

Policies to Promote Alternative Fuel Vehicles: What can we learn from the literature?

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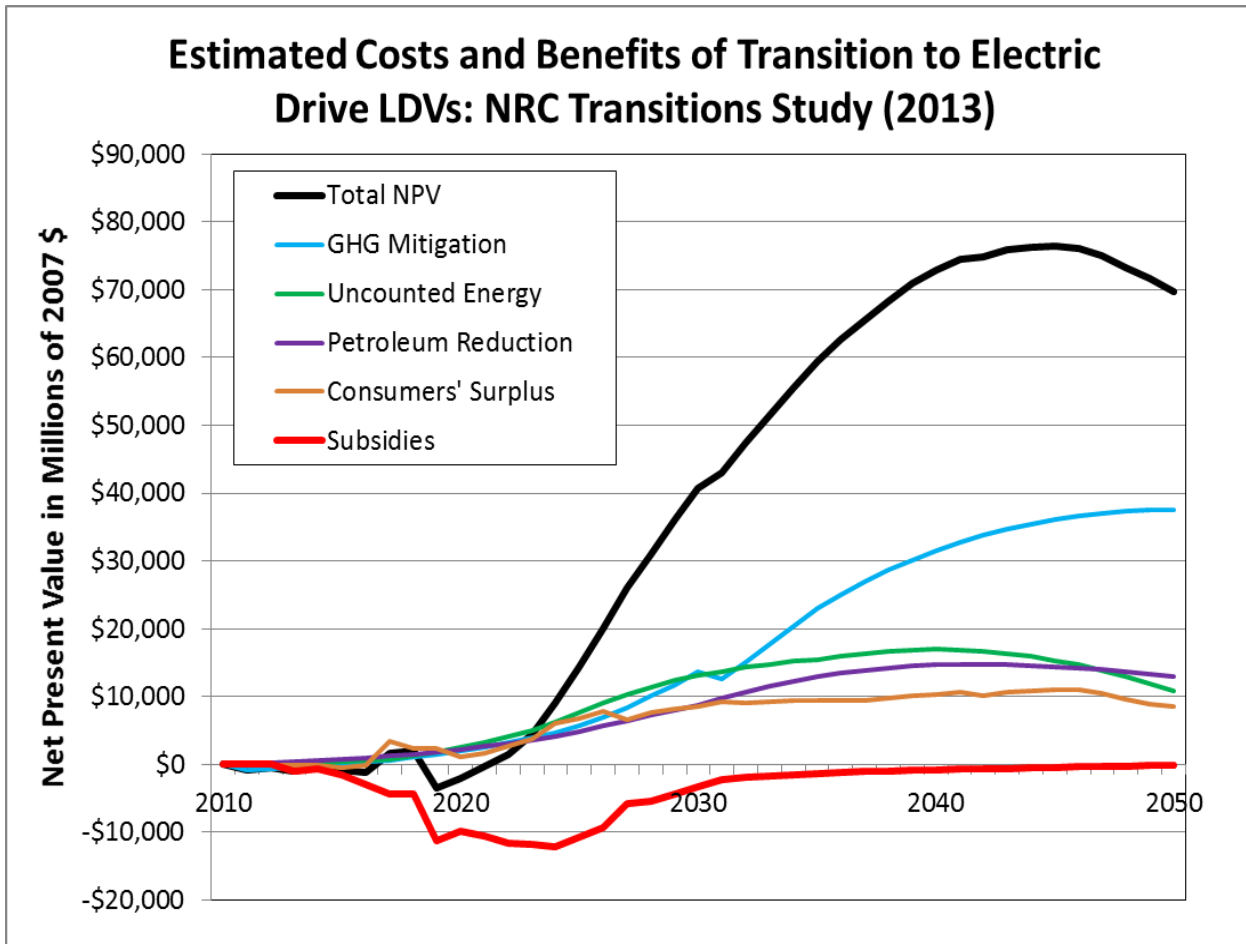
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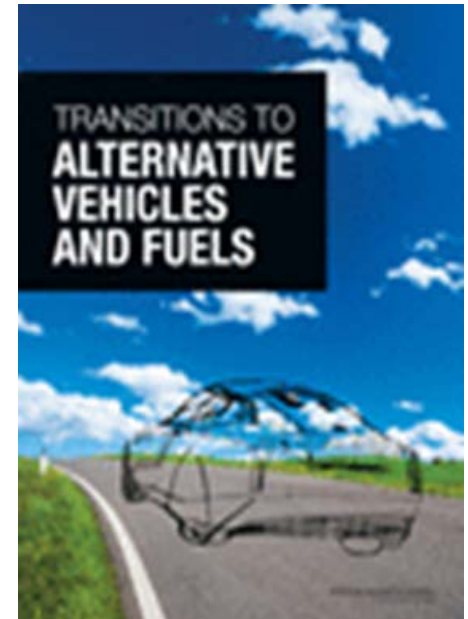
Creating an energy transition for the public good is a new challenge for public policy.

