Towards a Policy Framework for Transportation's Energy Transition

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The time has come to focus on the early market transition.

- Research & Development
  - Expert assessments
  - Hedging strategies
  - Analysts have few other good ideas
- Demonstration and Niche Market Deployment
  - Protected, special markets
  - Very limited numbers
  - Relatively small investments
- Early Market Transition
  - Significant market barriers
  - Potentially large investments
  - Sustained effort over decade or more
  - *Uncertain success*

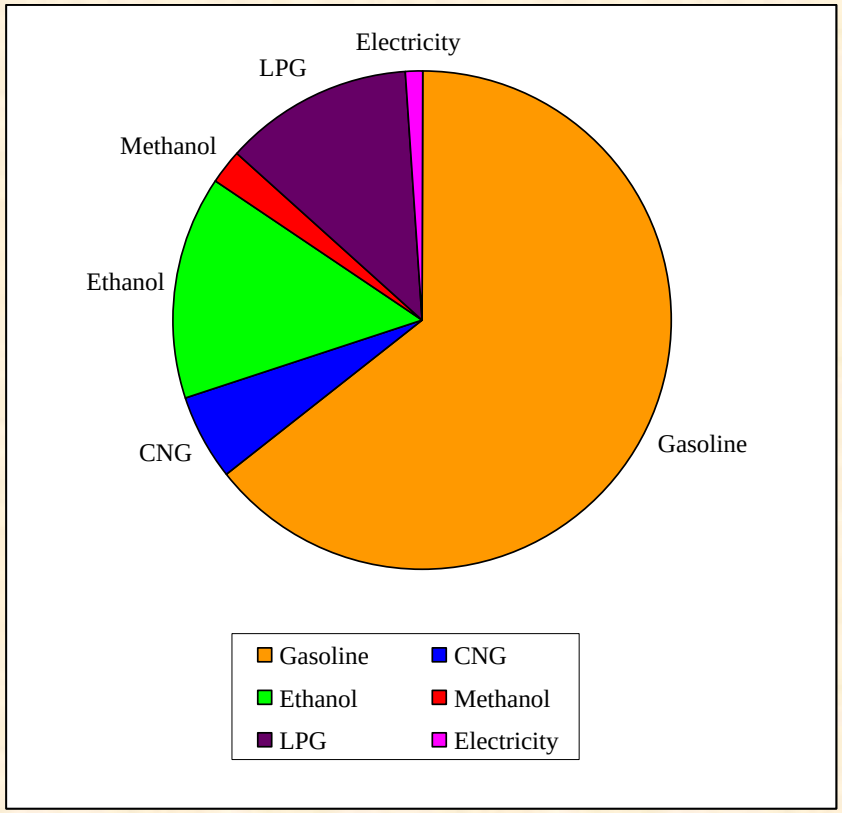
How're we gonna do that?

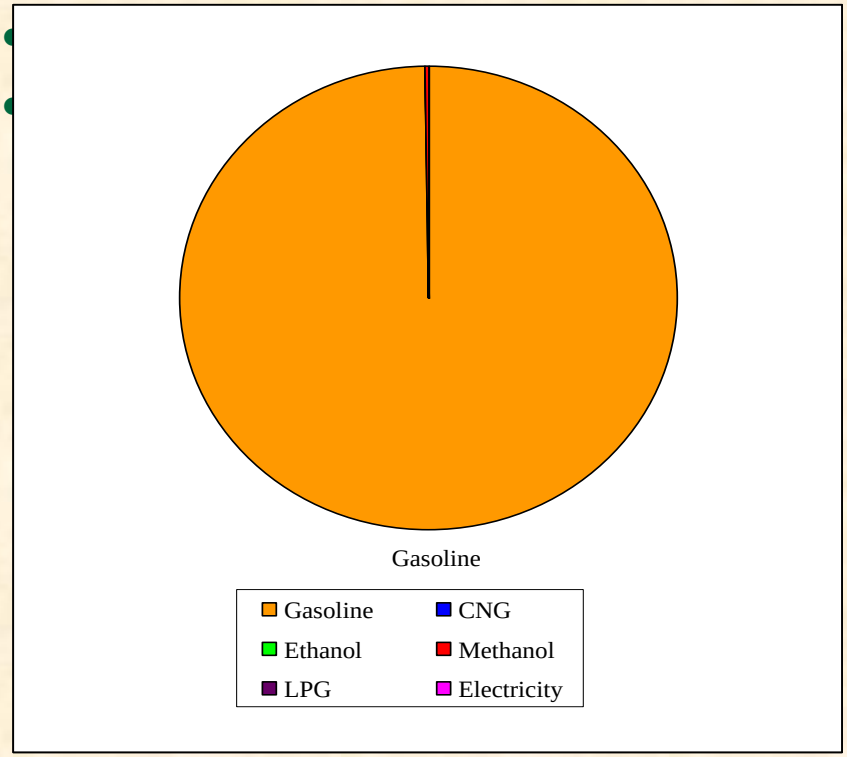
- **"Thus, the policy task may be less to promote zero carbon technologies from the laboratory bench to the market and more to explore ways to ensure that *network effects* enhance rather than bar those low-carbon technologies that on their own will become innovations and commercialized in niche markets." Grübler, Nakićenović and Victor (1999).**
- ***Emphasis added.***

What are the "natural market barriers"?

- Need for technological advances
- **Learning by doing**
- **Scale economies**
- **Resistance to novel technologies (early adopter, early majority, late majority, laggards)**
- **Lack of diversity of choice**
- **Chicken or egg?**
  - **Lack of fuel availability**
  - **Lack of vehicles to use new fuel**

Natural market barriers can and do prevent transitions to alternative energy sources.





The natural market barriers are costs, but looked at from another perspective they may be *positive externalities*.

- **"In economics and business, a** network effect **(also called** network externality**) is the effect that one user of a good or service has on the value of that product to other people. When a network effect is present, the value of a product or service increases as more people use it." (e.g., cellphones)**
- **http://en.wikipedia.org/wiki/Network_effect**

- **"More interestingly, network effects create incentives to "herd" with others. Self-fulfilling expectations create multiple equilibria and cause chicken-and-egg or critical-mass behavior with positive feedback or "tipping":" (points)**
- **Farrell and Klemperer, 2007, *Handbook of Industrial Organization, vol. 3., ch. 31,* "Coordination and Lock-in: Competition with Switching Costs and Network Effects".**

