

Automotive Industry – Alternative Fuel Vehicle Adoption

Client was seeking robust strategies to increase AFV¹ adoption

PwC enabled the client to explore the robustness of their proposed strategies across a vast range of uncertain future scenarios

Business Problem

- The client was evaluating new policies and strategies to shift the petroleum portion of US transportation energy consumption from 93% to 50% before 2040
- PwC recently developed a petroleum consumption model and a Total Cost of Ownership (TCO) model forecasting the cost of different technology platforms over time
- Client requested PwC to develop a model that would link the TCO model to consumer adoption, petroleum consumption, and economic output – and enable them to explore the impact of the proposed policies across a potential future scenarios

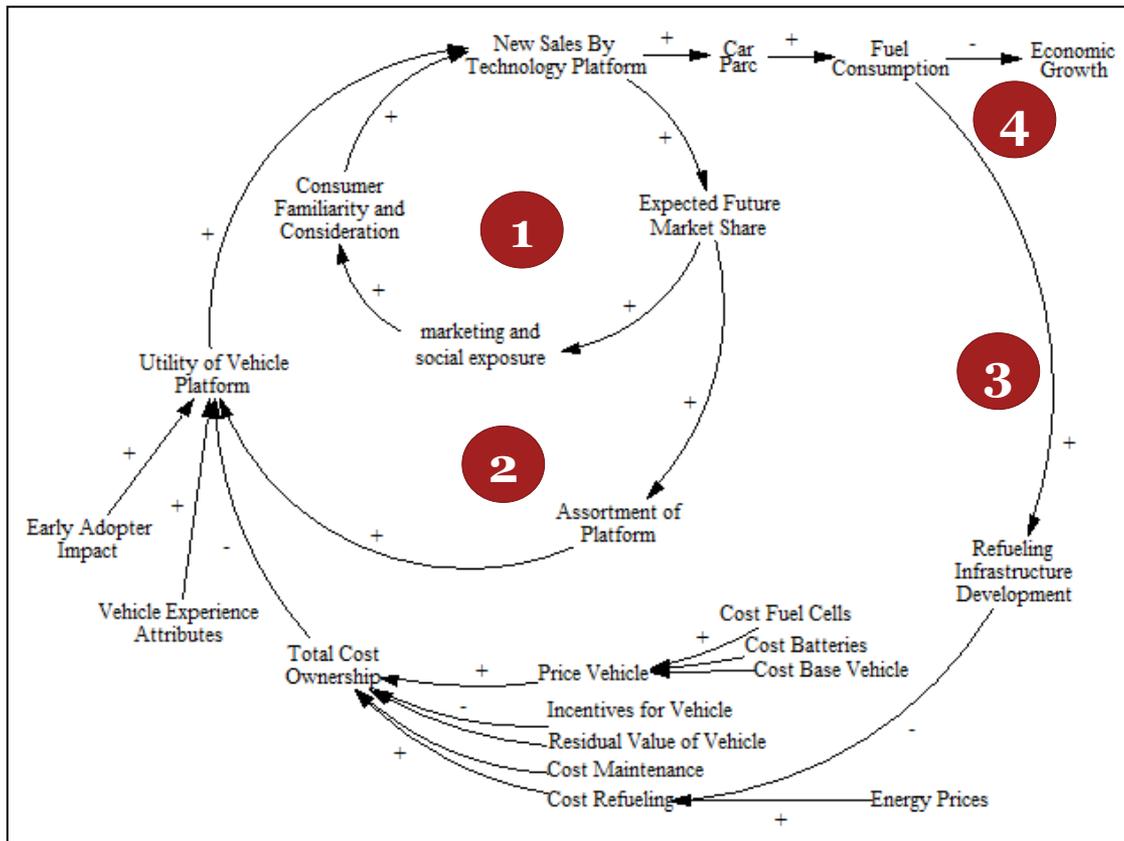
Impact and Outcomes

- PwC developed an integrated model combining TCO, consumer adoption, petroleum consumption, and economic analysis
- PwC enabled the client to capture and quantify the feedback between consumer adoption, manufacturer production, marketing, and the development of refueling infrastructure
- PwC simulated the outcomes of proposed strategies across a range of uncertain future scenarios, recommended a set of KPIs to track, and the combination of policies most likely to be effective as the cost outlook for each technology platform crystalizes

