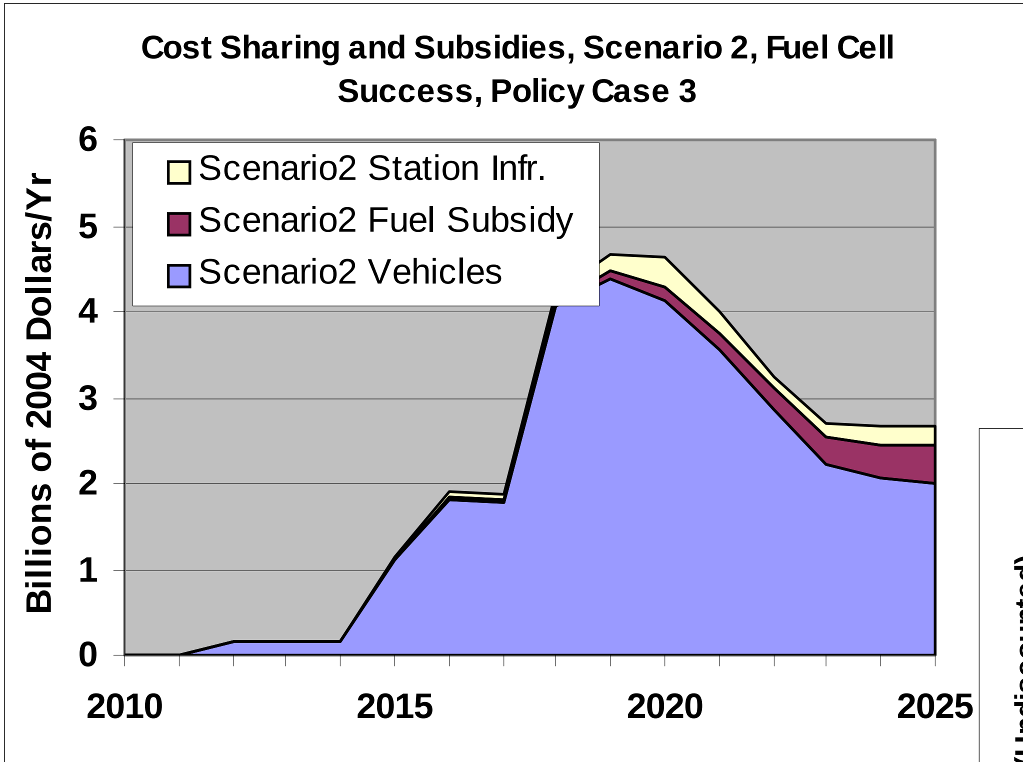
- "Fuel Cell Success"
- FCV vehicle production costs (RPE vs HEV) shared
  - 50% total vehicle cost through and including 2017
  - Tax credit cover 100% coverage of incremental cost 2018 to 2025
  - **$2000 additional** tax credit from 2018-2025
- Station capital cost starts at $3.3 million, declining to $2.0 million
  - Cost share $1.3 million/station, 2012-2017
  - Cost share $0.7 million/station, 2018-2021
  - Cost share $0.3 million/station, 2022-2025
- H2 fuel Subsidy
  - $0.50/kg through 2018
  - Declines to $0.30/kg by 2025

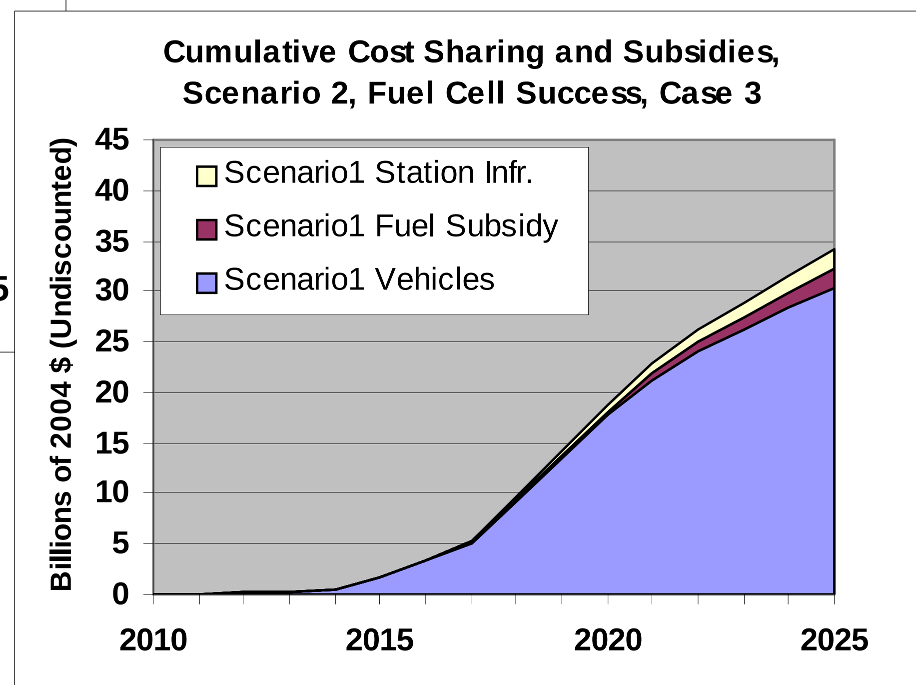
In policy case 3, the $2K subsidy after 2017 keeps government expenditures at $2B/year.