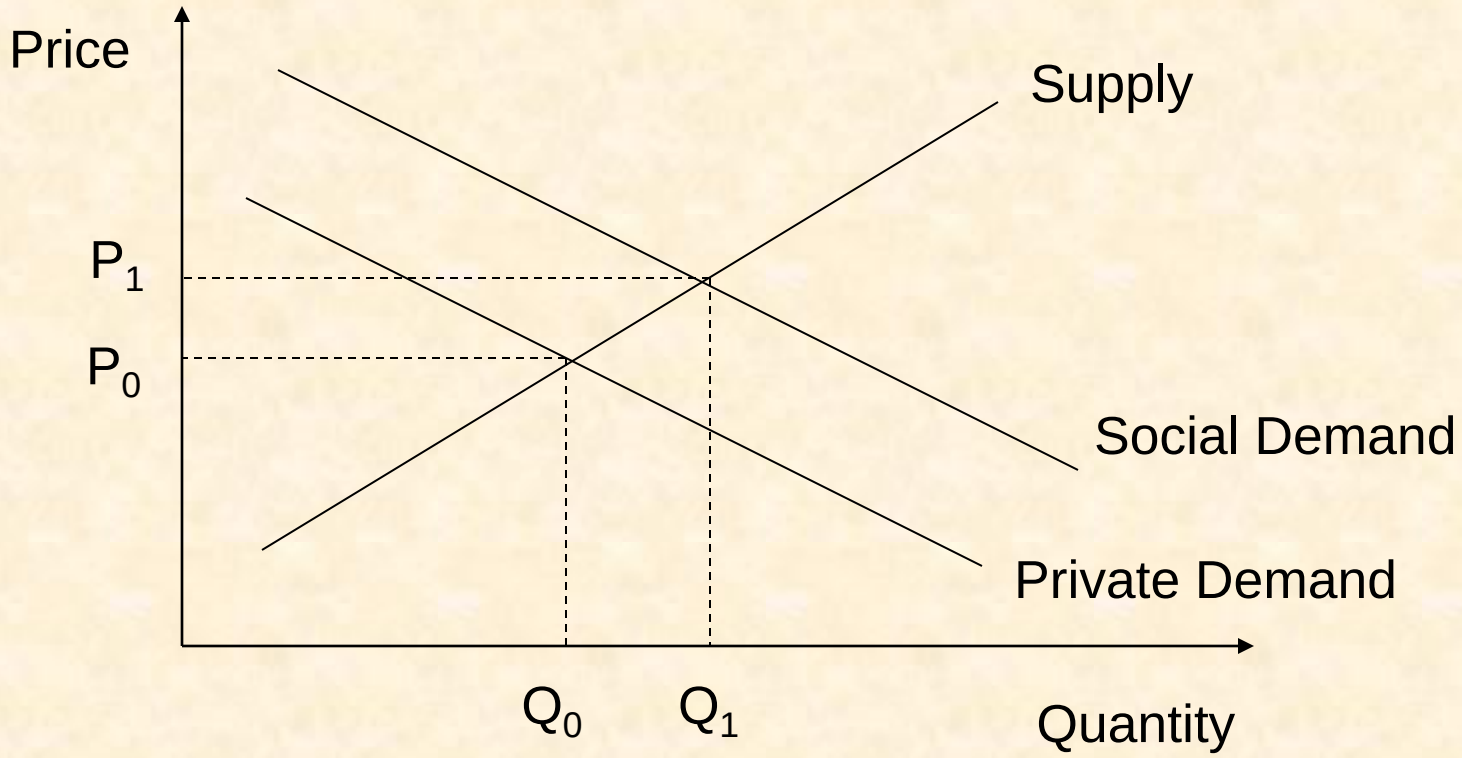
Network effects can be direct, or indirect.

- A good exhibits *direct* network effects if adoption by different users is complementary, so that each user's adoption payoff, and his incentive to adopt, increases as more others adopt.
- *Indirect* network effects arise through improved opportunities to trade with the other side of the market (i.e. vehicles and fuel) and are *almost always pecuniary.*

Which are external benefits and which are not?

- *Externality*: a cost or benefit not transmitted through prices, incurred by a party who did not agree to the action causing the cost or benefit.
- Just as there are optimal Pigouvian taxes for external costs, there are optimal Pigouvian subsidies for external benefits.
- A *pecuniary externality* operates through prices rather than through real resource effects and should not be taken into account in cost benefit analyses. Why not?

The existence of external benefits implies that a commodity will be under-produced and under-consumed. But this is a static analysis. Transitions are inherently dynamic.



"Sequential adoption translates multiple static equilibria into the adoption dynamics characteristic of network markets: *early instability and later lock-in*." (Farrell and Klemperer, 2007, p. 1975)

- **In that case, which are external benefits?**
  - **Learning by doing (supply side)**
  - **Scale economies**
  - **Diversity of choice**
  - **Learning on demand side (early adopter, etc.)**
  - **Chicken or egg (fuel availability)**
- **In a static market model, scale economies are clearly pecuniary externalities.**
- **But, in a dynamic market where the goal is to replace a locked-in technology with another whose public good benefits far outweigh the transition costs and any additional private costs, all off the above are external benefits.**

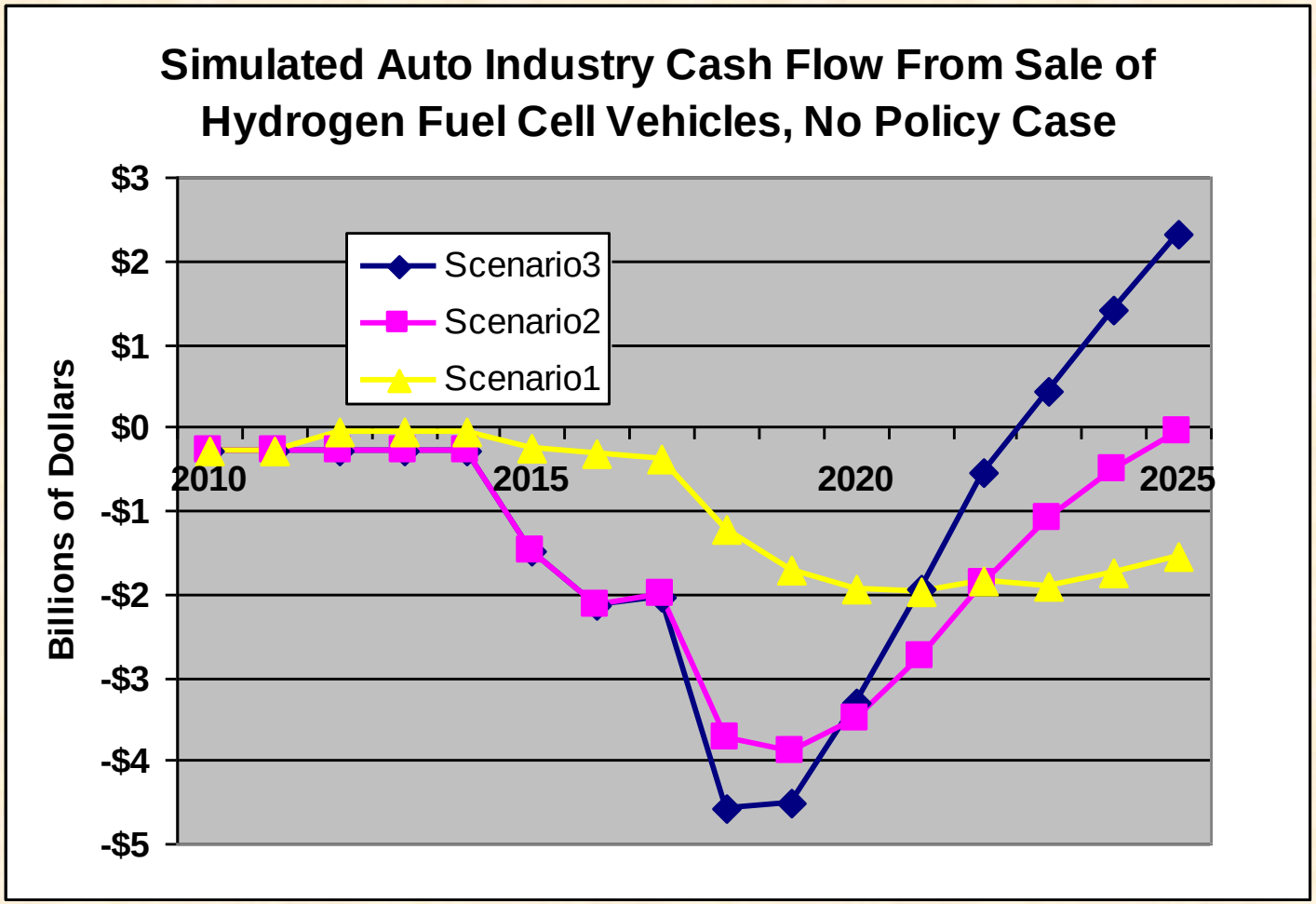
Step 1: Is the societal goal worth achieving.