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The core adoption drivers were mapped, 3 powerful feedback loops were identified, and impact of reduced oil demand was projected on the economy

PwC worked with the client to map the critical connections within the automotive ecosystem, and developed a dynamic simulation model to explore how future scenarios will unfold



Adoption Drivers

- 1. Familiarity & Consideration:** increased market share for AFVs increases marketing spending, consumer familiarity, creating sales
- 2. Manufacturer Assortment:** increased market share for AFVs increases manufacturer investment into the range of AFV produced, meeting the needs of an increased set of customers, creating sales
- 3. Refueling Infrastructure:** growth in AFV fleets changes fuel consumption, and cause developers to build new refueling infrastructure
- 4. Fuel Consumption & GDP:** changes in the composition of the Car Parc reduce domestic demand for petroleum products, increasing economic growth and decreasing volatility to shocks in oil prices

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Many adoption drivers were found to be interdependent, and capable of triggering paradigm shift to new fuel systems

*Widespread adoption for any AFV platform required more than just a cost advantage...
For BEVs, share remained low after prices dropped, until refueling stations became ubiquitous*

	Case #1: Favorable Assumptions AFV Adoption (Homo Economicus)³	Case #2: Less Favorable for AFV Adoption (Consumers Discount FV of Money)⁴
Battery Cost #A: Prices Remain Higher than Anticipated²	BEV market share in 2040¹: ~5% Cost parity is achieved late, and adoption is too slow to incentivize manufactures to market heavily and expand their production lines, and market forces are slow to build refueling infrastructure for PHEV / BEV vehicles	BEV market share in 2040¹: ~0% Although cost parity is eventually achieved, there is never enough adoption to spur manufactures and developers to invest enough to build out an ecosystem where BEV cars can effectively operate
Battery Cost #B: Prices Decline as Expected²	BEV market share in 2040¹: ~20% After an initial wave of HEV and PHEV vehicles, consumers begin to rapidly purchase BEV cars once manufactures start expanding their product lines. BEV trucks never take off	BEV market share in 2040¹: ~0% Cost parity is achieved early, but there is never enough adoption to spur manufactures and developers to invest enough to build out an ecosystem where BEV cars can effectively operate
Battery Cost #C: Prices Fall Faster than Anticipated²	BEV market share in 2040¹: ~45% After an initial wave of HEV and PHEV vehicles, battery prices drop and market share for new cars explodes from ~5% in 2030 to ~45% in 2040. The car market appears to be transitioning to a pure BEV marketplace	BEV market share in 2040¹: ~20% Despite pessimistic assumptions about the ability of consumers to accurately value NPV savings, low battery costs rapidly expand adoption from 5% to 20% of the market between 2033-2040 as manufactures expand their product lines.

¹ Market share refers to cars-only (cars represent roughly 55% of new car sales, trucks represent the other 45%)

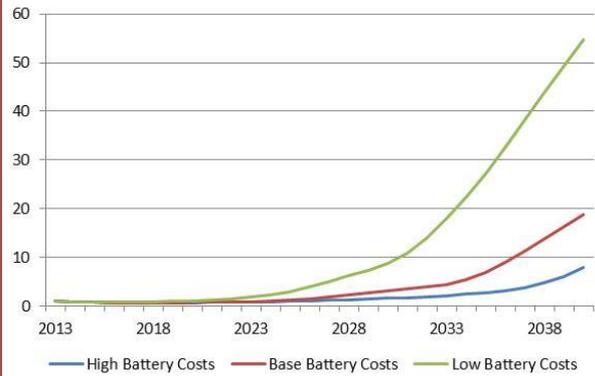
² Future battery prices were estimated from PwC-SAFE Total Cost of Ownership model

