

Where Cars are King: The Economics of Transitioning to Hydrogen Fueling Stations in California

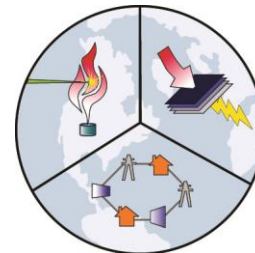
31st USAEE/IAEE North American Conference
6 November 2012 Austin, Texas

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Motivation

California has a long history of supporting alternative transportation fuels

- 1990: California Air Resources Board mandates Zero Emission Vehicles
- 2007: Executive Order S-1-07's Low Carbon Fuel Standard requires 10% average reduction in carbon intensity for transportation fuels by 2020
- 2012: Executive Order B-16-2012 to promote rapid commercialization of Zero Emission Vehicles by state agencies

Transitioning to hydrogen (“H₂”) fuel presents a “chicken or egg” dilemma

- Coverage/Convenience: Potential fuel cell vehicle (“FCV”) owners need to know that adequate H₂ filling stations will be available
- Capacity Utilization/Economics: Potential H₂ filling station owners need to know that low-utilization start-up period losses will be covered

Issue: How many H₂ fueling stations are required and at what is the required support to overcome this early mover dilemma?



Major Results

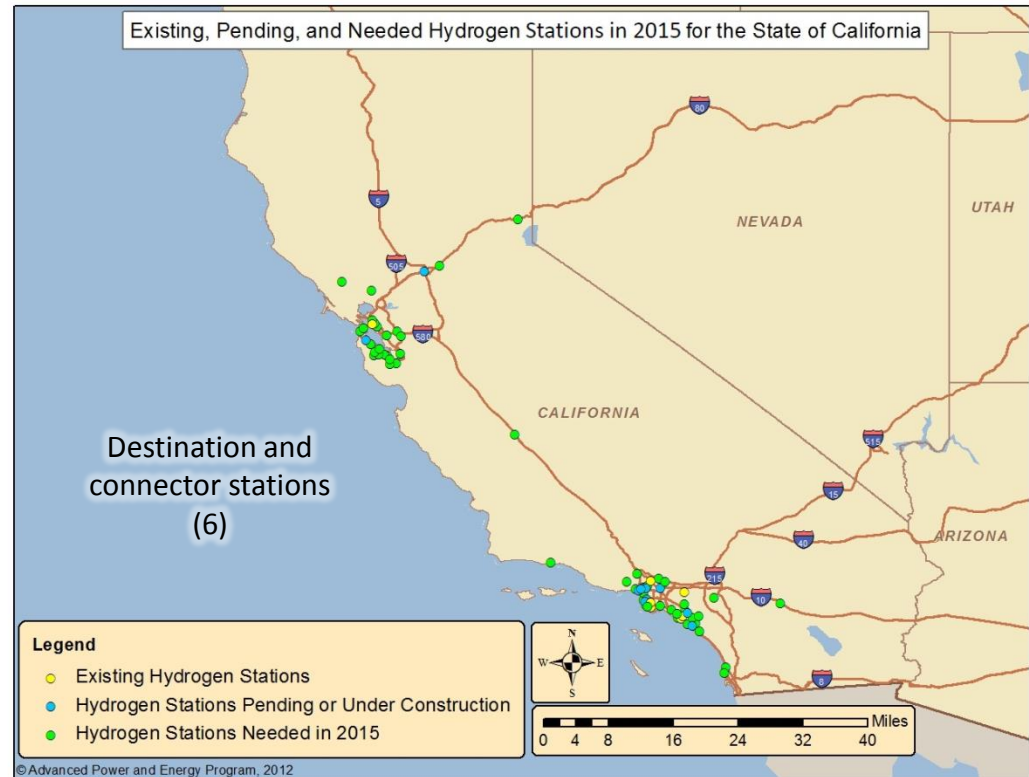
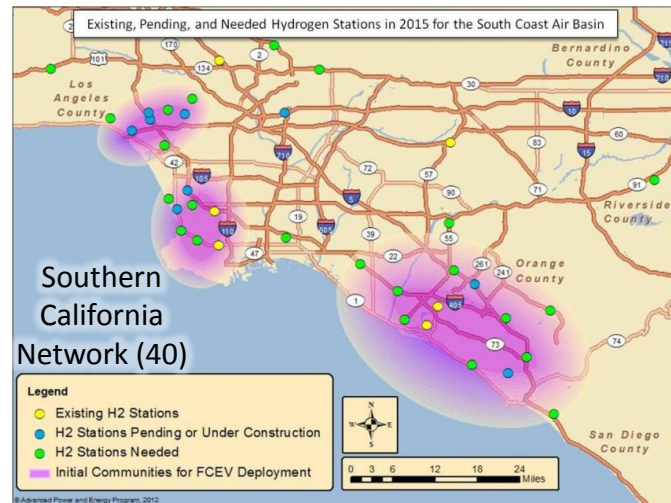
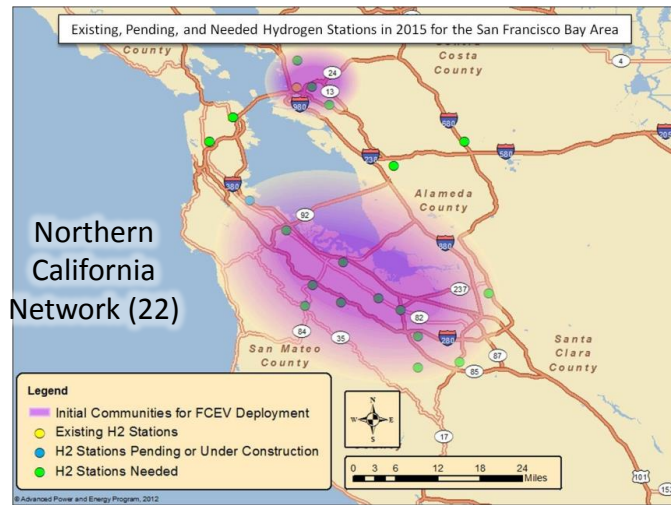
Spatially and Temporally Resolved Energy and Environment Tool (“STREET”) used to identify robust network of 68 existing, funded, and proposed H₂ fueling stations in California.