- In terms of the *net present value* of the transition:
  - Private benefits < Private costs ?
    - Short run: Yes, because of transition barriers and external costs of current system.
    - Long run: Uncertain
  - Public goods benefits > Transition + Long run private costs ?
  - Is the net present societal value of transition > net present societal value of no transition?
- What about uncertainty of technological progress?

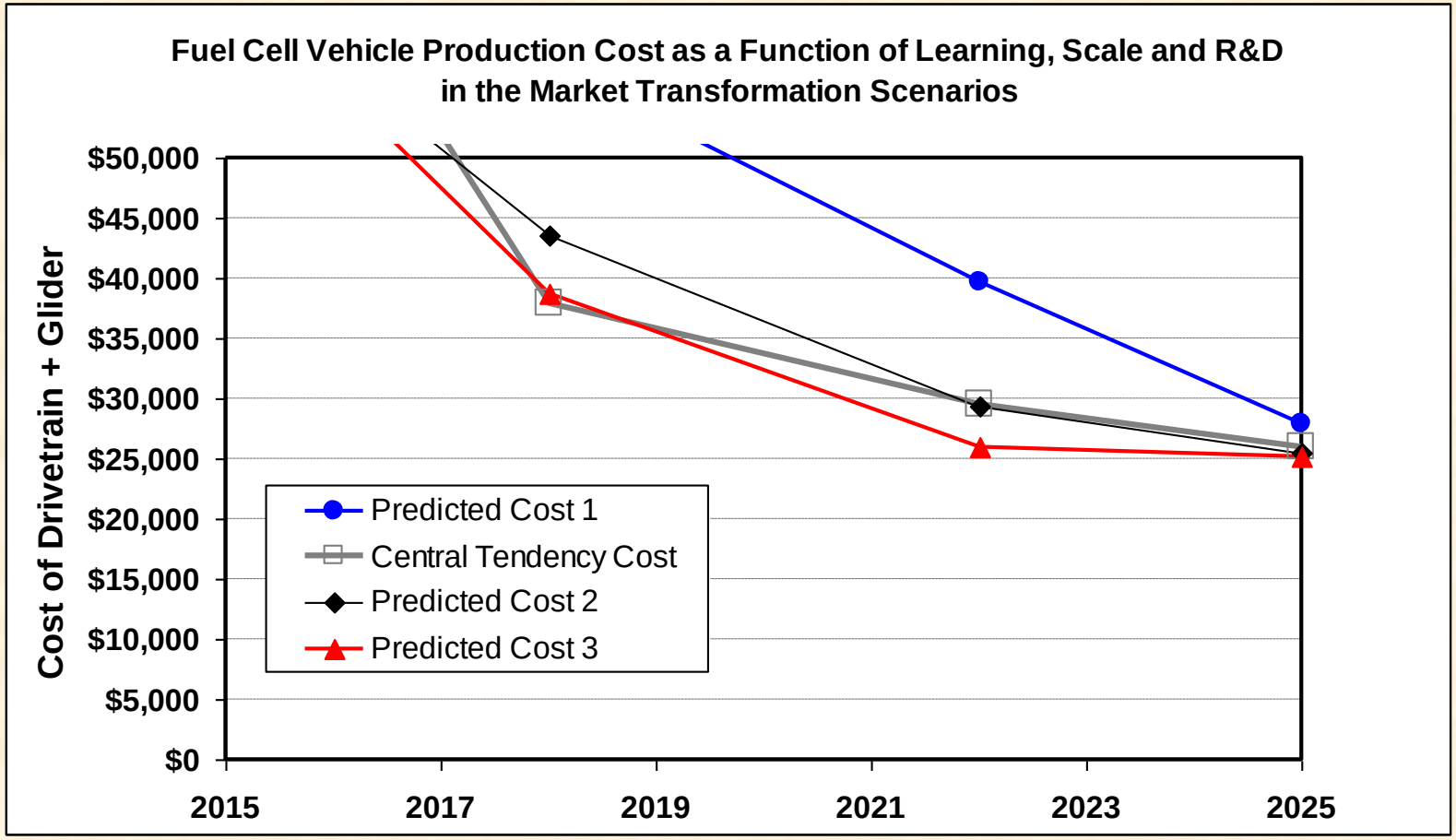
Transition to Zero Emission Vehicles: How big are the public benefits?