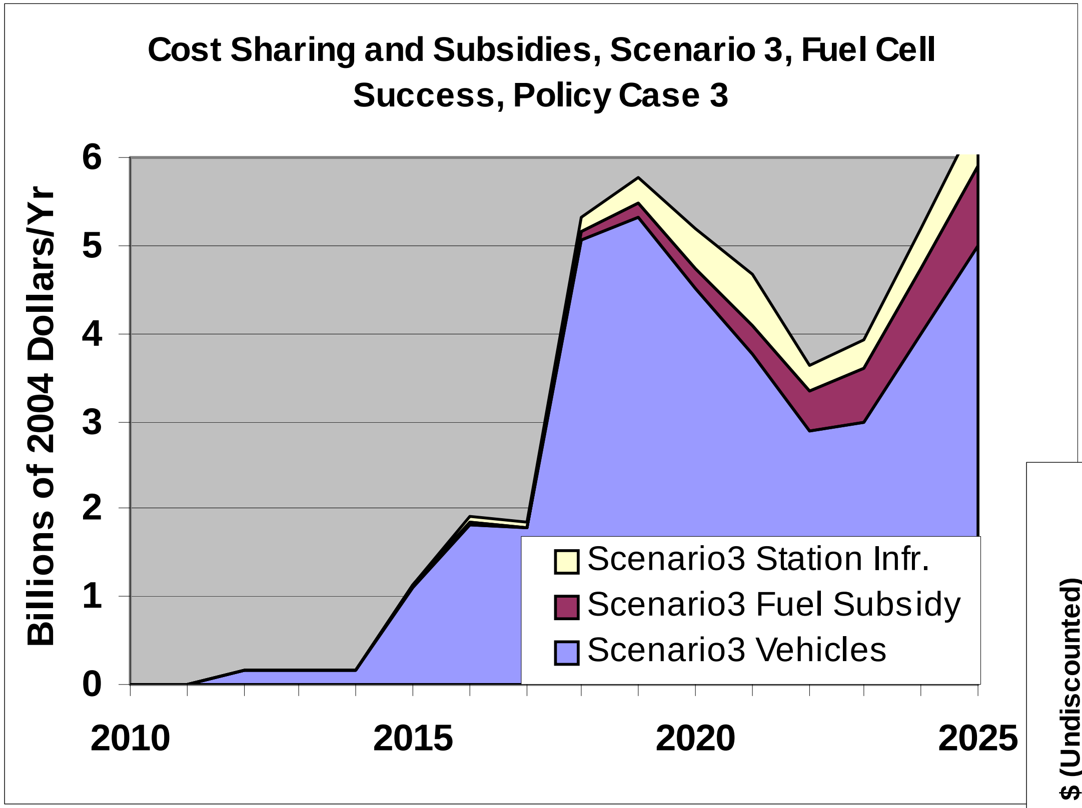


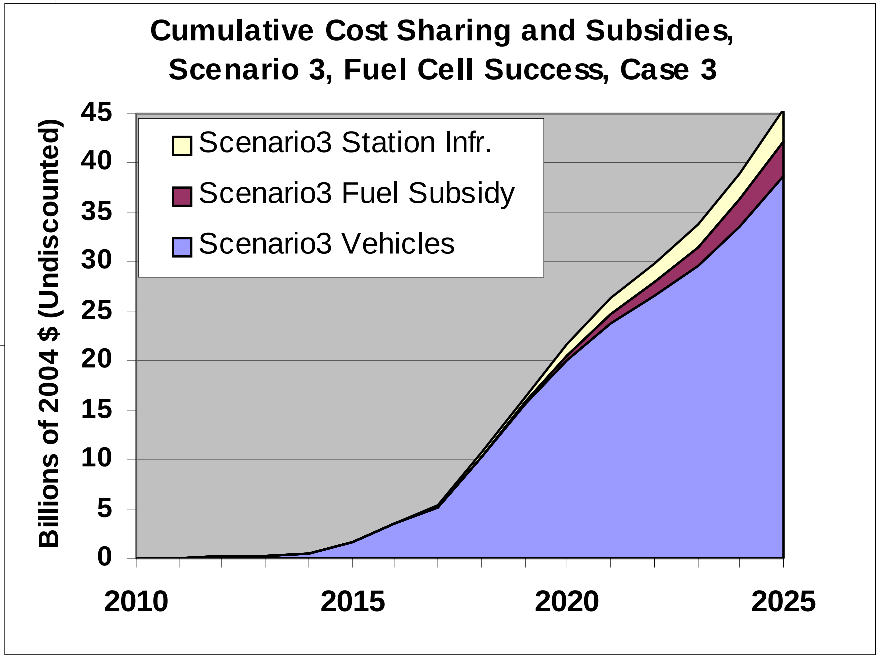
In scenario 2 annual costs do not exceed $5B.