- What problems (barriers) must be overcome?
- Policies to:
 - Reduce cost of vehicle
 - Reduce cost of fuel
 - Add value to choice of alternative
 - Build institutional infrastructure
- Large scale energy transitions need a complex, multi-dimensional policy strategy.

Energy transitions: Take decades, are uncertain, have strong positive feedbacks, are complex.



LDV =Light-Duty Vehicle



What barriers must be overcome?

- Reduce the costs of vehicles
 - Economies of Scale
 - Learning by doing
 - Technological progress
- Reduce the costs of refueling
 - Scale economies, Learning by doing (LBD), technological progress
 - Codes, standards, ordinances
 - Increase fuel availability & utilization
- Increase the value of the vehicle & fuel
 - Decrease majority risk aversion
 - Increase awareness & familiarity
 - Increase diversity of choice
 - Enhance image

McNutt & Rodgers' (2004) review of alternative fuel (AF) policies provides lessons that remain valid today

- **The incumbent vehicle and fuel technology** will be difficult to displace, in part because it **will adapt and improve** to compete with alternatives.
- Niche markets will not grow into mass markets unless alternative vehicles and fuels offer **compelling advantages to consumers**.
- Consumers make vehicle choices based almost entirely on **private not social benefits**.
- **Low energy density fuels** that require more frequent refueling **impose real costs** on users and are an important barrier to mass market adoption.
- A successful transition is likely to require **disincentives for continued use of conventional fuels** as well as incentives for alternatives.
- Unregulated and unsubsidized private sector investment in refueling **infrastructure was rarely built in advance of market development and when it was, the financial results were disappointing**.
- **Coordination between the automobile and energy industries is vital**.
- **Scale matters a great deal** in the automotive and fuel industries. Low volumes in early markets are a large financial barrier.

Reviewing the recent evidence.

- Much of the recent “revealed preference” evidence comes from studies of hybrid vehicle sales (1999-2014).
- Fuel availability was not an issue.
- Revealed preference studies of Plug-in Electric Vehicle (PEV) sales are less numerous and recharging availability is less critical than hydrogen refueling availability for a Fuel Cell Electric Vehicle (FCEV).
- Evidence for FCEVs comes mostly from “stated preference” surveys and simulation.

Reduce vehicle cost

Studies of hybrid sales offer relevant insights.

- Prius buyers received the full benefit of tax subsidies (Sallee, 2011).
- 3% to 20% of hybrid sales in 2006 due to the federal income tax credit (Beresteneau and Li, 2011).
- Subsidies at time of purchase worth ten times future tax credit (Gallagher and Muehlegger, 2011).
- Behavioral economic theory predicts immediate rebate worth 2X a future tax credit (Khaneman, 2011; Diamond, 2009; Axsen, 2009).
- The complexity of the federal tax credit for hybrids weakened its impact (Cahill, 2015).
- Size (salience) matters: only incentives above \$1,000 had a statistically significant impact on sales (Jenn et al., 2013).
- International studies: financial incentives most important factor in PEV sales (Sierzchula et al., 2014; Mock and Yang, 2014).

Reduce vehicle cost

Lessons from the literature

- Subsidies available at time of purchase have at least twice the impact of future tax credits.
- Subsidies must be large enough to get the consumers attention.
- Simple is better than complicated.

Non-financial incentives can also be effective but are location-specific.

