H2 Fuel Cell Vehicle Transition: Infrastructure Build-Out Scenarios for the US

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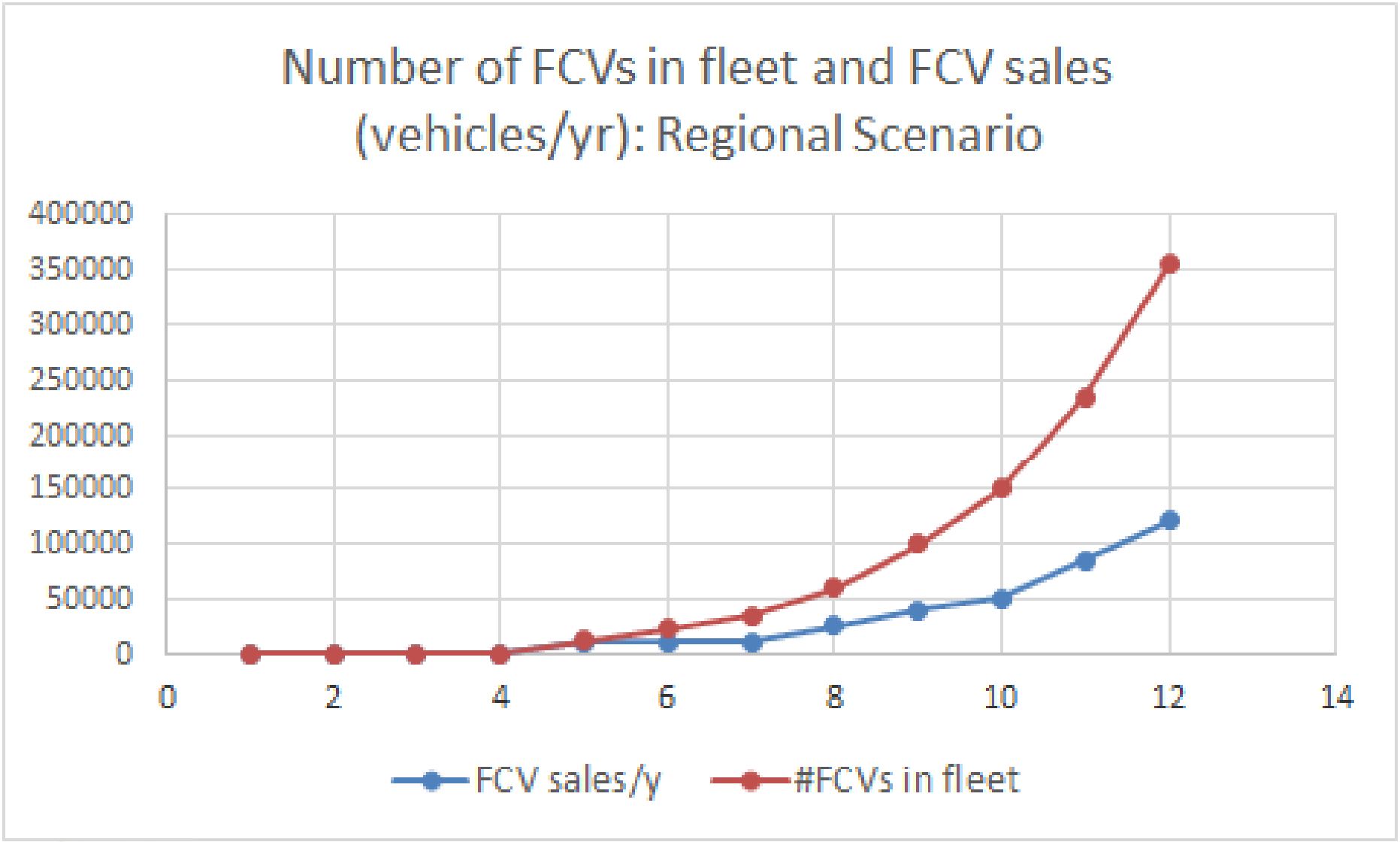
H2 FCV TRANSITION IN THE US 2015-2035