Economic analysis of these 68 H₂ fueling stations found:

- A strategically planned H₂ fueling station network can meet driver convenience needs while minimizing economic impact, with ***little dependence on vehicle adoption rate***
- Network analysis provides added portfolio insights based on individual H₂ fueling station economic attributes
- Operation & maintenance and capital costs are the largest contributors to the delivered cost of H₂.



68 H₂ Station Locations Identified Using STREET



This plan has been adopted by the California Fuel Cell Partnership (“CaFCP”) and forms the foundation for two recent CaFCP publications:

- *A California Road Map: The Commercialization of Hydrogen Fuel Cell Vehicles (June 2012)*
- *A California Road Map: Bringing Hydrogen Fuel Cell Electric Vehicles to the Golden State (July 2012)*



HY_COST Economic Model: Assumptions

- **General H₂ delivery station assumptions**

- Debt-equity ratio: 100% debt; 0% equity
- H₂ pump location: At existing gasoline station
- Interest rate (100% debt): 7.5%
- Fixed O&M: \$100 K per year
- Insurance: \$20 K per year
- Electricity rate: \$0.105/kWh
- Maximum station utilization : 90%
- Natural gas price: \$4.50/MMBtu in 2011; escalates at ~1.5% annual inflation rate
- Gasoline price, reformulated, premium \$3.40-6.70/gallon (Source: EIA, 2011 Annual Energy Outlook)

- **Gaseous H₂ delivery station (33 stations*)**

- Station equipment cost: \$1.0 MM
- Capacity: 180 kg/day
- Land lease: \$24 K per year
- Upgrade cost: \$500 K for an additional 180 kg/day of H₂ station capacity

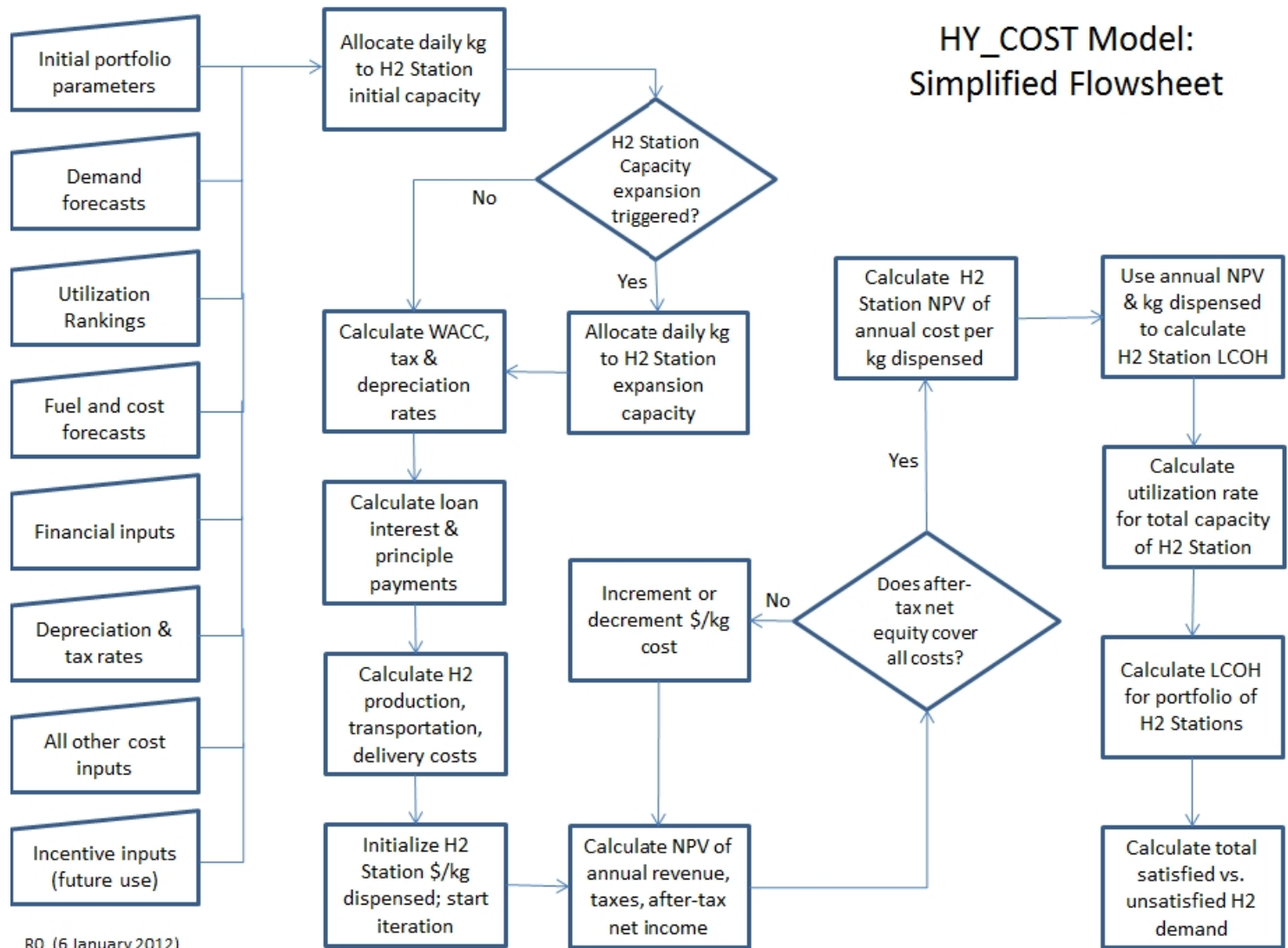
- **Liquid H₂ delivery station (17 stations*)**