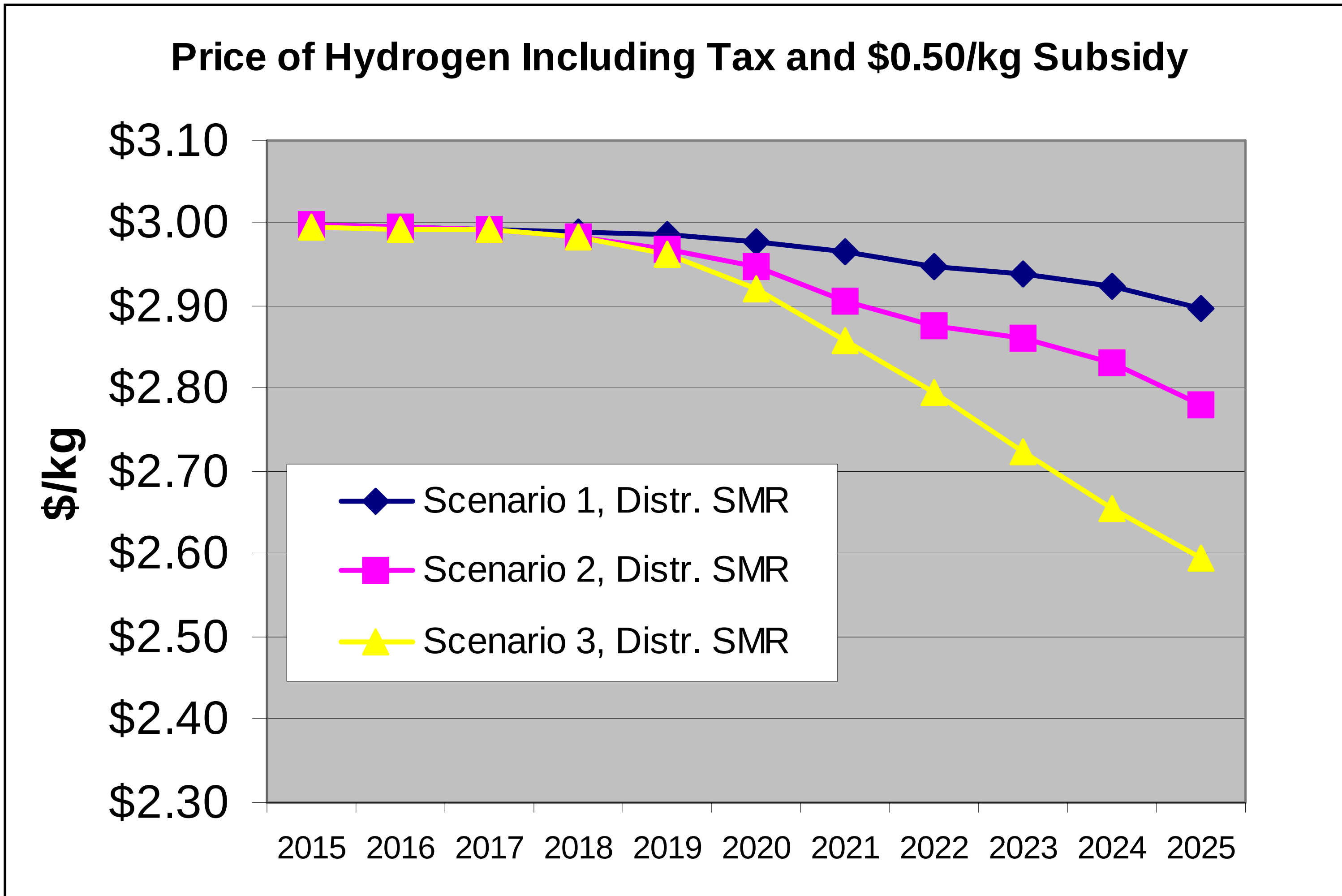


In scenario 3, annual expenditures stay near $5B/year for about 8 years, and cumulative costs exceed $45B.





Nearly all hydrogen through 2025 is produced at distributed SMR stations, which experience learning-by-doing.



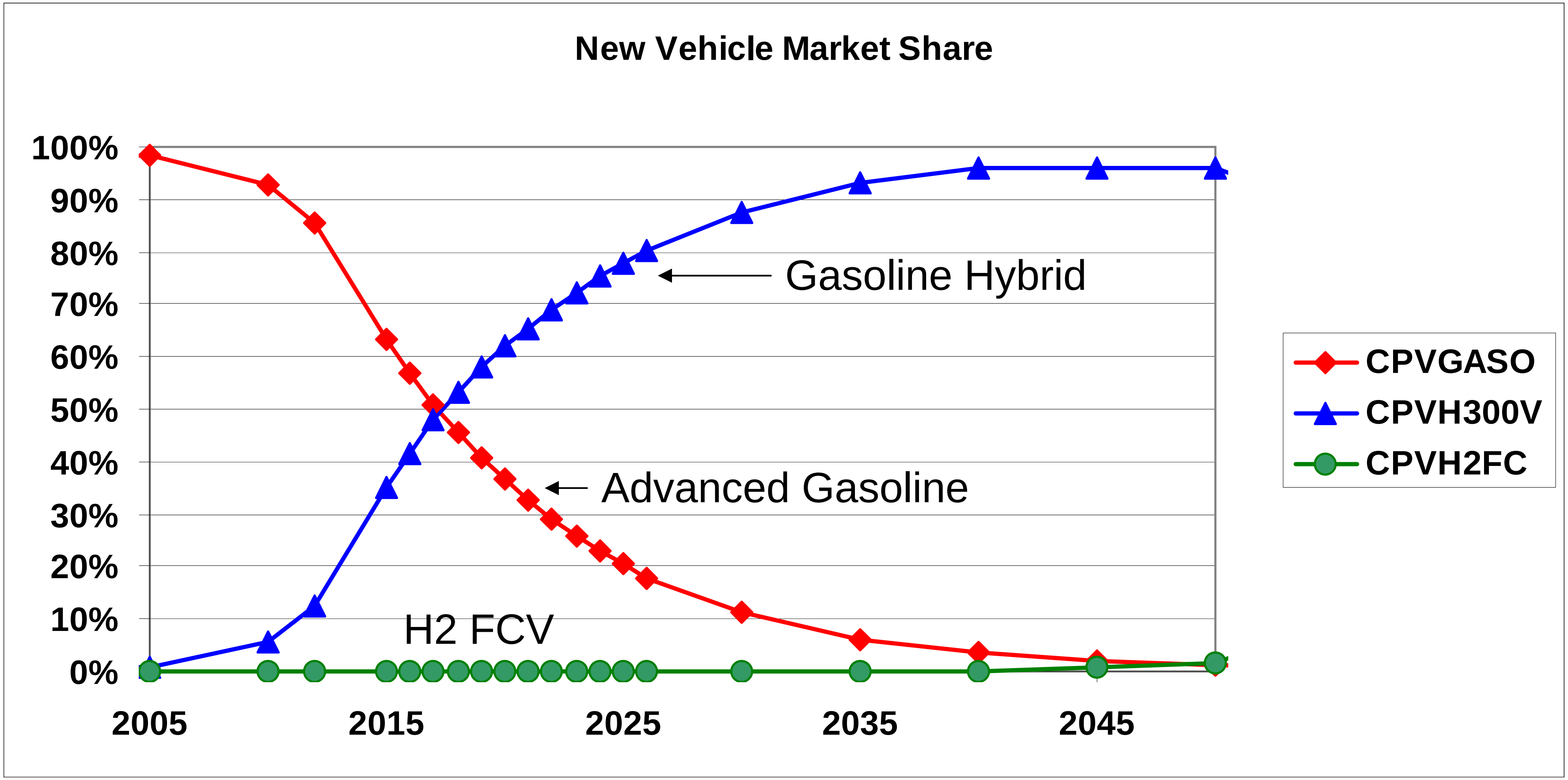
What about reference oil prices and other technologies' success?

