Alternative Fuels: What have we learned?

David L. Greene
Corporate Fellow, Oak Ridge National Laboratory
Senior Fellow, Howard H. Baker, Jr. Center for Public Policy, U. of Tennessee

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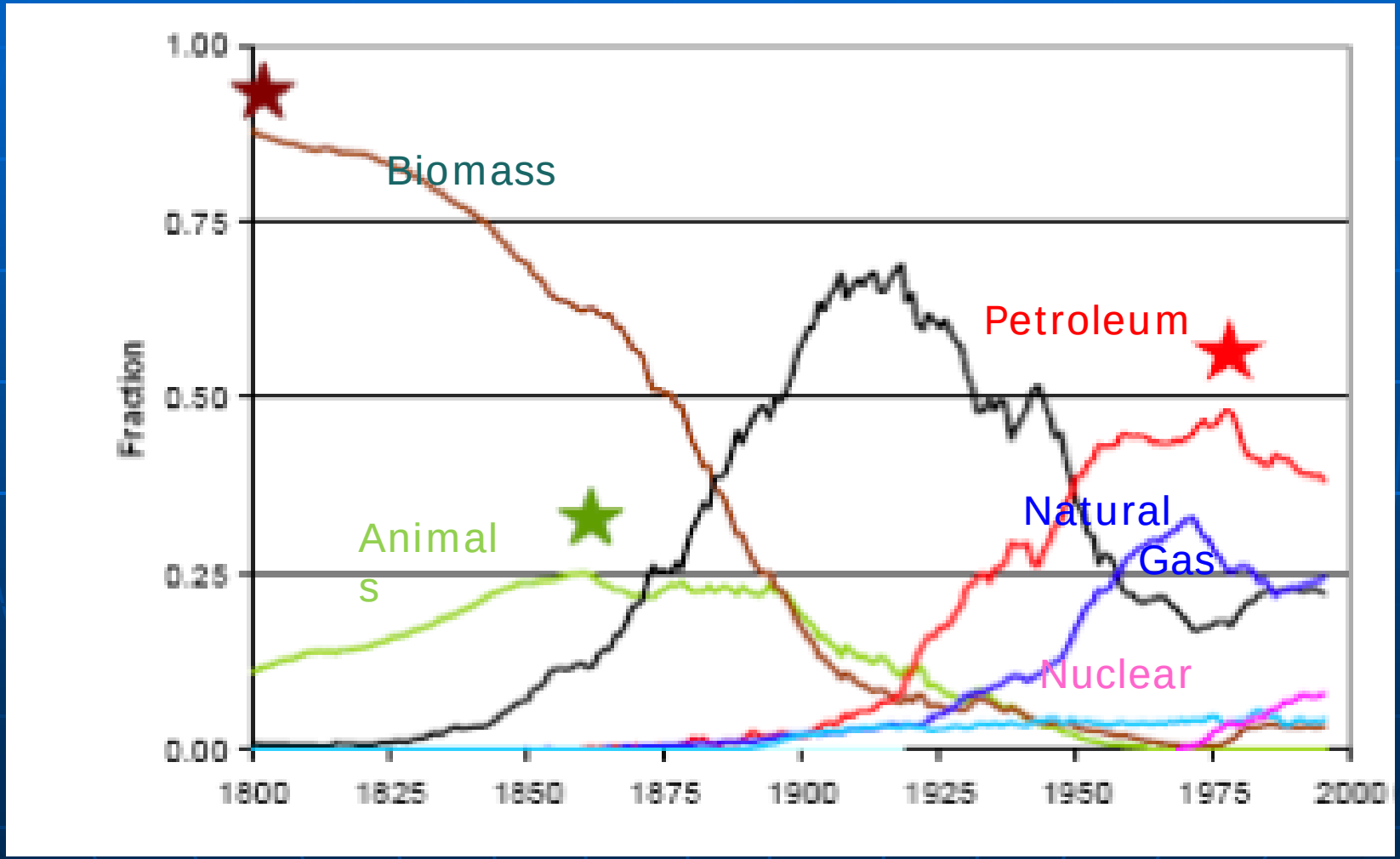
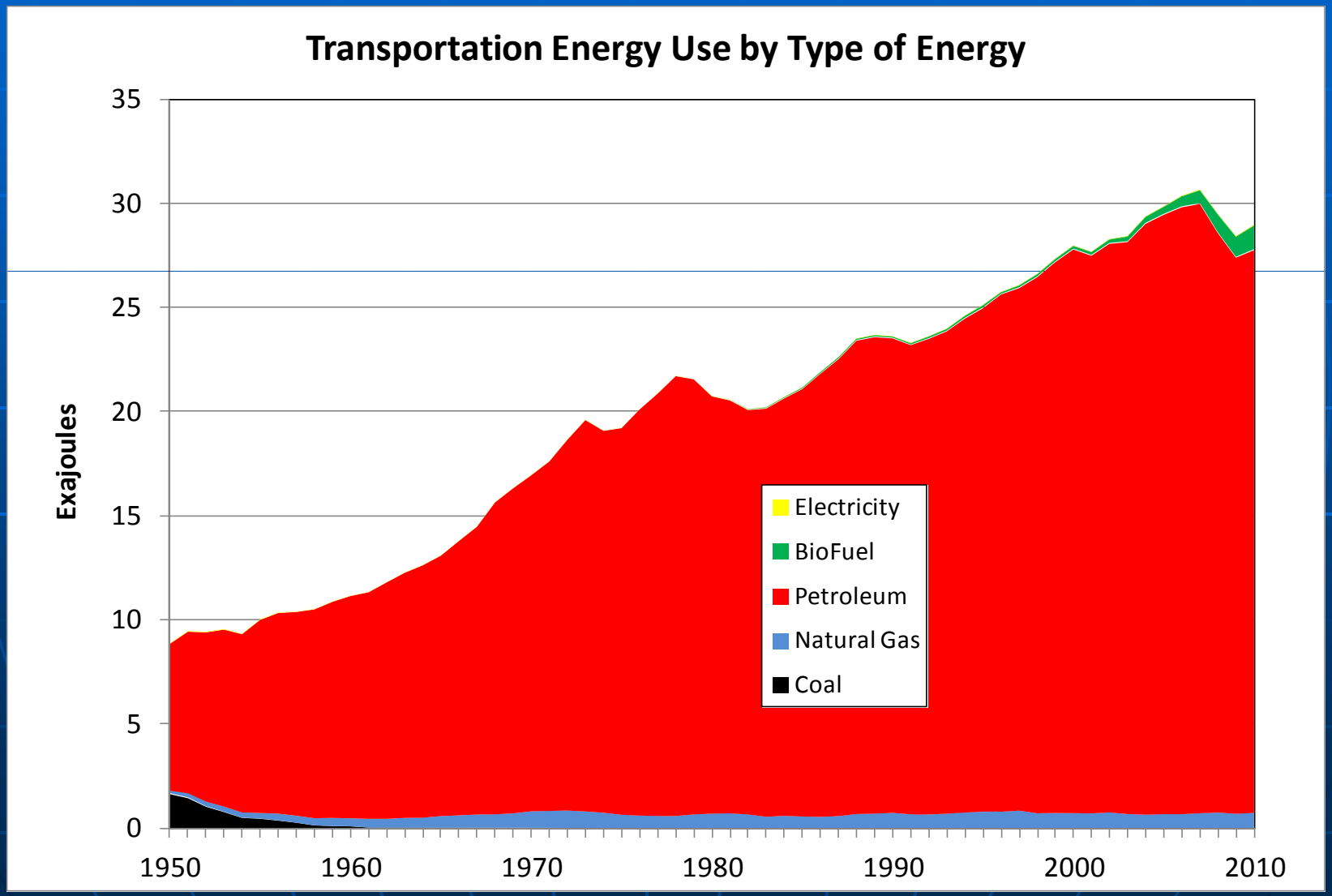
The great energy transformations of the past were driven by technological change and market forces.

Creating a transition for the public good poses a new challenge.



Source: A. Grubler, 2007, International Institute for Applied Systems Analysis.

Our transportation sector consumes more petroleum than any other nation's entire economy: 6,500 gallons per second. But petroleum also provides 95% of global transport energy.

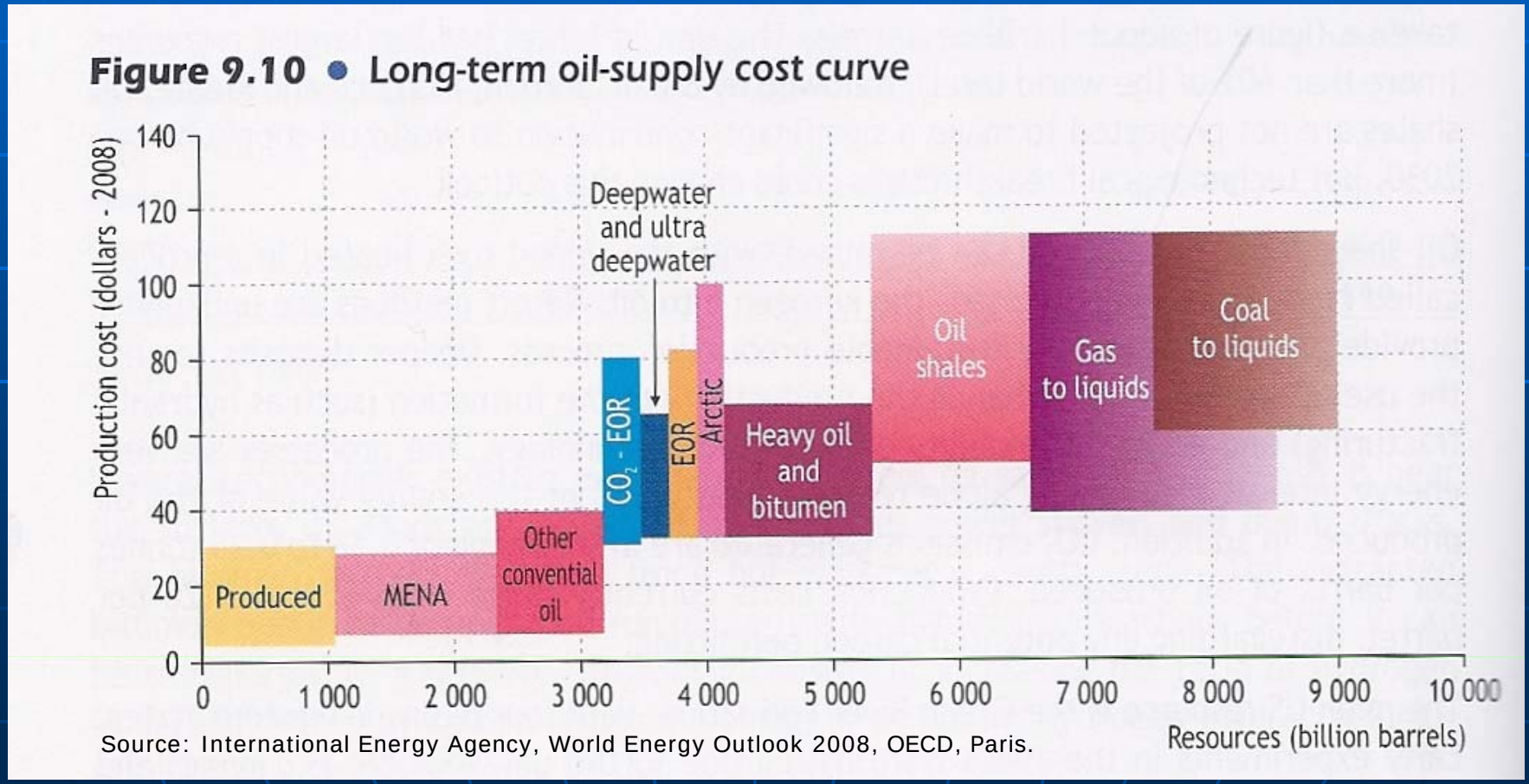


Energy Information Administration, Annual Energy Review 2010, table 2.1e.

What is an alternative fuel?

- Notionally:
  - Not derived from petroleum
  - Provides **public benefits**:
    - Fewer conventional pollutant emissions
    - Reduces oil dependence
    - Reduces greenhouse gas emissions
- What is petroleum?
  - Conventional v. unconventional
  - Other liquid hydrocarbons
  - Synthetic v. refined

Running out of or into petroleum?
Continuing current trends, the world will have used well over half of all conventional oil resources before 2050.
The path of least resistance is fuels from unconventional fossil resources at prices the world is willing to pay.