- Station equipment cost: \$2.0 MM
- Capacity: 400 kg/day
- Land lease: \$36 K per year
- Upgrade cost: \$600 K for additional 400 kg/day of H₂ station capacity

* Remaining 18 stations are one-of-a-kind (e.g., Torrance pipeline, Orange County Sanitation District); tax loss carryover assumed in all cases.



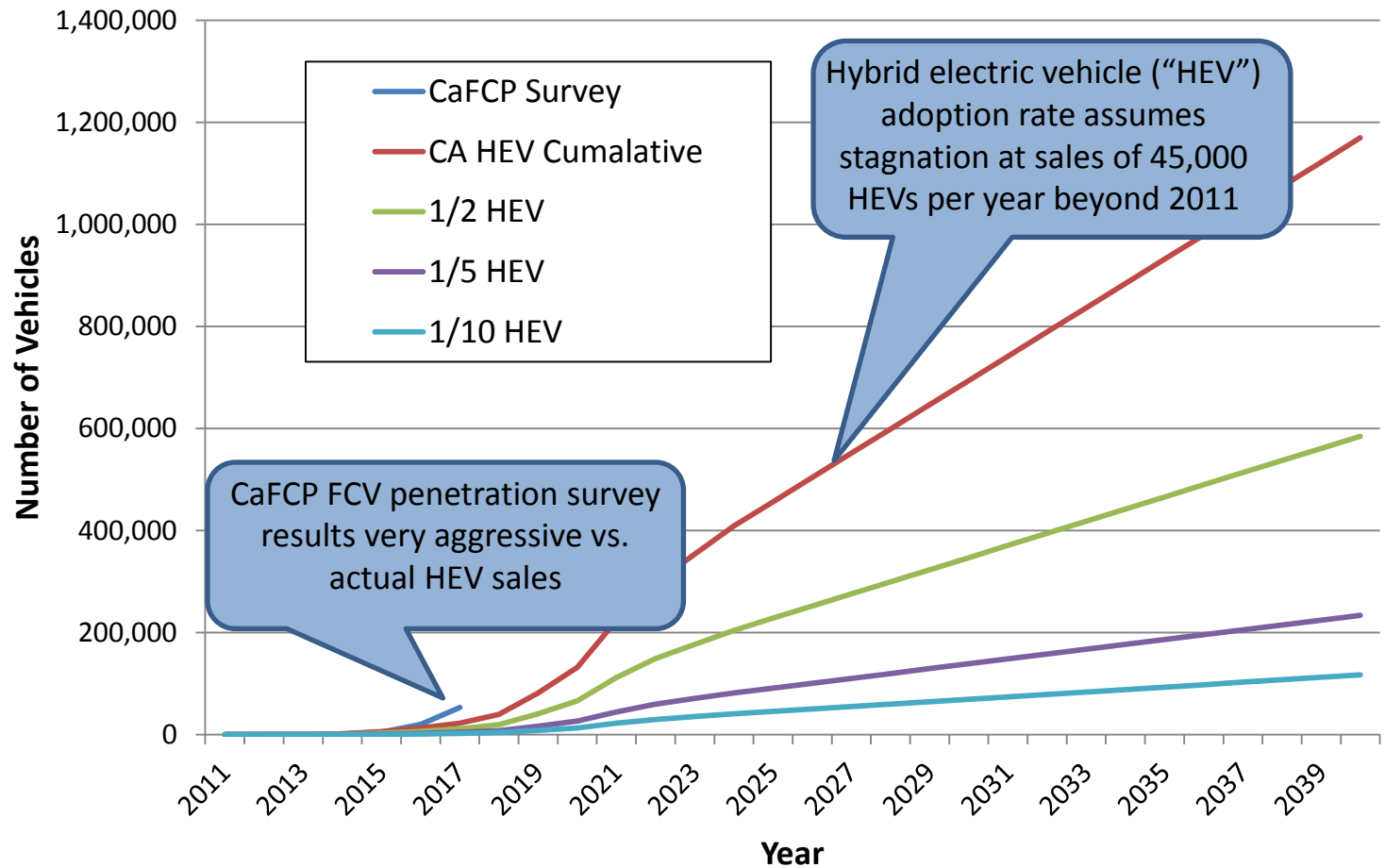
HY_COST Economic Model: Mechanics



RO (6 January 2012)