- Neither has a significant impact on costs through 2025.
  - When all technologies succeed, government costs are $2B to $5B higher in Case 1, $2B to $10B higher in policy Cases 2 & 3 because the HEV is cheaper.
  - Reference oil price assumptions increase costs by $1B or less.
- After 2025 the differences are very significant.

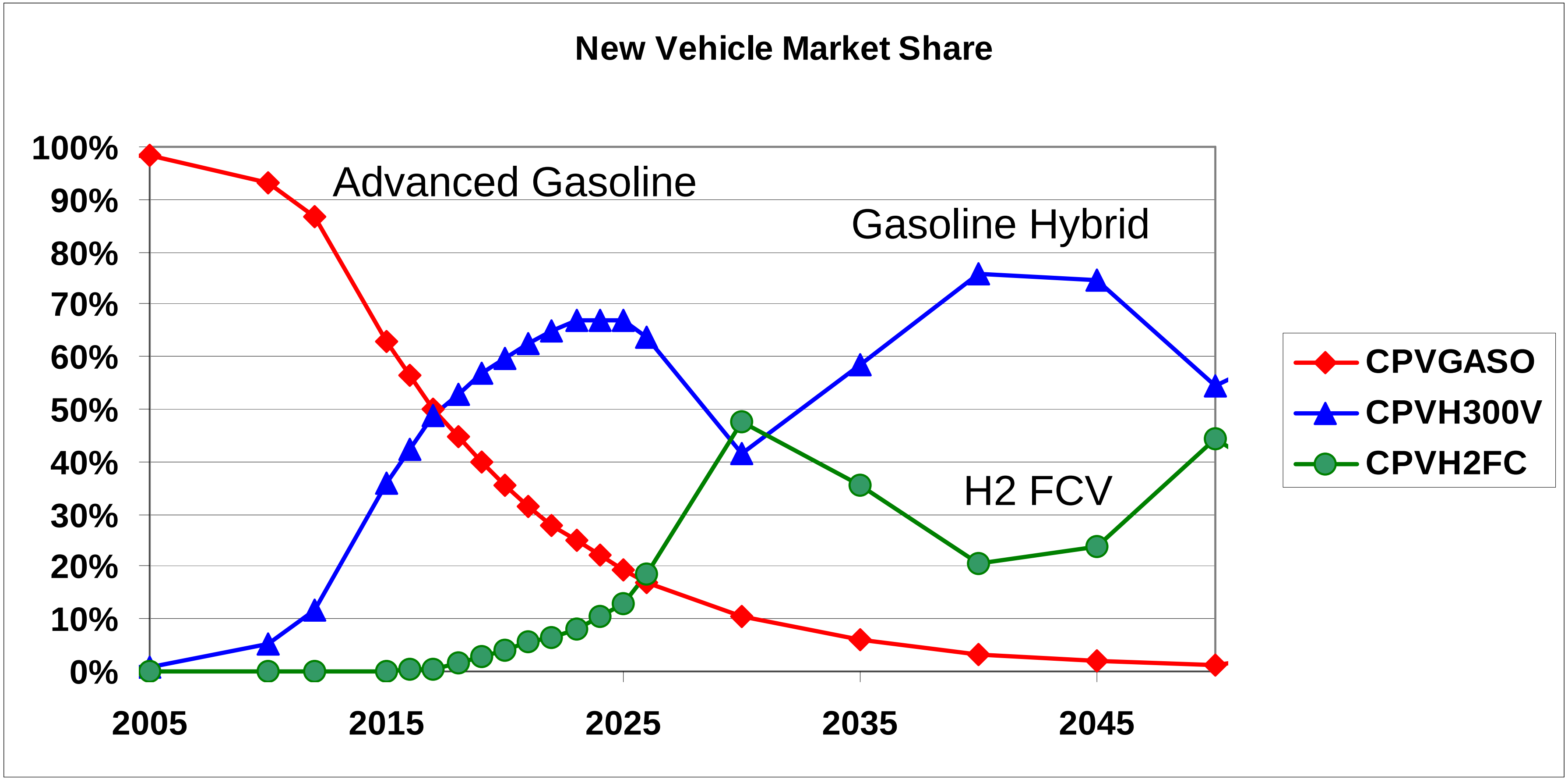
What happens after 2025?

- If no policy scenarios to 2025, there is not a plausible business case for FCVs.
- If “Fuel Cell Success” + High Oil Prices, all three policy scenarios lead to a sustainable transition.
- If “Fuel Cell Success” + Reference Oil Prices, scenario 3 can still lead to a 30% market share by 2050.