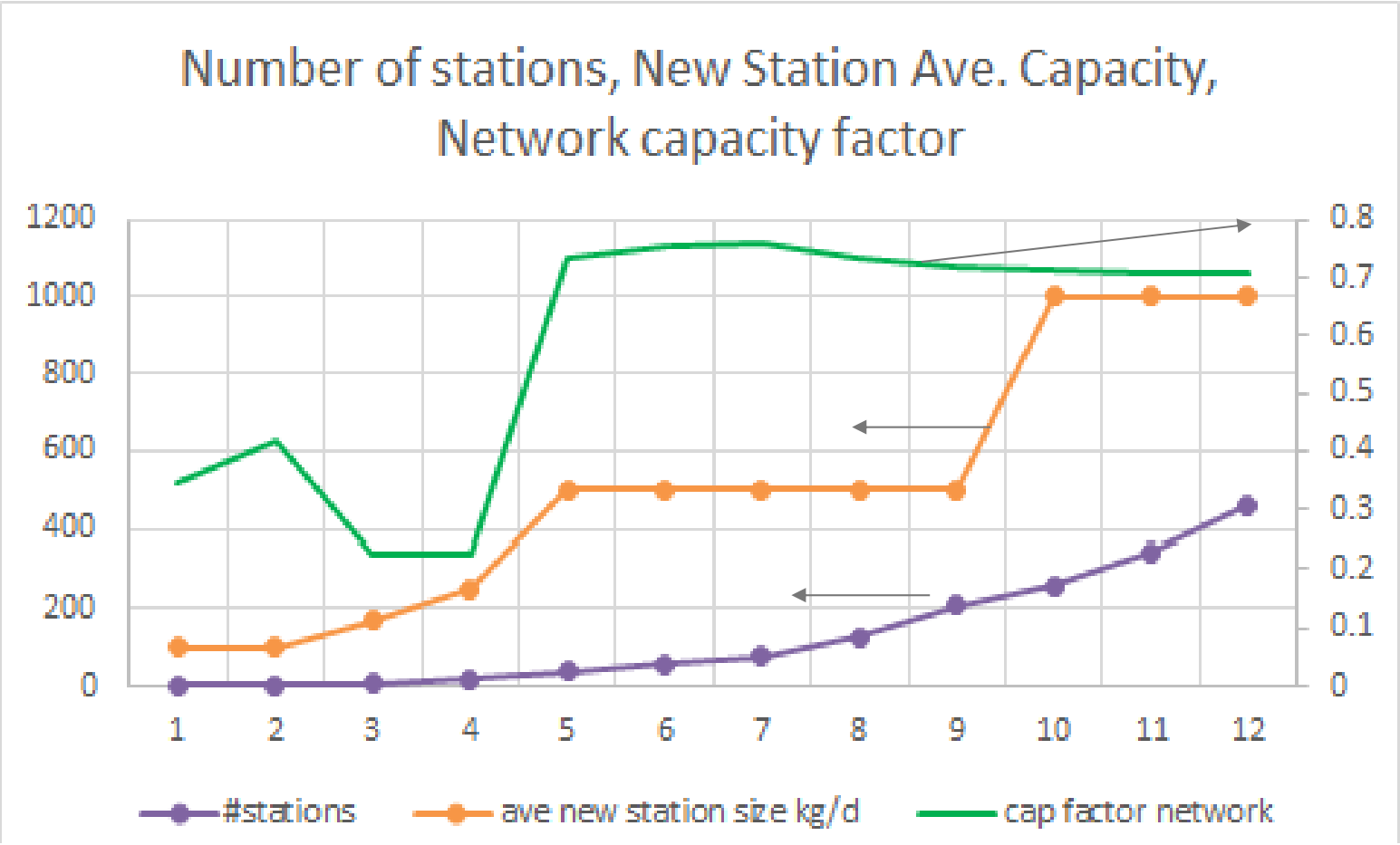
- What are required investments in vehicles and infrastructure
  - To provide initial infrastructure
  - to bring vehicles and fuel to breakeven "competitiveness" with incumbents
  - to fully build out fuel infrastructure
- What are subsidies might be needed to support this transition and possible policies?

This is a partial analysis. We do not address a transition to low carbon primary sources for hydrogen

REGIONAL PERSPECTIVE: How Much Investment is Needed to Launch Regional H2 Infrastructure: Years 1-12