- **Based on the NRC 2009 study of "maximum practicable" hydrogen fuel cell vehicles study.**
  - **Rough estimation based on figures 6.32 and 6.33:**
    - **Approx. 20 Gigatons cumulative CO_2 reduction by 2050**
    - **Approx. 50 billion barrels of reduced petroleum consumption**
  - **Converting to dollars & *undiscounted:***
    - **CO2 at $50/ton → $1 Trillion**
    - **Oil security at $20/bbl → $1 Trillion**
- Very roughly, **estimated cost of efficiently compensating for transition costs is on the order of 2-5% of estimated of public benefits.**

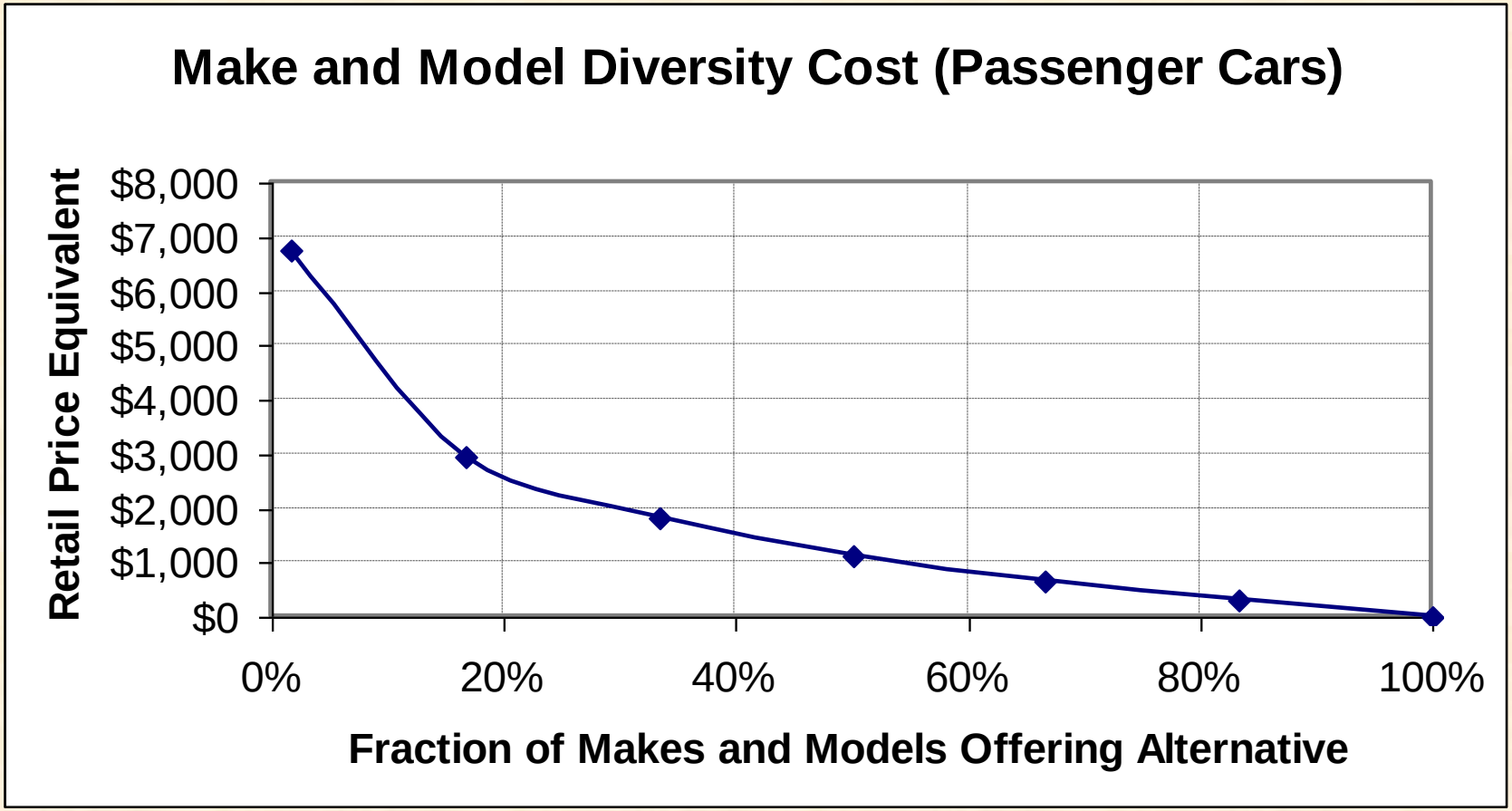
What about the private costs?: The transition's extended period of negative cash flow can make the transition's private NPV unattractive.



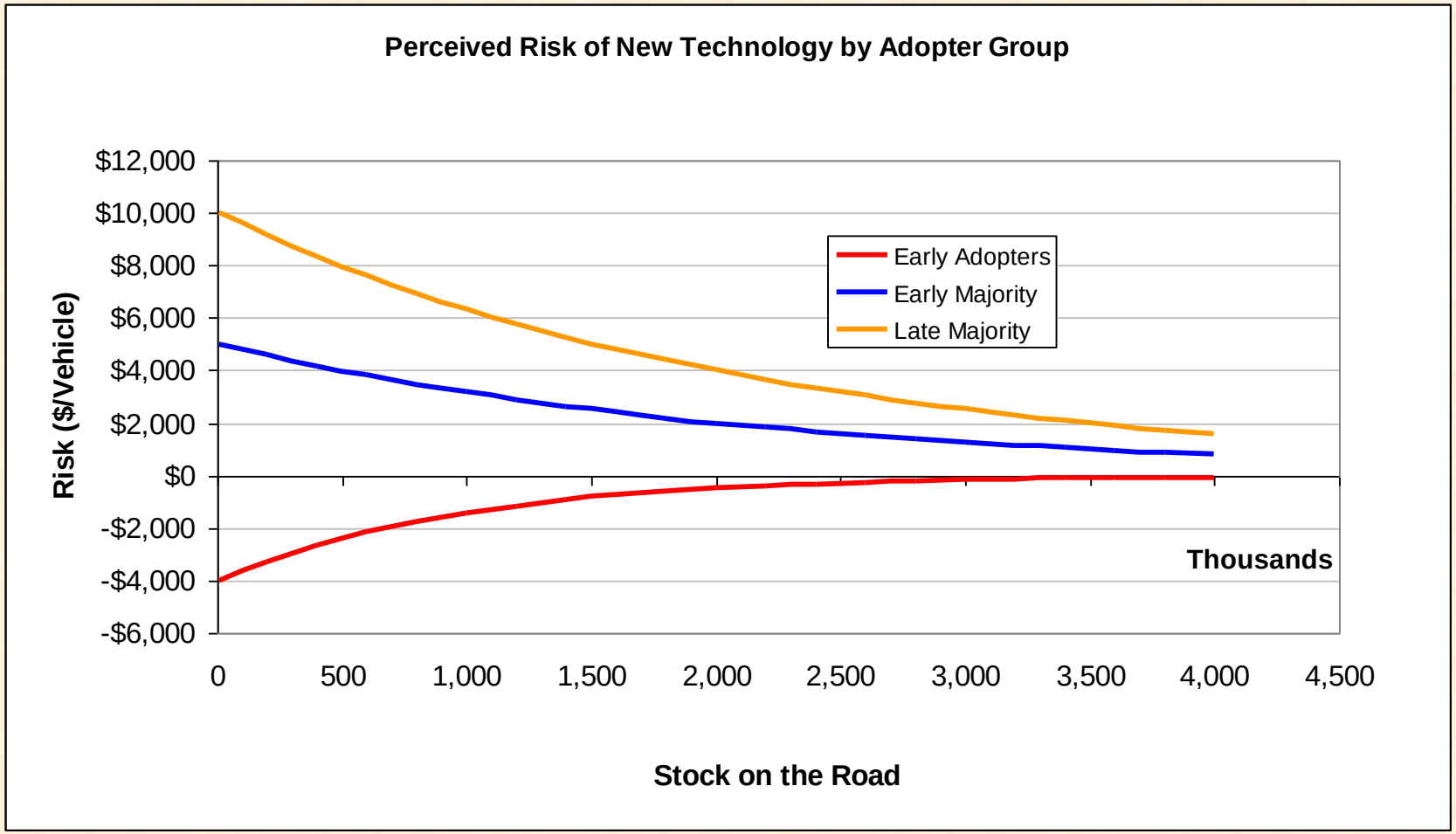
Some of the costs can only be reduced by learning by doing and scale economies. In a static context, these are pecuniary externalities that market actors will take into account. In a dynamic market with sequential adoption this will not generally be the case.