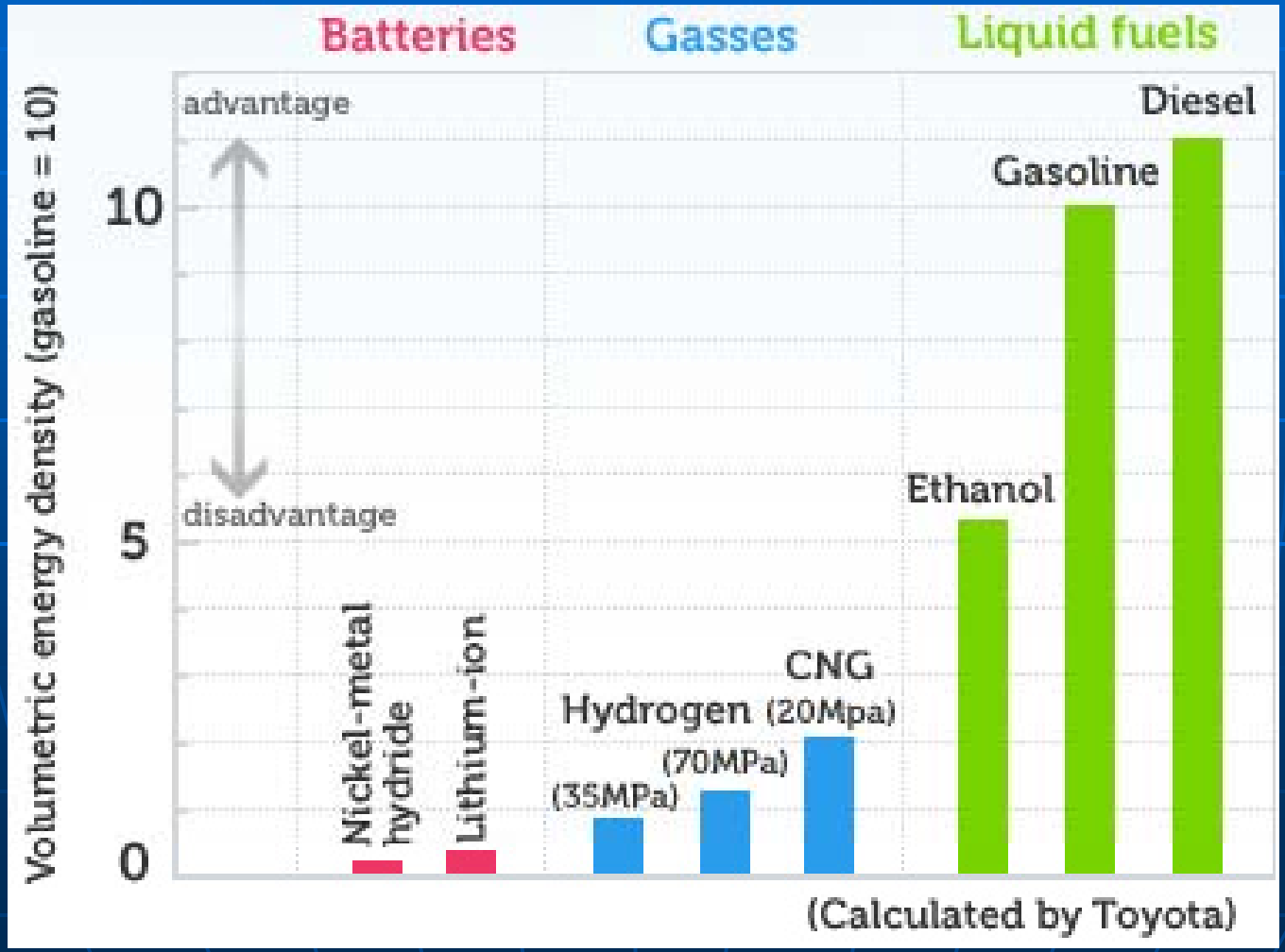


Source: International Energy Agency, World Energy Outlook 2008, OECD, Paris.

What is an alternative fuel? EPACT 1992/1999

- Biodiesel
- Natural gas
- Propane
- Electricity
- Hydrogen
- Alcohols (ethanol, methanol, isobutanol, etc.)
- Gasoline + >=85% alcohol blends
- xTL Fuels (Gas-To-Liquids, Coal-To-Liquids)
- P-series fuels (NGLs+EtOH+Methyltetrahydrofuran)

…you have seen this 1,000 times: alcohols have lower energy density, gaseous fuels less range and higher storage costs, electricity in batteries less range, higher storage costs and longer recharging time.



http://www.toyota-global.com/innovation/vision/oil_alternative_fuels.html

McNutt and Rogers (2004) summarized the obstacles faced by alternative fuels.

- Lack of refueling infrastructure
- Lack of vehicles engineered to operate on the fuel
- High cost
- Difficulty breaking into an established market
- Perceived or real issues of safety and reliability
- Lack of driving range

McNutt, B. and D. Rodgers, 2004. “Lessons Learned from 15 Years of Alternative Fuels Experience: 1988 to 2003”, in D. Sperling and J.S. Cannon, eds., *The Hydrogen Energy Transition*, Elsevier, London.

They noted the following key elements of early and continuing efforts to expand the use of alternative fuels.

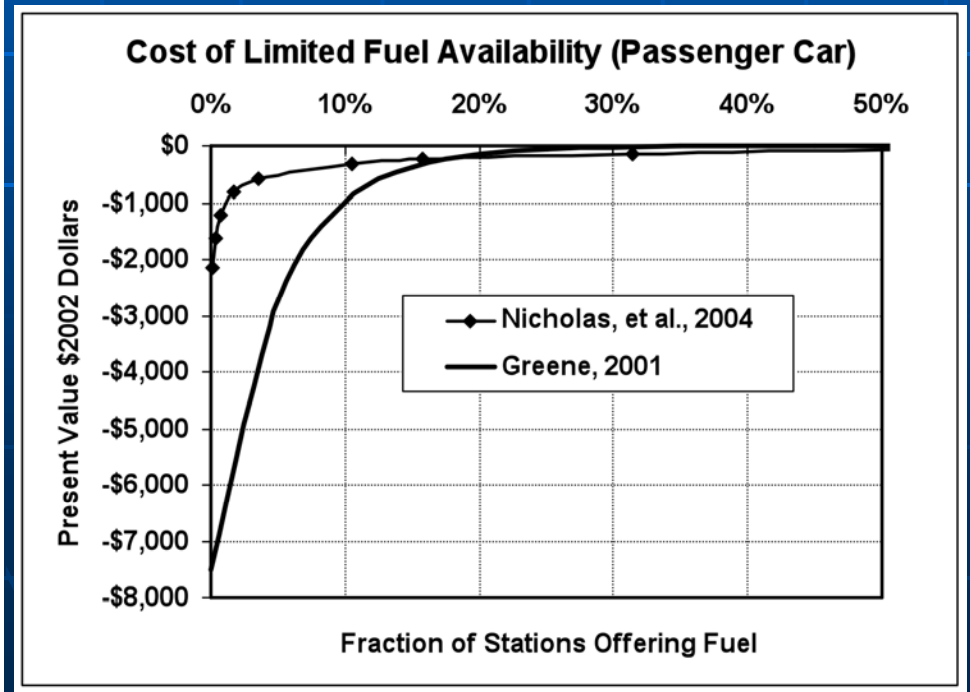
- Research and development
- Demonstration projects
- Fleet deployment
- Niche market development
- Public-private partnerships

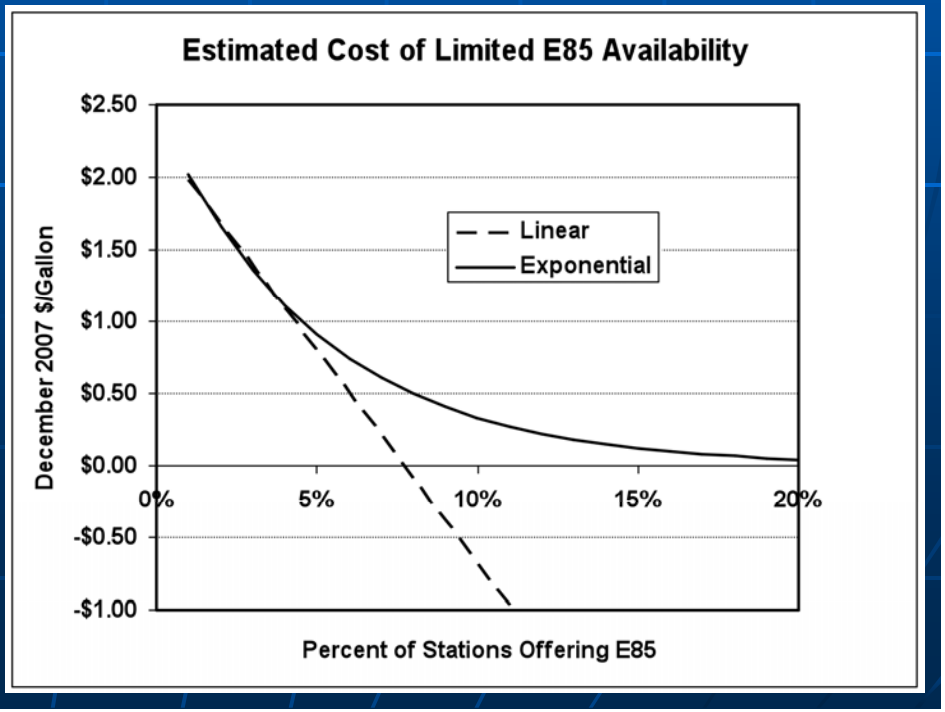
The U.S. Alternative Fuels and Data Center lists 26 federal and 543 state laws, regulations and incentives for alternative fuels.

- CAFE credits for AFVs (AMFA 1988):
  - MPG based on petroleum only
  - Dual and FFVs assumed to use 50% AF
- Energy Policy Act 1992:
  - Fleet requirements for feds states & fuel providers
  - Grants to state & local governments
  - 10% AF use by 2000, 30% by 2010
- Various tax credits
  - $0.54/gal. ethanol motor fuel tax exemption.
  - Now supported by RFS2, ethanol near 10% blend limit

Tighter emissions standards and reformulated gasoline nearly eliminated the emissions advantages of methanol, propane and CNG.

- MTBE from 1% to over 4% by 1995.
- Ethanol 0.5% to 2% by 2000.
- FFV production maxed out 1.5 MPG CAFE credit but the growth of E85 stations did not keep pace.

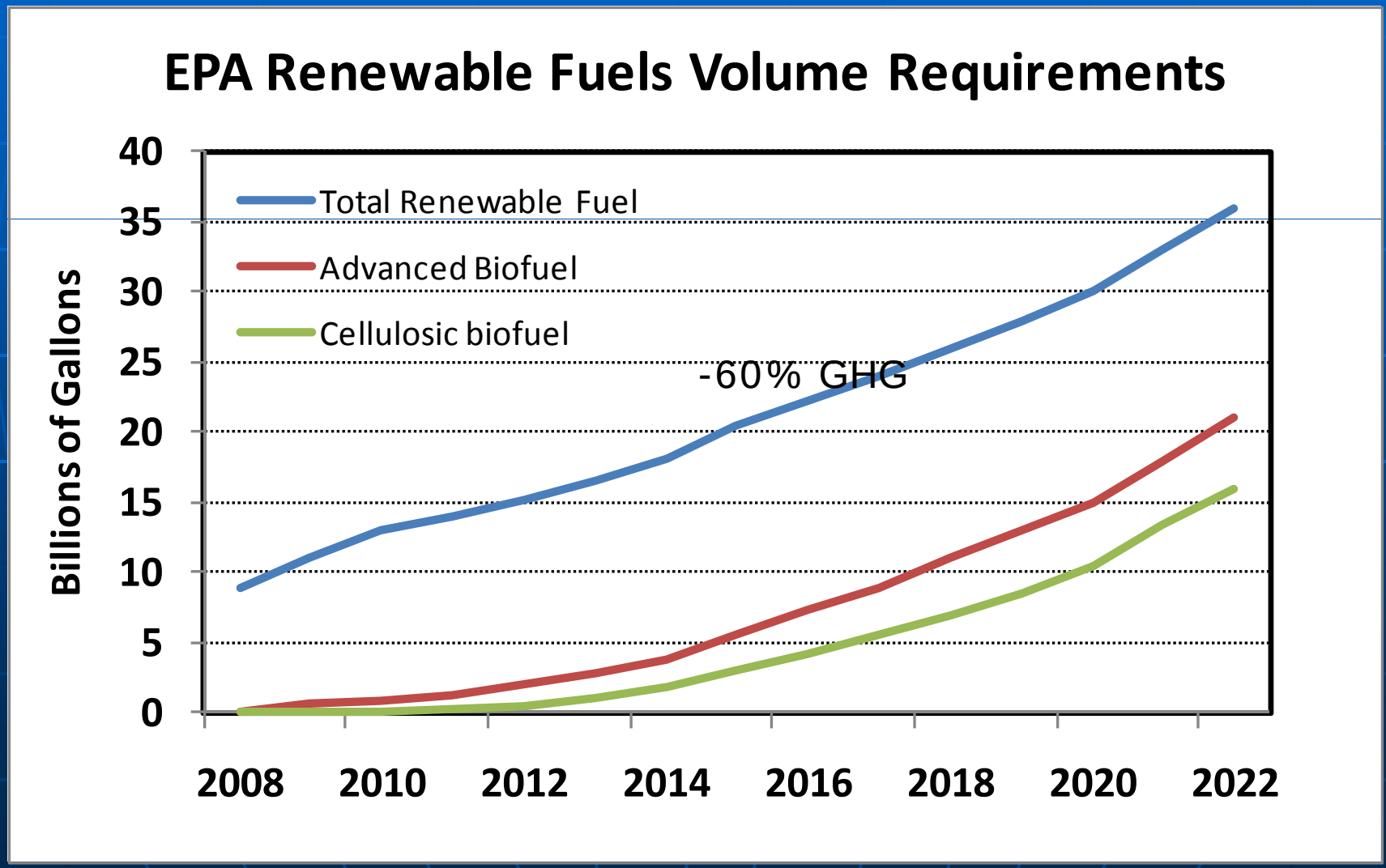




The United States has conducted a broad and expanding alternative fuel program since 1988. What has been the result? (McNutt & Rodgers, 2004)

- No significant change in alternative fuel use.
- Cleaner conventional fuels and significantly lower vehicle emissions.
  - In 1999 the Toyota Prius and Honda Insight
  - Honda's low-emission Accord produced tailpipe emissions cleaner that the ambient L.A. air.
- Millions of alternative fuel compatible vehicles on the road dominated by ethanol compatible vehicles.
- Better understanding of alternative and conventional fuel markets, and consumer-producer behavior.

The Renewable Fuels Standard 2 focuses on GHG emissions. Cellulosic biofuel is off to a very slow start. The 2011 requirement of 250 million gallons was reduced to 6.6 million.



California's Low Carbon Fuels Standard combines performance-based regulation and emissions trading.