- High-Occupancy Vehicle (HOV) lane sticker worth \$1,200 to \$4,000 in CA (Blanco, 2009; Wood yard, 2007).
- HOV access increased sales in VA but not 5 other states (Gallagher and Muehlegger, 2011).
- Non-HOV incentives were not statistically significant (Diamond, 2009).
- HOV access incentivized CNG sales in LA but not other cities (Kelley, 2015).
- HOV access, exemption from emissions testing and annual fee reductions boosted PEV adoption but public charger availability, home charger subsidies, license fee exemptions and free parking did not Jin et al. (2014).
- In Germany, free parking and bus lane access valuable to alternative fuel vehicle purchasers.

What about attitudes and greenness?

- Environmental issues weaker motivation than economics
- BUT those concerned about climate change were 44 times more likely to be willing to consider a plug-in vehicle.
- Those concerned about energy independence 71 times more likely to consider PEV (Krupa, 2014).
- Even pro-environmental: 1 in 10 considered environmental impacts in most recent vehicle purchase.
- Early adopters of Electric Vehicles (EV) are more highly educated, environmentally sensitive and believe that reducing oil dependence is important (Carley et al., 2013).
- Consumer awareness of BEVs, educational attainment, warm climate, and population density as strongly related to EV market shares as the price of gasoline and the extent of charging infrastructure (Vergis and Chen, 2015).

Word of mouth, advertising, reviews and ratings, dealer experience

- Public knowledge of PEV policies ranged from 0.3% to 5.5%.
- 4 out of 5 said incentives increased likelihood of PEV purchase (Krause et al., 2013).
- Most say opinions of others would have little influence on likelihood of buying a Plug-in Hybrid Electric Vehicle (PHEV) (Krupa et al., 2014).
- Majority say at least 18% of the vehicles on the road must be PHEVs before they would consider buying one.
- Target policies to areas where early adopters are most concentrated (Skerlos and Winebrake, 2010; Green et al., 2014).
- New car dealers influence sales but the evidence is based on customer satisfaction surveys rather than sales impacts.
 - PEV buyers rated the dealer experience lower than conventional vehicle buyers (Cahill et al., 2015).
 - Sales personnel misperceived the value of time spent selling a PEV.

Other barriers:

Lessons from the literature

- The right non-financial incentives in the right locations can be almost as important as financial incentives.
- Well educated, green consumers concerned about energy security are most likely to be early adopters.
- Increasing consumer awareness of vehicles, fuels and incentives is considered important but has received relatively little study.

Reduce the cost of refueling.

Fuel prices matter.

- Higher gasoline prices increased HEV & BEV sales (Vergis and Chen, 2015).
- Price of electricity negatively correlated.
- Hybrid buyers willing to pay only $\frac{1}{2}$ present value of fuel savings (Gallager and Muehlegger, 2011).
- 86% said fuel savings an important factor in likelihood of purchasing a PHEV (Krupa et al., 2014).
- Those considering purchasing a PHEV willing to pay only \$1,858 for \$500/year in fuel cost savings, a 3.7 year payback (Krupa et al., 2014).
- Majority (not interested in a PHEV): 1.6 year payback.
- Two studies: BEVs could compete with gasoline vehicles when gasoline prices exceeded \$5/gallon (Deloitte, 2011; Egbue and Long, 2012).
- Results are consistent with other survey evidence on willingness to pay for fuel savings (Greene et al., 2013).

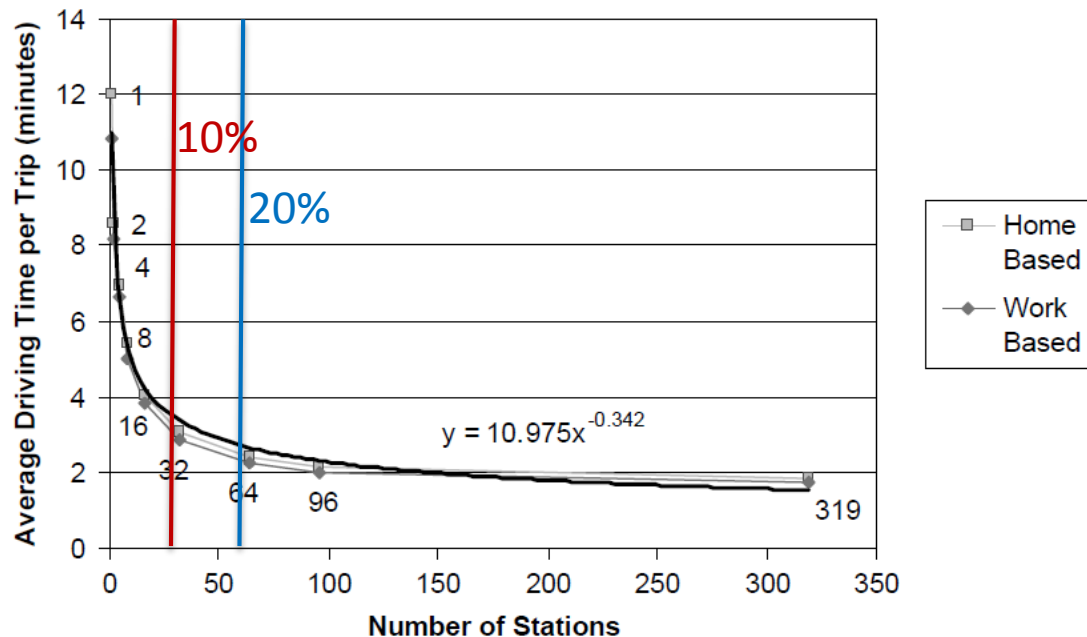
Reduce the cost of refueling:

Fuel availability

- Importance varies greatly by vehicle technology.
- One US survey: availability of 1% to 10% like price increase of \$4,250 to \$16,000 (Melaina et al., 2013).
- Those not interested in Alternative Fuel Vehicles (AFV) more worried about fuel availability than early adopters.
- PEV owners do 75%-80% of recharging at home (INEL, 2014).
- Awareness of public recharging weakly related to interest in PEVs (Bailey, 2015).
- Value of recharging networks in San Francisco and Seattle, \$1,000-\$2,000 per BEV. Other cities, \$100-\$1,000 (Lutsey, 2015).

How much fuel availability is enough?

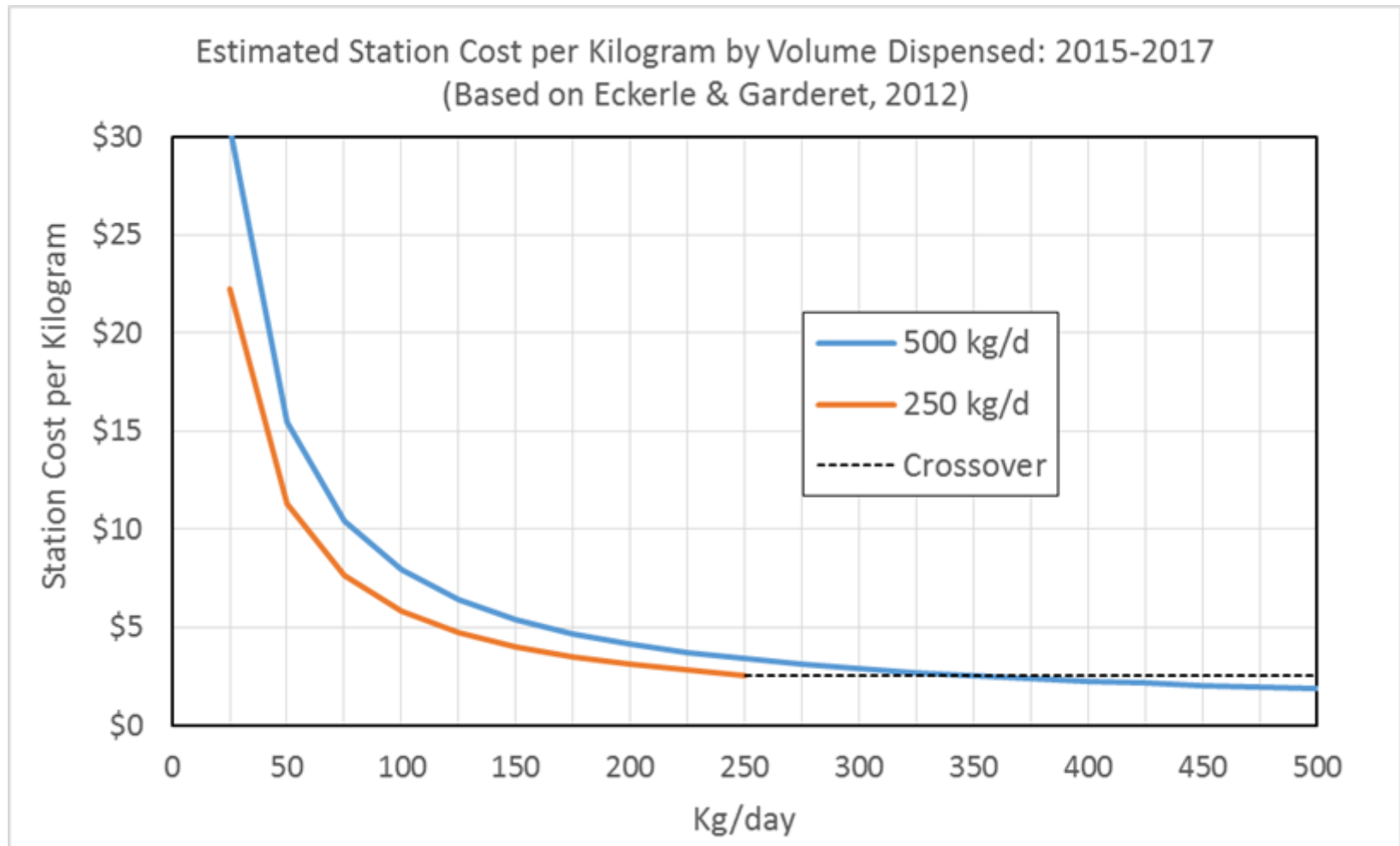
- Minimum for first adopters is 15% to 20%, according to a modeling analysis by Gnann and Plotz (2015).
- Fuel availability does not become a minor concern for most until availability reaches 15% to 20% (Sperling and Kurani, 1987; Greene, 1998; Liu and Greene, 2015).
- The time cost of access decreases exponentially with the number of stations (Nicholas, Sperling and Handy, 2004).