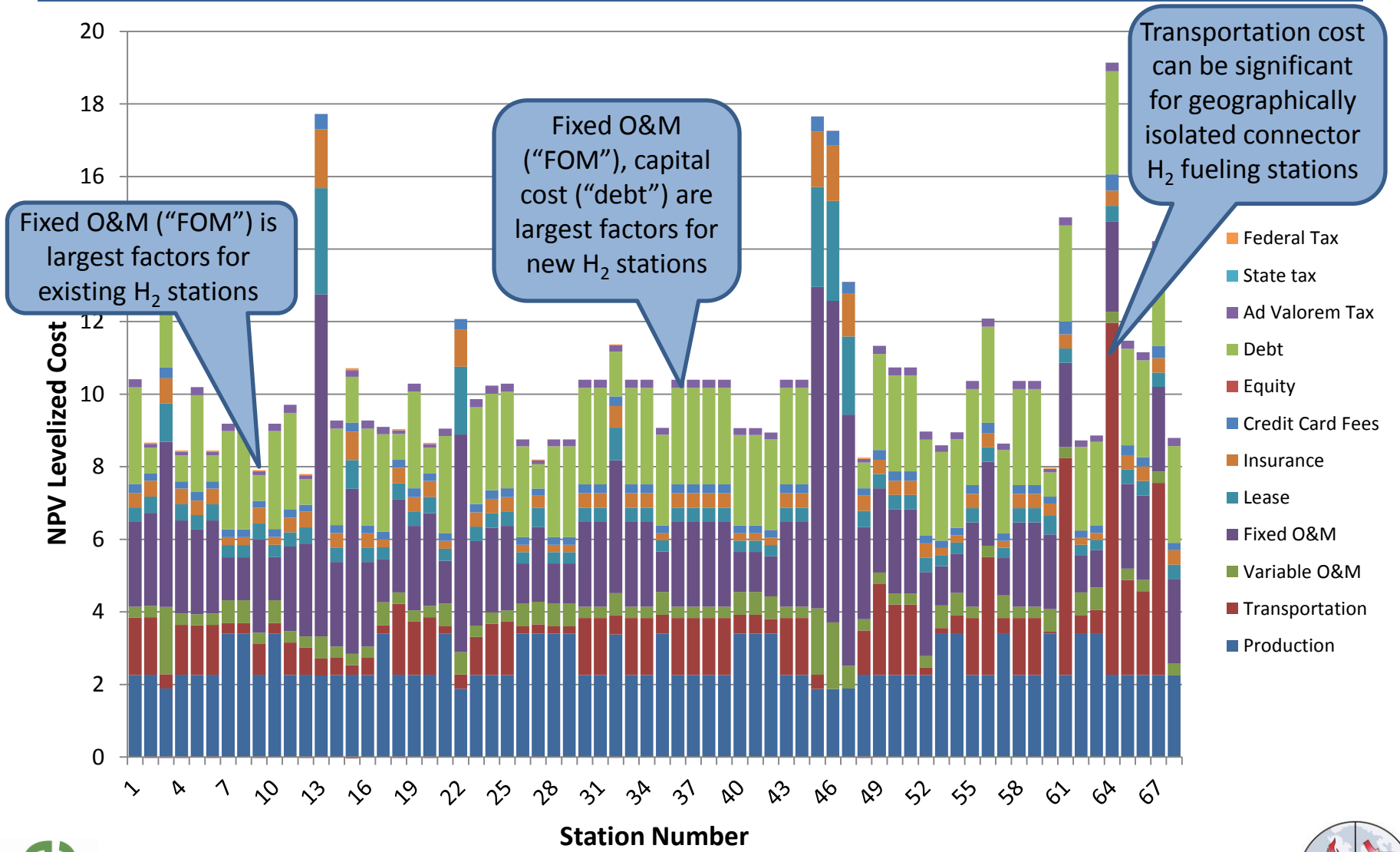
FCV Adoption Rate Projections vs. HEV Rate



FINDINGS: Economic analysis of 68 existing, funded, and proposed H₂ fueling stations in California