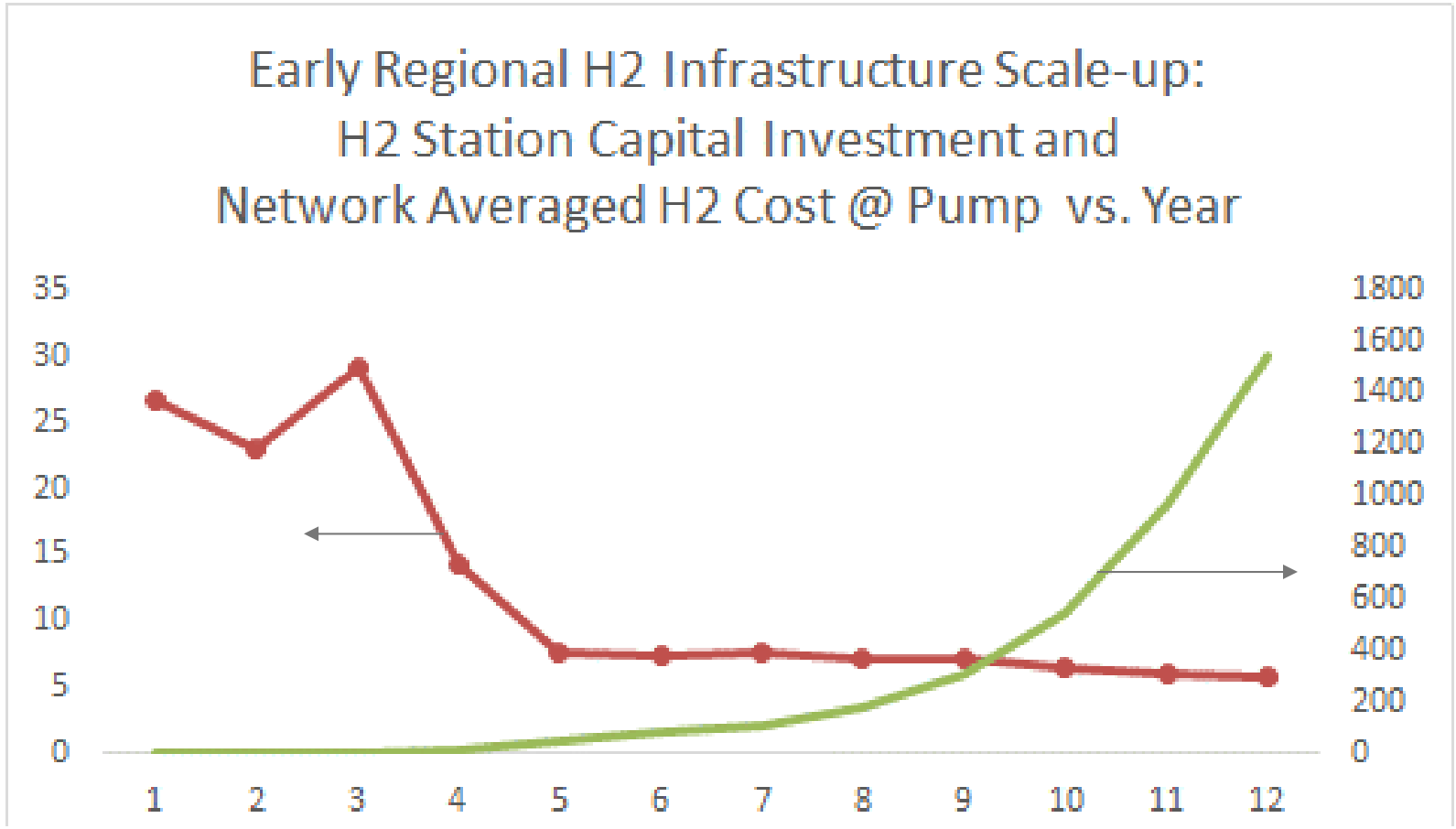


Regional Scenario for station rollout to year 12



At first, network capacity factor low, as stations are built ahead of vehicle deployment. In first few years stations small, located to provide coverage for early adopters

Investment to launch regional H2 fuel supply



$100s million capital investment for ~100s stations (serving 100,000-250,000 FCVs) to reach H2 <$7/kg, Assumes FCV market grows rapidly.