Reduce cost of refueling: Lessons from the literature

- Fuel prices matter, especially gasoline price.
 - Innovative policies to increase gasoline prices?
 - Reducing petroleum demand will reduce its price.
- A minimal refueling network may be OK for innovators but the transition to mass market adoption will likely require 20% of gasoline availability, or more.

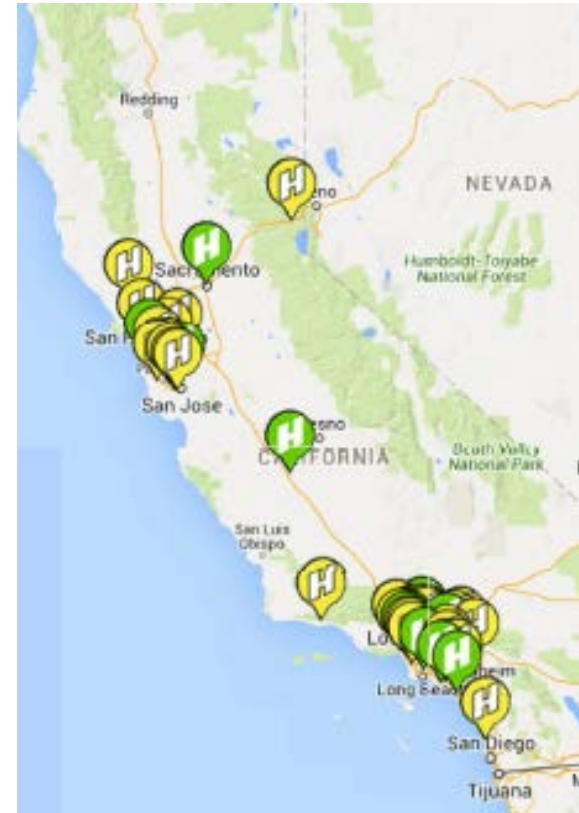
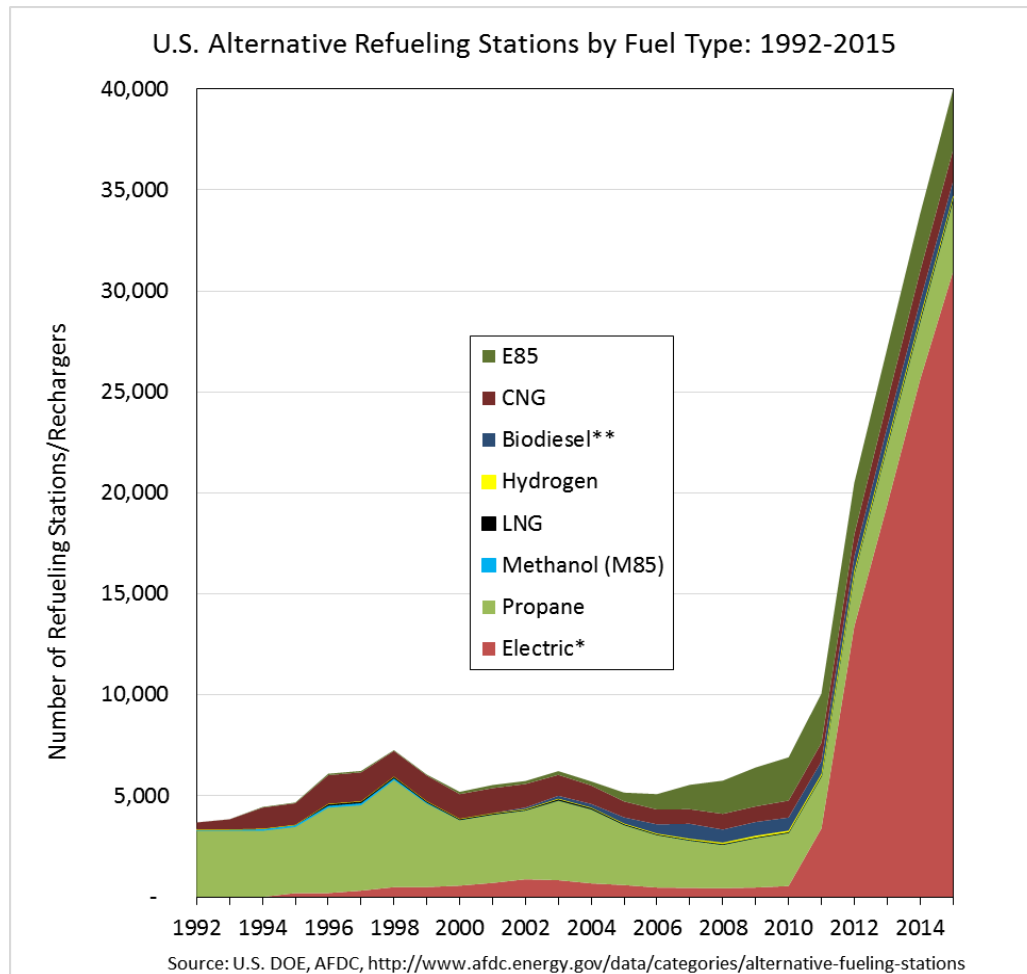
Business models for early AF refueling infrastructure are problematic because it appears that capacity must exceed demand for the vehicle market to grow.



Early alternative fuels infrastructure requires support. What works best?

- Low utilization and uncertain future demand makes investment unattractive in early markets (Eckerle and Garderet, 2012; Brown et al., 2013; Botsford, 2012).
- Requires capital and/or operating subsidies to create 3-5 year payback (IPHE, 2010).
- ARRA provided \$400 million for vehicle electrification, increased the AF infrastructure tax credit to 50% or \$50,000.
- With 50/50 ARRA funding, EV Project installed 12,000 level 2 chargers (residential and public) and 100 DC fast chargers.
- The 12,552 public charging stations in the U.S. (AFDC, 2016) have very low utilization rates (Green et al., 2014).
 - Sites with at least 3 events/week averaged 4-7 per week (INEL, 2014)
 - Most sites had fewer charging events.
 - NRC (2015) EV Barriers Committee: federal government should refrain from further investment until relationship between infrastructure and PEV adoption are better understood.

Investment in Electric Vehicle Service Equipment (EVSE) has far exceeded all other alternative fuels infrastructure. But a combination of state subsidies, ZEV mandates and other incentives is building a hydrogen refueling network in CA.



12 Open, 29 to open in 2016.

By requiring manufacturers to sell Zero Emission Vehicles (ZEV) the mandates induce more than subsidies.

- Manufacturers market more models in ZEV states (Lutsey et al., 2014).
- ZEV also increases manufacturers' motivation to help solve the “chicken or egg” problem.