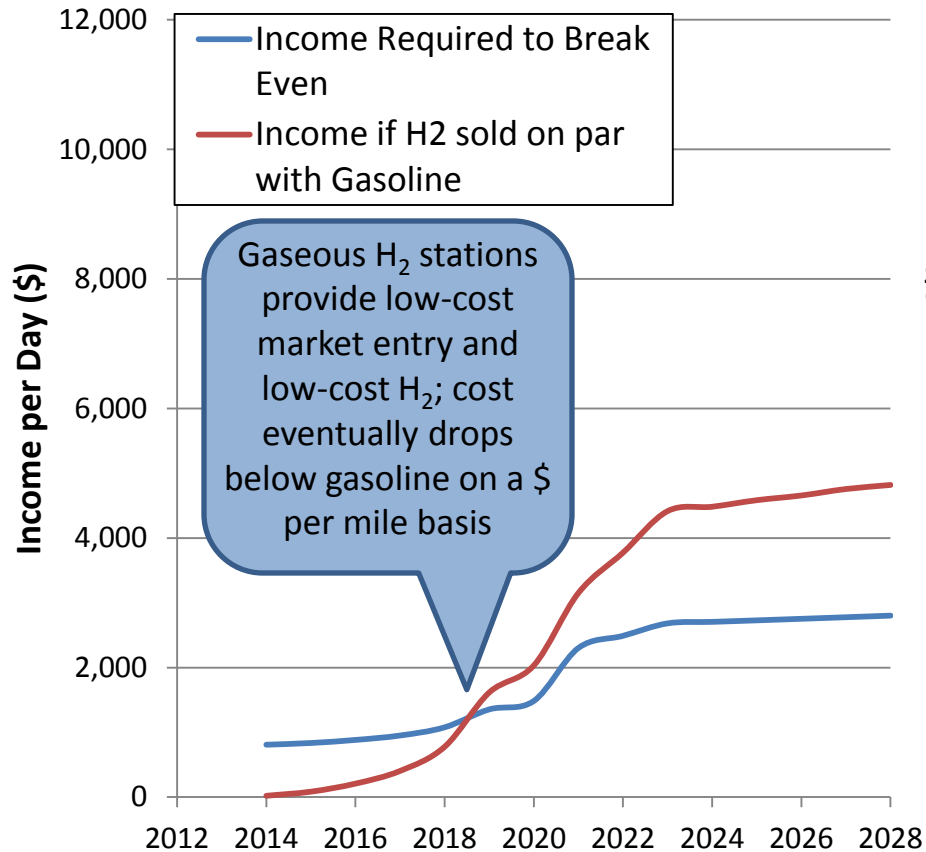


Delivered H₂ Costs Vary by Station

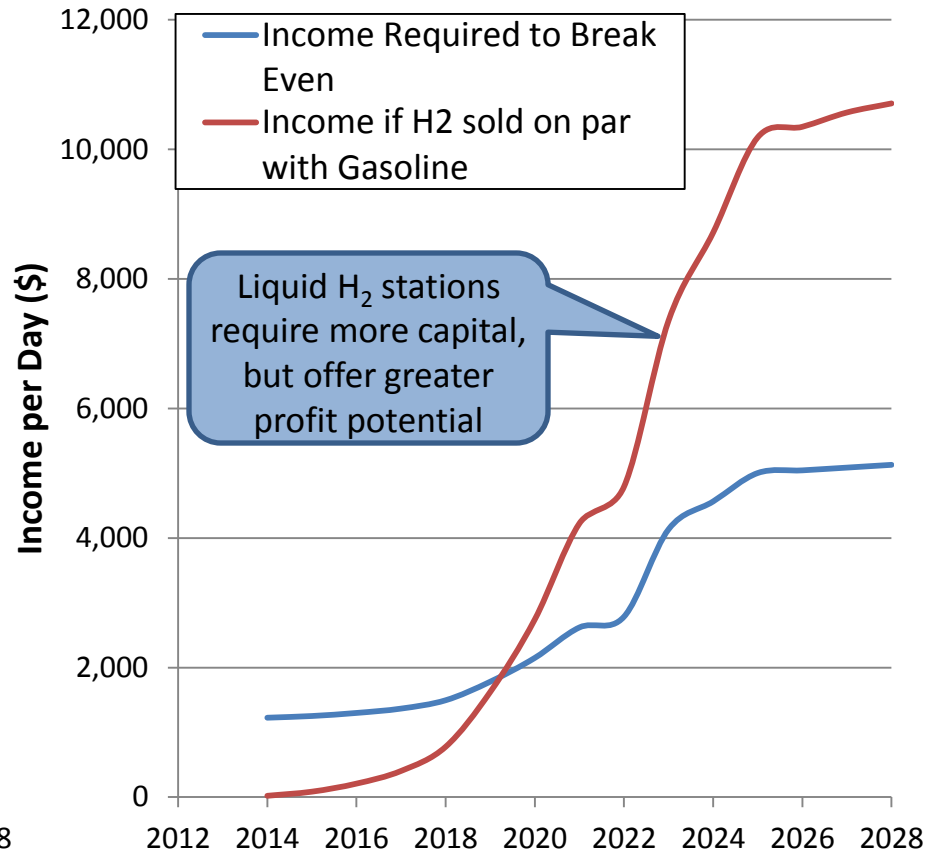


Case Study: H₂ Fueling Station Cash Flows (2014 Build)