ANALYZE US NATIONAL H2 FCV ROLLOUT SCENARIO AS A SERIES OF REGIONAL ROLLOUTS

- **Introduce H2 in Series of 60 Lighthouse Cities by 2035**

  5 cities 2016-2020

  +5 cities 2021-2025

  +16 cities 2026-2030

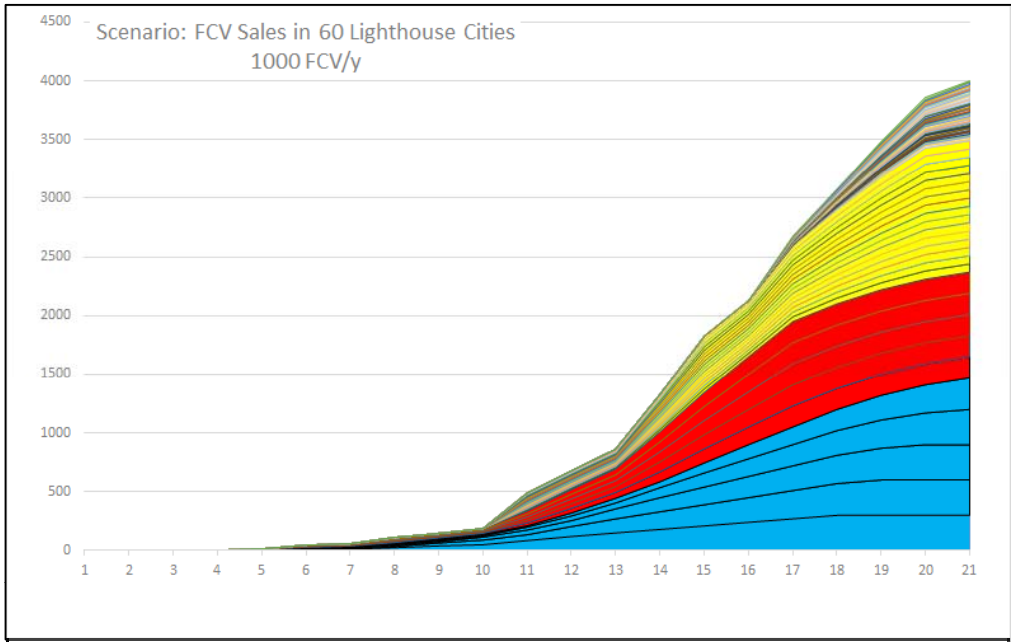
  +34 cities 2031-2035

- Scenario for number of FCVs in each city => H2 Demand
- Design H2 Network in Each City Based on Cluster strategy: Stations with Truck Delivery, Onsite Production
- Find station investment ($), H2 cost ($/kg) vs. time
- Aggregate to Get National Numbers