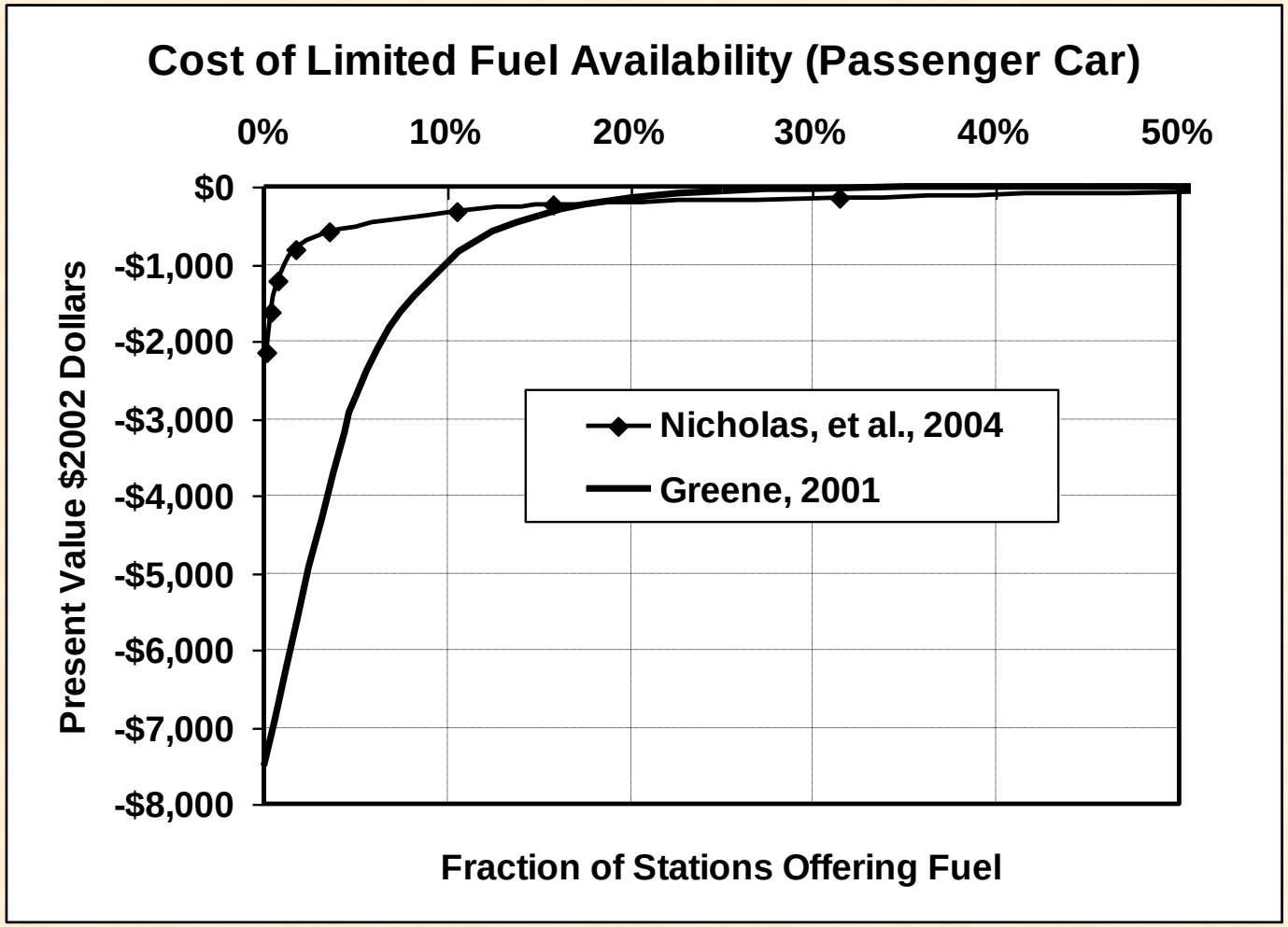
Lack of choice diversity decreases the chance than a given consumer will choose an advanced technology vehicle, and that can be translated into an equivalent price effect. Increased sales lead to greater diversity. Choice diversity is clearly a network external benefit.



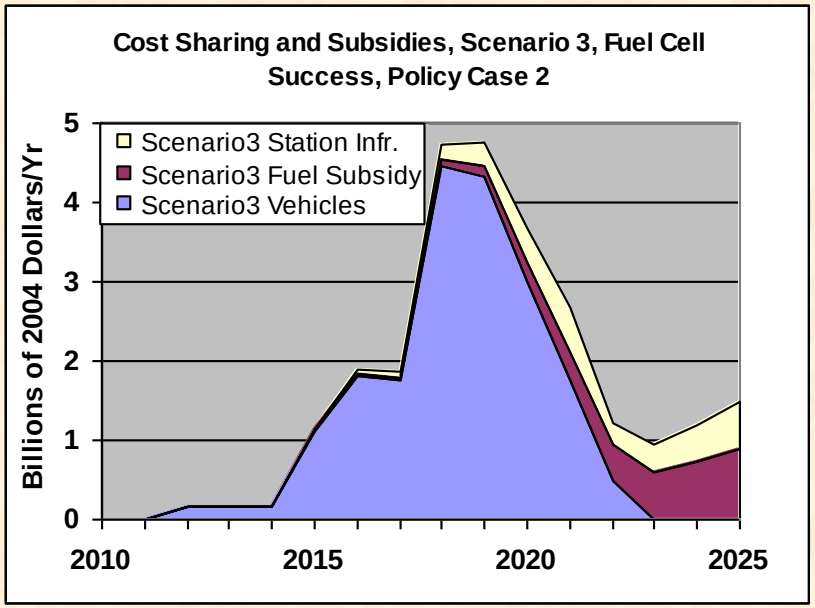
Early adopters reduce the risks of novel technologies for later adopters but reduce the value for their own group. The net effect is also a network external benefit.