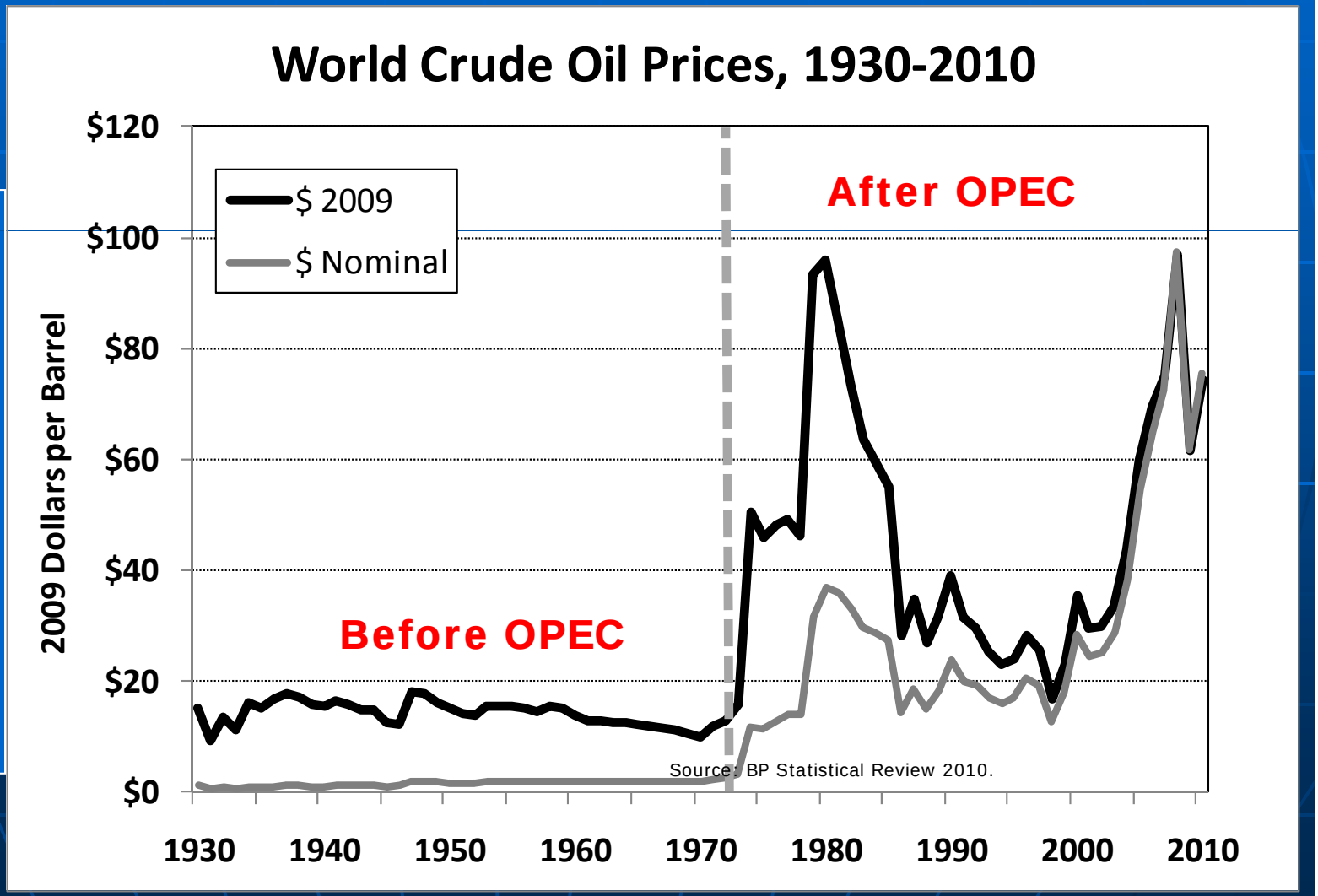
- Goal: reduce transportation GHG emissions while equalizing MSC across fuels and suppliers.
- Argument over ability to estimate ILUC
  - Insufficient knowledge makes it difficult to realize the ideal of fuel neutrality.
  - But the RFS 2 has the same problem.
- Last year's ruling by federal judge:

  "impermissibly treads into the province and powers of our federal government, reaches beyond its boundaries to regulate activity wholly outside of its borders."
- If the standard is not applied nationwide the potential for leakage is significant.

Lesson 1:
The incumbent technology will adapt.

Oil prices statistically appear to be a random walk, but they respond to market changes and the limits on OPEC's market power. Low oil prices can strand investments in alternative fuels.

Algeria
Angola
Ecuador
Iran
Iraq
Kuwait
Libya
Nigeria
Qatar
Saudi Arabia
UAE
Venezuela



Lesson 2:
Mass markets don’t necessarily grow out of niche markets.

Lesson 3:

Fleets are often not the best place to nurture alternative fuels and vehicles.

Lesson 4:

The political system has not yet shown a willingness to impose significant visible costs on private players.

Lesson 5:

Unregulated and unsubsidized private sector investment in refueling infrastructure has been very limited. (vehicle manufacturing)

Lesson 6:

Mainstream consumers are unwilling to accept the disadvantages of alternative fuels.

The social benefits of alternative fuels are not valued by mainstream consumers.

Lesson 7:
Coordination between auto and oil industries is vital.

Lesson 8:

In both the auto and oil industries, scale is critically important.

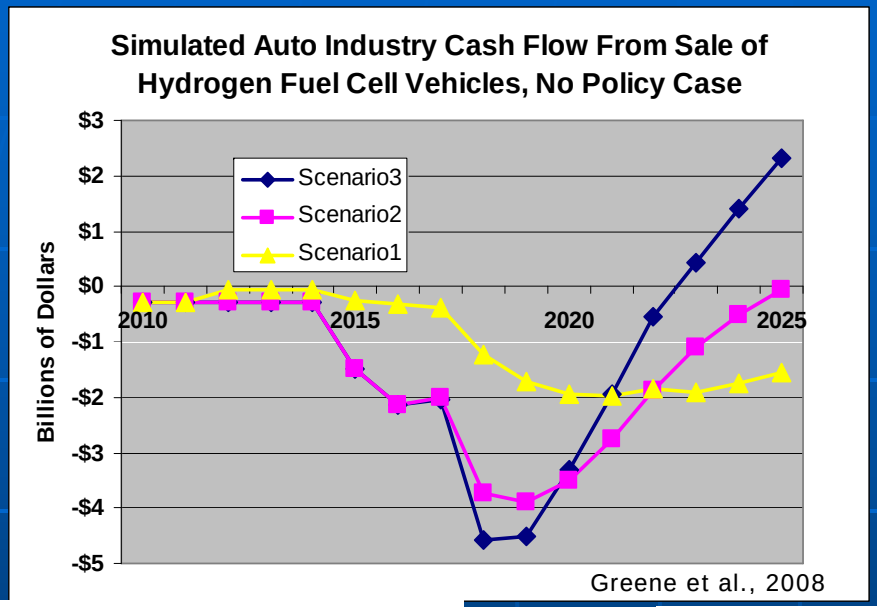
McNutt and Rodgers conclusions still seem valid today.

- Lower energy density fuels significantly raise the cost of infrastructure and impose ongoing time costs on consumers.
- The incremental private benefits of AFVs to consumers are likely to be small. Policies to value the social benefits will be needed.
- Infrastructure development may be the limiting factor. Private sector investment is likely to be inadequate to traverse the “valley of death”.
- **What’s different:**
  - **Climate Change**
  - Sustainability

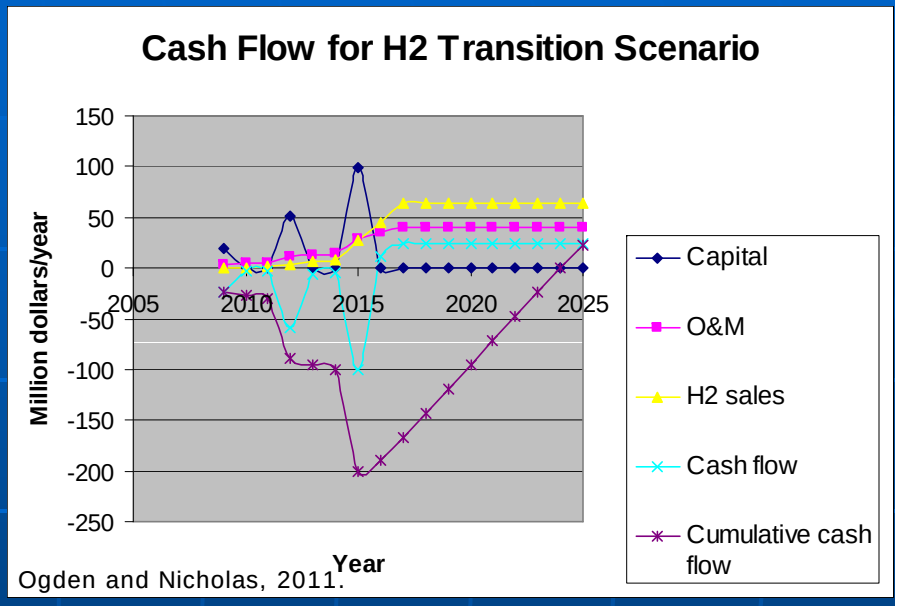
Achieving climate protection goals will likely require a large-scale energy transition. There are real economic barriers to displacing the incumbent technology.

- Lack of scale economies
- Need for learning by doing
- Lack of choice diversity
- Risk aversion
- Fuel availability “chicken or egg”
- Uncertainty of technological change
- Petroleum price response
- + market imperfections
  - Externalities
  - Energy efficiency paradox (behavioral economics)
  - Monopoly power in world oil markets

Upfront costs of a fuel transition can prevent or significantly delay the transition.



Greene et al., 2008



Ogden and Nicholas, 2011.

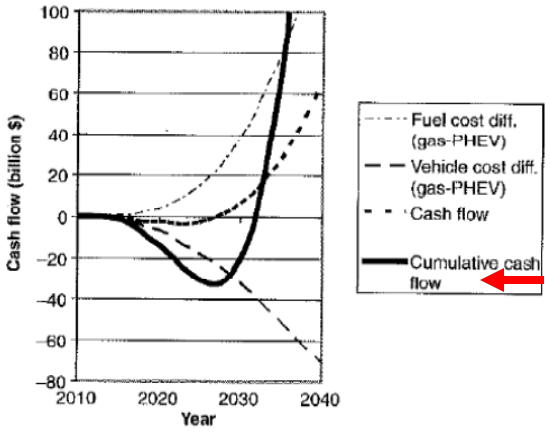


FIGURE 4.10 Cash flow analysis for PHEV-10, Maximum Practical Case, Optimistic technical assumptions. The break-even year is 2028, and the buydown cost is $33 billion.