³ See slide 5 for a summary of the assumptions made for Case #1

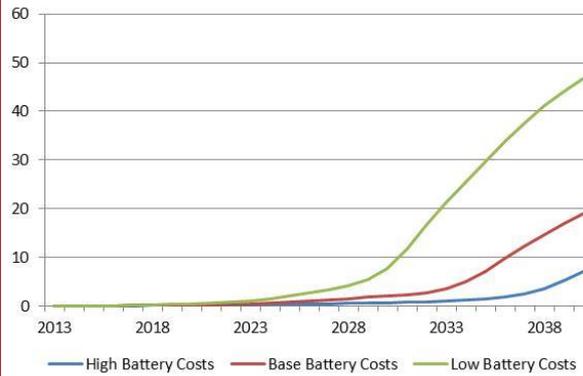
⁴ See slide 6 for a summary of the assumptions made for Case #2

Case #1: Potential adoption of BEV vehicles, favorable conditions¹

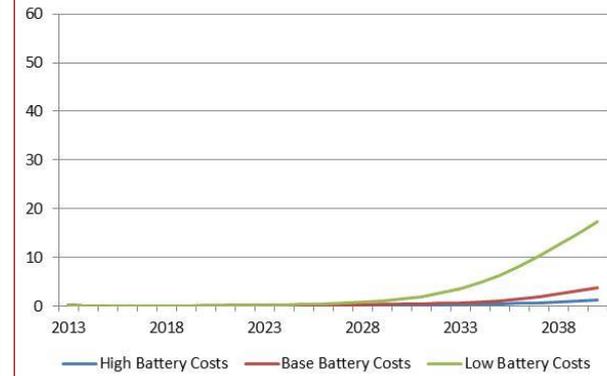
New Purchase Consideration % (BEV)



Market Share % (BEV Cars)



Car Par (BEV)

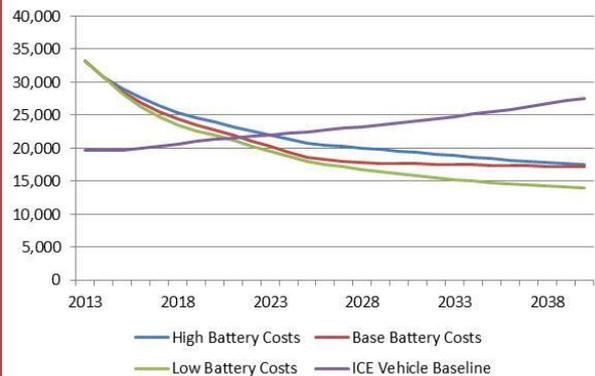


❑ The rapid drop in TCO in “low battery cost,” causing manufactures to increase marketing trigger a feedback loop.

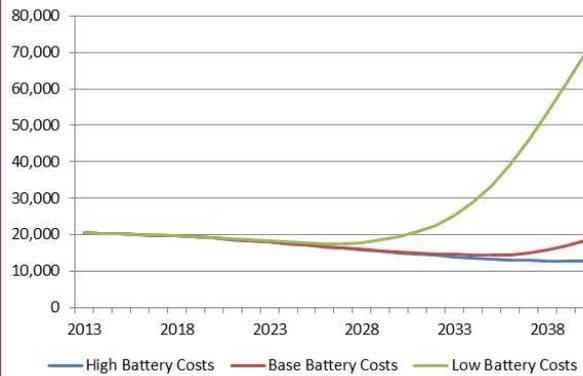
❑ Despite BEV cost parity in 2020, it takes an additional 10 years for the platform to take off (due to assortment, consideration, pumps)

❑ Car Parc lags market share due to the long ownership time-horizon – and grows slowly because it is less suitable for trucks (50% mkt)

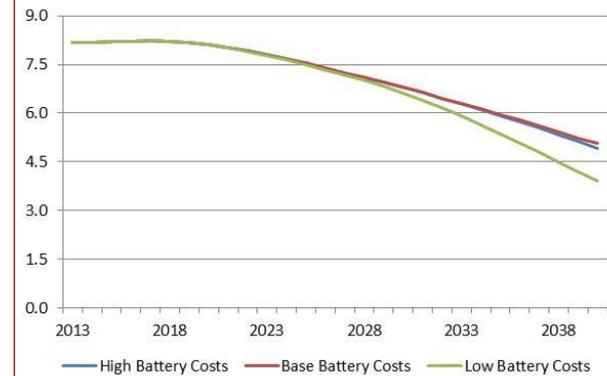
Total Cost Ownership (BEV Cars)