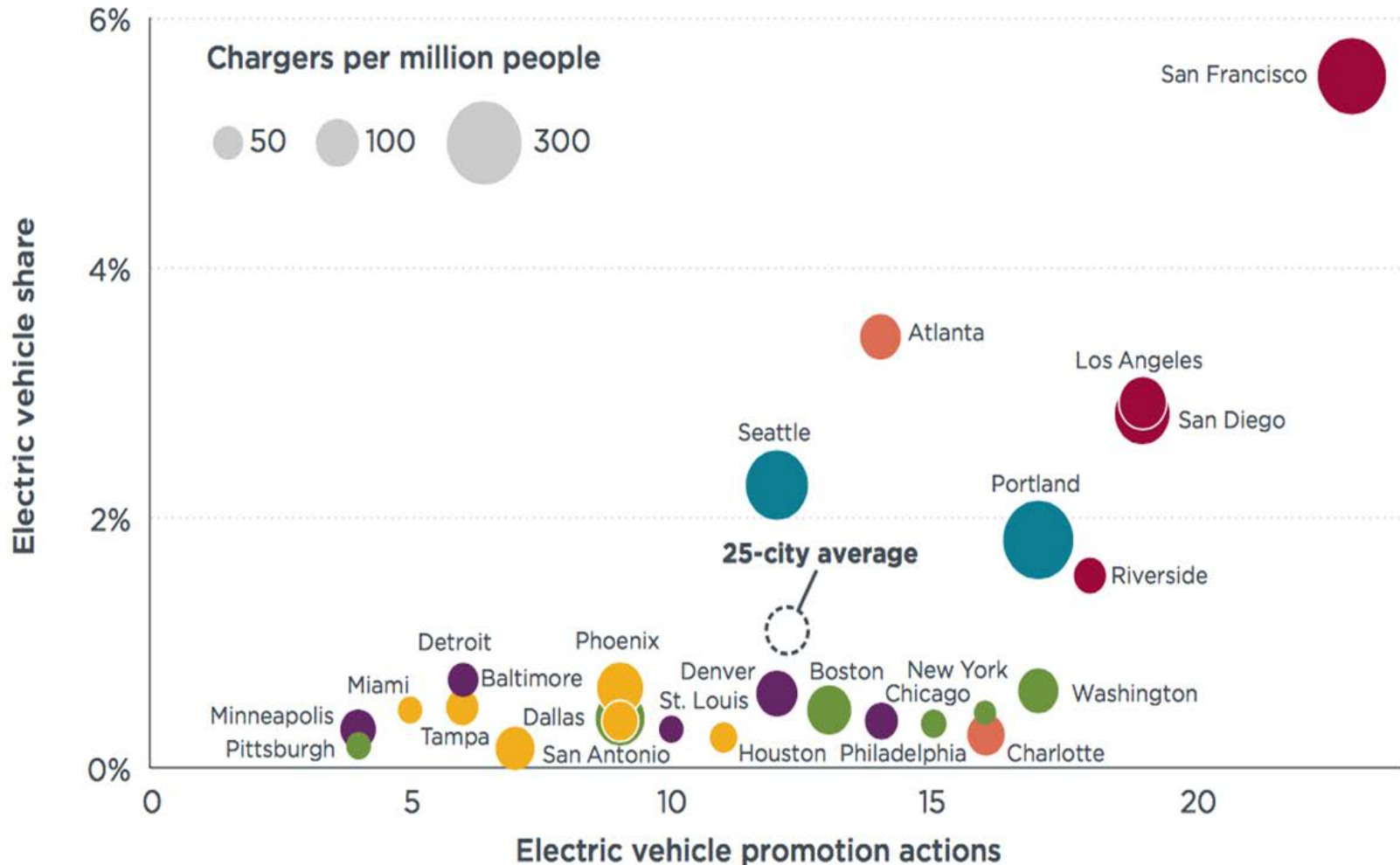
By John Goreham G+ 2014-05-09 13:42

Toyota, California, and FirstElement Fuel to build 100 hydrogen stations

Source: John Goreham, TorqueNews, www.torquenews.com/1083/toyota-california-and-firstelement-fuel-build-100-hydrogen-stations

Given their importance, the ZEV mandates have received too little attention in published studies.

- Leading cities in PEV deployment tend to be in states that have adopted California's ZEV requirements (Lutsey et al., 2015).