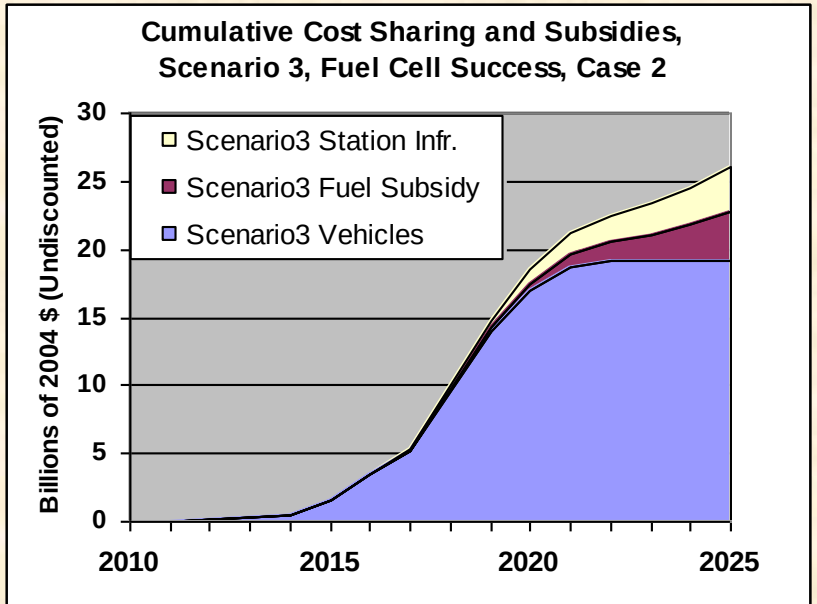


Adding refueling stations increases the value of alternative fuel vehicles to potential buyers. Adding vehicles increases the value of existing stations. (Indirect network external benefit)

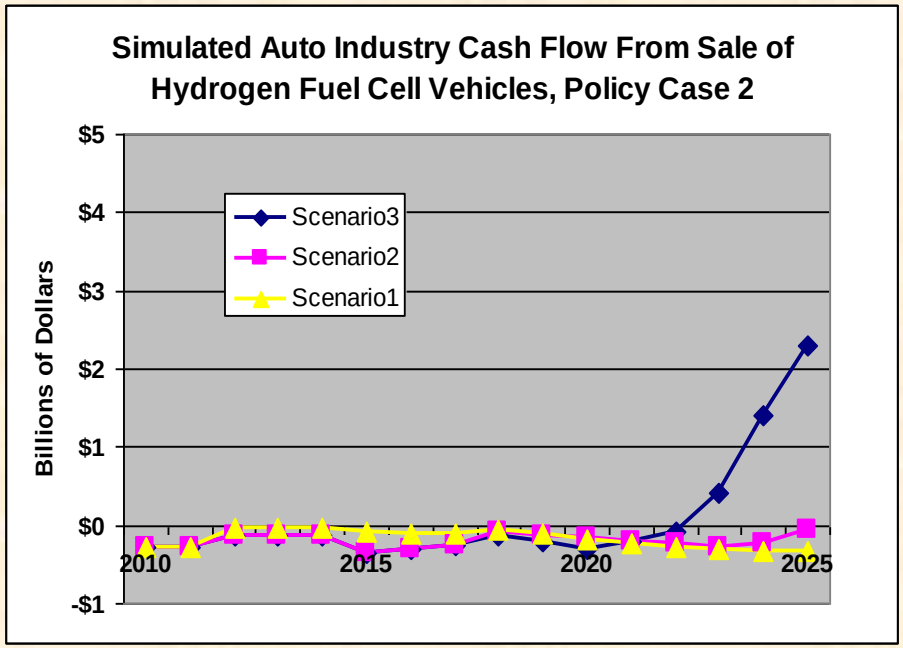


It appears that the transition costs may not be large from a societal perspective. DOE's hydrogen study estimated $25-40B. NRC estimated $55B. ***Both assumed technological success.***





These are not total costs. NAS estimated H2 infrastructure cost alone at $400B.