NRC 2008

NRC 2010

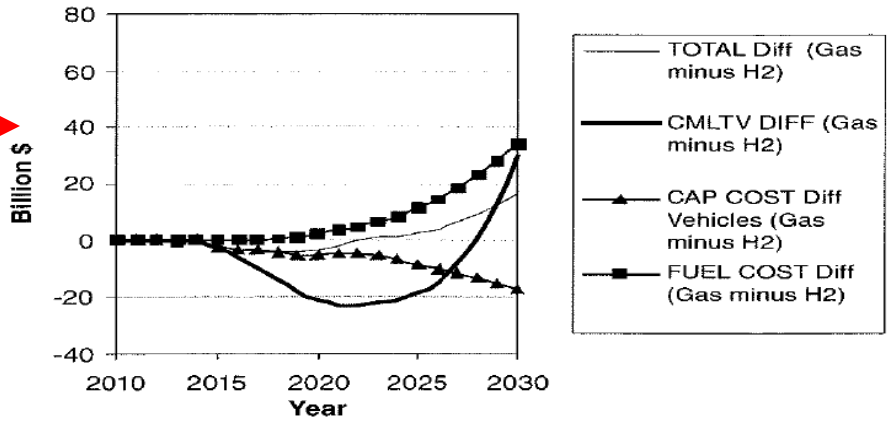
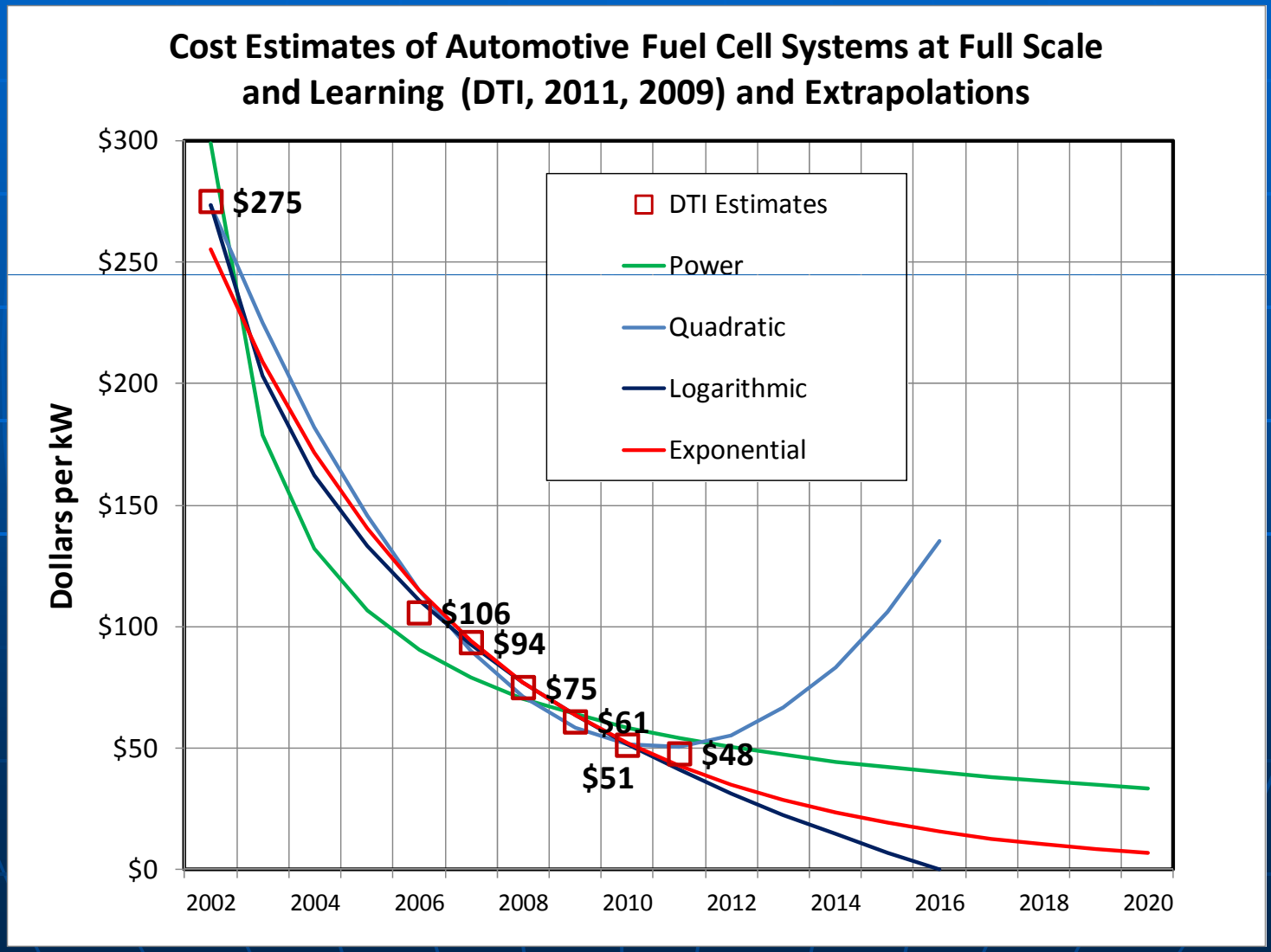
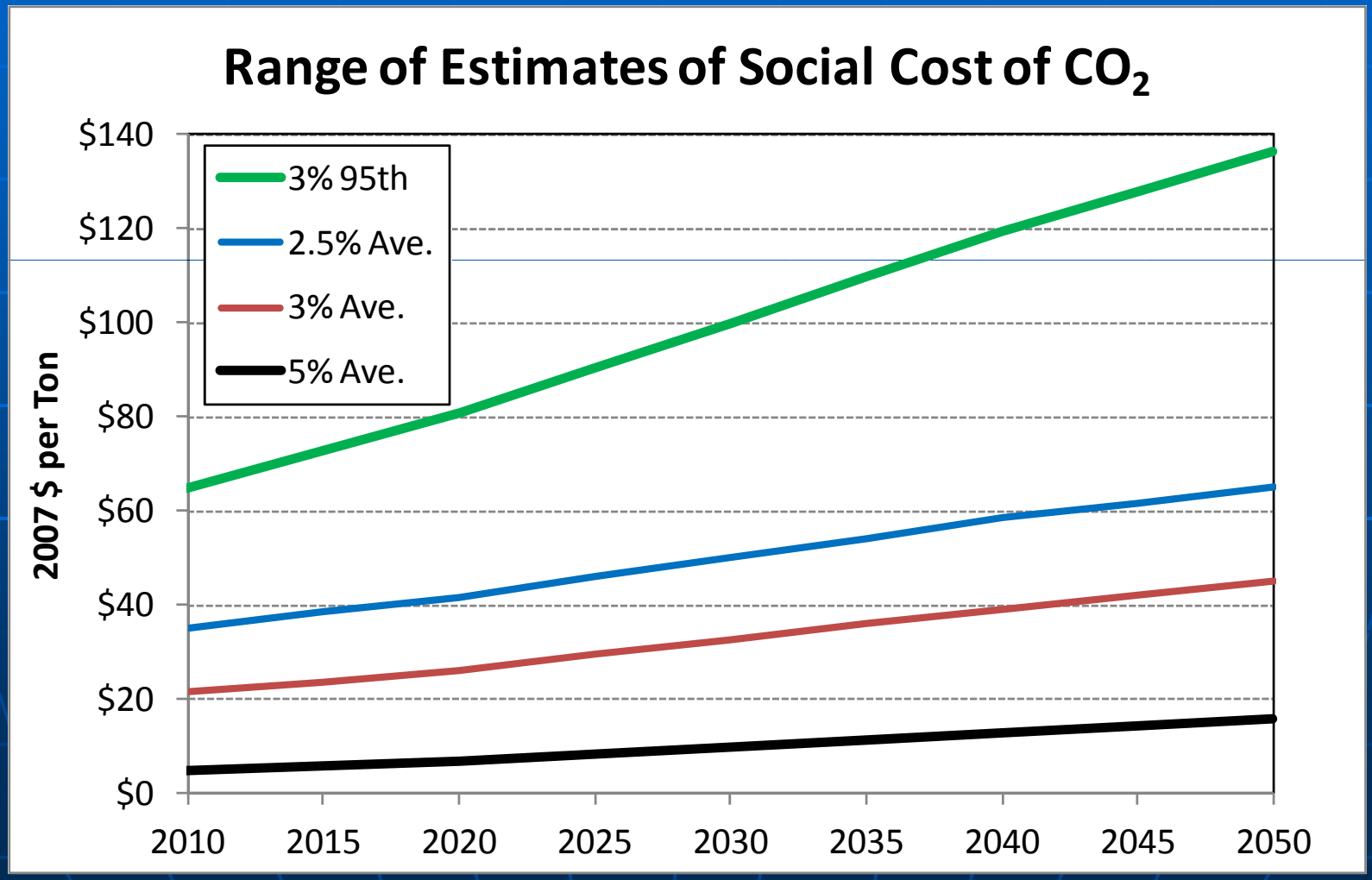


FIGURE 6.13 Cash flows for Case 1.

Technological progress is uncertain.
(And the incumbent technology will adapt.)

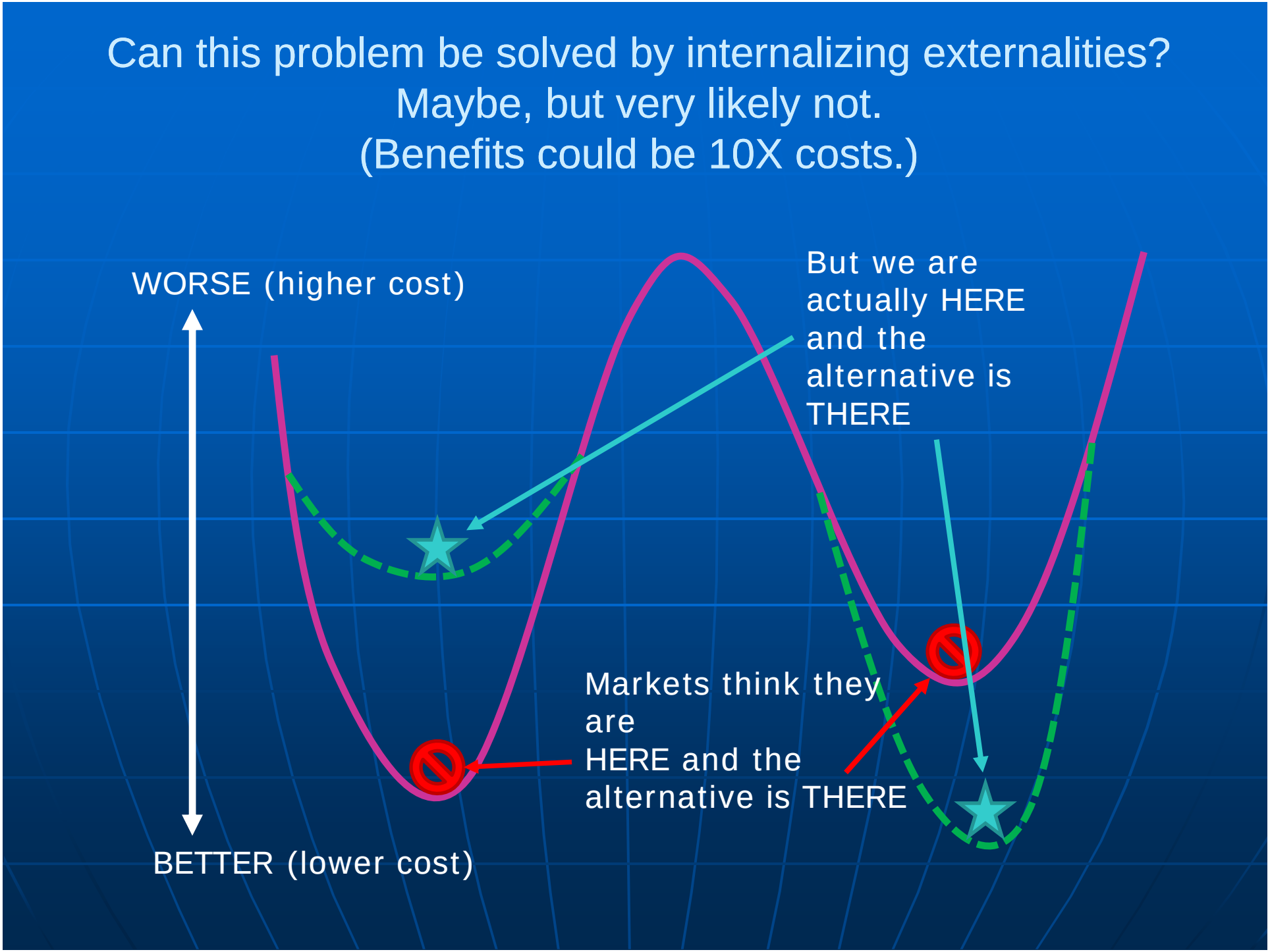


There is great uncertainty about the value of the social benefits, as well.



Interagency Working Group on the Social Costs of Carbon, U.S. Government, Feb., 2010.

Can this problem be solved by internalizing externalities?
Maybe, but very likely not.
(Benefits could be 10X costs.)



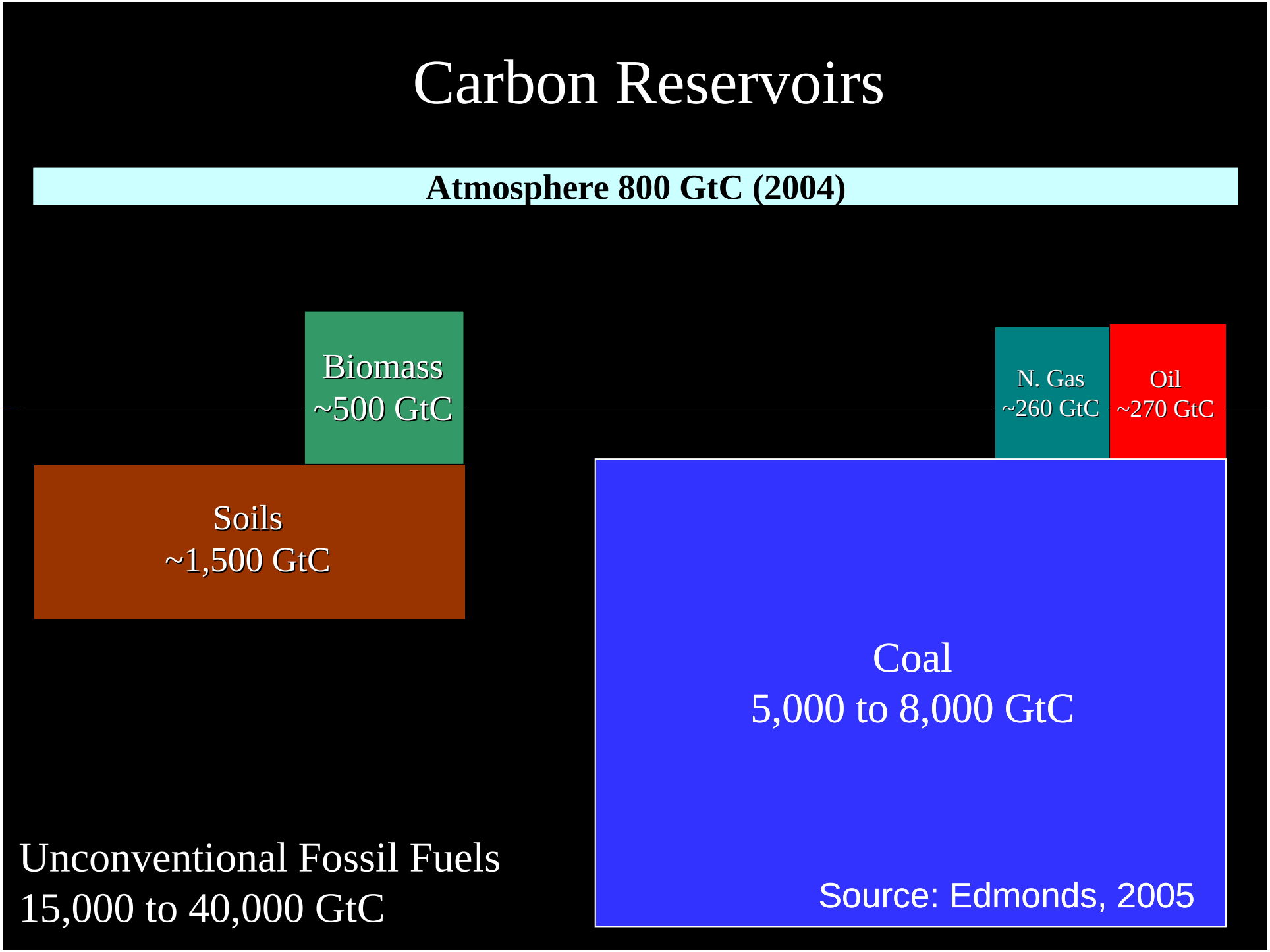
It's a network market.