Gaseous H₂ Fueling Station



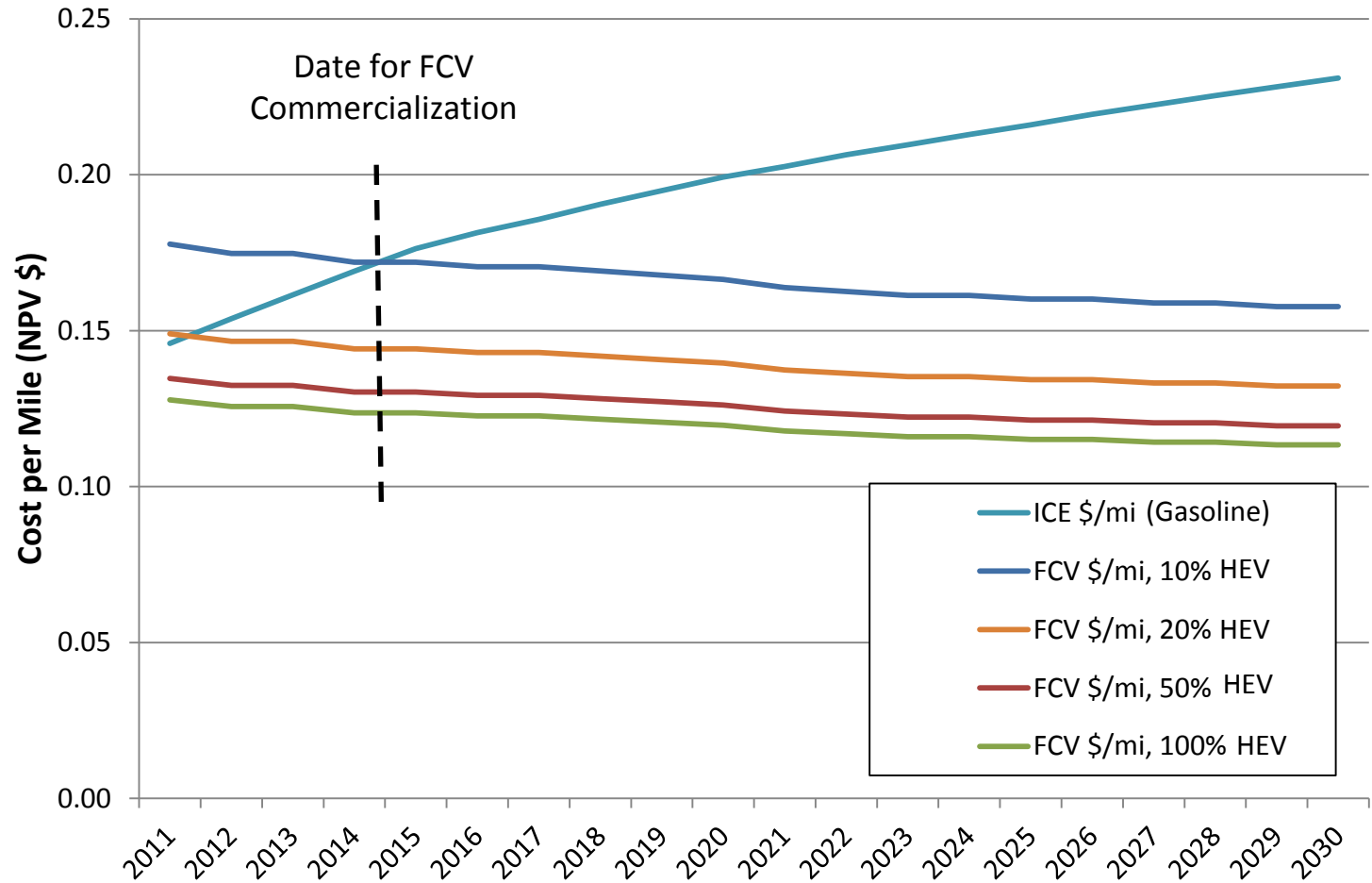
Liquid H₂ Fueling Station



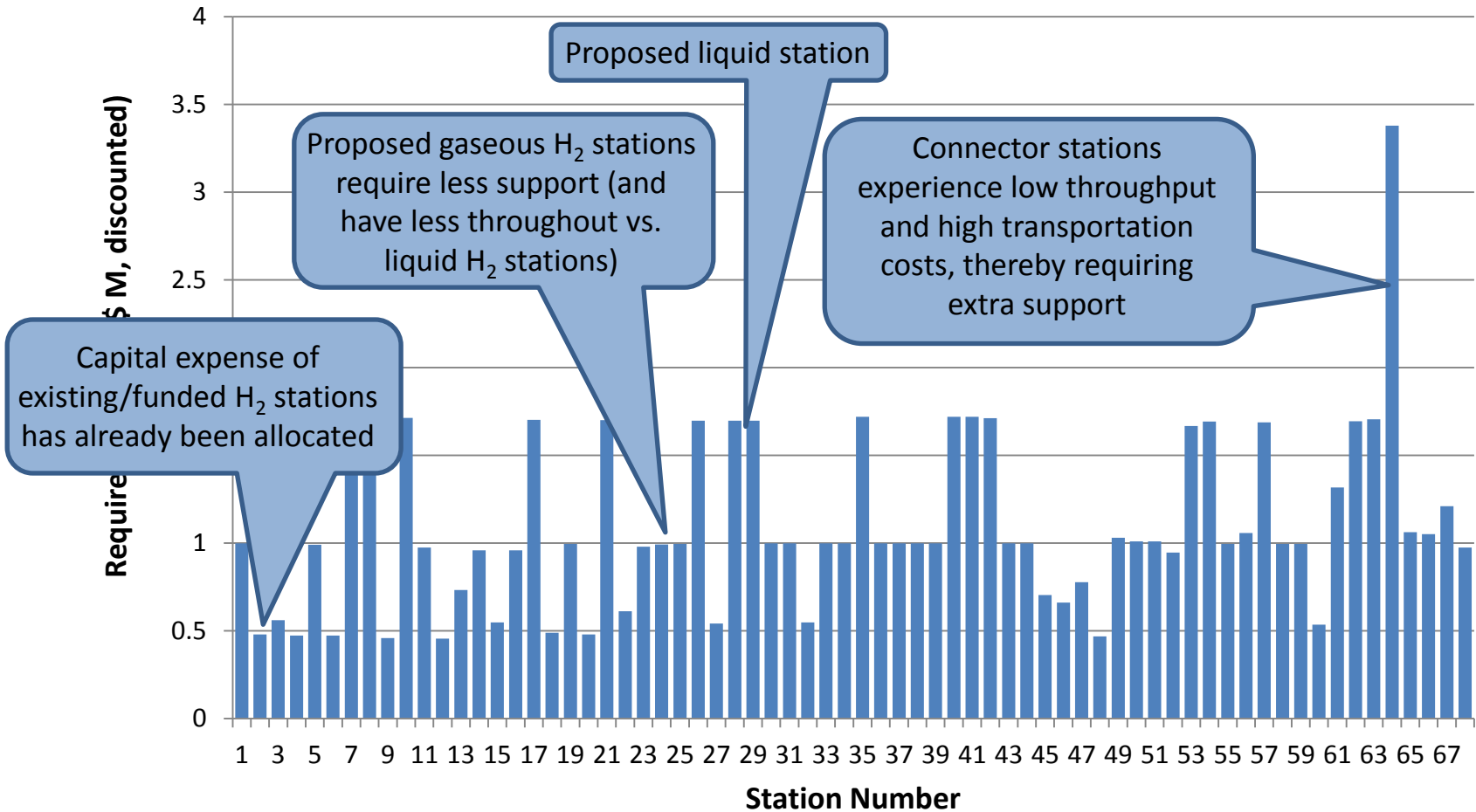
* Assuming 1/5 HEV adoption rate for FCVs.