Refueling Pumps Operating (Electric)



Barrels Oil Consumed Per Day (M)



❑ BEV cost parity occurs ~2020
 ❑ Consumer adoption is very sensitive to changes in TCO

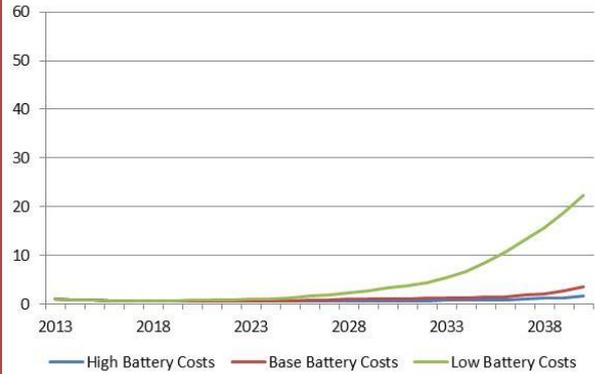
❑ Refueling infrastructure development lags market demand. If infrastructure is developed by a third party, adoption increases sooner

❑ Interesting, BEV and PHEV cannibalize HEV when adoption is low, and less oil is actually consumed in the High -than Base-cost scenario

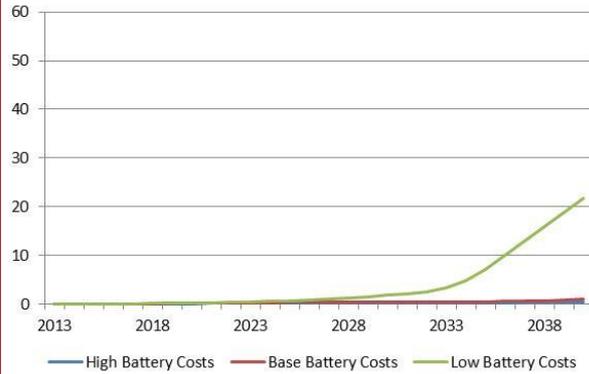
¹ Assumptions: Consumer values FV savings on fuel at NPV, Marketing effectiveness on upper end of typical values (0.018) AFV infrastructure requires less utilization before 2030 (0.1, 0.2, 0.3, 0.4), petroleum price 1.25x EIA forecasts after in 2020. Economic volatility in normal range (0.03). FC and CNG excluded

Case #2: Potential adoption of BEV vehicles, pessimistic conditions¹

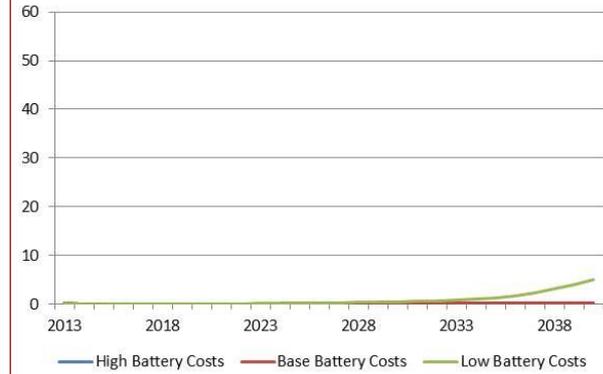
New Purchase Consideration % (BEV)



Market Share % (BEV Cars)



Car Par (BEV)

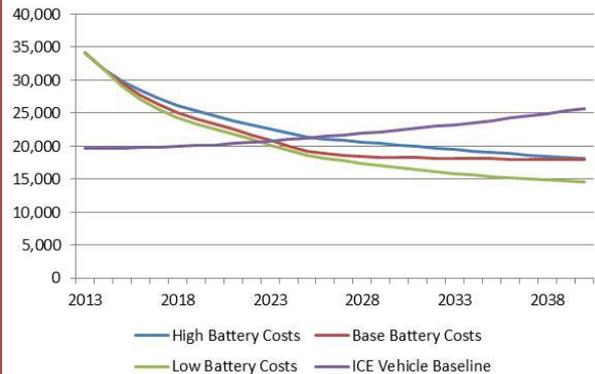


❑ With realistic but less favorable assumptions, only the 'low-battery-cost' scenario is detectable