"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)

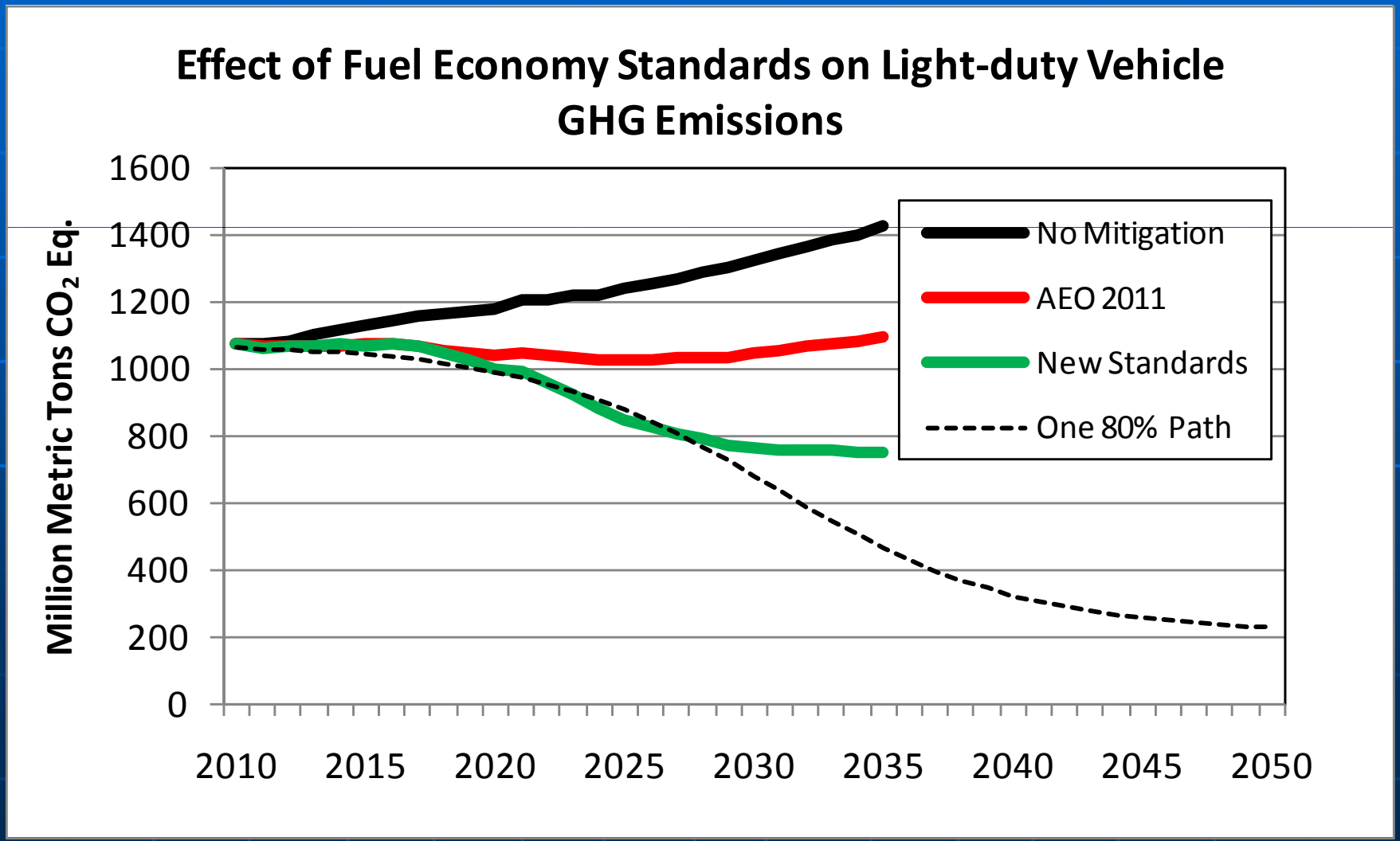
- Looked at another way, the reductions in transition costs created by early adopters become external benefits.
  - Learning by doing
  - Scale economies
  - Diversity of choice
  - Learning on demand side (early adopter, etc.)
  - Chicken or egg (fuel availability)
- Another refueling/recharging station produces indirect external benefits for vehicle owners.
- Another vehicle on the road makes alternative fuels stations more profitable.
- Early adopters: pioneers who will change the world?

Thank you.

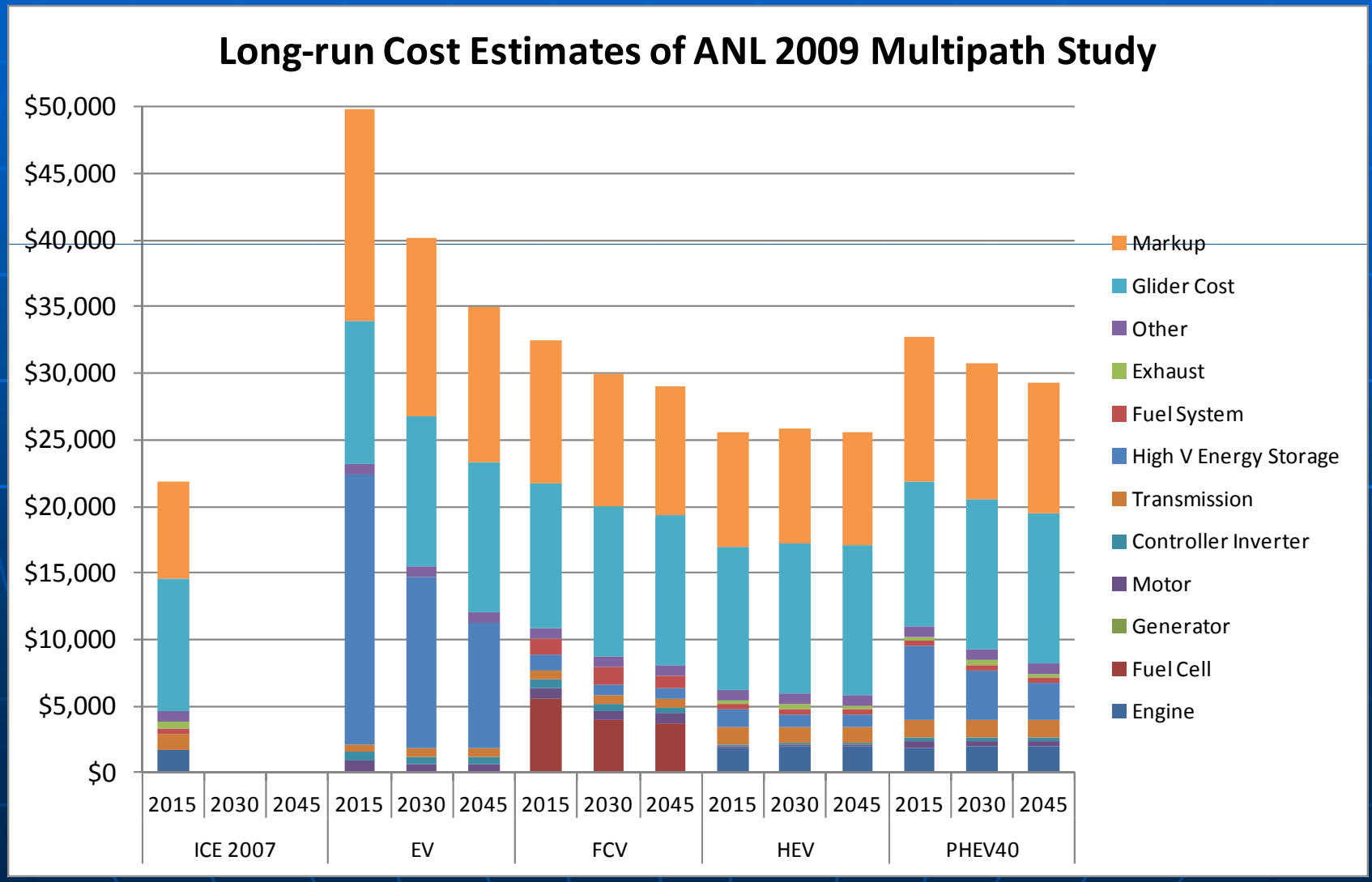
Carbon Reservoirs



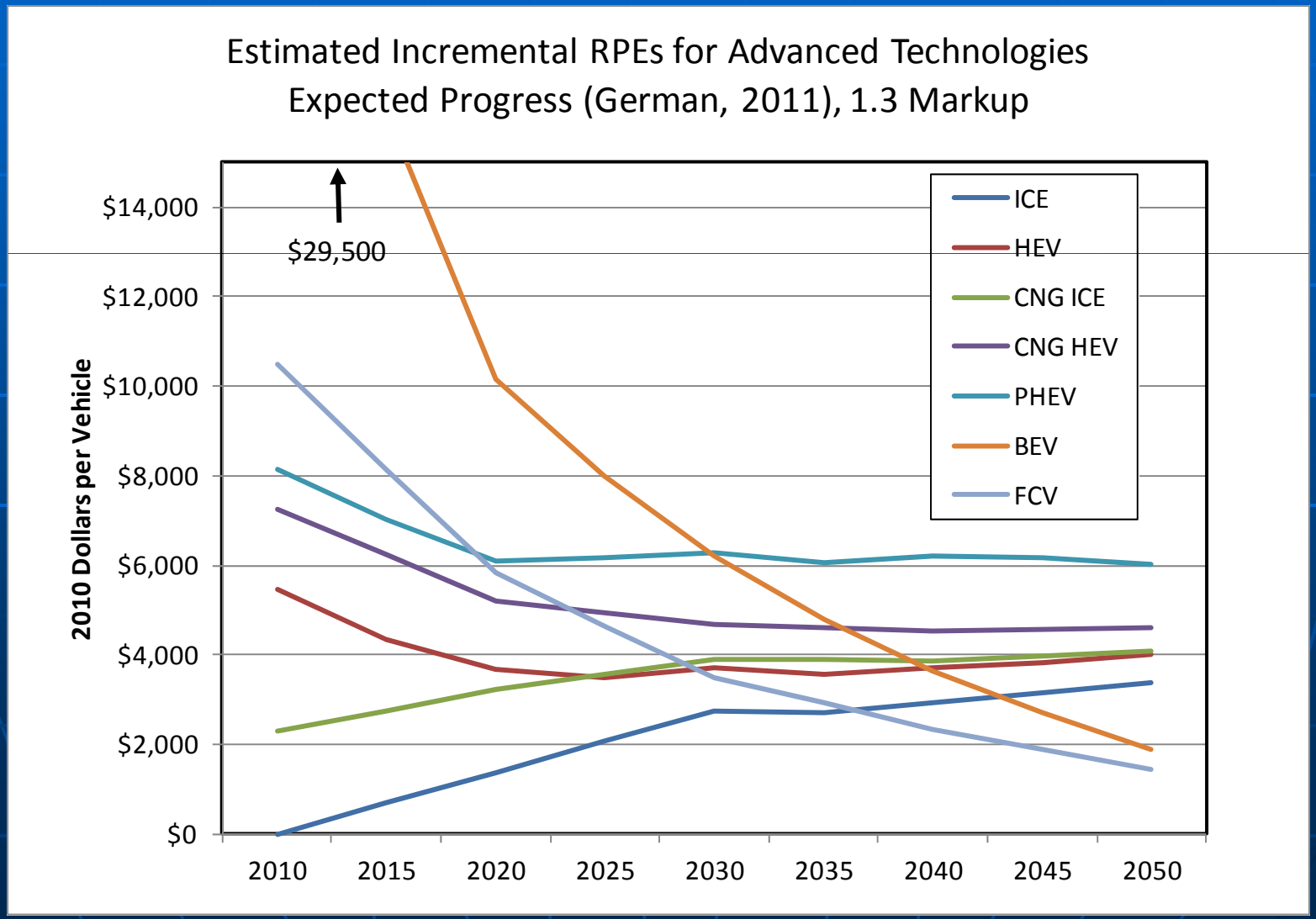
The proposed 2017-2025 US standards appear to put light-duty vehicles on a path toward an 80% reduction in CO_2 emissions through 2025. What then?



Argonne's Multipath study, like MIT's *On the Road in 2035* foresees gradual improvements in technology but not enough to make their prices less than an ICE.



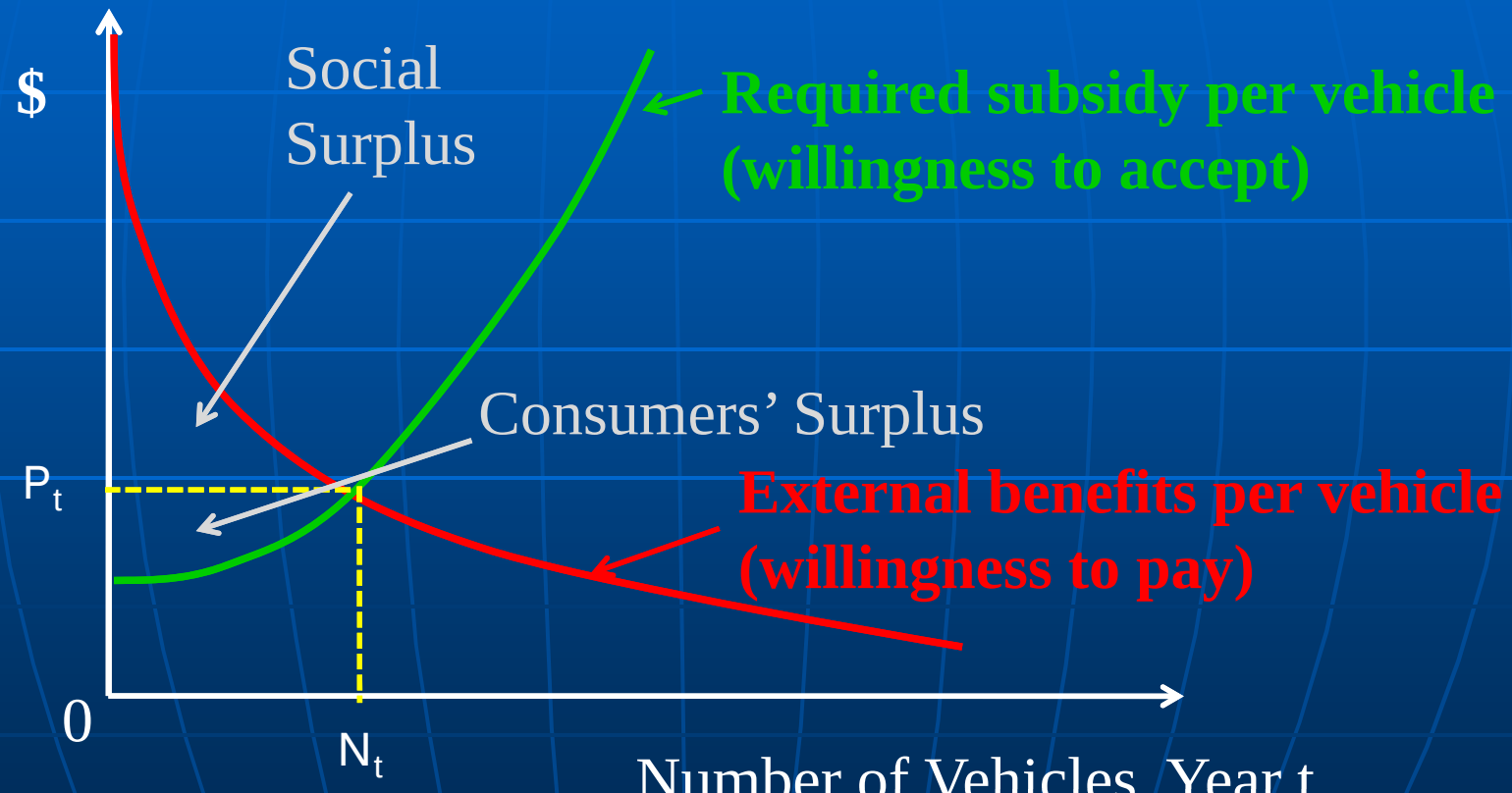
Other estimates show BEVs and FCVs eventually becoming cheaper than ICEs and HEVs.