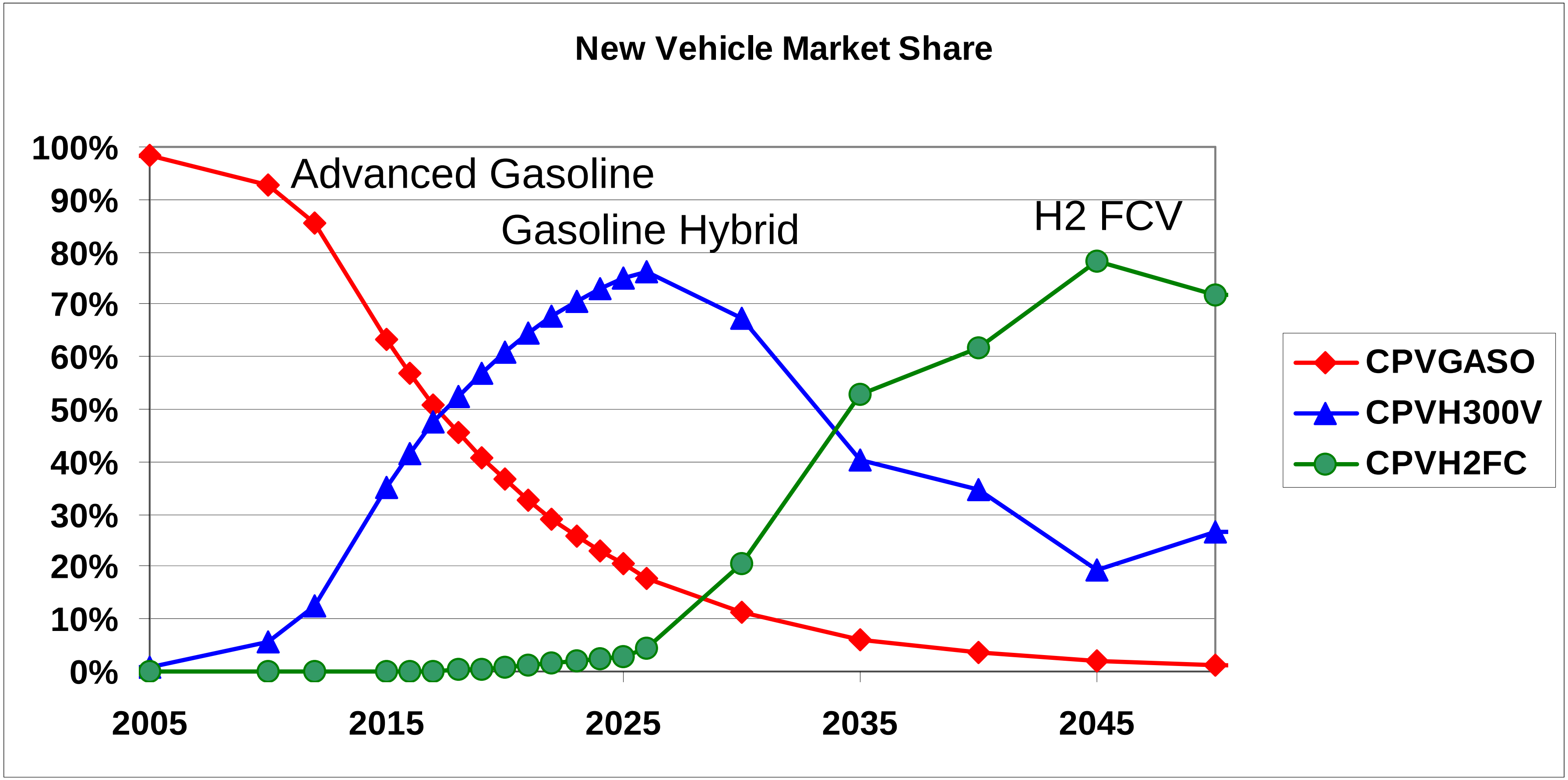
Even with "Fuel Cell Success" and High Oil Prices, without the transition scenarios the business case for a transition before 2050 is not there.



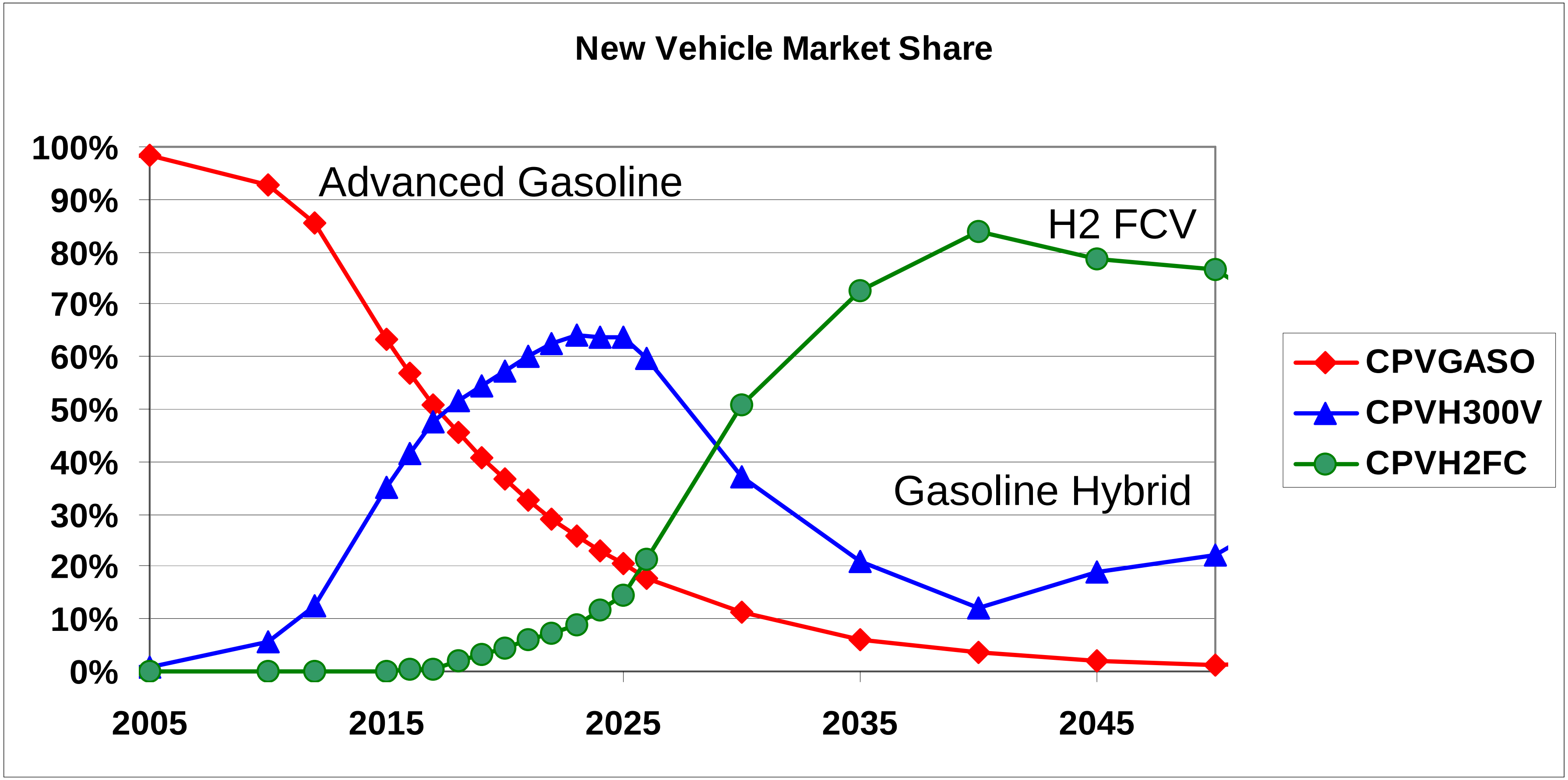
Even if oil prices are not high, there is a competition between fuel cells and hybrids for market share (scenario 3).