SALES IN LIGHTHOUSE CITIES

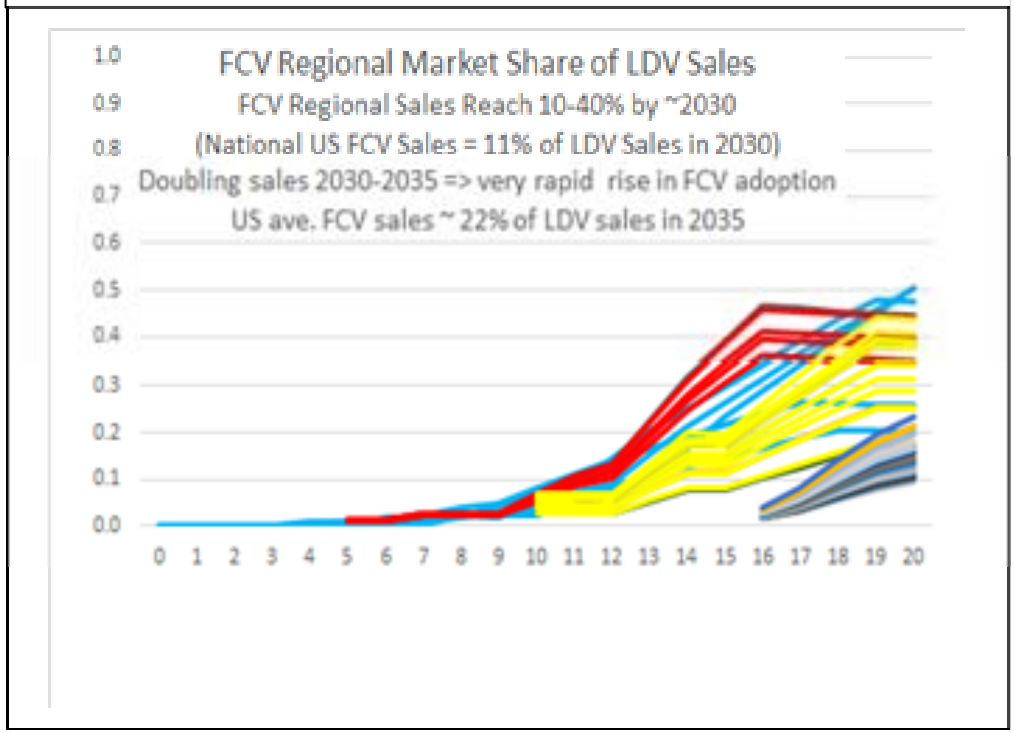
#FCV Sales/Year

H2 FCVs = 7% of on-road LDVs in 2035

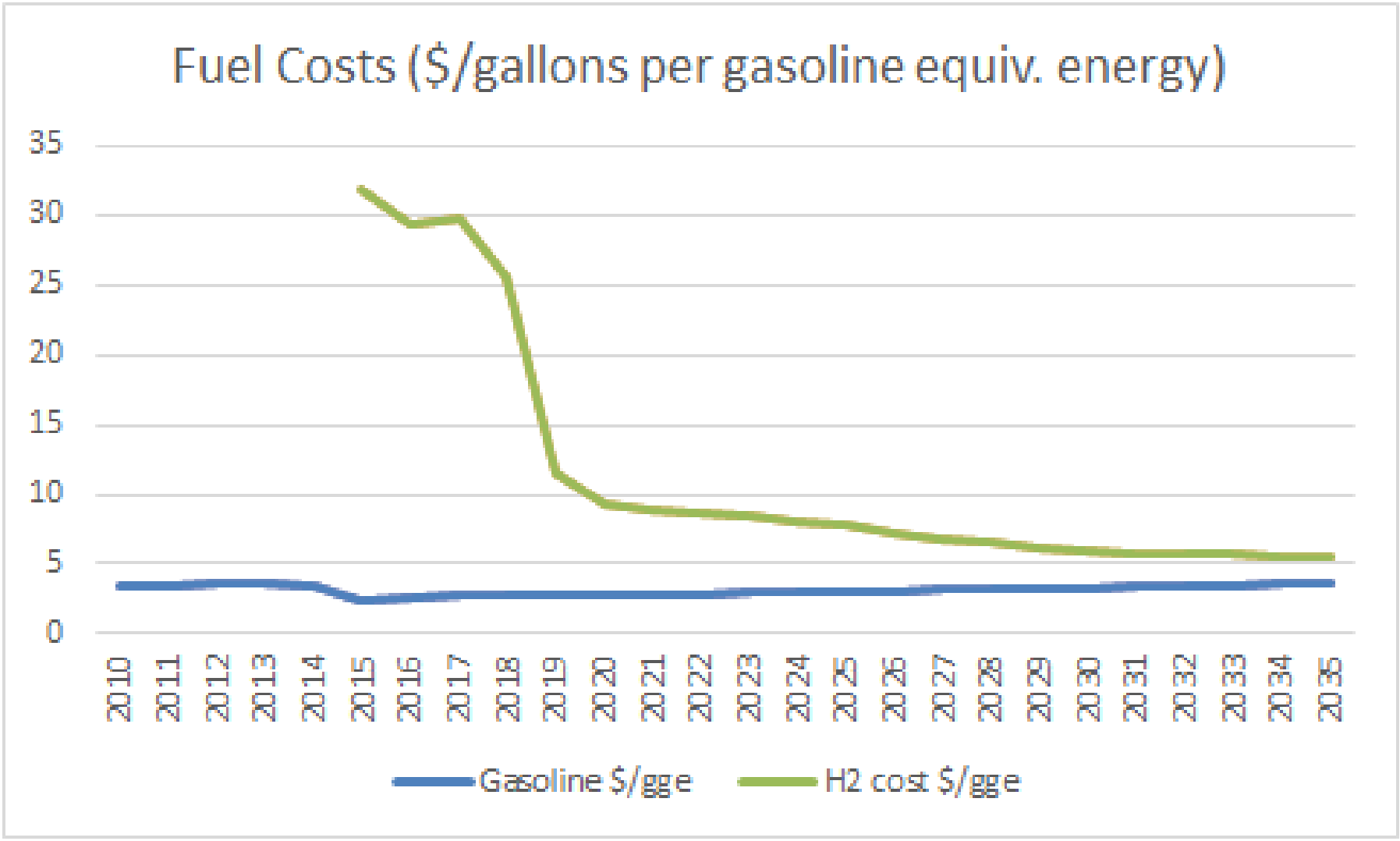


FCV Sales Fraction in Each Regional Market