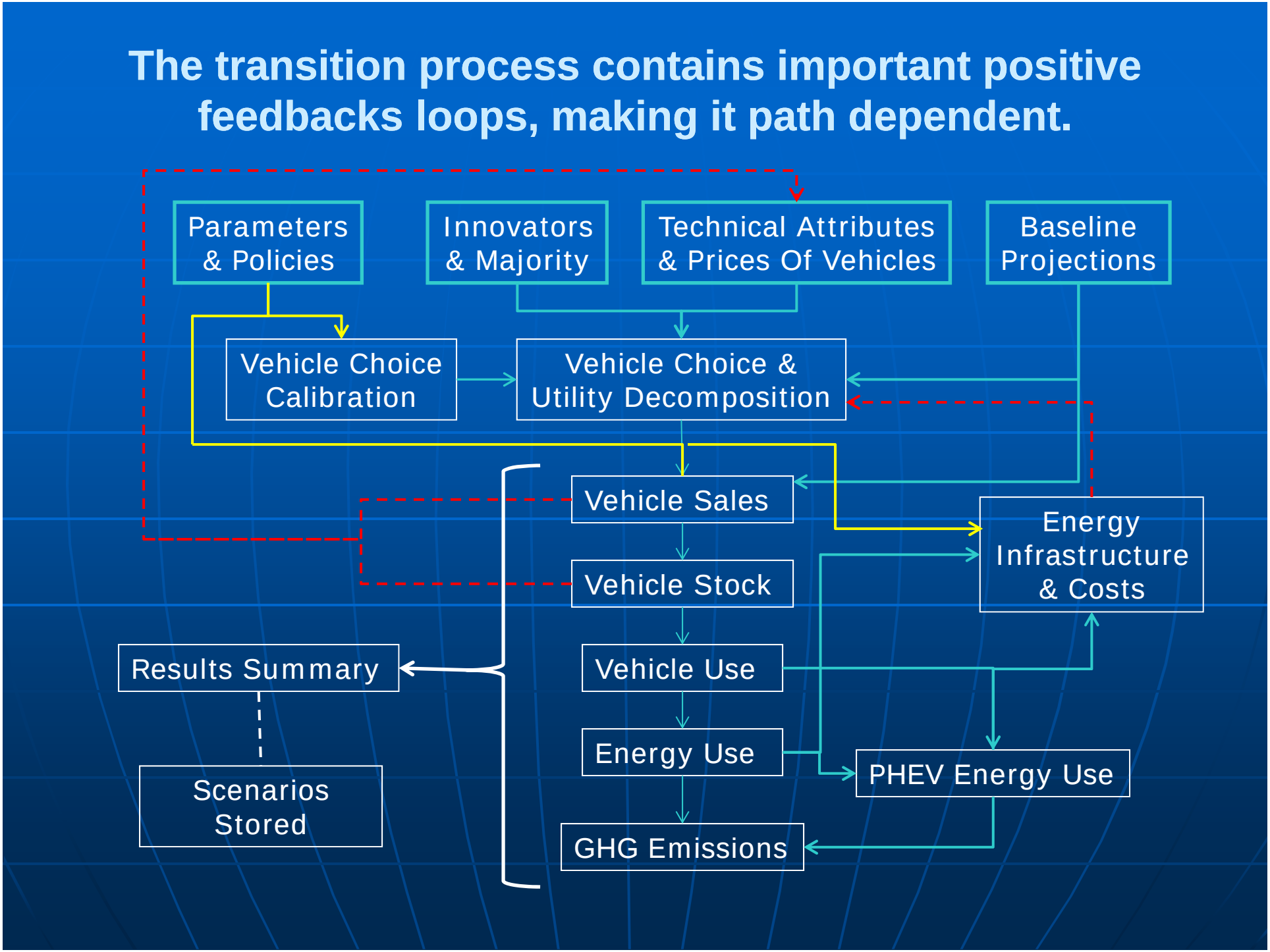
Is a transition to alternative energy vehicles likely to be worth it?

- 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 excess cost of transition appears to be an order of magnitude smaller than the estimated value of public benefits (assuming technology development is successful).

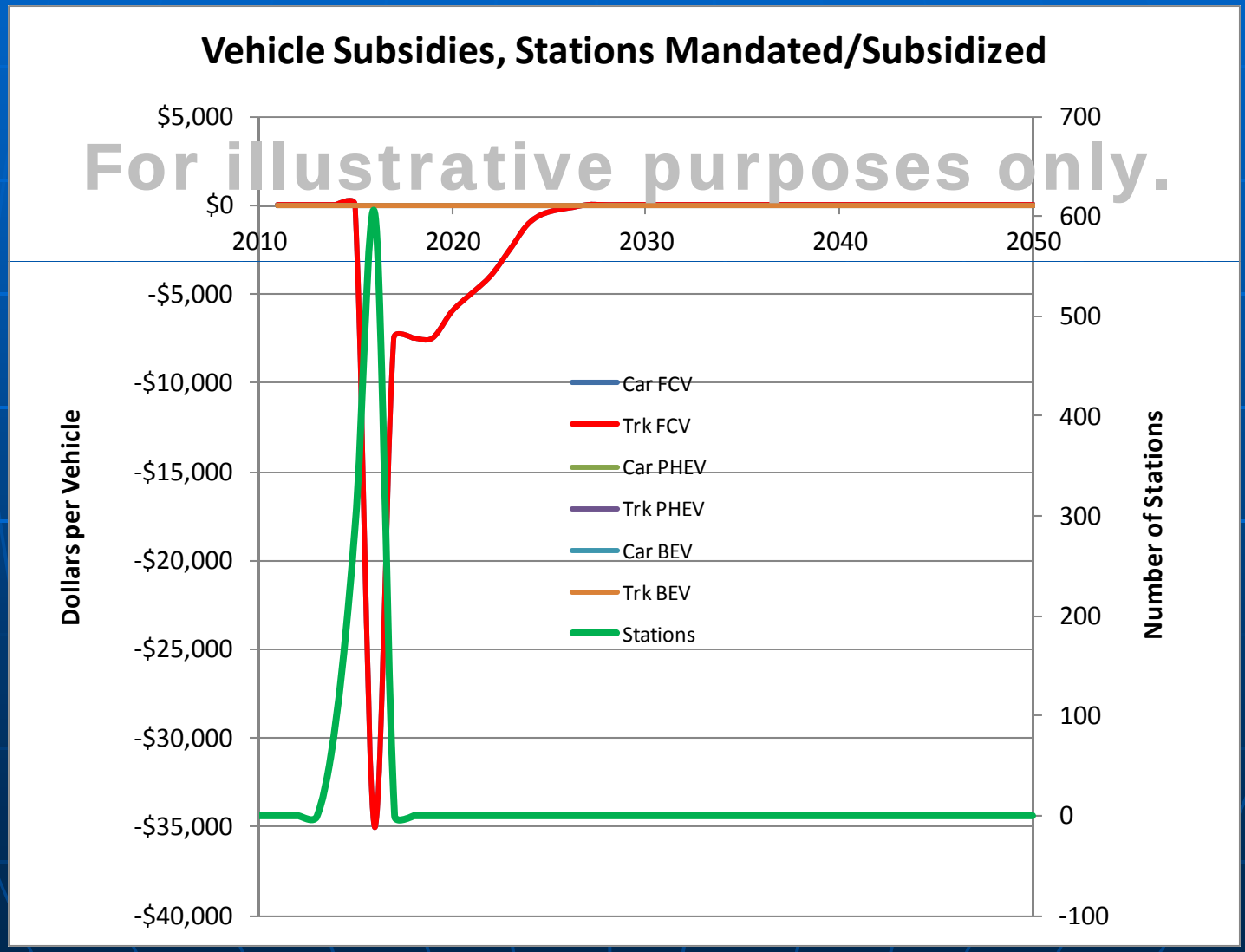
If the external benefits of early adoption were "visible" there would be a societal "willingness-to-pay" for placing more vehicles in operation as well as consumers' "willingness-to-accept" a vehicle.



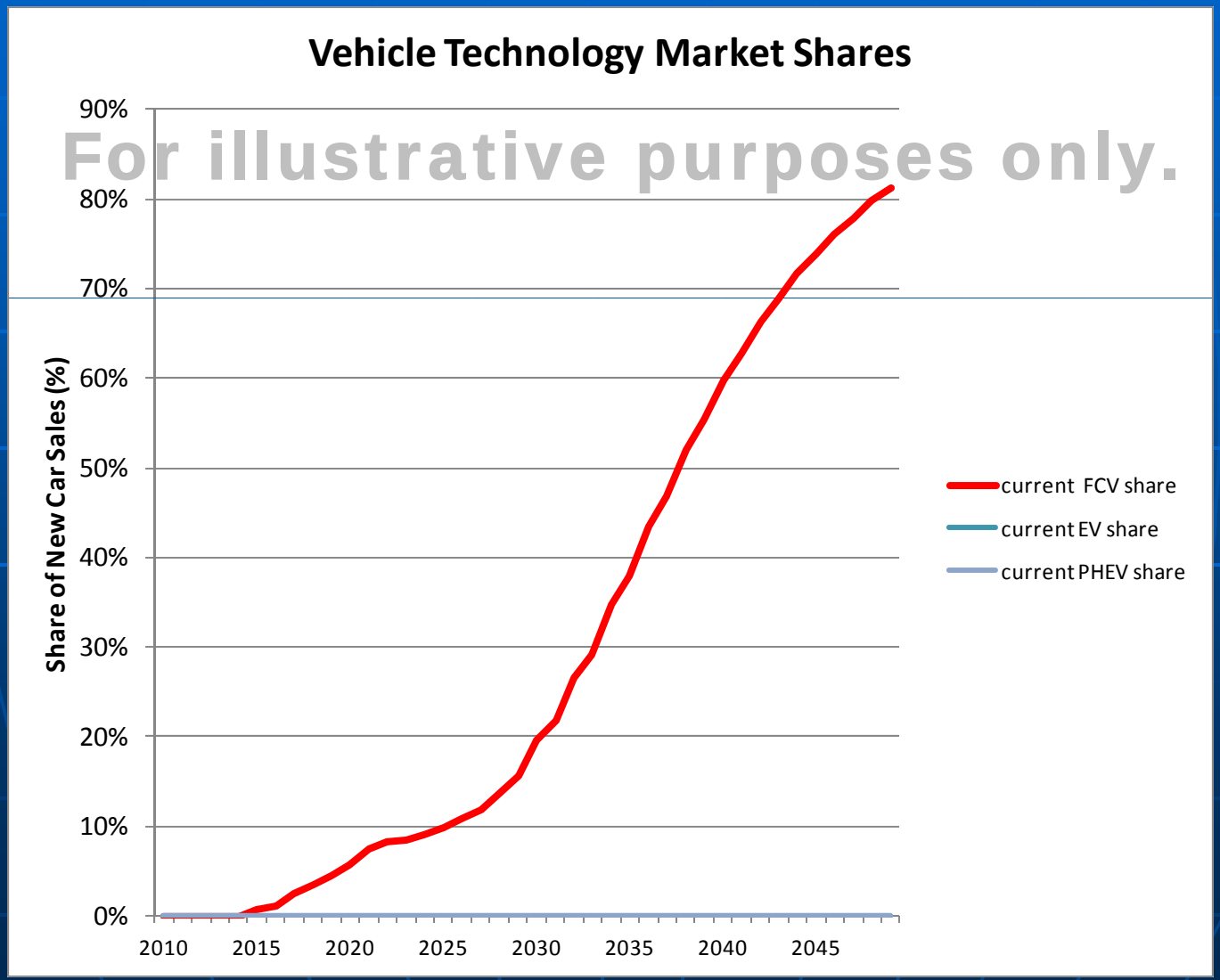
The transition process contains important positive feedbacks loops, making it path dependent.