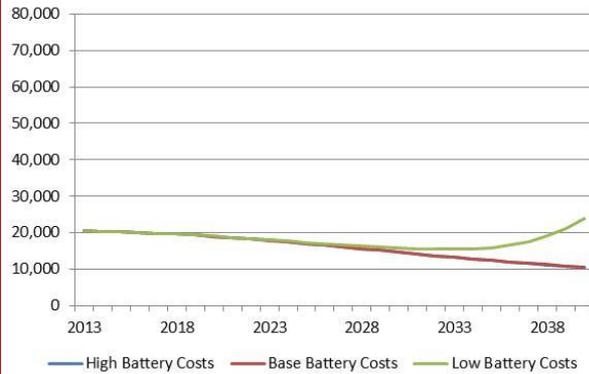
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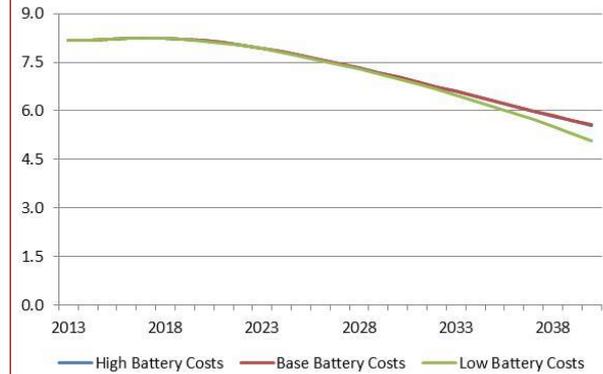
Total Cost Ownership (BEV Cars)



Refueling Pumps Operating (Electric)



Barrels Oil Consumed Per Day (M)



❑ When customers discount NPV, perceived cost-parody is not achieved until 2025

❑ Due to low adoption, refueling infrastructure demand remains low and infrastructure is removed or ceases to operate

❑ Oil consumed per day decrease due to increased fuel efficiency and the adoption of HEV vehicles, but BEV (and PHEV) do not impact

¹ Assumptions: Consumer discounts fuel savings at 0.75 NPV. Marketing effectiveness on lower end of typical values (0.013) AFV infrastructure requires less utilization before 2030 (0.1, 0.2, 0.3, 0.4), petroleum price match EIA forecasts. Economic volatility set to within normal range (0.03). FC and CNG excluded

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Preliminary Findings...

*A **first wave of HEVs**, followed by **second wave of PHEVs** is the most likely scenario...
But a very **wide range of potential futures** could unfold, and strategic investments (made at the right time) have the potential to push the market towards completely new fuel paradigm*

Preliminary findings by technology platform

- **HEV:** hybrid vehicles are the most likely to be widely adopted before 2030. If they succeed early, they could crowd out investments into other technology platforms, but it is most likely a second AFV will take over as gasoline prices continue to rise.
- **PHEV:** plug-in hybrids have two paths towards market dominance: (1) if battery costs come down early, they could replace the HEV as the dominant AFV right away. Alternatively, (2) if more revolutionary technologies fail and petroleum costs rise, then PHEVs will likely to begin to replace HEVs as the market-share leader by 2040.
- **BEV:** battery electric vehicles could dominate the car market under the right conditions (drop in battery prices, increase in range, available refueling infrastructure), but if the stars do not align they are likely to flop (with very little middle ground). BEVs are unsuitable for trucks, ¹ and it is unlikely manufactures/developers will invest if even the potential market share among cars is in doubt.
- **Hydrogen :** fuel cell vehicles are the market's wildcard. Heroic cost reductions are necessary and seem unlikely in the near future. However, their suitability for both cars and trucks is attractive to manufactures, and their inability to be refueled at home makes investments into refueling infrastructure less risky for developers should they gain momentum. If costs come down enough for fuel cell vehicles to be taken seriously, then hydrogen could emerge as the fuel of the future.