2035 FCV LDV Market Shares
US 22%; Regional 10-40%

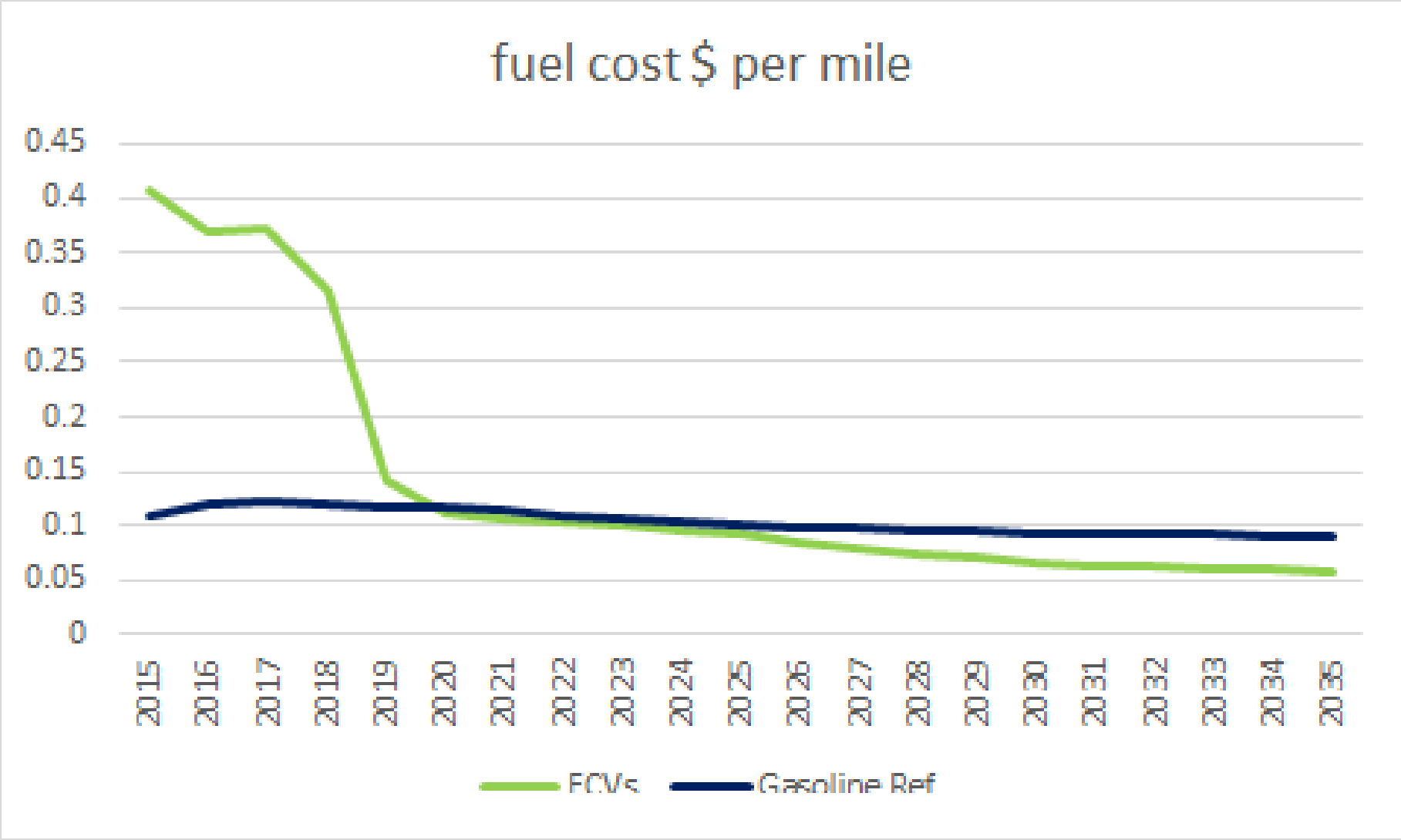


US Average Estimated Fuel Cost ($/gallon gasoline eq.)

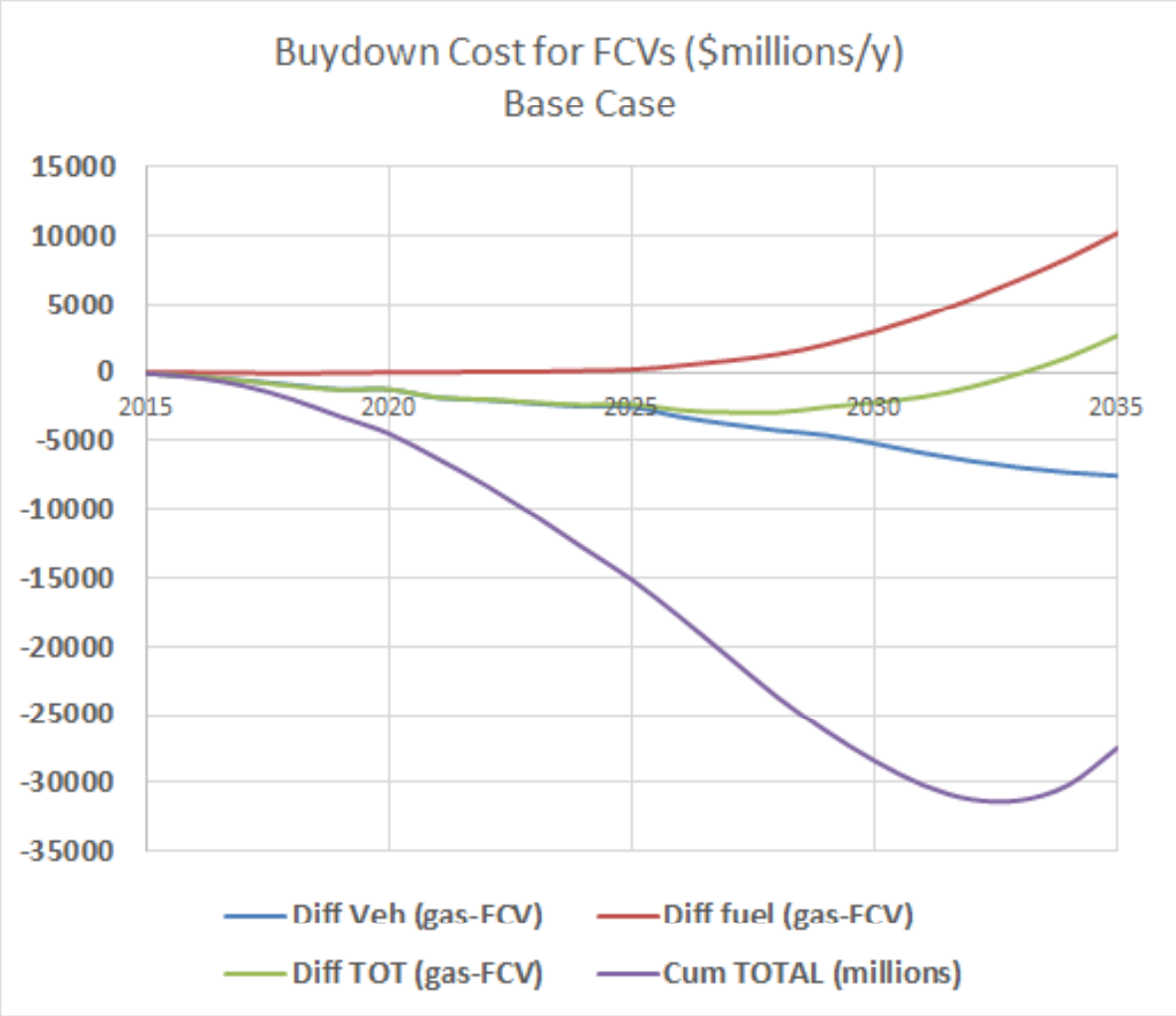


Estimated "Fuel Cost Breakeven" ($/mile)