POLICY STRATEGIES: Countries with a large share of EV sales:

- Support R&D
- Have efficiency standards (all) with incentives for AFVs (except 1)

Area	Action	China	France	Germany	Japan	Netherlands	Norway	United Kingdom	United States (excl. California)	California
Global market share	Vehicle sales in 2014 (million vehicles)	22	2.2	3.3	4	0.5	0.2	2.6	14	1.7
	Vehicle manufacturing in 2014 (million vehicles)	22	1.7	5.7	10	<0.1	<0.1	1.6	11	<0.1
	Percent of 2014 global electric vehicle sales	17%	4%	4%	10%	5%	6%	5%	19%	19%
Vehicle manufacturer	Research and development support	X	X	X	X	X	X	X	X	X
	Long-term efficiency standards	X	X	X	X	X	X	X	X	X
	Incentive provisions within efficiency regulations	X	X	X		X	X	X	X	
	Cumulative sales goal	X	X	X		X	X	X	X	X
	Vehicle deployment requirements									X
	Vehicle production subsidy	X								

They also have vehicle cost subsidies (except 1), fund public charging infrastructure and have public outreach programs.

Consumer purchase	Vehicle purchase subsidy (tax credit)							X	
	Vehicle purchase subsidy (rebate)	X			X			X	X
	Vehicle purchase tax exemption					X	X		/
	Vehicle fee-bate scheme		X					X	
	Government fleet vehicle purchasing preferences		X		X			X	X
	High fuel price and greater fuel savings		X	X		X	X	X	
Consumer use	Annual vehicle fee exemption			X	X	X	X	/	/
	Discounted/free electric charging				X	X	X	/	/
	Preferential lane (e.g., bus, HOV lane) access			/		X	X		/
	Reduced roadway tax or tolls			X	X	X	X	X	
	Preferential parking access		/	/		/	/	/	/
Fuel provider, infrastructure	Carbon pricing scheme	X	X	X	X	X	X	X	/
	Low carbon fuel incentive for electricity providers							/	X
	Public charging network funding	X	X	X	X	X	X	X	X
	Home charging equipment tax incentives		X						/
Consumer awareness	Public outreach activities to educate on consumer benefits	X	X	X	X	X	X	X	X

Based on IEA, 2015a; Jin et al., 2014; Mock & Yang, 2014; NRC, 2015; OECD, 2015; OICA, 2015a,b; "X" denotes national program; "/" signifies smaller local or regional program

Early alternative fuels infrastructure: Institutional issues also matter.

- DOE's Clean Cities EV Readiness Project examined planning and regulatory issues at all levels of government.
 - State planning toolkit for local governments and agencies
 - Local coordinating councils
 - Workshops with local leaders
 - Panel of experts at state level to assist localities
 - Comprehensive program of education and outreach for public and governments
- Low cost incentives at community level:
 - Waive or reduce EVSE permitting fees
 - Streamline permitting procedures
 - Real estate or sales tax incentives

Refueling infrastructure investment: Lessons from the literature.

- High cost, uncertainty and low utilization make early alternative fuel infrastructure investments unattractive to private investors.
- Public subsidies, ZEV mandates and auto/energy industry cooperation have induced infrastructure investments in ZEV states.
- Institutional issues also must be addressed.
- The literature has almost nothing to say about how best to bridge the gap from niche to mass market (e.g., how to get from 100 stations to 3,000 stations in California).

The complexity of the transition problem appears to require a comprehensive policy strategy addressing all major barriers because of:

- Consumer behaviors that aren't "economically rational"
 - The majority's risk aversion to novel technologies
 - Lack of information and unfamiliarity
 - The tendency of markets to undervalue energy efficiency
- Important non-market processes, including changing government codes, standards and ordinances
- Positive and negative external costs and benefits
 - "chicken or egg" network external benefits
 - Technology "spillover" effects
- Strong positive feedbacks create tipping points.
- Uncertainty and long time constants for change require persistent, adaptive strategy.

What are the most effective and efficient policies?

- Studies do not support an objective, quantitative answer.
- Here is my subjective opinion:
 1. ZEV Mandates
 2. Vehicle subsidies: preferably at time of sale
 3. Fuel and infrastructure subsidies
 4. Low GHG fuel standards
 5. Fossil fuel taxes
 - Road user fee on energy
 - Carbon tax
 6. Building institutional infrastructure
 7. Location-specific non-monetary incentives
 8. Public information and education (but inexpensive)
 9. CAFE/GHG emission standards AF incentives
- Multidimensional policy strategy is far better than a single strategy, such as a carbon tax or cap and trade.

We have a lot to learn.

THANK YOU.