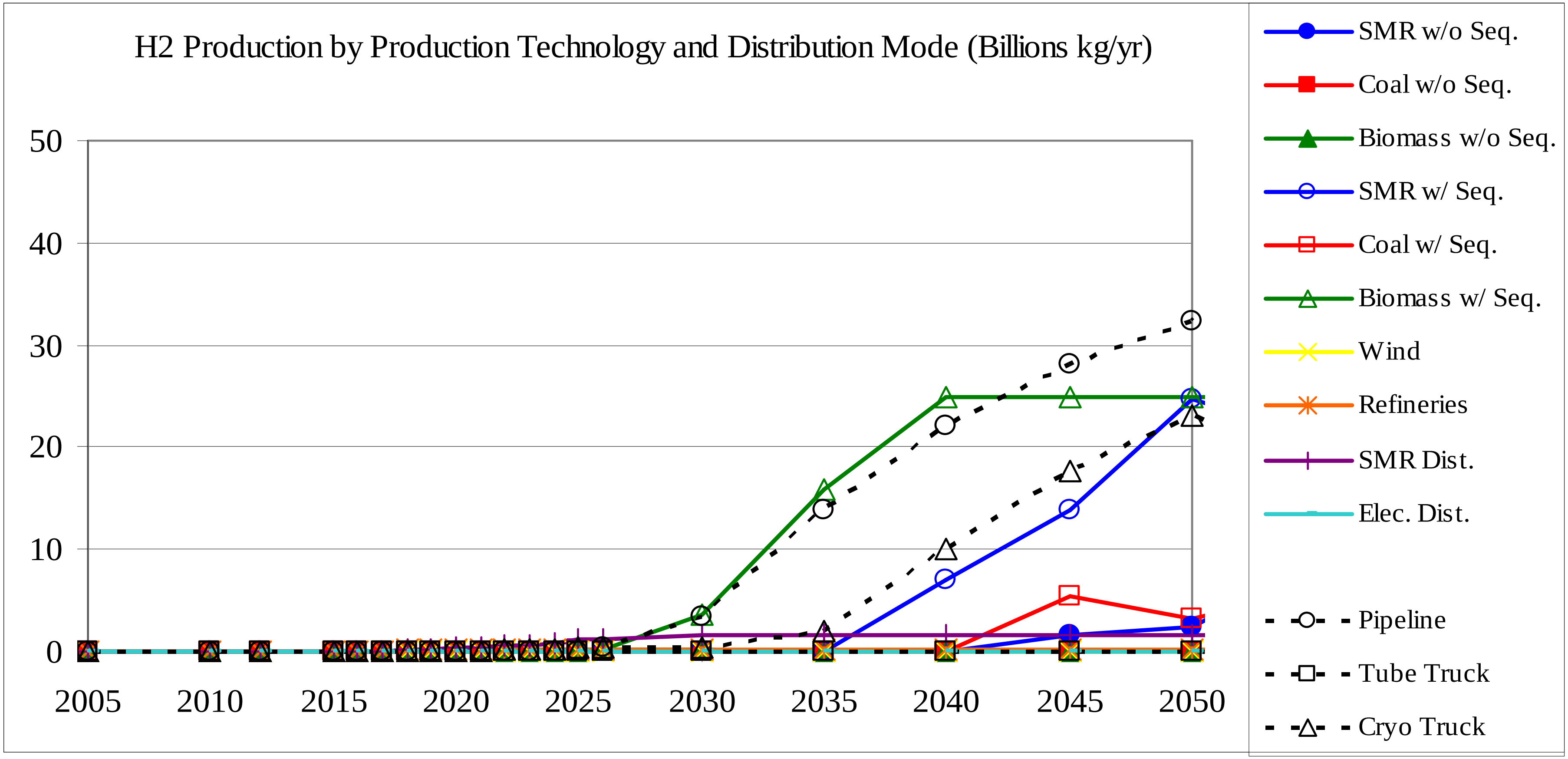
Scenario 1 may be adequate to trigger a transition for the "FC Success" + High Oil Prices case.



Scenarios 2 & 3 create greater market share options.



Serious climate policy is needed to get to “clean” hydrogen.



Carbon price rising to $90/MT CO2 by 2025.
Fuel Cell Success, High World Oil Prices, Scenario 2.

Hydrogen pathways, production AND delivery are sensitive to GHG policy.