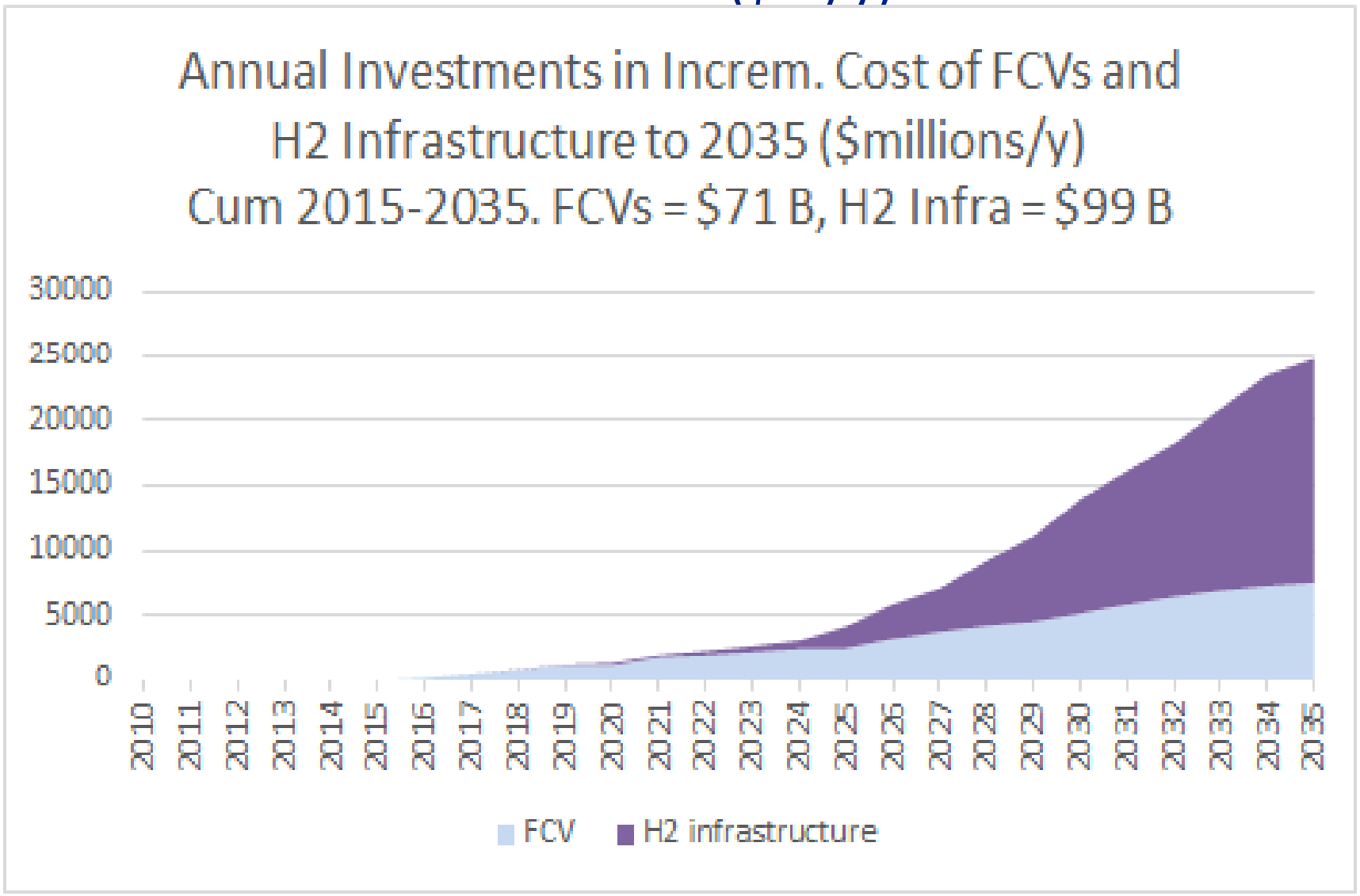
FCV (H2 US ave.) < gasoline ICEV after ~2024