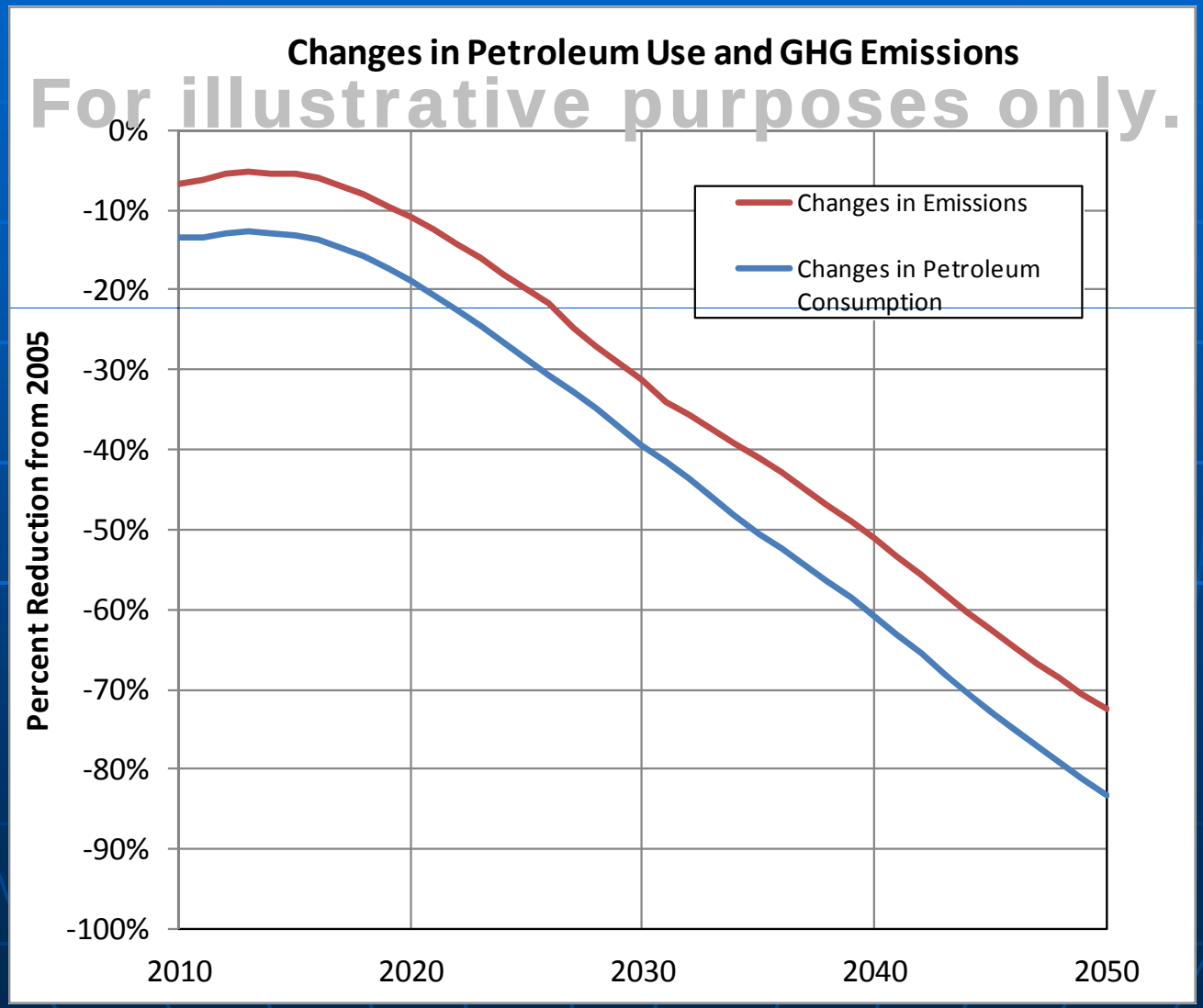
FOR EXAMPLE, 1,000 hydrogen stations are put in service by 2016, when mass-produced fuel cell vehicles are first available to the public. Manufacturers heavily subsidize the first few vehicles sold, then the government provides a $7,500 tax credit which is phased out by 2026.



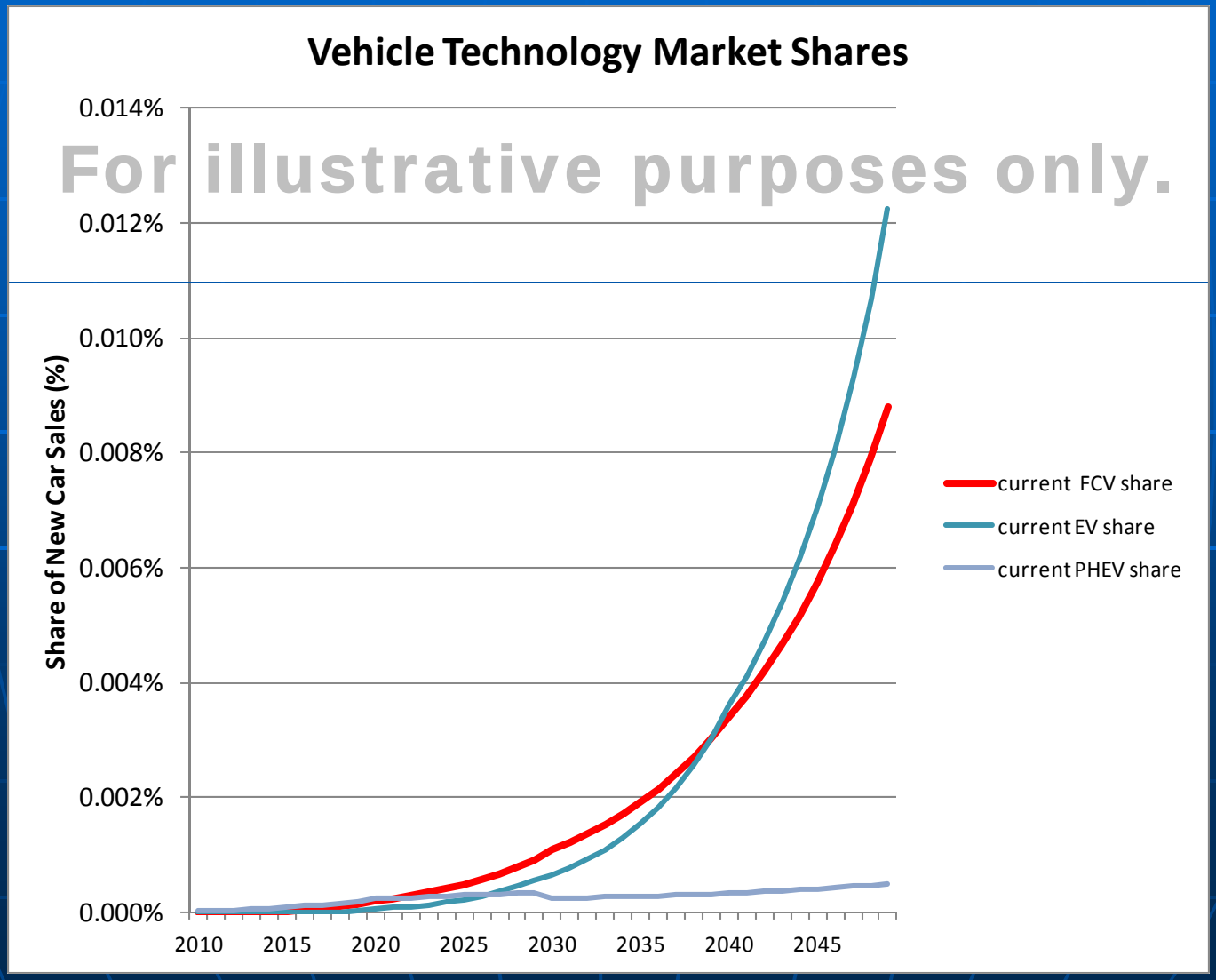
Although it takes 10 years to reach 10% of the market, fuel cell vehicles eventually reach an 80% market share.



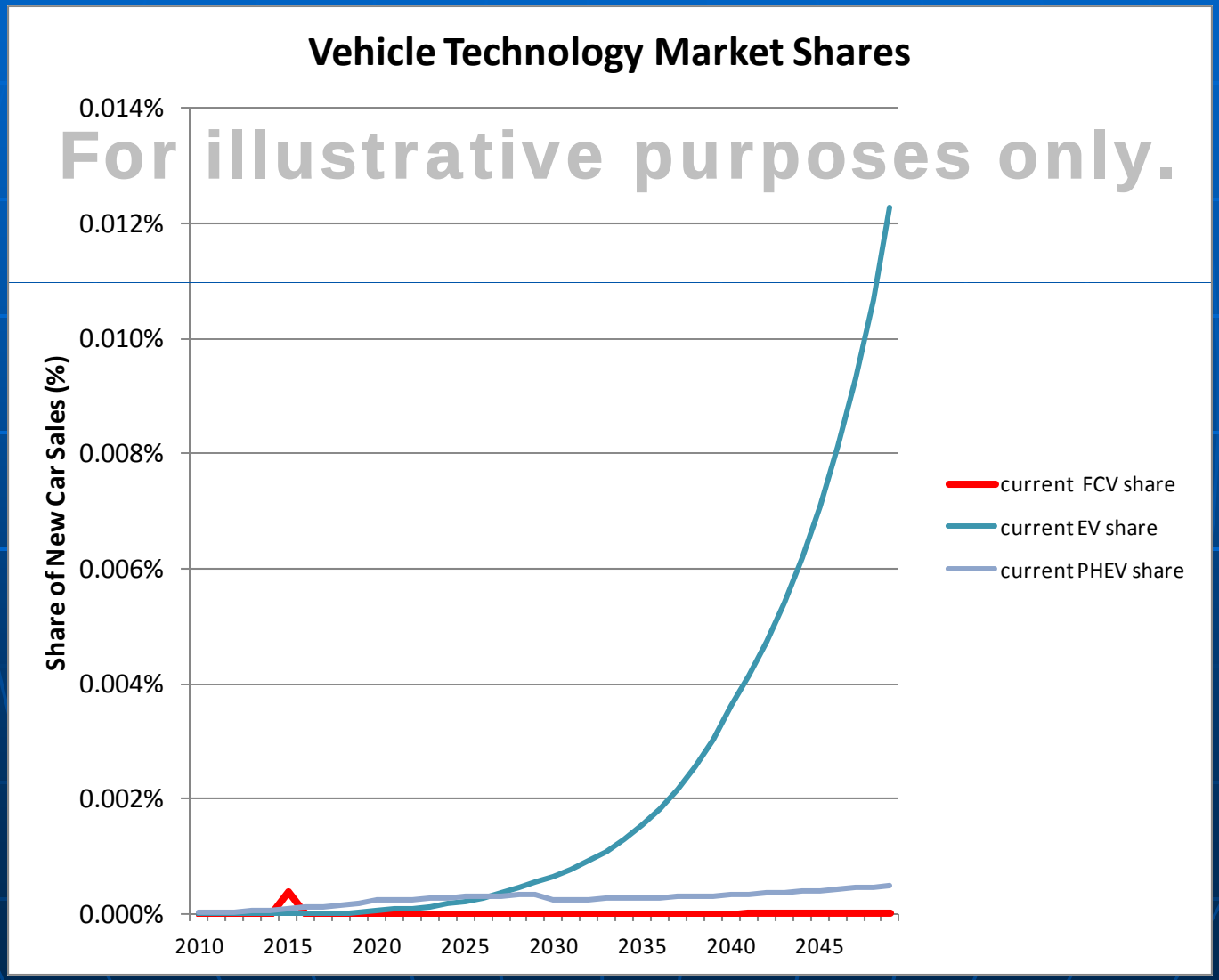
The reduction in GHG emissions versus 2005 is almost 80%.



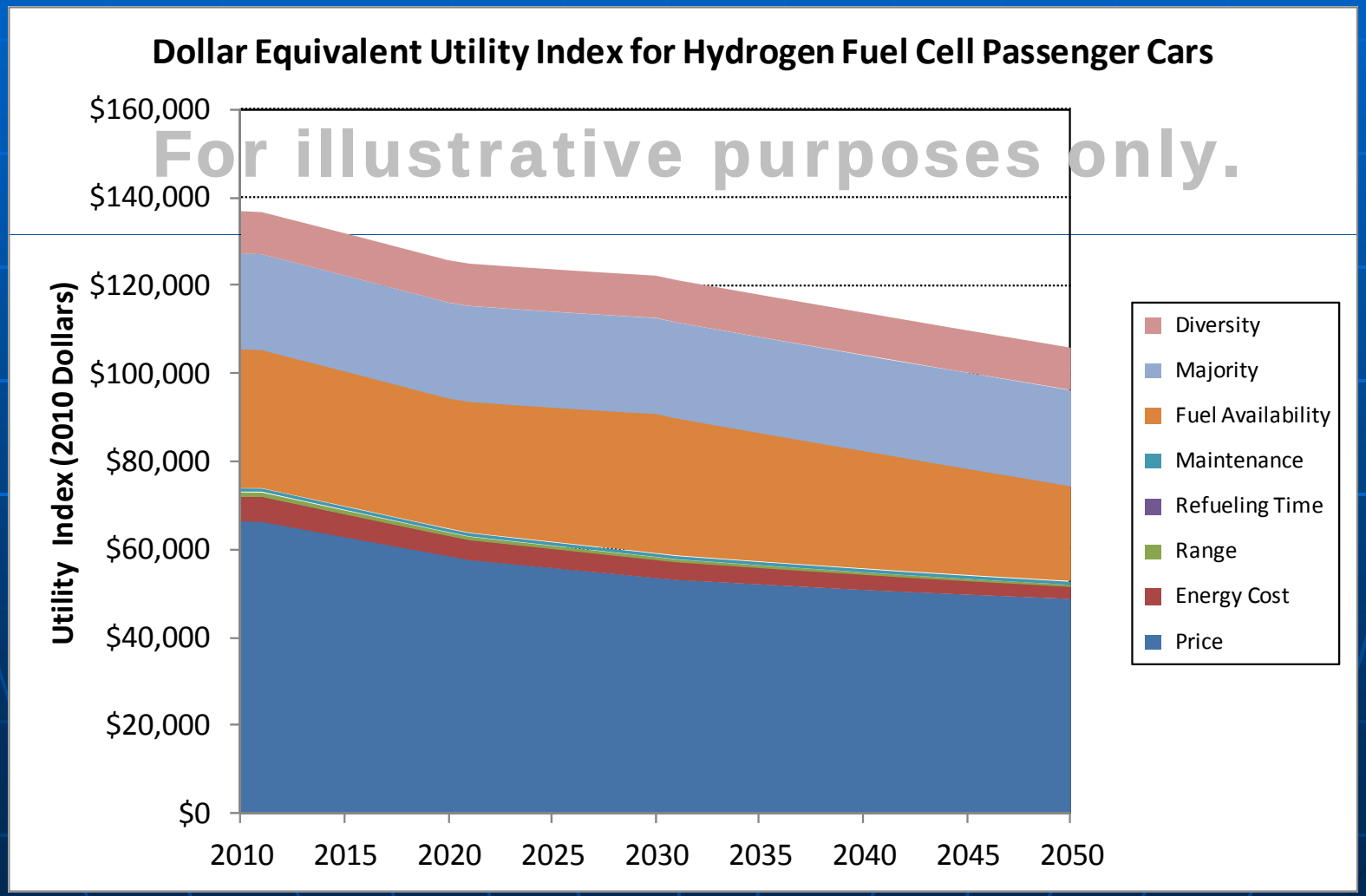
Take away the subsidies but keep the pre-installed infrastructure and the transition disappears.