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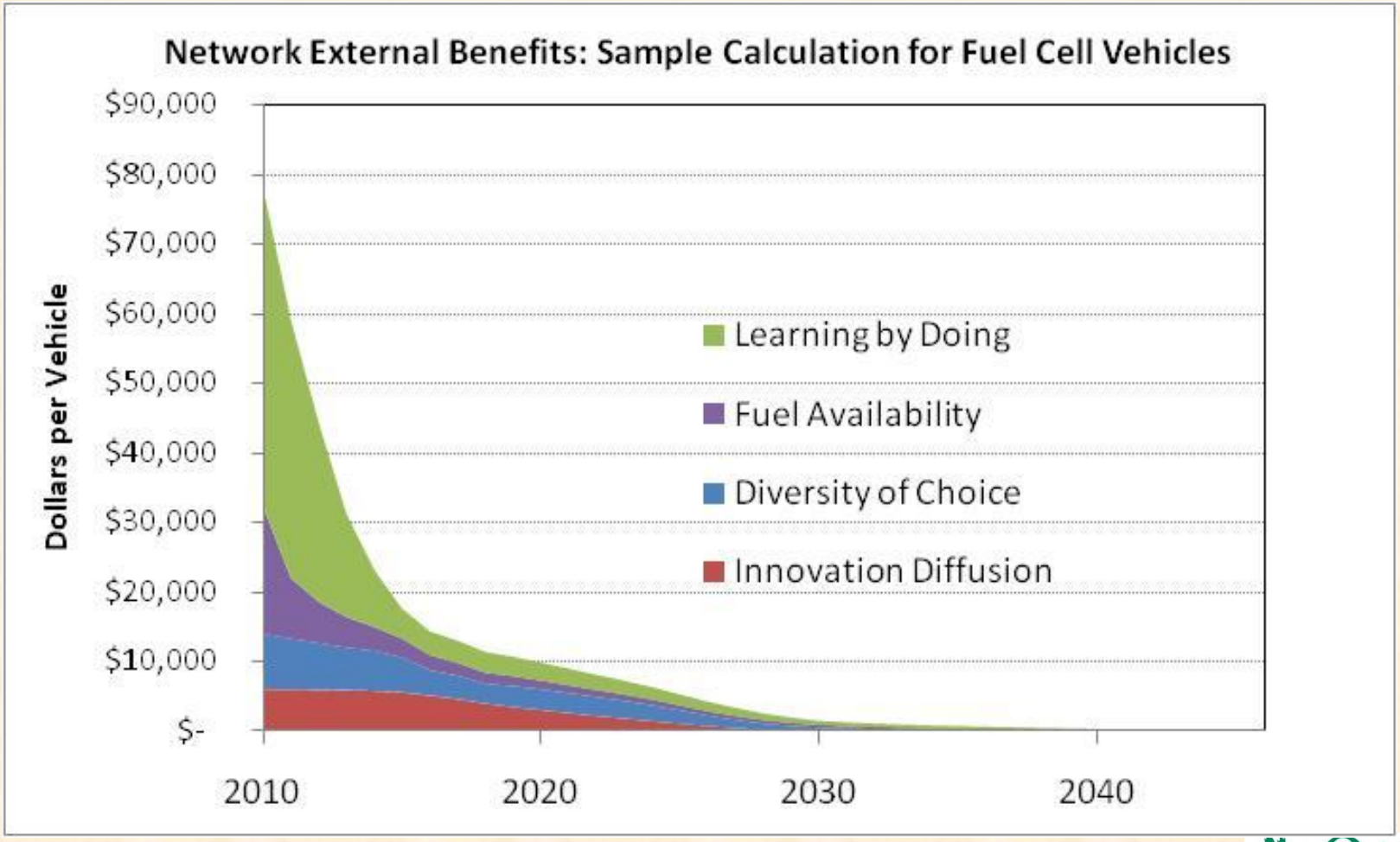
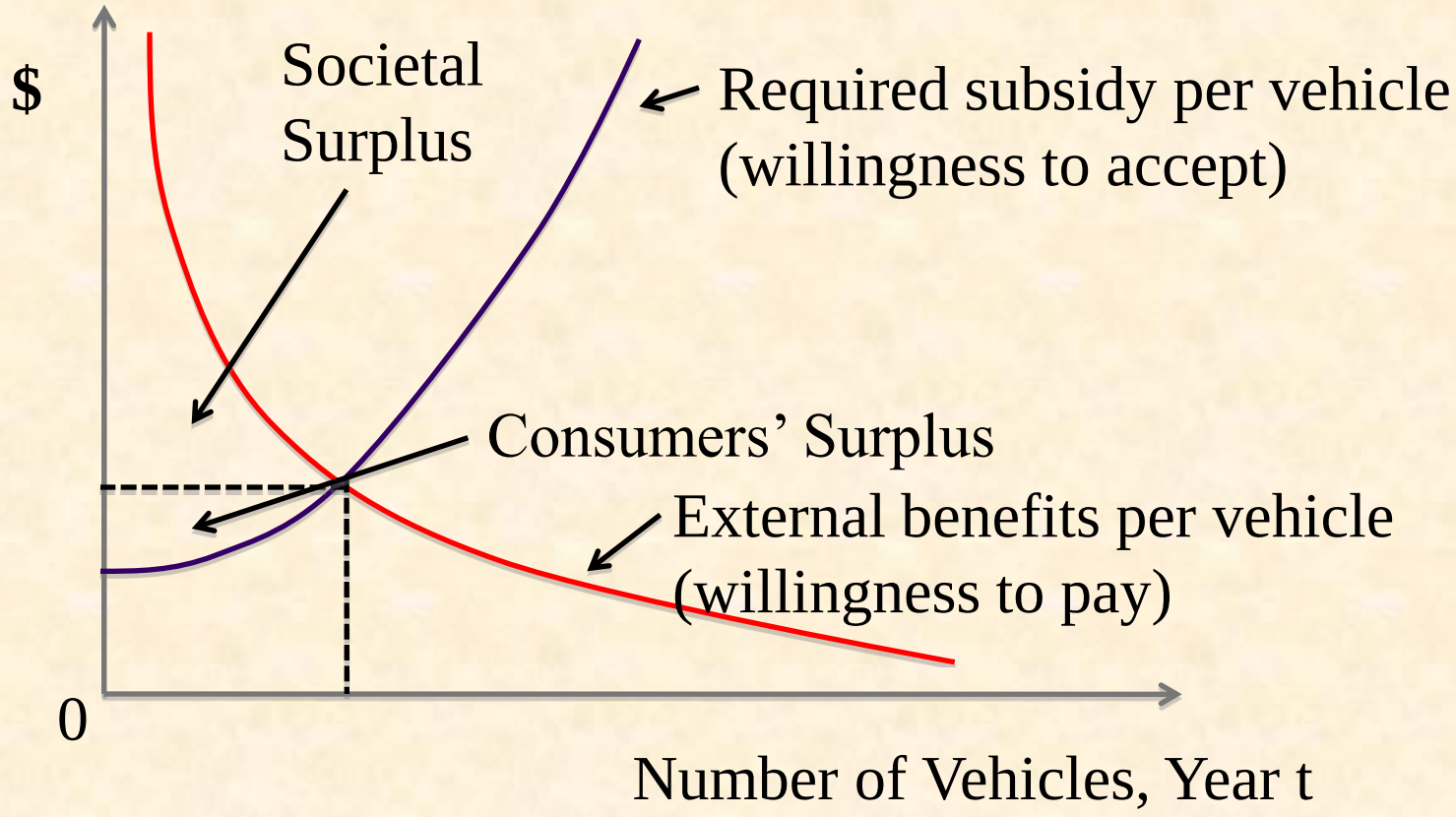
THIS SLIDE IS ENTIRELY NOTIONAL.

Adding the external benefits yields a total societal willingness to pay function, if cumulative costs < PV benefits.



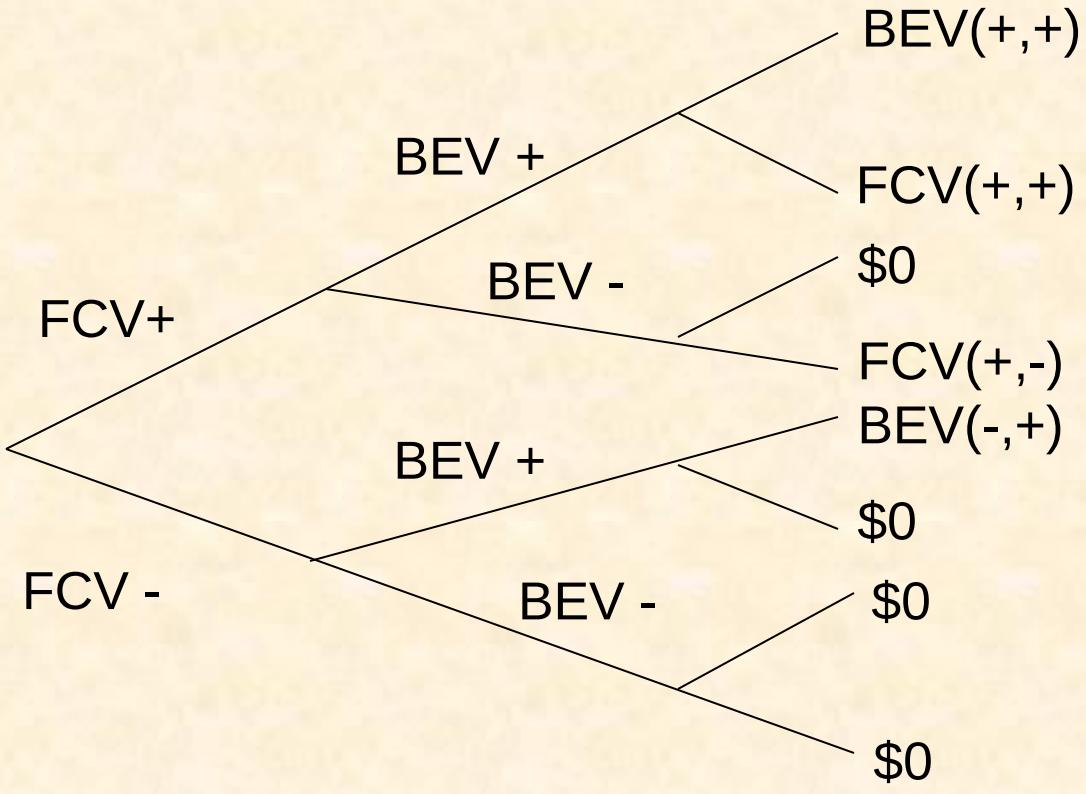
In a given year, there is a societal willingness to pay for placing more vehicles in operation and a consumer willingness to accept a vehicle. There is an equilibrium price that provides "surplus" to both.