Gaseous H₂ Station: Operating Cost Comparison



Required Support per H₂ Fueling Station Varies*



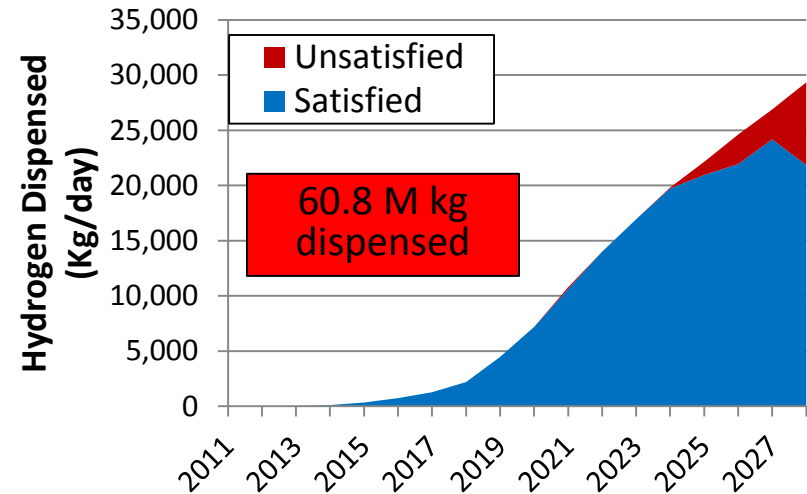
* Represents the negative cash flow that must be offset in the early years of each H₂ fueling station's life; does not consider any potential profits occurring in later years.



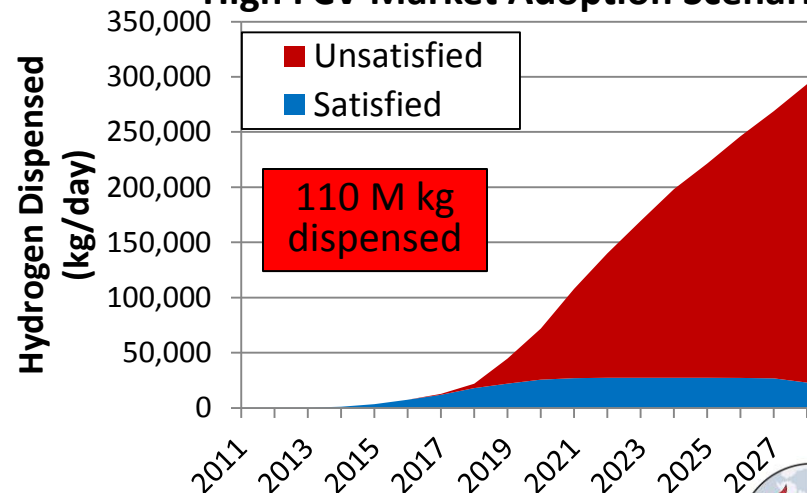
Unsatisfied Demand “Balances” H₂ Network

- In both the high FCV adoption rate (HEV) scenario, and the low FCV adoption rate (1/10 HEV) scenario, the max H₂ throughput is over 20,000 kg/day
- For the low scenario, max is attained just before H₂ stations start to reach end of life in 2025
- For the high scenario, max H₂ throughput is attained in 2021 and maintained for 6 years
- Max H₂ throughput results for all FCV adoption rates; unsatisfied demand “balances” H₂ network.