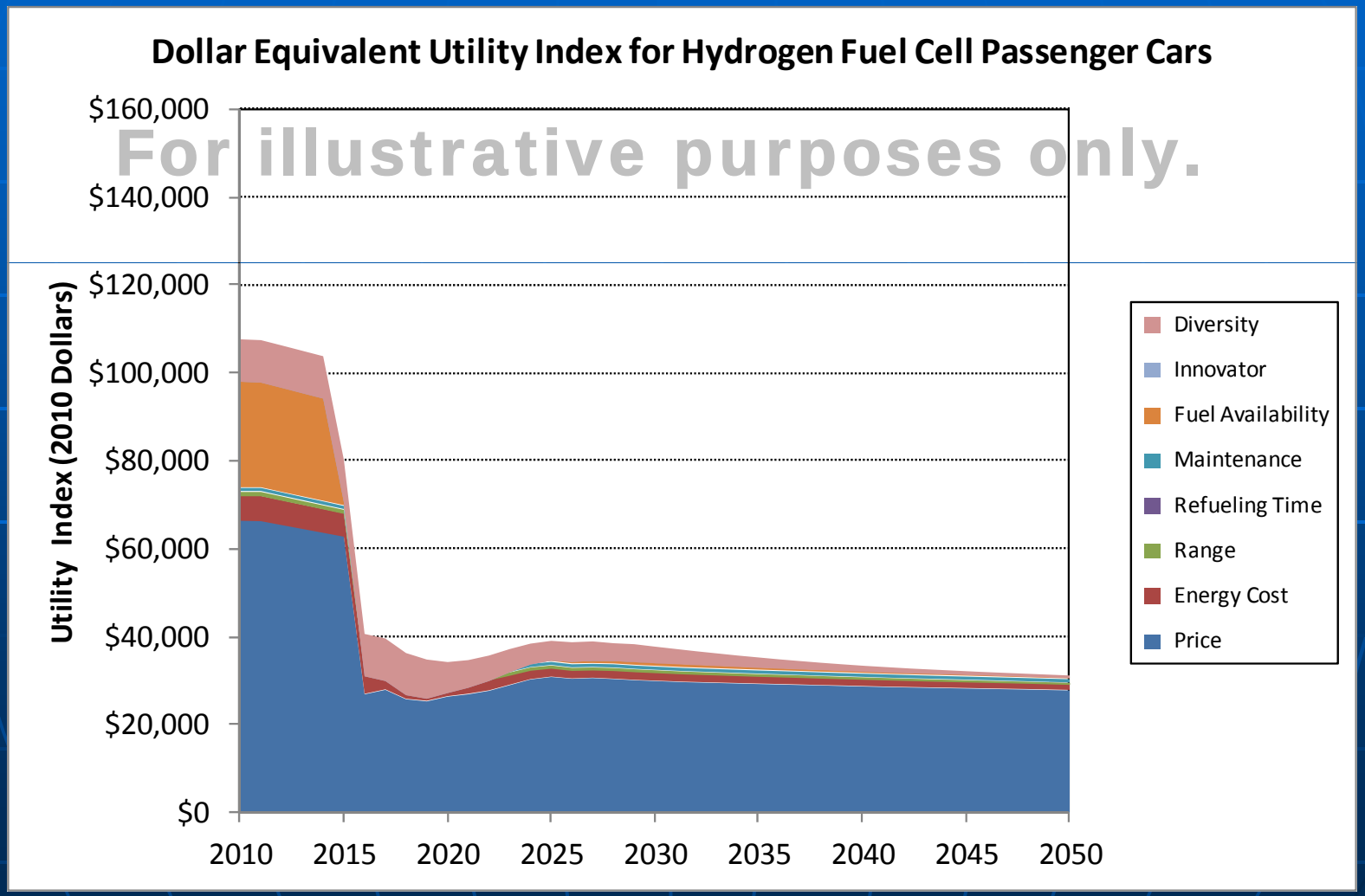
Take away the pre-installed infrastructure but keep the subsidies. The response is highly non-linear with strong positive feedbacks.



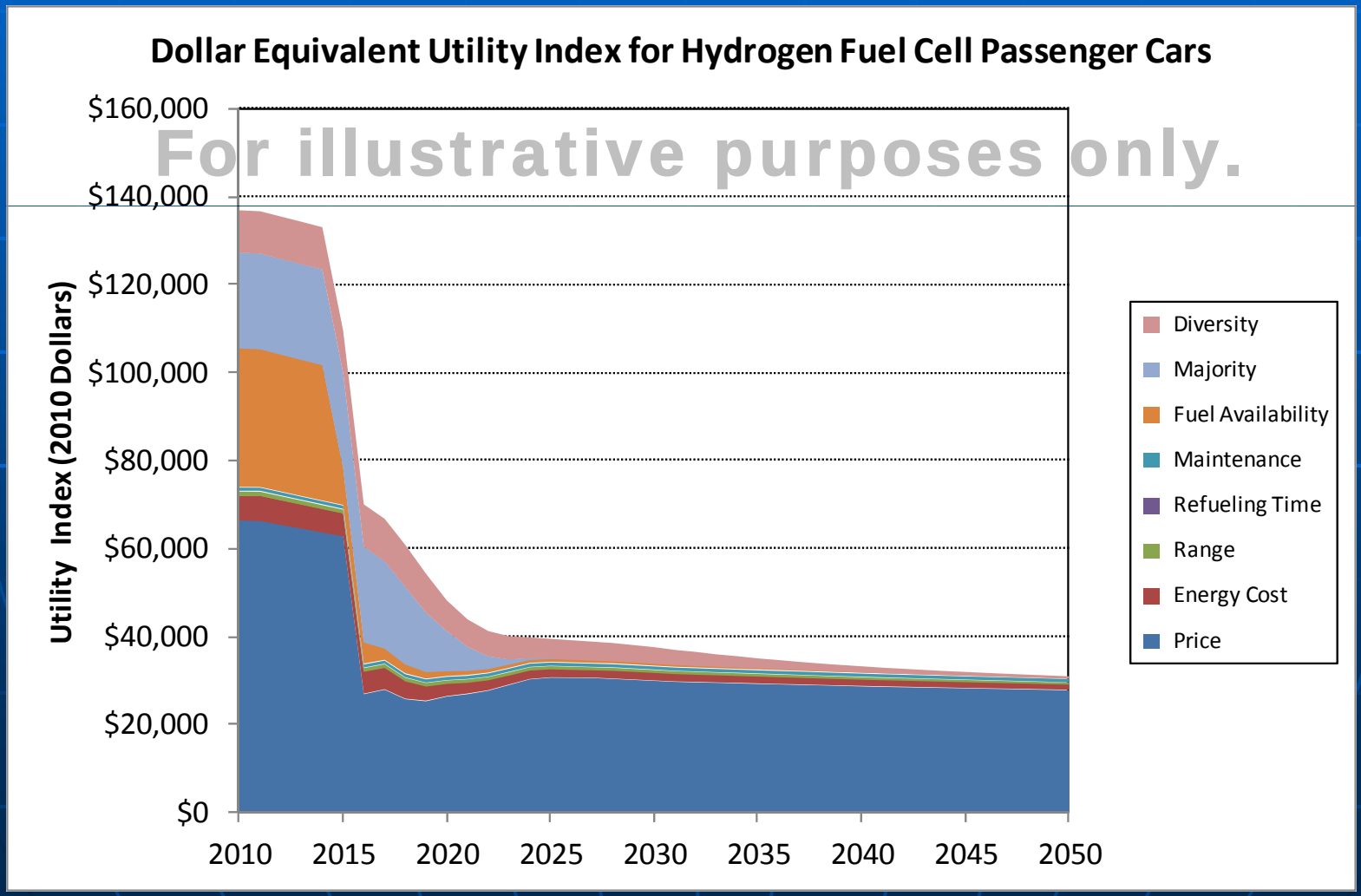
Without any market interventions to break down the transition barriers costs decline over time, mostly due to technological progress, but not nearly enough.



The innovators and early adopters drive the early market.



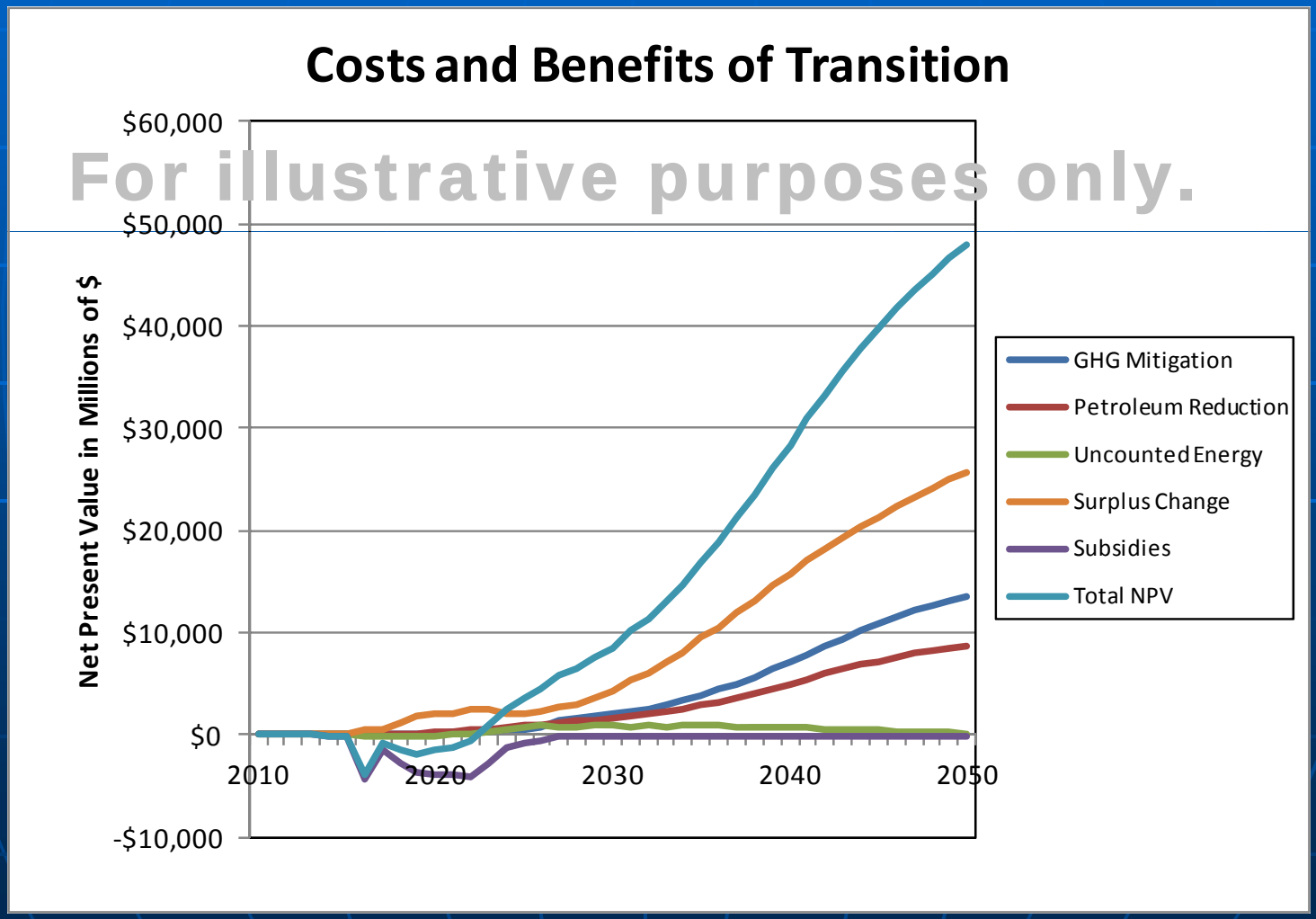
Pre-installation of refueling infrastructure and vehicle subsidies are effective even though majority consumers' risk aversion, lack of diversity in vehicle choices, and higher fuel costs must still be overcome.



Important questions remain to be answered.

- How can we accomplish large-scale energy transitions for the public good?
  - Are there ways to transform the market so that positive external benefits are valued?
  - How can the private benefits of alternative technologies be made known and enhanced?
  - How can we cope with technology & market uncertainties?
  - What are the robust, efficient supporting policies?
- How much can we reduce uncertainty about the transition processes and parameters so that we better understand the challenges?

Two NRC studies and one DOE study concluded that transition costs, though they may persist for a decade or so, may be a small fraction of total social+private benefits.



Thesis: We lack a public policy paradigm and the analytical tools to manage such a large scale energy transition for the public good.

- Technological outcomes are uncertain.
- Energy prices are uncertain.
- Magnitudes of the market barriers are uncertain.
- Consumer values are uncertain.
- Value of public goods also uncertain.
- And yet, solutions appear to require urgent, transforming action.

Petroleum also provides 95% of the energy for global transport.