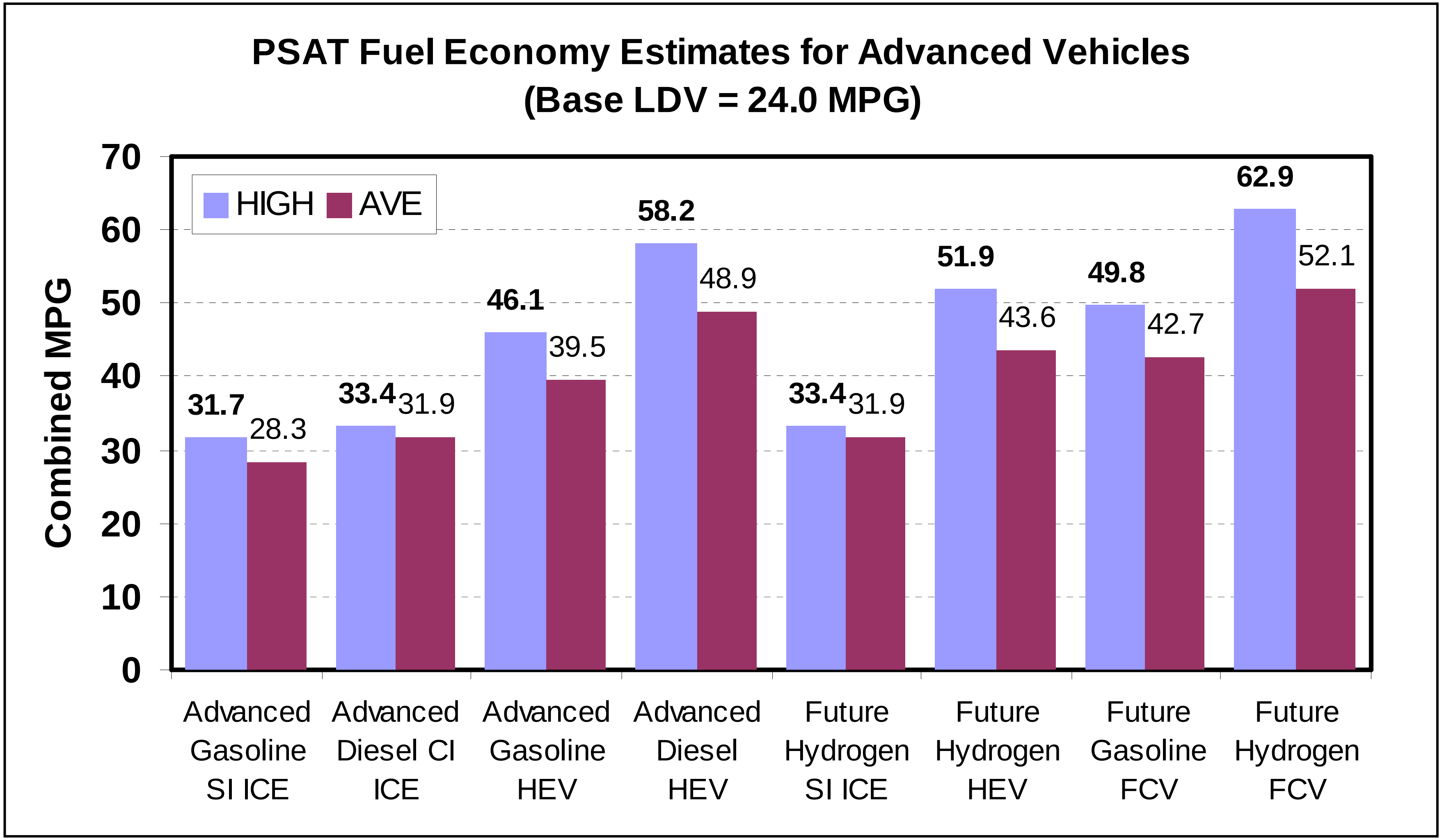
- Delivered costs are nearly the same for several production processes.
- C emissions in delivery are significant due to electricity use in compression or liquefaction.
- This makes fuel cycle C emissions dependent on C-intensity of electricity generation.
- H pathways thus depend on effective price of C and rest of energy sector response.

Several policy pathways can produce a transition to hydrogen.

- FC technology success insures transition will proceed without further policy intervention beyond 2025.
- All technologies succeed also successful with high world oil prices.
- Transition policy is required.
  - Costs are feasible - $10B to $50B over 14 yrs.
  - HyTrans is a complex model including many assumptions that are uncertain. This calls for,
    - Sensitivity analysis of key uncertainties
    - Continuous monitoring of the effectiveness of the transition
- GHG or Energy Security policies not essential to making the transition but strong GHG policy is essential to insuring hydrogen is produced w/o carbon emissions.
- Success of competing technology matters a lot.
- The price of oil matters in the transition but it is critical in the long run (although strong policies can substitute).

THANK YOU.

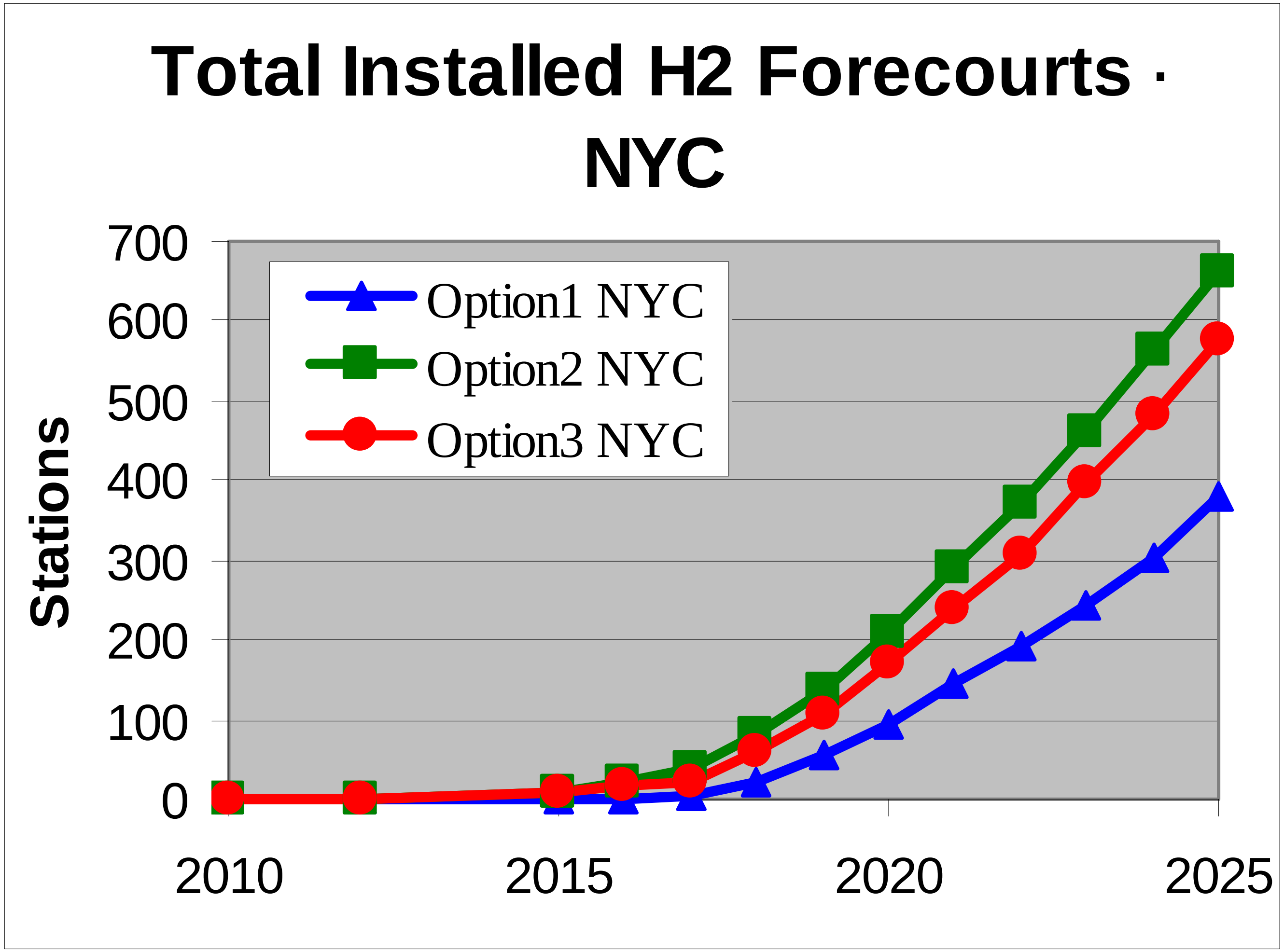
The DOE 2010 Goals scenario estimates higher MPG, especially for electronic drive systems.