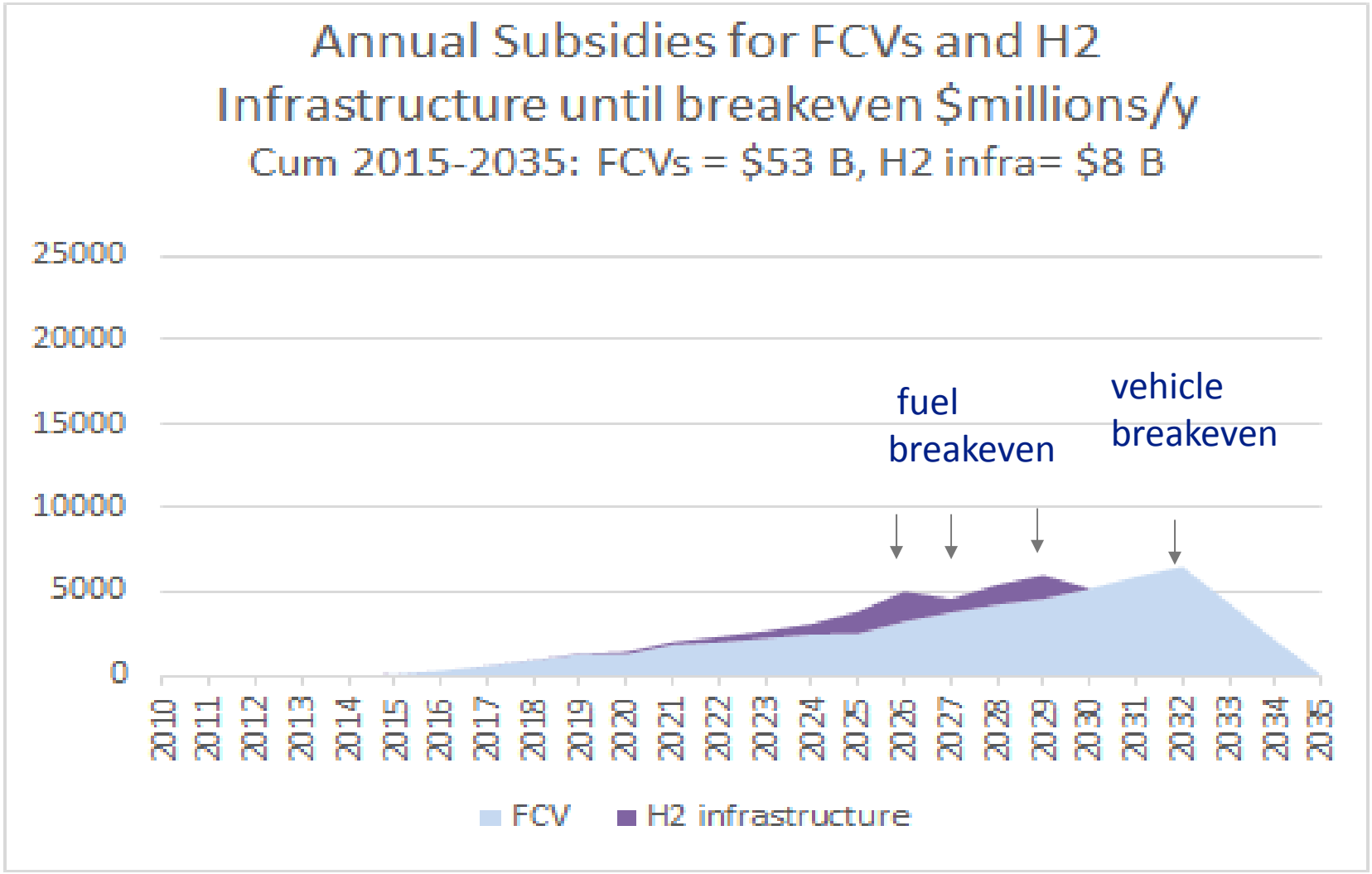
“Vehicle Breakeven” when fuel savings > extra cost of FCVs compared to gasoline ref. vehicle
H2 FCV breakeven in 2032, ~15 million FCVs



Incremental INVESTMENTS for H2 FCVs and H2 Infrastructure to 2035 ($M/y)



SUBSIDIES for Fuel Cell Vehicles and Infrastructure til Breakeven, w/ 3-yr phase out after Breakeven ($M/y)



US Transition costs

- **Regional station networks in lighthouse regions can break even in 5-10 years depending on many factors**
- National US H2/FCV scenario breaks even ~2032. Beyond this, fuel savings outweigh incremental costs for vehicles.
- **Cumulative INVESTMENTS** to 2035 for fuel stations serving 22 million FCVs are about $100 B
- **Cumulative infrastructure SUBSIDIES** are only about $8 B (assuming we subsidize station cost until delivered H2 cost reaches $7/kg in successive lighthouse cities)
- The results are sensitive to a lot of assumptions

IS THIS A LOT OF MONEY? (yes and no)

- $8B spent over 15 years ~a few cents gasoline tax
- Total subsidies for veh + fuel ~ a few % of total expenditures