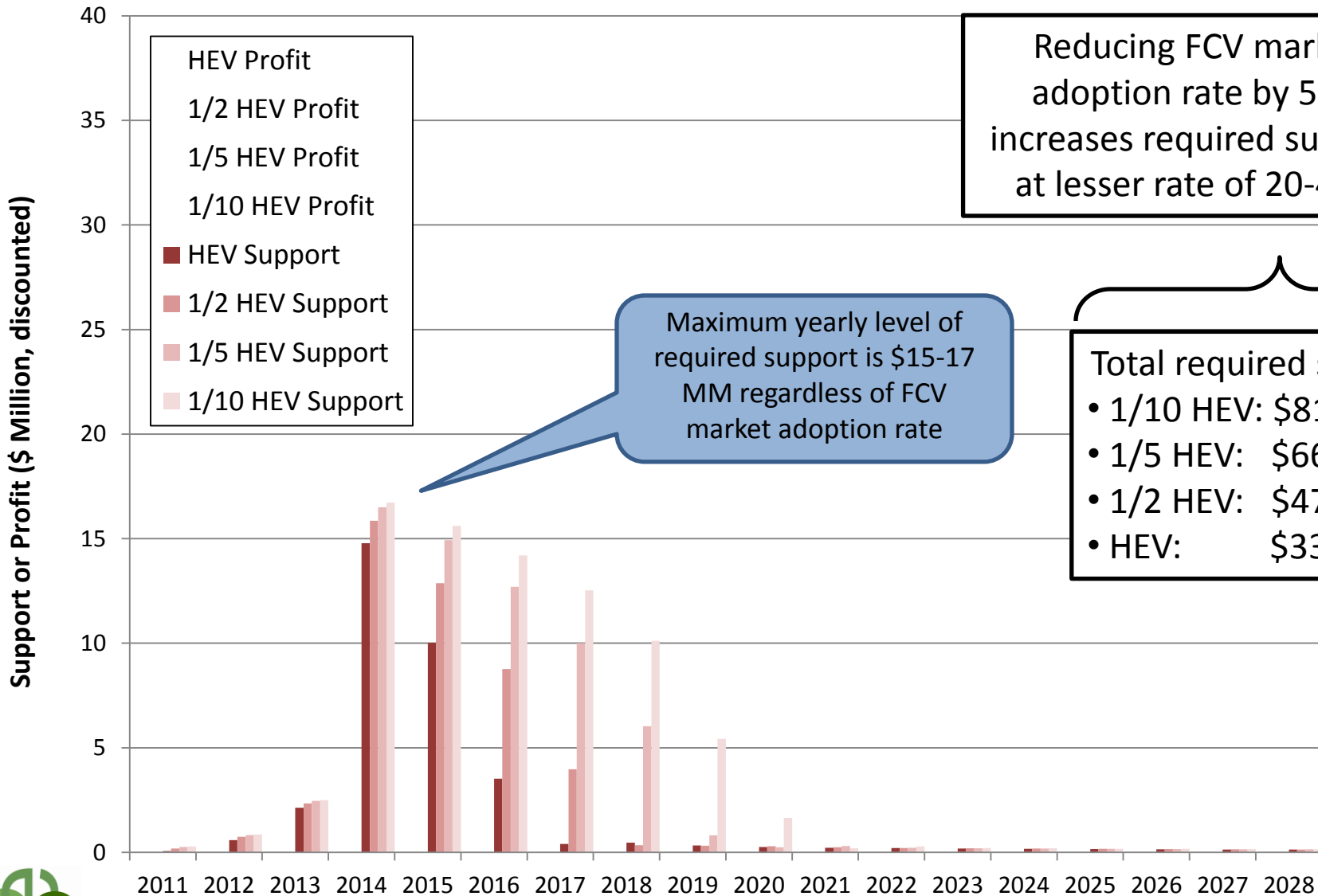
Low FCV Market Adoption Scenario



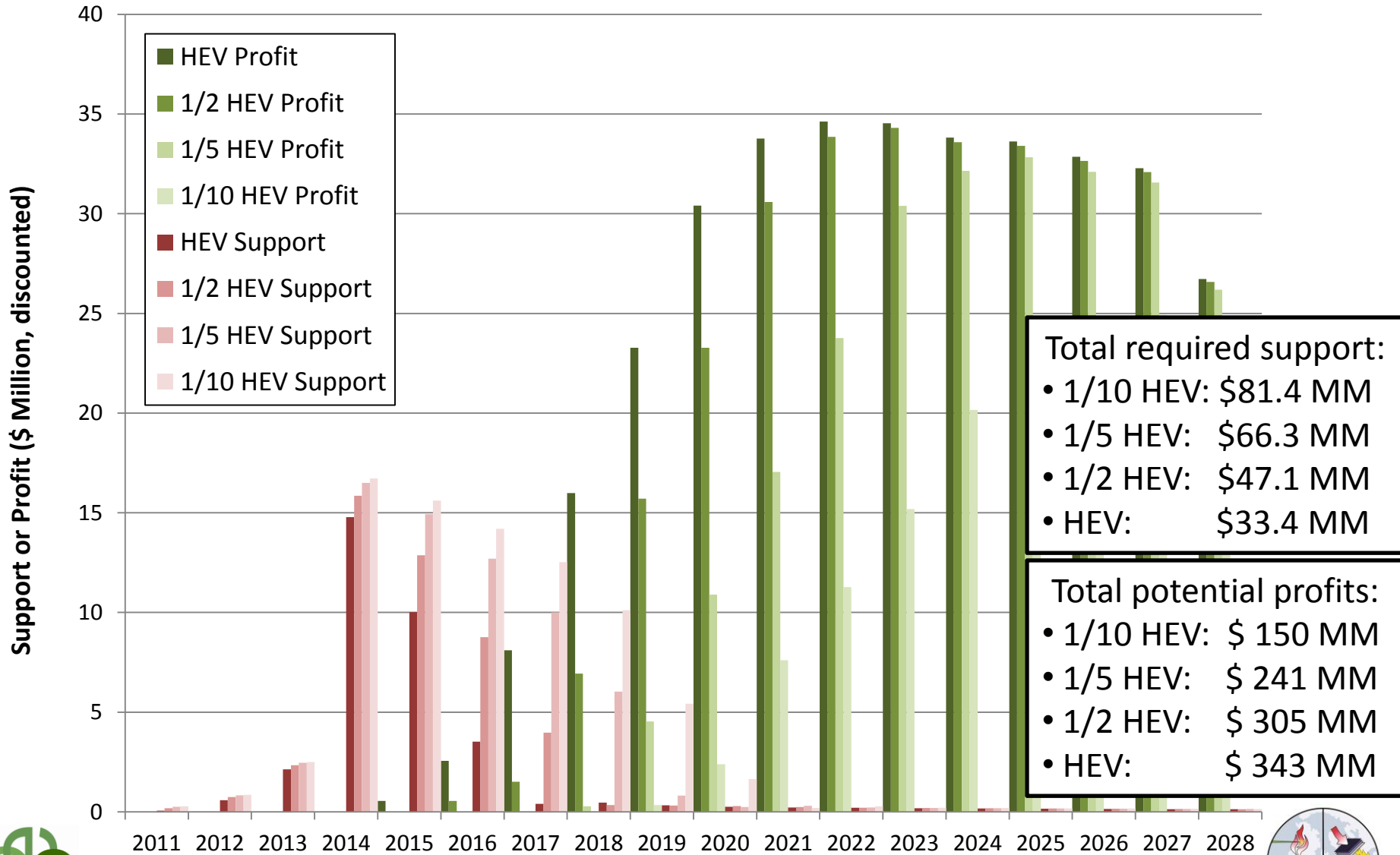
High FCV Market Adoption Scenario



Required Support for 68 H₂ Station Network



Overall Economics of 68 H₂ Station Network



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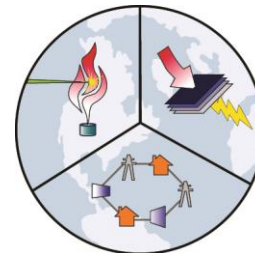
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