Conditions and Policies Applied – Case 4: Case 1 + Carbon Tax in Succession Period (2056-2050)

- All results for “Fuel Cell Success” Case
- Vehicle cost decline with an “asymptotic learning” model
  - Mature learning achieved by cumulative vehicle production of ~5 million vehicles
- FCV incremental vehicle production costs (vs HEV) shared 50% through 2025
- Station capital cost starts at $3.3 million, declining to $2.0 million
  - Cost share $1.3 million/station, 2012-2017
  - Cost share $0.7 million/station, 2018-2021
  - Cost share $0.3 million/station, 2022-2025
- H2 fuel Subsidy of $0.50/kg through 2018
  - Declines to $0.30/kg by 2025
- C-Tax = $50/ton CO2, phased in (To be determined)

Time Path of Infrastructure Development (Cumulative Number of Forecourts, NYC)



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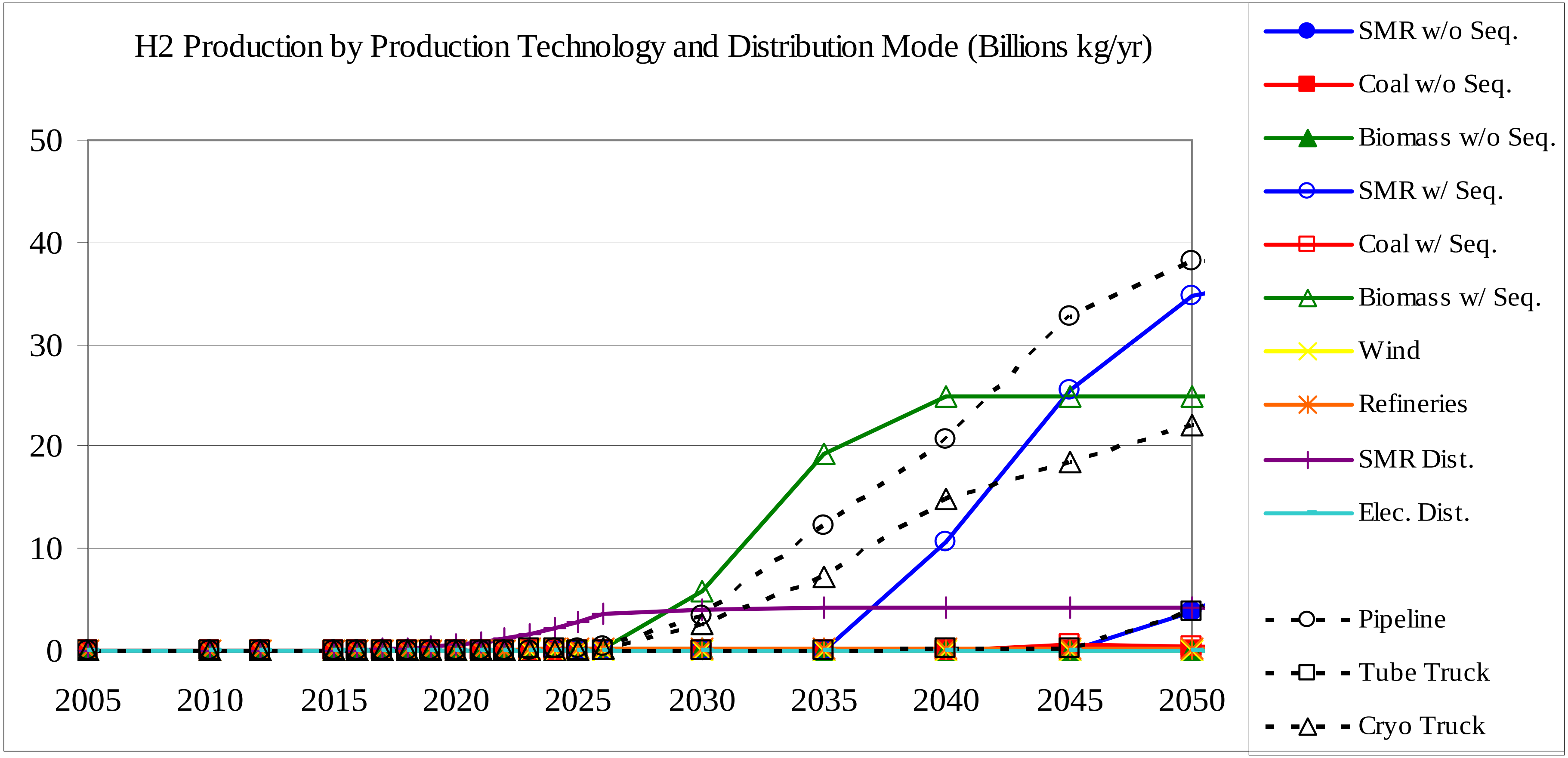

Carbon price rising to $90/MT CO2 by 2025
Fuel Cell Success, High World Oil Price, Scenario 3.