Who should pay for the transition?

- Economic theory of public goods
  - **Climate protection, energy security, sustainable energy are clearly public goods**
  - **No definitive answer based on economic efficiency**
  - **Alternative principles:**
    - **Charge based on willingness to pay**
    - **Charge users**
    - **"Polluter pays"**
- Polluters pay options
  - **Light-duty vehicle users cross subsidize**
  - **Pay out of C tax or cap-and-trade revenue**

It may be possible to deal with uncertainty using familiar decision analytical methods. Each technology (FCV = fuel cell vehicle, BEV = battery electric vehicle) has a payoff that depends on its own success and that of the other technology. Expected payoff depends on the probability of each outcome. Discontinue when PV Expected Payoff < PV Expected Costs.



If we are to make a transition to hydrogen or electricity, we will need a policy framework to guide our decisions (Not to decide is to decide).

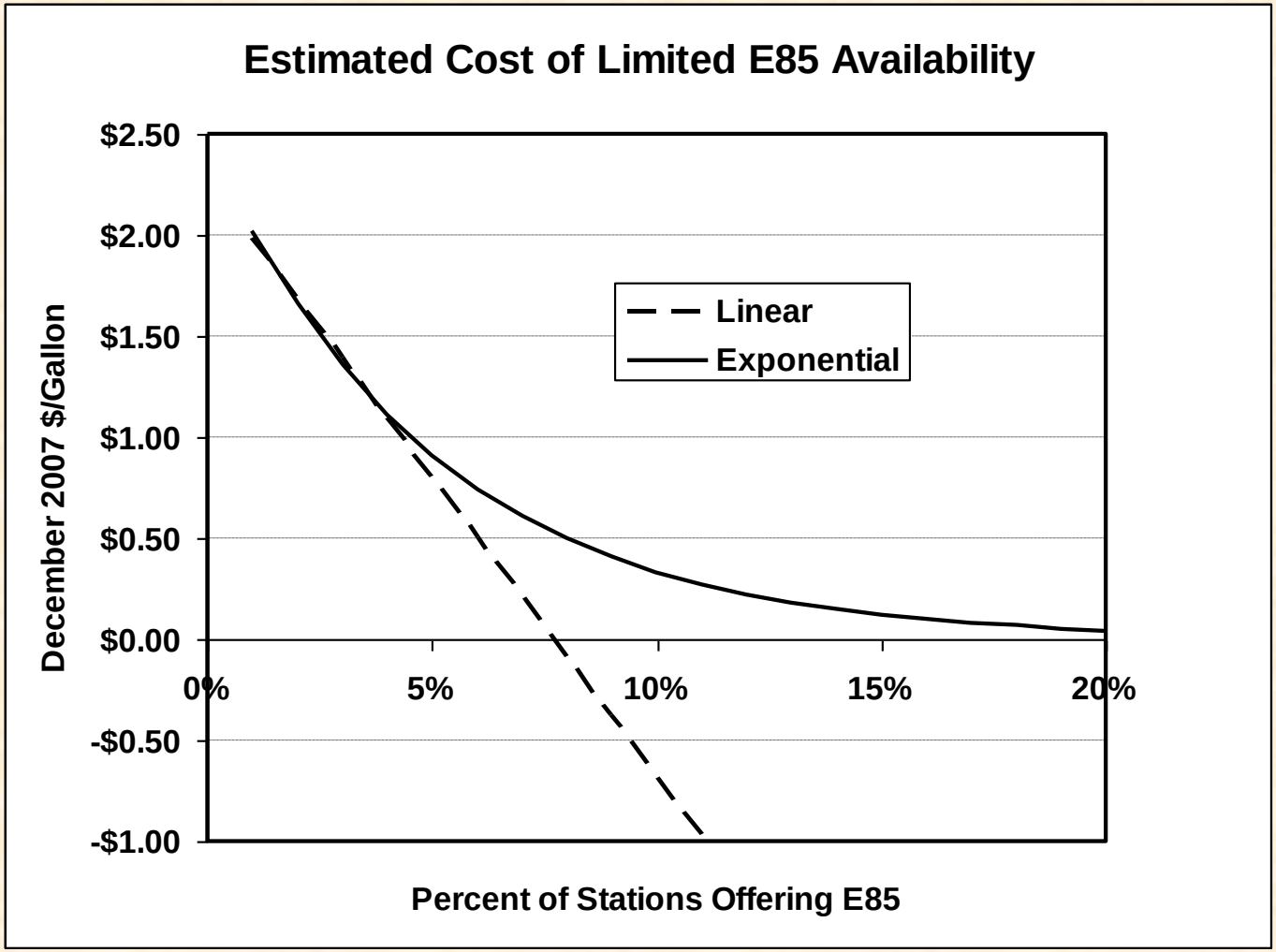
- Subisidies
  - **How much?**
  - **For what/whom?**
  - **When?**
  - **Why?**
  - **From whom to whom?**
- Uncertainty must be integrated
  - **Does it change society's willingness to pay?**
  - **Need robust, adaptive strategy (when to quit?)**

THANK YOU.

What do you mean, “policy framework?”

- Policies that are:
  - Necessary
  - Economically efficient
  - Realistic
  - Coherent
  - Sustainable
  - Sufficient
  - Consistent with other national objectives
    - Economic growth
    - Energy security
    - Environmental protection
    - Energy sustainability

Though details vary, there seems to be a consensus that fuel availability costs are initially very large and become small beyond 10% availability relative to the current gasoline network.



Why a "policy framework"?

- **Transitioning transportation to a new energy source to accomplish "public goods" is unprecedented.**
  - **Greenhouse Gas Mitigation**
  - **Oil Independence**
  - **Sustainable Energy**
- **Natural market barriers appear to be sufficient to prevent a "free market" transition.**
- **Technologies and energy markets are** uncertain**.**
  - **Electricity?**
  - **Hydrogen?**
  - **Biofuels?**